Cold Spray System Reliability and Advancement for DOD

Presenter: Rob Hrabe

14 June 2017

OSD Mantech Phase III: Cold Spray Additive Manufacturing (AM) and Structural Repair (SR) Technology

Defense-Wide Manufacturing Science & Technology (DMS&T) Program

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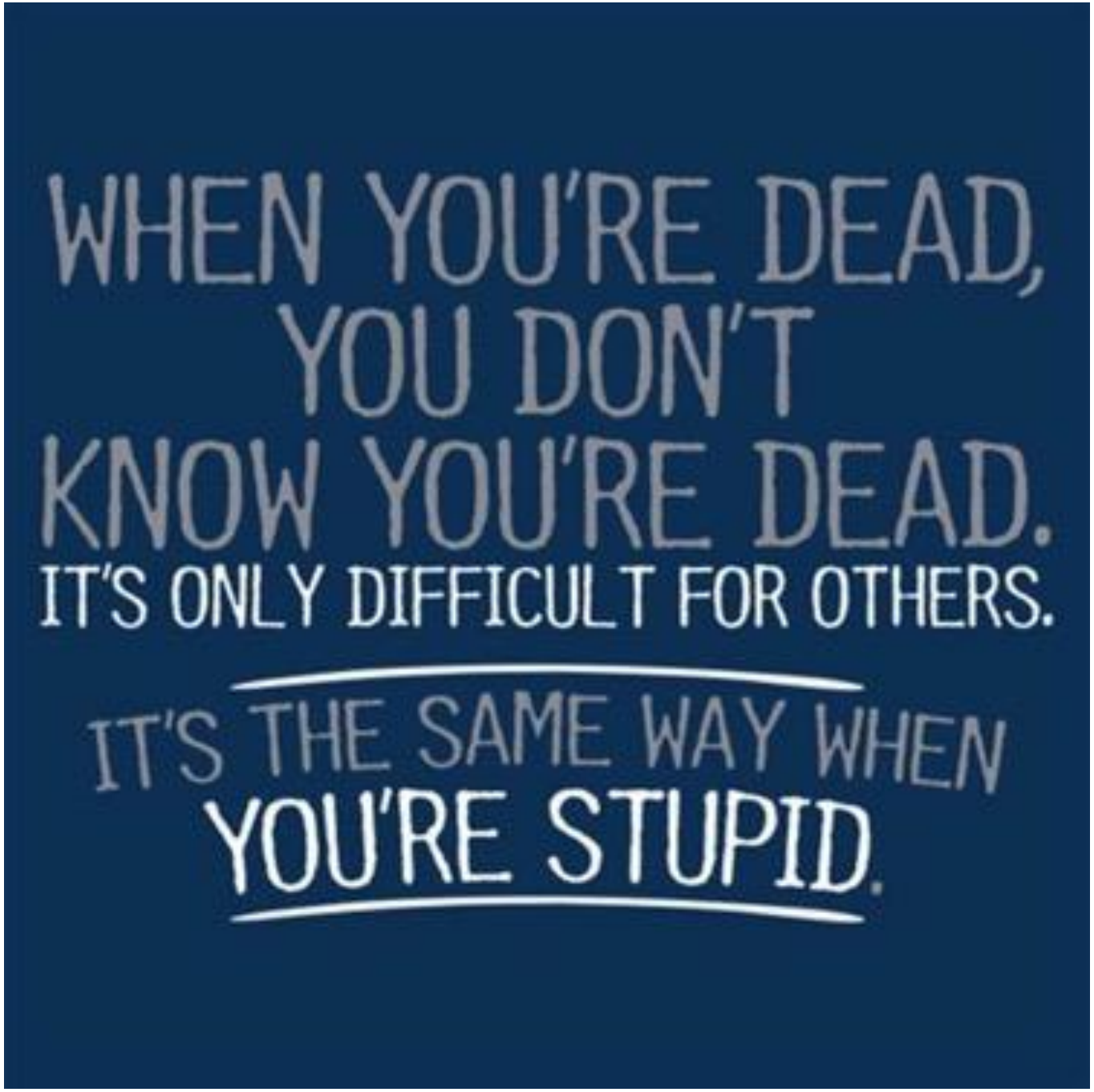
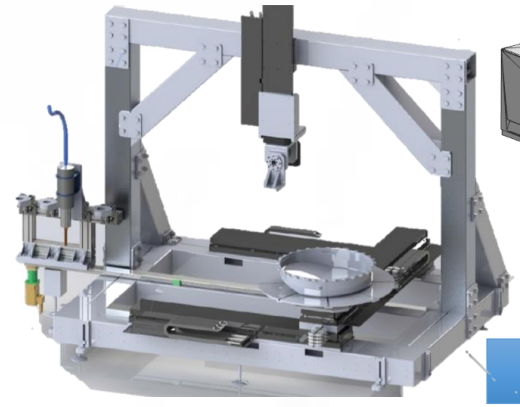
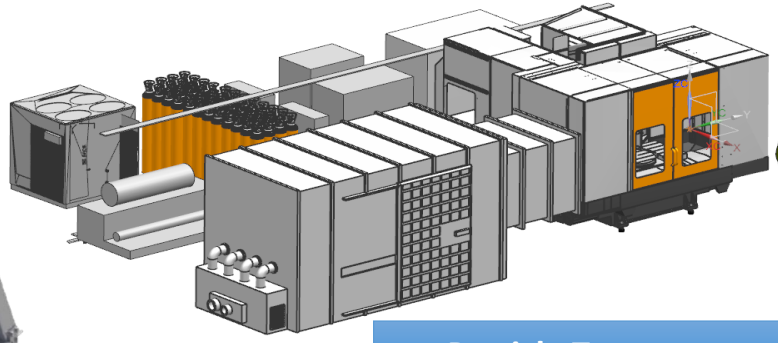

WHEN YOU'RE DEAD,
YOU DON'T
KNOW YOU'RE DEAD.
IT'S ONLY DIFFICULT FOR OTHERS.
IT'S THE SAME WAY WHEN
YOU'RE STUPID.

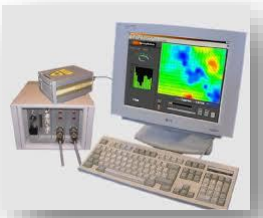
ARL Vision for Cold Spray Development

Non-structural Repair → Structural Repair → Near-net Parts

DMS&T Phase I	DMS&T Phase II	DMS&T Phase III
Enabled Cold Spray Repair Production High Volume Flexible	Increased Operating Envelope & Established Helium Recovery to Reduce Costs	Incorporate Advanced Automation & System Controls
2012-2014	2014-2016	2017-2019







Intelligent Automation & Controls

Particle Temperature, Velocity, and Particle Size Measurement

Advanced Motion and Path Planning Capability and Automated System Process Controls

Ensure Predictable, Repeatable and Reliable Material Properties/integrity of AM and Structural Applications

Government / COE Team Members

Government PM & Technology Transition Lead
Victor Champagne, Technical Team Leader
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Roles:
- Component Engineering
- Requirements Development
- Qualification Engineering

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Roles:
- Cold Spray Production
- Qualification Operations

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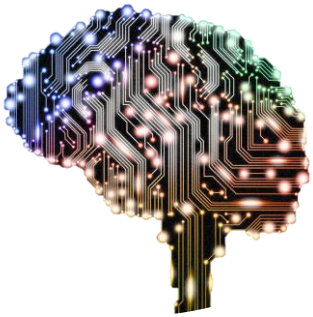
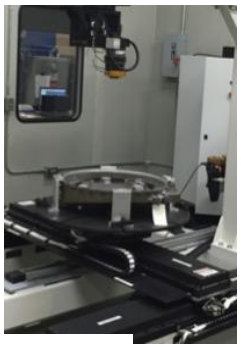
nardiat@utrc.utc.com

Roles:
- Research, Development
- Test

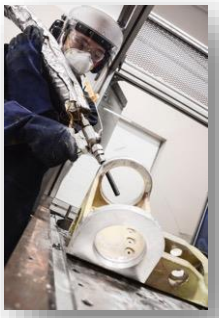
Phase 3 Objectives

2. Process & Equipment Scale Up

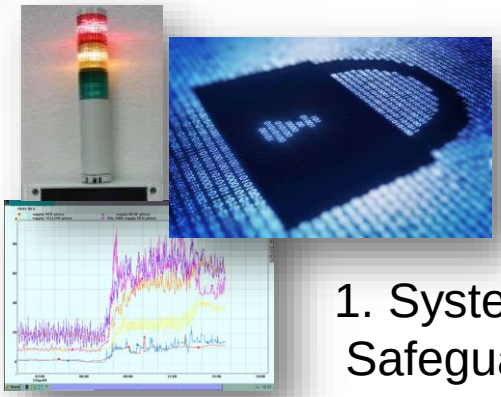




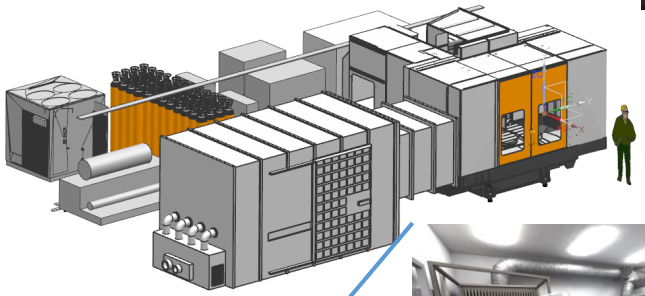
3. Intelligent Automation

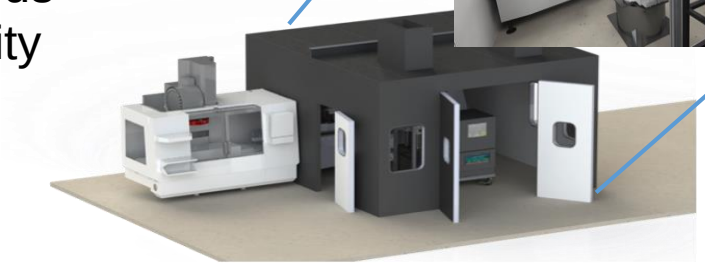


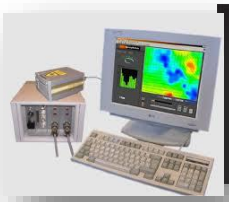
4. Human Systems Integration



1. System Safeguards & Security







5. Upgraded Sensors

Approach

1.System Safeguards and Security

Year 1

- Enhanced Data Logging and Storage Capabilities
- Haptic/Audible & Visual Alarms for Process Variables & Tolerances
- Enhanced Data Control & Security for Control Programs and Recipes

2.Process Equipment Upgrades

- Closed Loop Powder Feed System, High Flow Heater, Gas Train Control, and Powder Processing and Quality Control
- Increased Portability, Reliability, & Repeatability of Spray Parameters

3.Human Systems Integration

- Enhanced HMI Screens, Built-in Troubleshooting, System Ergonomics

4.Upgraded Sensors

Year 2

- Expand 3-D Scanning and Reverse Engineering Capabilities
- Include In-Process Verifications for Quality Control and Tolerancing

5.Intelligent Automation

Year 3

- Autoset Functions & Standard Work to Reduce Operator Workload
- Path Planning & Control – Layer by Layer Path Adjustment

Feedstock Control

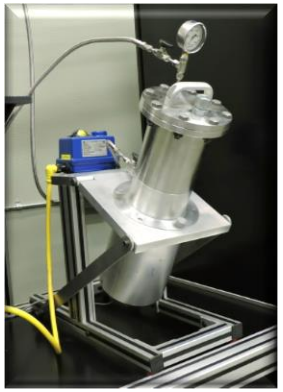
Powder Delivery Chain

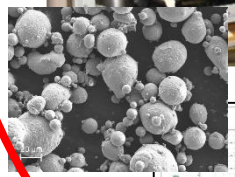
Production
- Process
- Quality
- Certification

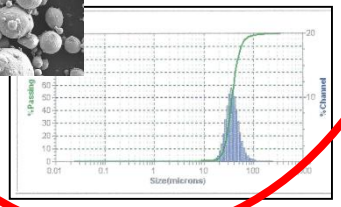
Processing
- Characterization
- Quality Control
- Preparation

Delivery
- Packaging
- Loading
- Efficiency

Feeding
- Control
- Consistency
- Efficiency







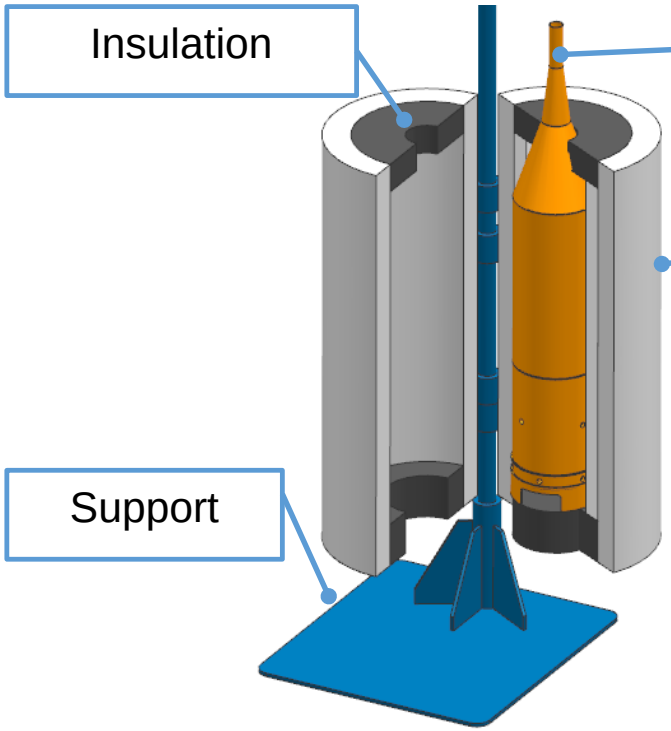
Chemical and Physical Characteristics of Valimet Spherical Aluminum Powder Specifications									
	H-2	H-3	H-5	H-10	H-15	H-30	H-50	H-60	H-95
Aluminum, wt. %, min.	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7
Volatile, wt. %, max.	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Oil & Grease, wt. %, max.	0.2	0.2	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									
-80, wt. %									100
-100, wt. %, min.									95.0
-200, wt. %						99.5 min.	90.0 min.	85.0 min.	10.0 max.
-325, wt. %	99.0 min.	99.0 min.	99.0 min.	98.0 min.	99.0 min.	85.0 min.	20.0-40.0	15.0 max.	
Microtrac Analysis (Nominal Values)									
90%	7.5	10.5	15.0	22.0	40.0	58.0	92.0	105.0	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

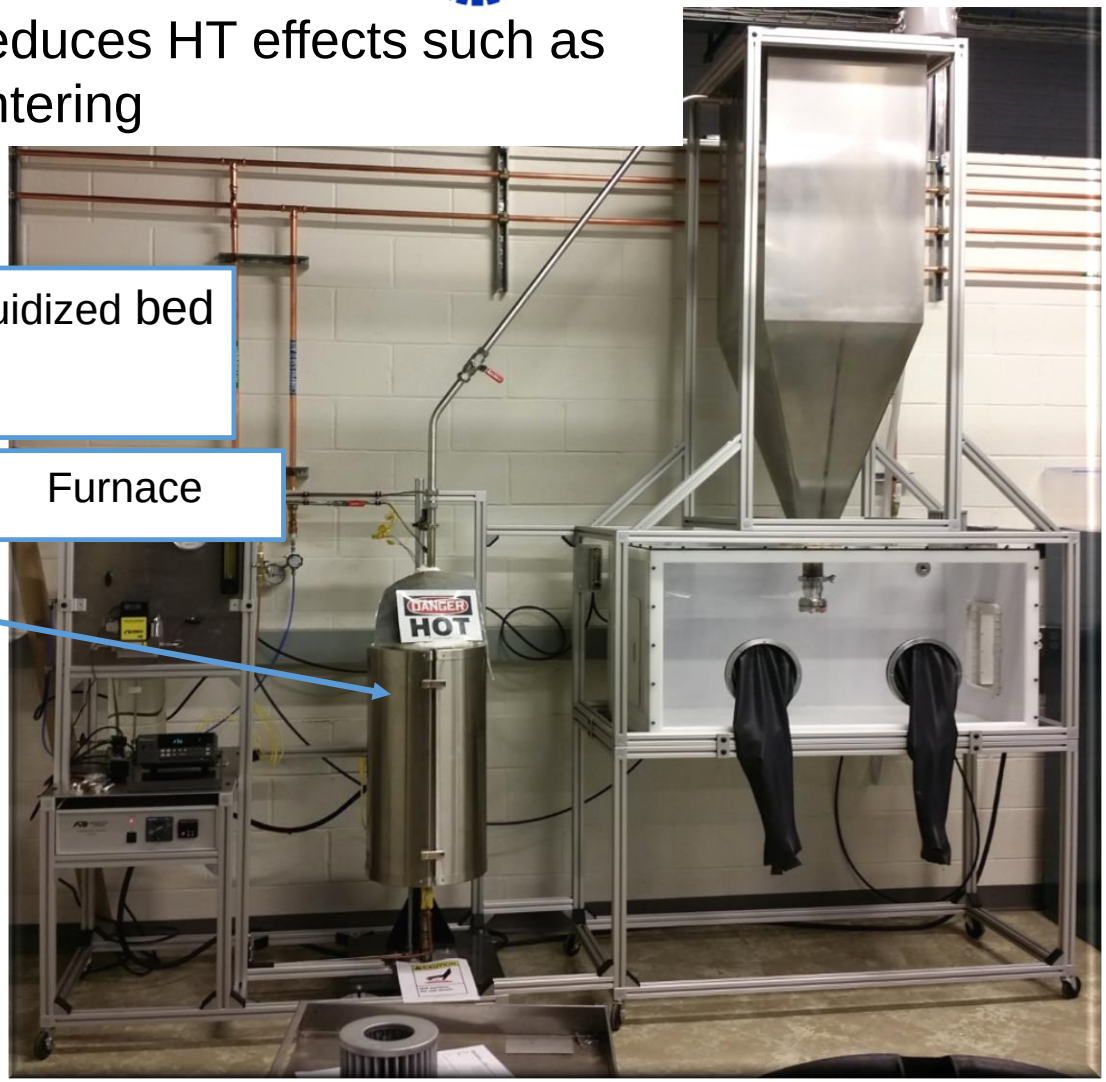
Bottom Line: Structural repair requires equipment that can control the process from beginning to end

Processing Scale Up

Prototype Production Fluidized Bed System

- 10 lb capacity per bed
- Classification
- Heat treat/quench/ de-gas
- Reduces labor cost
- Reduces HT effects such as sintering





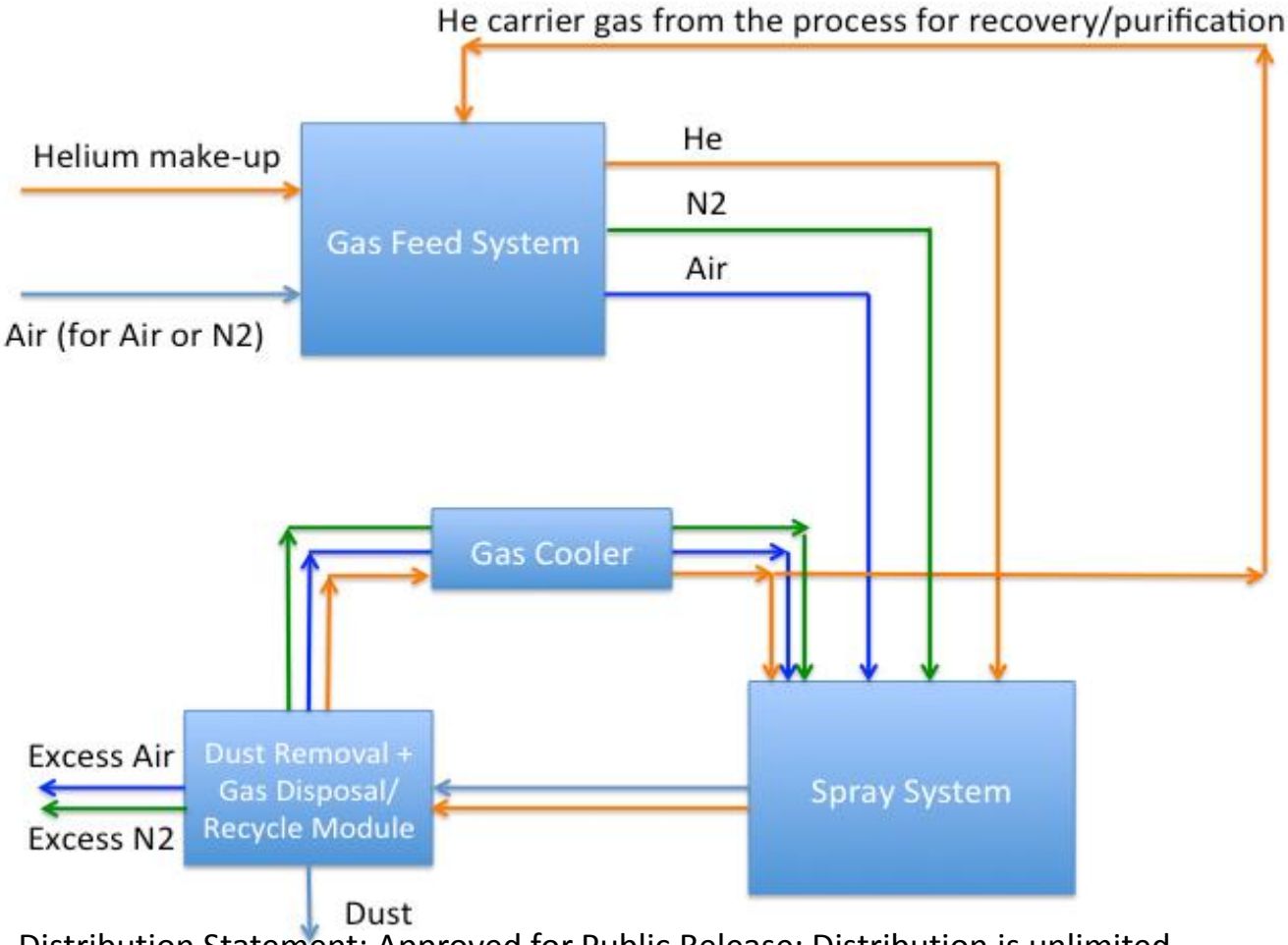
* Patent Pending

Helium Recovery

Developments

QuantumPure CS-TGM™

Proprietary Total Gas Management System



- All-encompassing gas management system
- Designed to allow the user to optimize carrier gas:
  - ➢Air
  - ➢Nitrogen
  - ➢Helium
- Full Recovery capabilities when necessary.

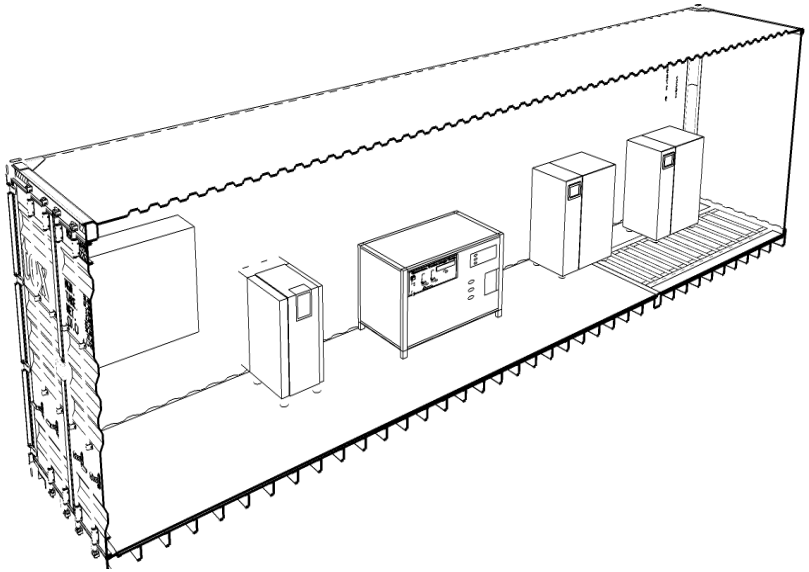
Patent Pending

Quantum technology
Custom industrial gas solutions since 1981

Helium Recovery

VRC METAL SYSTEMS

QuantumPure CS™
Stand-Alone
Gas Management System



Specifications & Capabilities

- Containerized, independent, plug-and-play system
- Purities of output Helium >95+%
- Flowrates: 0.5 – 4 m^3/min (20 – 150 scfm)
- Storage Pressures up to 186 bars (2700 PSI)
- Fully automated system with high recovery rate
- Wide range of input purities from 0% to 100%.

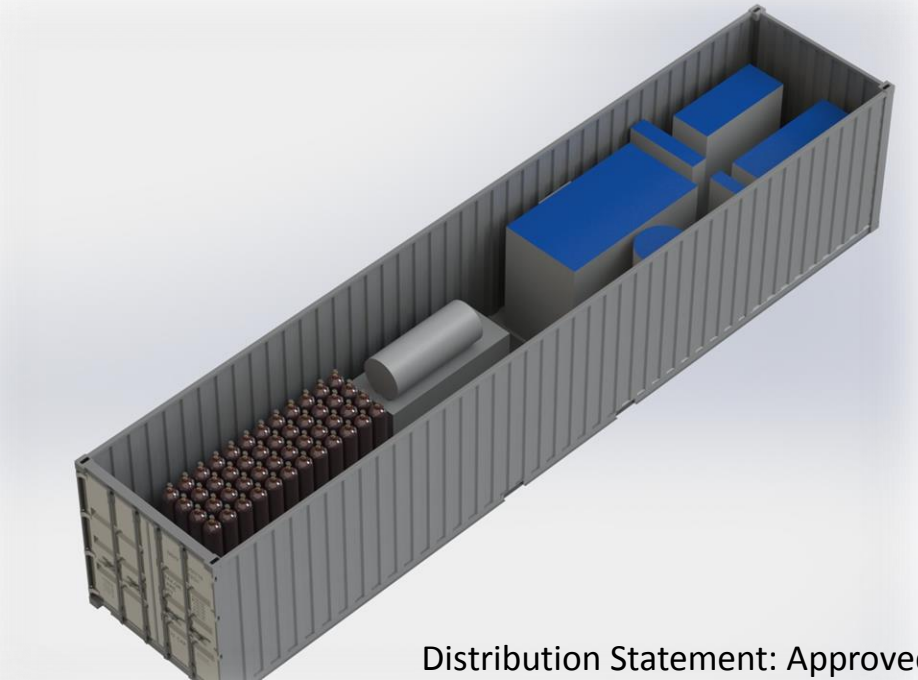
Helium Recovery

QuantumPure CS™

Stand-Alone Gas Management System

Economics

- 90% of Helium saved /year
- =~ $800K (2M cf/year @$0.4/cf)
- Total investment: $500-700k
- Minimal Operating expenses
- Saves inside lab space,
- Reduces noise pollution
- Lower installation costs
- ROI: ~1Year



Specs & Standards

In Effect

MIL-STD-3021 “Materials Deposition, Cold Sprav”

In Work

MIL HDBK –xxxx (Similar to MIL-HDBK-17-1F)
POCs: Sophia Lauwers, Gehn Ferguson
Expected Completion: Dec 2018

MIL-DTL-xxxx “Powders for Cold Spray Deposition.”
(will supersede MIL-DTL-32495)
POC: Dr Baillie McNally, Gehn Ferguson
Expected Completion May 2018

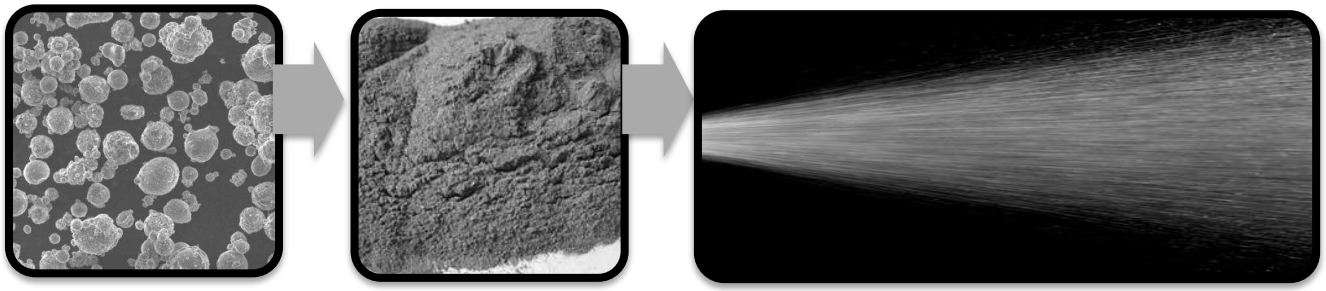
- Overall POC: Richard Squillacioti,
  ARL Specs & Stds


I'm not bossy!
I have skills...leadership skills!!
Understand?
Vic
Baillie

Specs & Standards

MIL-DTL-xxxx "Powders for Cold Spray Deposition."

- Currently in Data Collection Phase
- Materials included (unprocessed/processed):
  - Aluminum CP, HP, 5056, 6061, 7075
- Pure Powders:
  - Titanium, Nickel, Niobium, Copper, Tantalum, Zinc
- Carbide based blended powders, CrC-NiCr, CrC-Ni
- Nickel-chrome based super alloys: Inc 625 & 718
- Steel and steel-based alloys: 316 SS
- Bronze



Specs & Standards

MIL-DTL-xxxx "Powders for Cold Spray Deposition."

Qualification requirements (each will include ASTM Std):

- Chemical composition
- Max non-metallic impurities (Oxygen content)
- Particle size distribution
- Quality
  - Blended, dry, free flowing, free from foreign materials, clumps & agglomerates
- Min flowability value
- Spray-ability:
  - Metallographic coupon
  - Bond button
  - Visual inspection
  - Images of powder
  - Maximum porosity
  - Bond strength
- Mechanical properties
  - Tensile properties
  - Surface hardness

Specs & Standards

MIL-DTL-xxxx "Powders for Cold Spray Deposition."

ASTM Standard references to be used for:

- Test methods
- Packaging details
- Intended use of the materials
- Shelf-life/storage of powder

Currently collecting data for chemical composition, oxygen content, and particle size distributions of the powders.

Summary

- ***To have systems capable of additive manufacturing & structural repair using cold spray we're defining:***
  - *Integrated process control technology*
  - *Automation Systems with the unique motion characteristics required to achieve structural properties*
  - *Powder processing and handling equipment capable of processing the quantities and quality of powder needed to produce structural repairs*
  - *Specifications and Standards*
- ***<u>Cost Reduction & Improved Readiness</u>***

Cold Spray System Reliability and Advancement for DOD

Presenter: Rob Hrabe

14 June 2017

OSD Mantech Phase III: Cold Spray Additive Manufacturing (AM) and Structural Repair (SR) Technology

Defense-Wide Manufacturing Science & Technology (DMS&T) Program

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Org: ARL RDRL-WMM-C
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Objective: *Develop Systems Capable of Additive Manufacturing (AM) & Structural Repair (SR) using Cold Spray Technology*

- ***Develop integrated process control technology***
  - *Provide in-situ process control, monitoring, and recording*
    - *Pressure, temperature, standoff, particle velocity, flow rate, deposit efficiency, motion path & angle*
  - *Ensures integrity of AM & structural repair processes*
- ***Develop Automation Systems with the unique motion characteristics required to achieve structural properties***
  - *Achieve wrought properties in AM & cold spray repairs*
- ***Develop powder processing and handling equipment capable of processing the quantities and quality of powder needed to produce structural repairs***

Benefit to the defense industrial base

- *Establish new additive mfg and structural repair capability*
- *Reduced cost, cycle time, scrap, improved readiness*
- *Prepare the way ahead for multiple repair technologies & multifunctional work stations that incorporate advanced materials processing.*
- *Structural repairs are available but need automation*
- *Reduces cost and timeline associated with structural cold spray repairs by improving efficiency and repeatability*

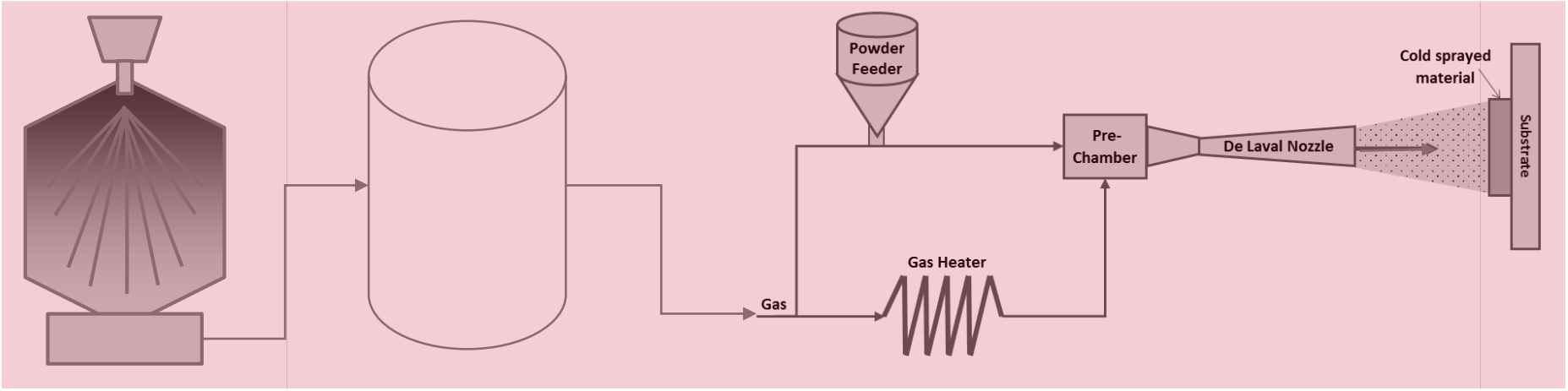
Allows for Near-Net Forming

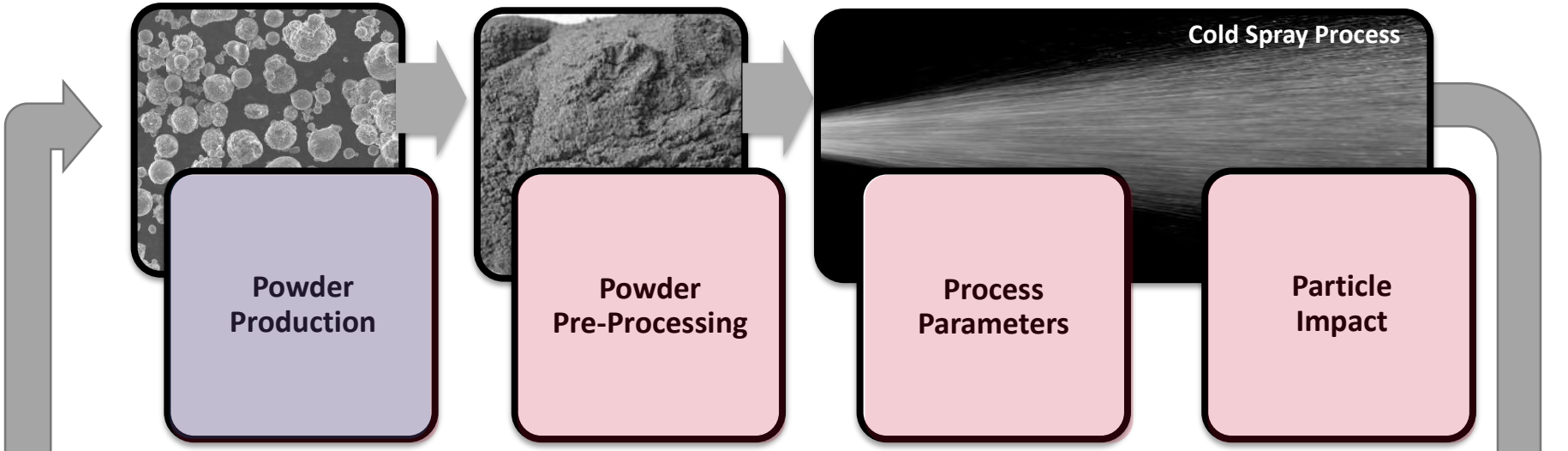
Problem: Ensuring Integrity of *Additive Manufacturing (AM) & Structural Repair (SR)* Cold Spray Repairs

- ***Structural additive manufacturing and repair feasibility proven in previous development efforts***
  - ***Requires process control beyond current equipment capabilities***
    - *Powder has to be processed to highly stringent specifications*
      - *Rudimentary fluidized bed systems are capable of producing small quantities but scale up has presented challenges with consistency of feedstock resulting in inconsistent properties*
    - *Post processing handling and control of feedstocks needs to be addressed to ensure properties are consistent*
    - *Cold spray systems need to incorporate process control and monitoring to ensure the end product meets specifications*
      - *Post cold spray NDI techniques can't fully evaluate part integrity*
  - ***Requires unique motion control and path planning to achieve structural properties not available in current robotic systems***
    - *Layer to layer in-situ control needs to be built into the system*

Approach

Cold Spray Feedstock Powder Holistic Approach





Inputs
- Raw material
- Requirements

Outputs
- Microstructure
- Mechanical properties