



U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND –  
ARMY RESEARCH LABORATORY

JEG Virtual Tech Forum - “Better Ways to Adopt and Develop New Capabilities”

## Technology Transition Lessons Learned: “Bridging the “Valley of Death”

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DB-IV  
US Army Research Laboratory



Approved for Public Release



# Technology Transfer Successes 1984-2020



- |  |                     |                  |
|--|---------------------|------------------|
| • Thermal Spray  | GP Bombs            | Navy & Air Force |
| • Powder Coatings  | MK-Series Bomb Fins | Navy & Air Force |
| • Laser Shock Peening  | F100 Engine         | Air Force        |
| • MWM (NDT Technique)  | T-700 Engine        | Army             |
| • Waterjet Rifling   | Cannon Tubes        | Army             |
| • Cold Spray (Aerospace, Vehicles, Tanks, Electronics, Nuclear, Medical) |                     | DoD & OEM's      |

Maintenance Engineering Order (MEO)

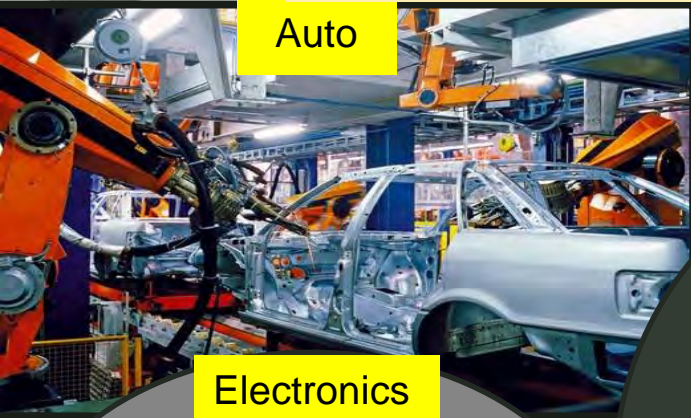
Overhaul Repair Instruction (ORI)

Engineering Technical Assistance Request (ETAR)

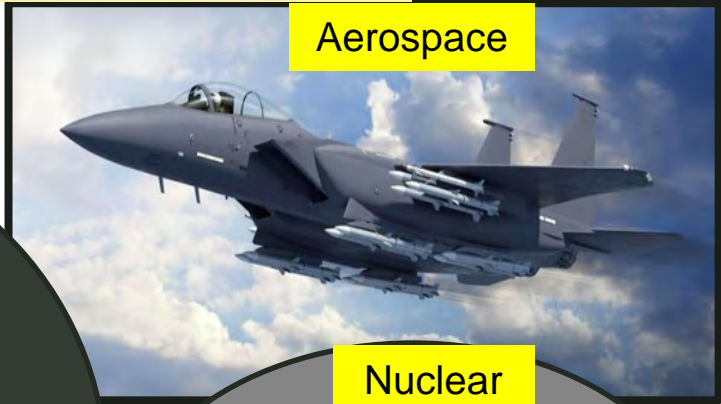
Uniform Industrial Process Instruction (UIPI)



# OEMs, Depots, Shipyards, Air Bases, Cognizant Engineering Authorities and other O&R Facilities



Auto



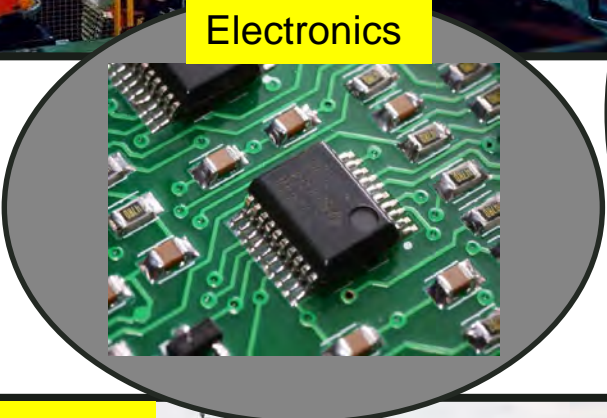
Aerospace



Medical



Nuclear



Electronics



Gas & Oil



Ship



Submarine



# THE DOUBTERS



“good enough for our transatlantic friends.....but unworthy of the attention of practical or scientific men -**British Parliamentary Committee, 1878** referring to Edison’s light bulb.

"Fooling around with alternating current is just a waste of time. Nobody will use it, ever." -  
**Thomas Edison, 1889**

"Heavier-than-air flying machines are impossible." - **Lord Kelvin, 1895** president, Royal Society.

"Who the hell wants to hear actors talk?" - **H.M. Warner, Warner Brothers, 1927.**

"There is not the slightest indication that nuclear energy will ever be obtainable. It would mean that the atom would have to be shattered at will." – **Albert Einstein, 1932**

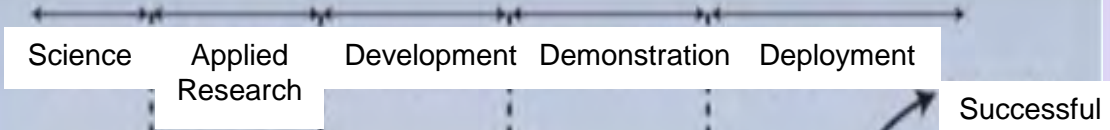
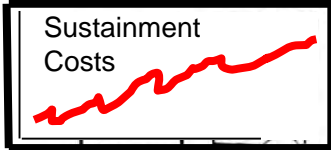
"640K ought to be enough for anybody." - **Bill Gates, 1981**

“Everything that can be invented has been invented”

**Charles H. Duell, 1899**  
US Commissioner, Office of Patents.



# Technology Transition Lessons Learned



Cash Flow



"Valley of Death"

"What if we don't change at all ... and something magical just happens?"





# Cold Spray Vision & Army Roadmap



**VISION: Non-structural Repair** → **Structural Repair** → **Near-net Parts**

Industry  
AF & Army RIF **TRL 9**

RDECOM  
TMR **TRL 8**

OSD & Army  
Mantech **TRL 7**

NAVAIR **TRL 6**

AFRL **TRL 5**

Navy-TIPS **TRL 4**

ESTCP **TRL 4**

DLA **TRL 3**

SBIR **TRL 3**

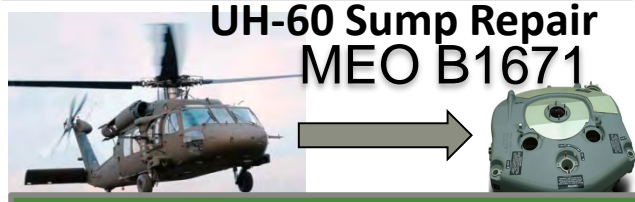
SERDP **TRL 2**

ARL,ONR **TRL 1**



Flexible Robot Environment

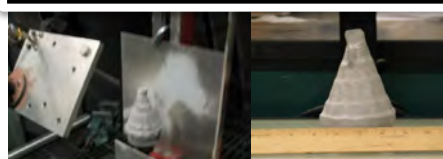
## PRODUCTION



First Approved Army-Navy & Air Force Applications



TD-63 Actuator



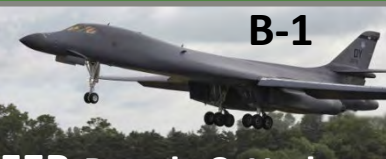
Shaped Charge Liners



Cold Spray 5056Al UTS = to wrought

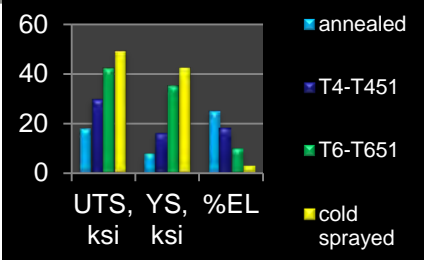
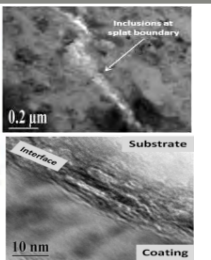
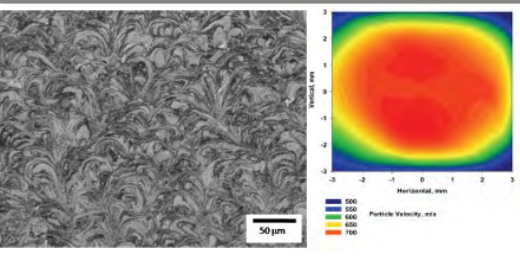


Powder

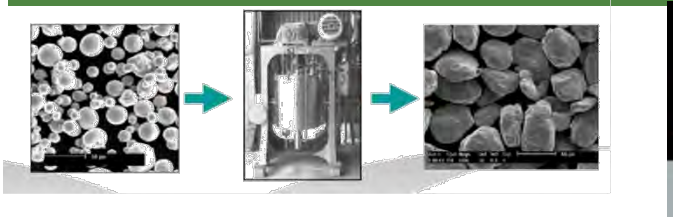


B-1  
FEB Panels & Hydro

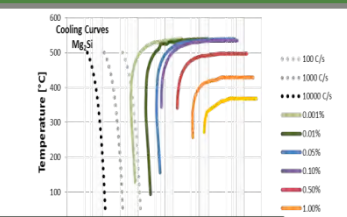
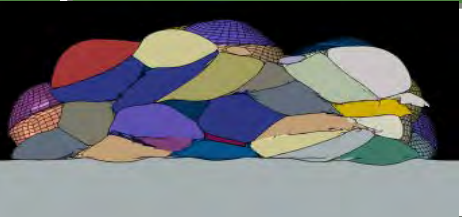
## CHARACTERIZATION & TESTING | PROCESS DEVELOPMENT



## POWDER SYNTHESIS



## MODELING & SIMULATION



High strength/ductile AL (SAM), Encapsulation, WIP, Low Oxide Ta

Particle Interaction & Simulation



# Technology Transfer Workshops



Government

Technician

Engineer

Industry

Academia

Policy Maker

Sales

Mechanic

Research

Manager



# ARL Cold Spray-AM Transition



**Enabled Cold Spray Production Capability for High Volume**

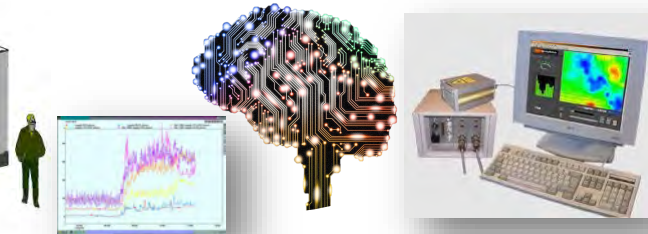
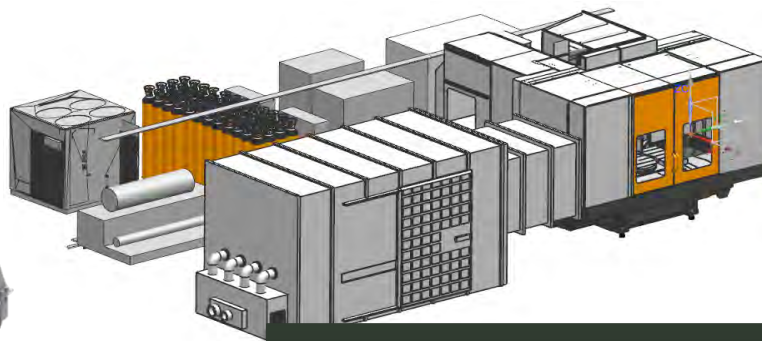
2000's

**Increased Operating Envelope & Established Helium Recovery to Reduce Costs**

2012-2016

**Incorporate Advanced Automation & System Controls**

2016-Present



Intelligent Automation & Controls

In-flight Particle Temperature, Velocity, and Particle Size Measurement

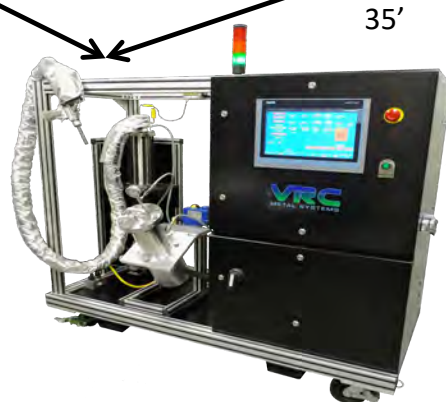
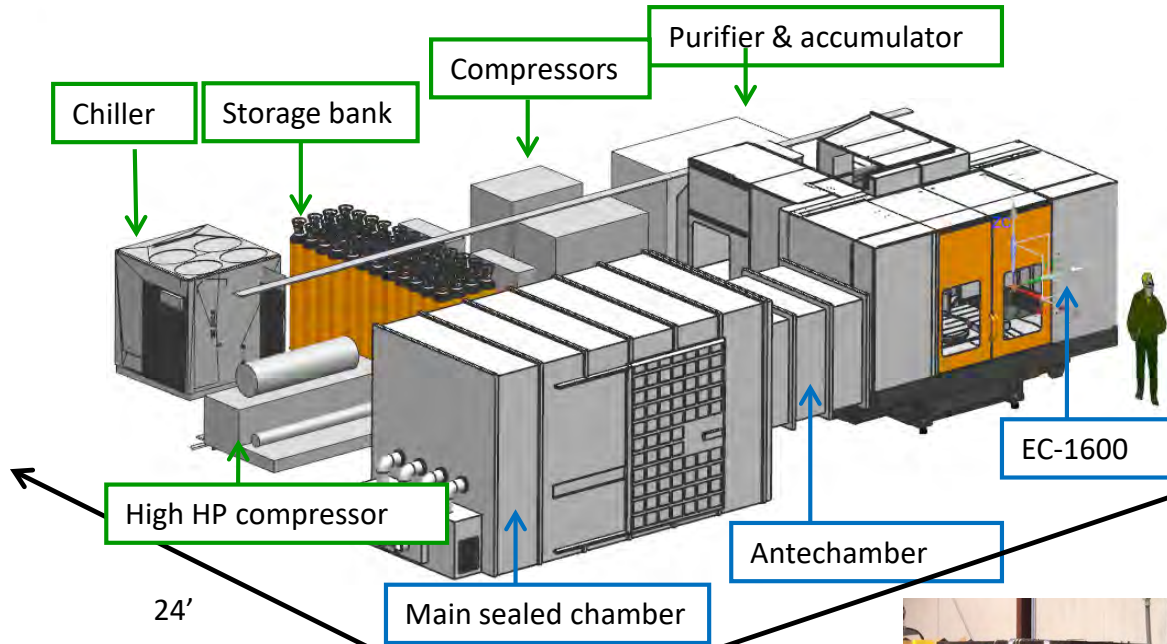
Advanced Motion and Path Planning Capability and Automated System

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





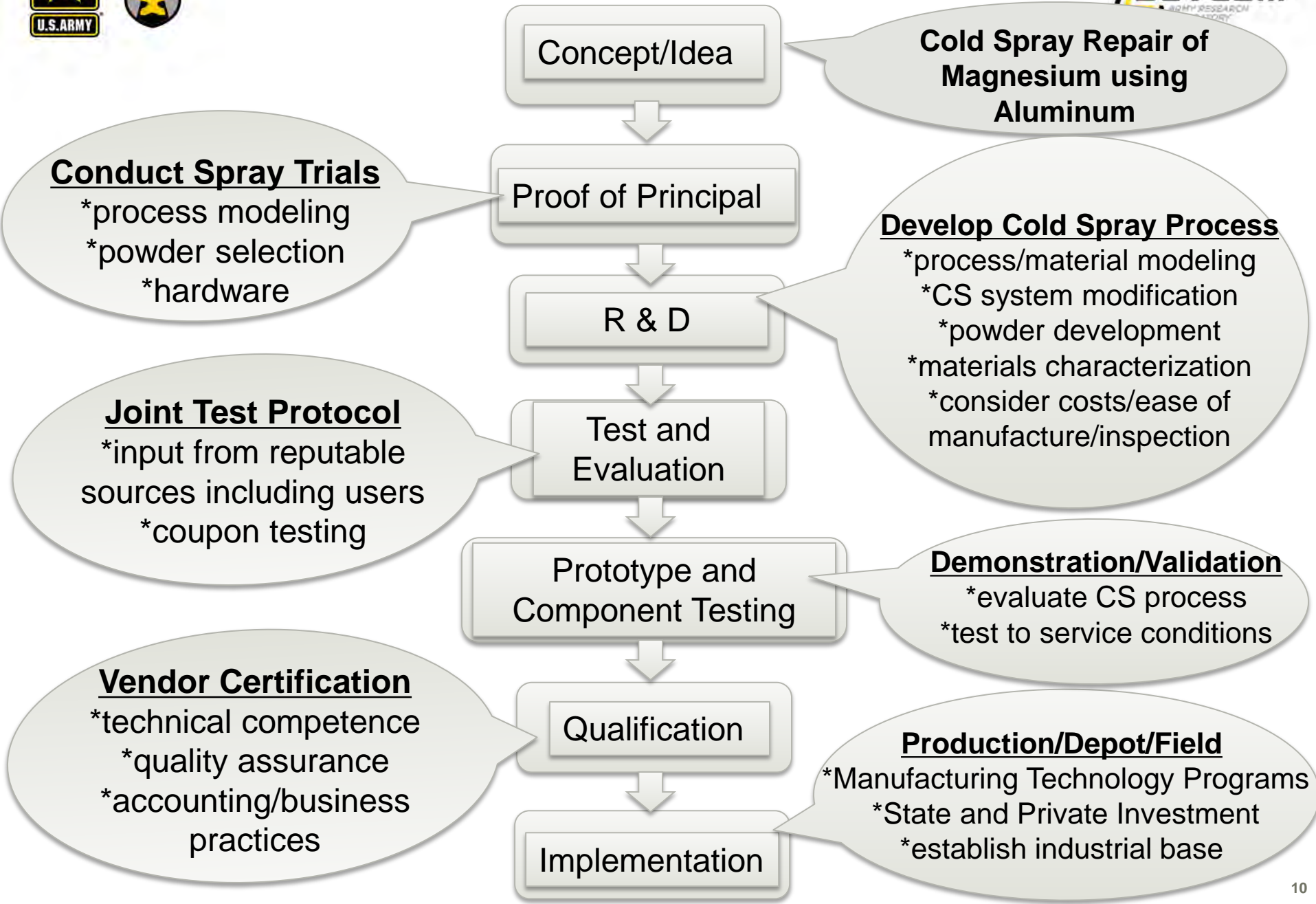
# Cold Spray-Helium Automated Recovery & Repair Manufacturing Production System (CS-HARRPS)



2020 ASM Engineering Award



# Qualification & Approval Process

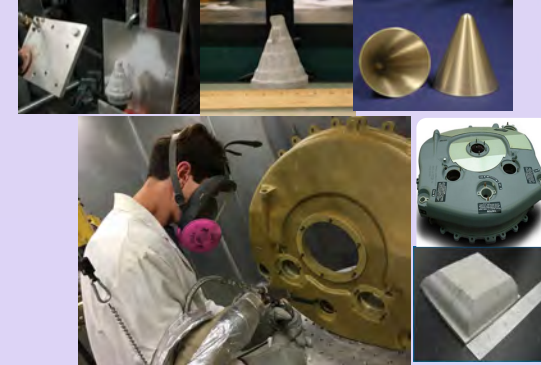




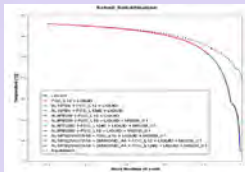
# ARL Holistic Approach to CS Development



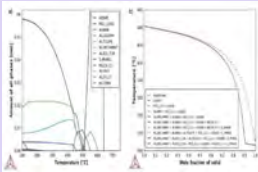
## Applications



### Solidification



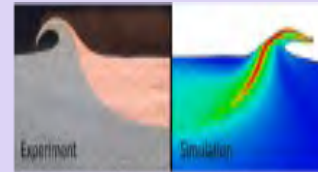
### Thermodynamic



### Particle Acceleration

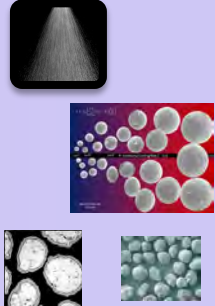


### Particle Impact



## Theoretical Models & Empirical Studies

- Chemistry
- Manufacturing process
- Particle Size and



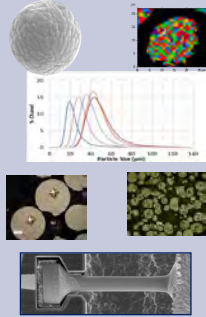
Powder /  
Material Selection

- Degassing
- Heat Treating
- Blending
- Milling



Powder  
Processing

- Microstructure
- Particle Size
- Morphology
- Mechanical Properties



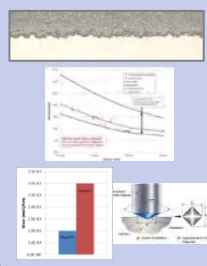
Powder / Material  
Characterization

- Pressure
- Temperature
- Nozzle Geometry
- Substrate Preparation
- Motion Control



Cold Spray  
Process

- Porosity
- Microstructure
- Interface
- Hardness
- Wear
- Mechanical



Post-Processing  
Characterization

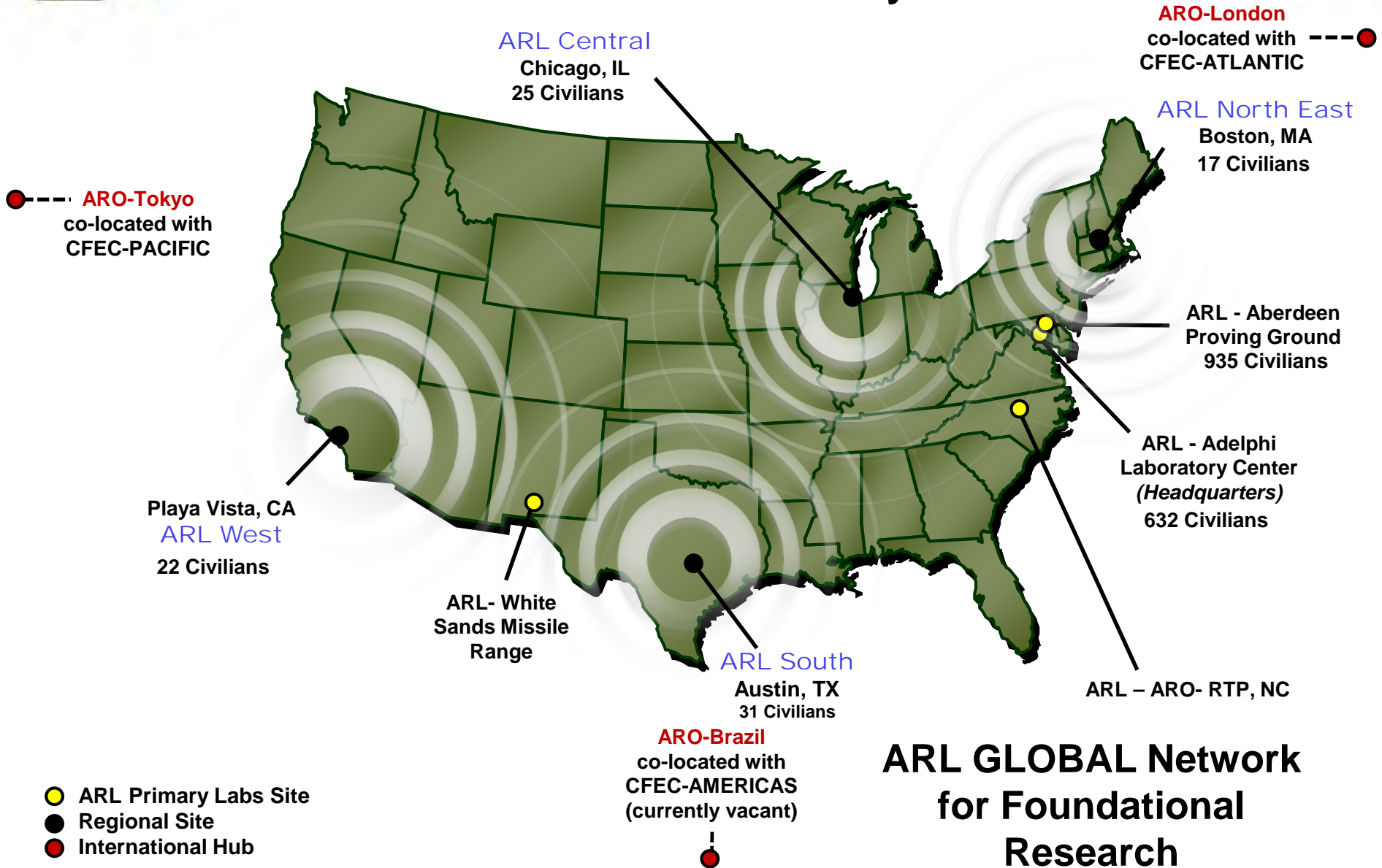
Production &  
Portability

## Transition

- Repair
- AM Parts
- Advanced Automation
- Sensors & Controls
- Machine Learning
- NDT
- Hardware & Software



# ARL is the Army's "Face" to the world-wide Academic Community



## ARL GLOBAL Network for Foundational Research



# Open Campus Initiative: Reduce Barriers to Collaboration or Risk Being Left Behind



**Less bureaucracy and paperwork**



**Open areas for researchers and access to existing facilities**



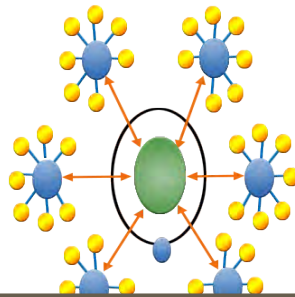
**Collaboration between ARL and external scientists**



**Virtual research centers**



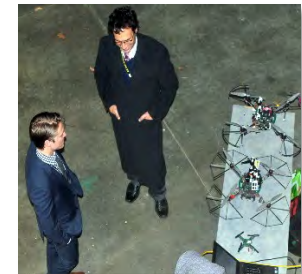
**Career path for students and scientists**



**Hub and spoke Model**



**Collaborator presence through EUL**



**Novel staff opportunities**

**An enhanced defense research environment that fosters discovery and innovation through collaboration on foundational research.**

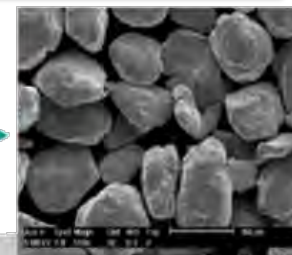
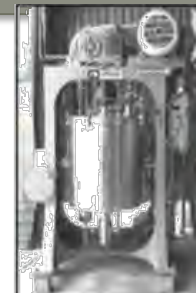
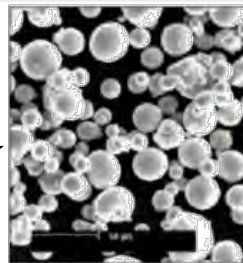


# SUCCESS STORIES-SAM & WIP POWDERS



- Modeling & Simulation
- Powder Processing
- Process Development/Optimization
- Characterization/Materials Database
- Hardware/Software Development
- Nondestructive Inspection/Controls
- Specifications & Standards
- Materials Properties Prediction
- Applications Transition

## MATERIALS BY DESIGN APPROACH



### Aerospace Aluminum

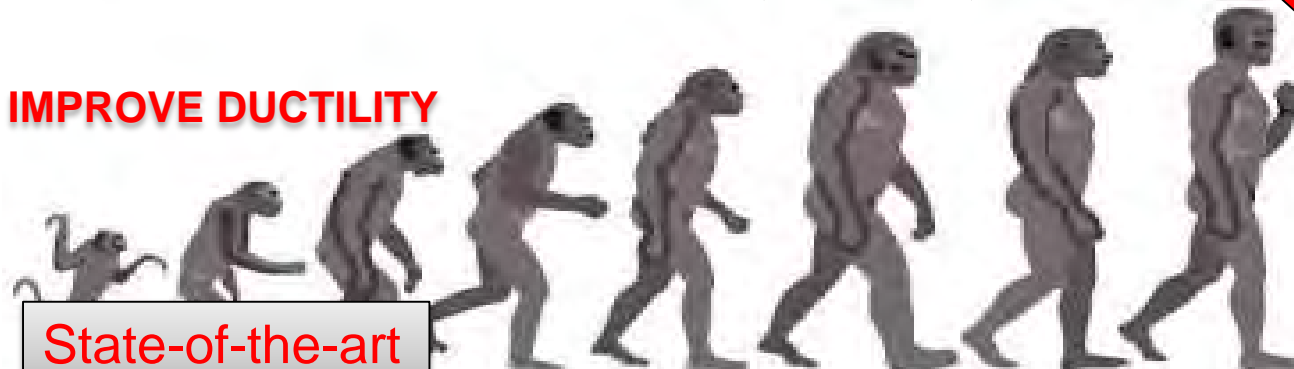
- Modeling & Simulation
- Powder Synthesis
- Intelligent Processing & Controls
- Alloy Development/Optimization



From 1/2 % → 3% → 6% → 15% →



IMPROVE DUCTILITY



State-of-the-art



# Phase 1 of Powder Production Scale-Up



## Inert Gas Fluidized System

- Inert gas system for simultaneous heat treating and fluidization
- Up to 400 °C
- 150 lb per week production
- In-line filtration & quenching systems available
- Presently doubling capacity through introduction of second fluidized bed (2X capacity)



- Inert Package
- Electrostatic dissipating mylar package
- Heat sealed (inert) or vacuum packed for materials that settle
- QR scan for quick ID of powder & properties
- UN Certified Steel pail with lid lock and desiccant
- UN-rated high volume pail
- Easy-adapt system for pouring powder into cold spray feeders (available separately)

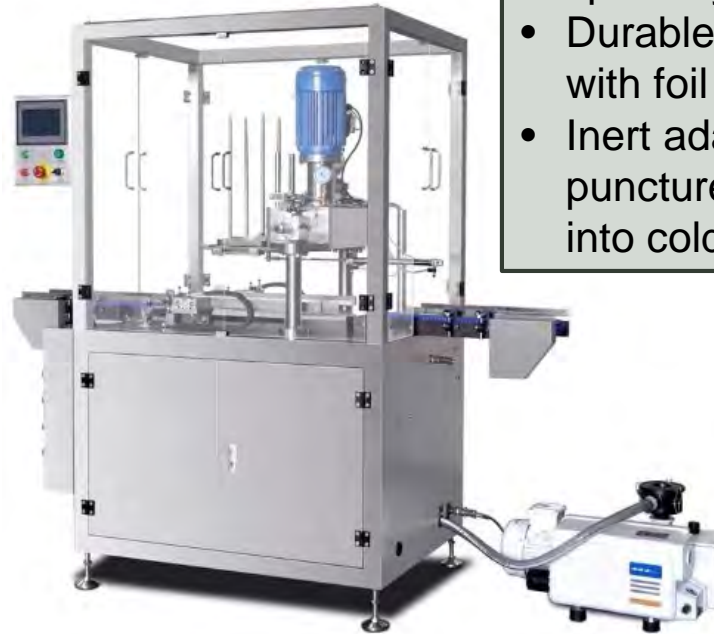


# Phase 2 of Powder Production Scale-Up



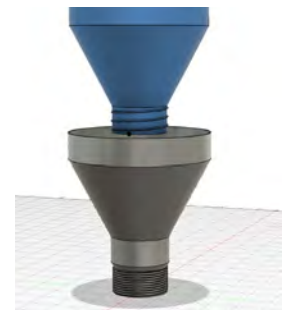
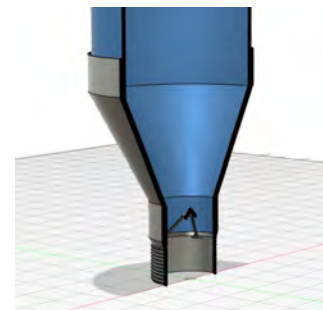
## Rotary Furnace

- Specially designed and built for cold spray powders
- Receives Pre-sized powders (sizing handled via customized fluidization system)
- Up to 1200 °C
- Built in Rapid Quench
- Up to 800lb/wk



## Auto Package

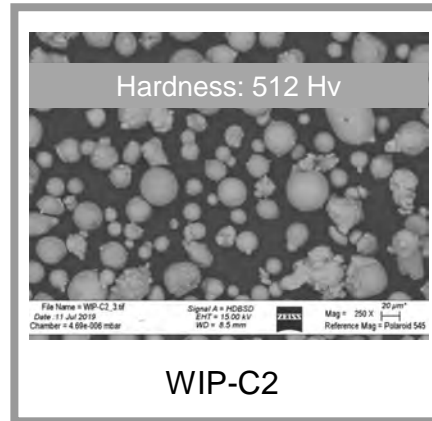
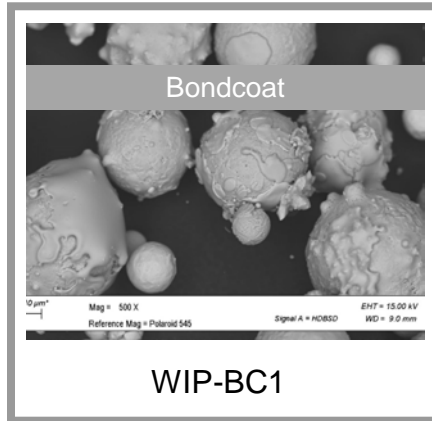
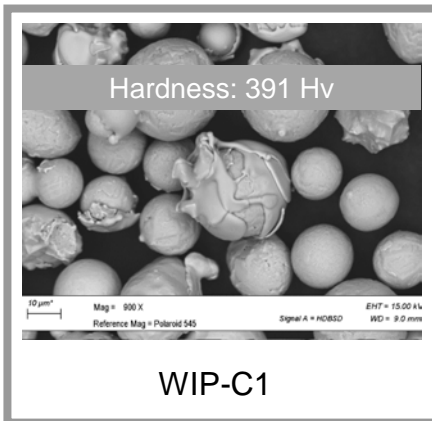
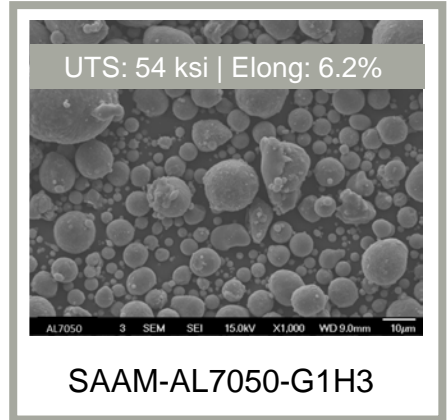
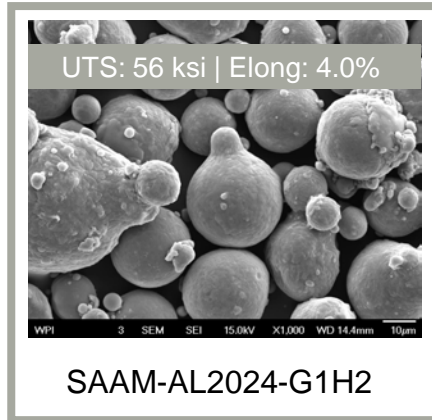
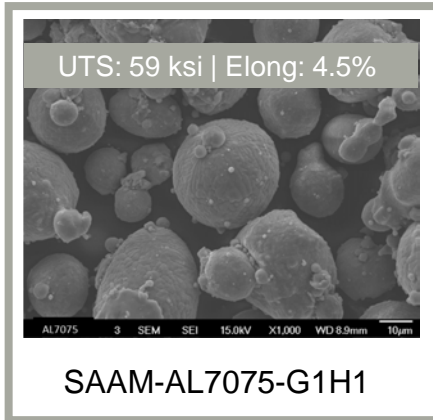
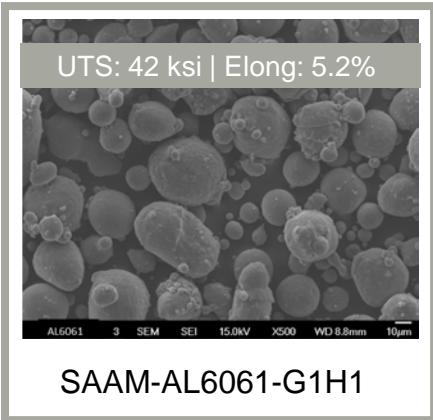
- Up to 10,000lb/wk
- All inert packaging
- Multi-material feed from specialty mixing hopper
- Durable aluminum cans with foil "sure-seal"
- Inert adapter for puncture and feeding into cold spray system







# Current Production Materials

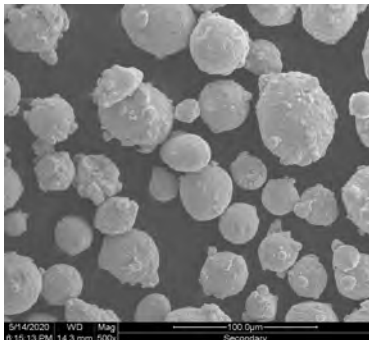




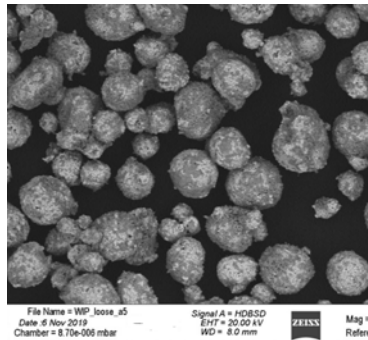
# Near-Term Production Materials



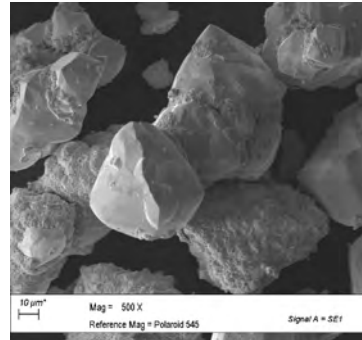
4340 Alloy Steel



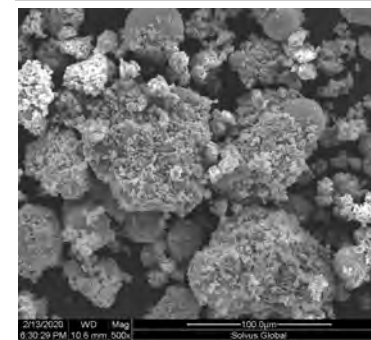
WIP-W1 (WC-Ni)



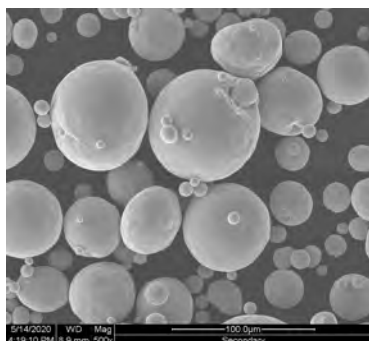
Cu-W



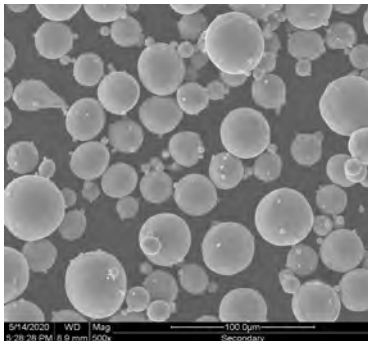
Nitinol



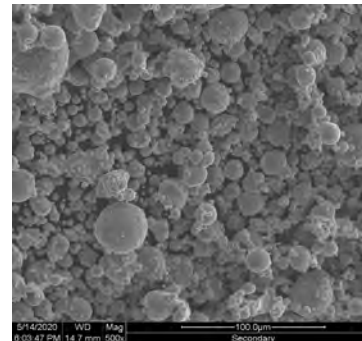
High Purity Copper



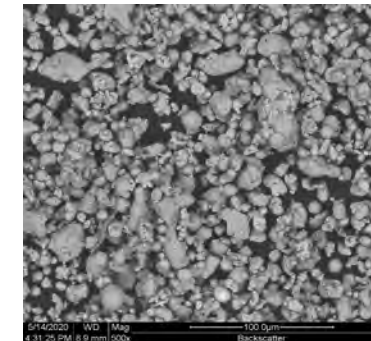
CP Titanium



FeCrAlY



Bronze





# B-1 Air Force Applications

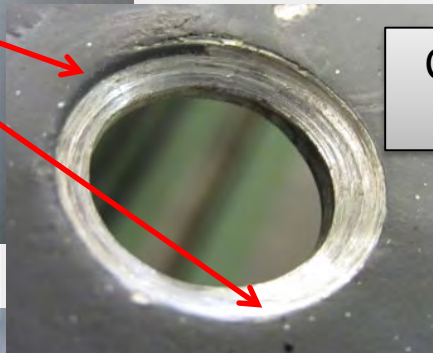
## Chafing - Aircraft Skin Panels & Hydro Tubes



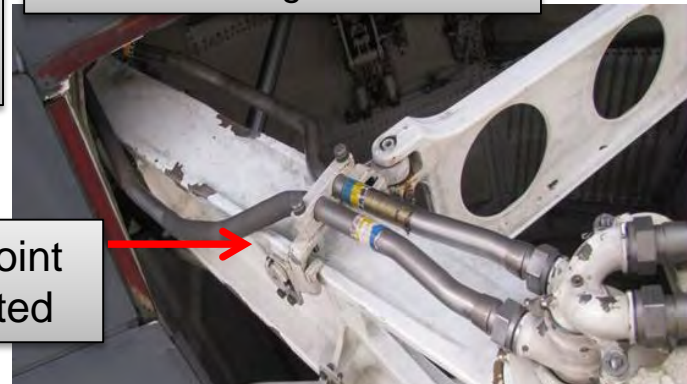
8 panels/aircraft, 4 panels/side  
Lt and Rt sides

Wear beneath bolt  
heads on FEB panels

Main Landing Gear Line



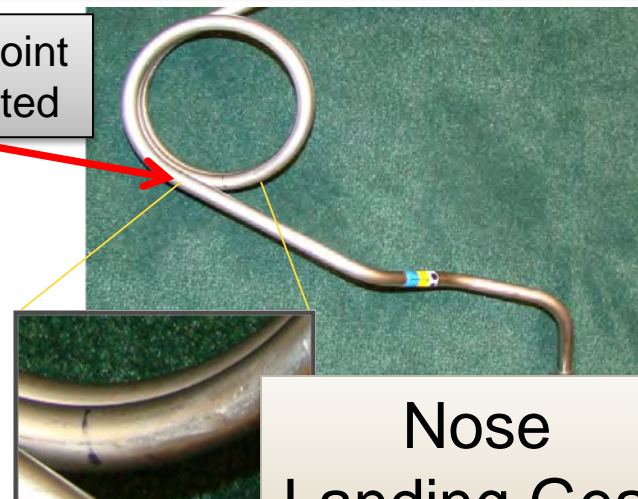
Chafing Point  
Wear Tested



CS Applied Jan 2011 (2 A/C)  
6+ Years 5,379 Combined Flt Hrs



Chafing Point  
Wear Tested



Nose  
Landing Gear

CS Repaired June 2012  
5+ Years, 2,363 Flight Hours

CS Applied Mar 2009  
8+ Years, 2689 Flight Hours



# Technology Transfer Vehicles



## **AMRDEC:** Maintenance Engineering Order (MEO)

- UH-60 Sump approved 2012 (MEO T7631a)
- Numerous aerospace parts have been approved since
- MEOs 1671b, 1718, 2475b, 2722b

## **AIR FORCE:** Engineering Technical Assistance Request (ETAR)

B1-Bomber Hydro-Tubes and FEB Panels approved 2009, 2011 & 2012

## **NAVSEA:** UNIFORM INDUSTRIAL PROCESS INSTRUCTION (UIPI)

- Cold Spray UIPI approved June 2019

- This Type A instruction is applicable to all non-nuclear cold spray repairs performed by or for US Naval Shipyards. Cold spray has been shown to effectively restore surface finish and dimension to damaged components with little risk of distortion to the repaired part.
- Cold spray is suitable for applications not requiring restoration of tensile strength and for which limited ductility is acceptable. When cold spray repairs are required, this UIPI shall be specifically referenced by the technical work document (TWD) or contract.



# How does someone engage in ARL's Open Campus?



- **Explore**  
[www.arl.army.mil/opencampus](http://www.arl.army.mil/opencampus)
  - Review collaboration opportunities and ARL facilities
  - Start a dialog with ARL researcher or regional lead
  - If appropriate, develop joint statement of work within CRADA
- **More Information at**  
[www.arl.army.mil](http://www.arl.army.mil)
  - Army Science Planning & Strategy
  - ARL Technical Strategy 2015-2035
  - Research@ARL
  - ARL Facilities
- **Open Campus Open House**



Collaboration Guide Book

**ARL**  
U.S. Army Research Laboratory

**FACILITIES OF ARL**  
Foundations for the Future



# MECHANISMS FOR COLLABORATION



## ARL with Academia, Small Business and Industry:

- **Cooperative Research and Development Agreement (CRADA)**
- **Patent License Agreement (PLA)**
  - Joint Ownership Agreement (JOA)
- **Educational Partnership Agreements (EPA)**
- **Small Business Innovation Research (SBIR)**
- **Cooperative Agreements (CA)**
- **Grants**

## ARL with Foreign Military / Foreign Government:

- **MOA, MOU**
- **Data Exchange Annex (DEA)**
- **Project Agreements (PA)**
- **Engineer and Scientist Exchange Program (ESEP)**

## ARL with US Military / US Government:

- **Memorandum of Agreement (MOA)**
- **Memorandum of Understanding (MOU)**

## Exchange Staff

Govt  
Industry  
Faculty  
Post Docs

## Leverage Facilities

In House Labs  
Enhanced Use Lease  
Equipment

## Share Data

Reports  
Joint Pubs

## Intellectual Property

Protect IP  
License IP

(Government funding provided to Collaborator : **NO YES**)