

Supersonic Particle Deposition (Cold Spray)

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**US Army Research Laboratory
Weapons & Materials Research Directorate**

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**Cold Spray Center of Excellence at the
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ARL Cold Spray Research Team

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Cold Spray Briefing Objectives

- Overview of ARL Cold Spray Efforts
- Discuss ARL Capabilities and Advantages of Cold Spray
- Present Three Applications of Cold Spray Being Developed at ARL
 - EMI Shielding for HMMWV Electronics Shelter
 - Wear and Corrosion Protection for Rotorcraft Mg Housings
 - Electromagnetic Gun Rails



ARL Cold Spray Customer & Research Programs



Customer/Collaborator

Application

- | | |
|--|----------------------|
| •Defense Science Technology Organization-Australia | Corrosion Protection |
| •National Center for Manufacturing Sciences-MI | Corrosion Protection |
| •ESTCP-NRL-NADEP-AMCOM-PennState-Sikorsky | Corrosion / Wear |
| •Lockheed Martin-CRADA | Nondisclosure |
| •General Dynamics-CRADA | Nondisclosure |
| •NSWC-Dahlgren, VA | Nondisclosure |
| •John Hopkins Applied Physics Laboratory-MD | Nondisclosure |
| •University of Maryland-UMBC,MD | Power Electronics |

6.2 Research

Application

- | | |
|----------------------|---|
| •Electromagnetic Gun | High Temperature/ Wear Resistant Coatings |
| •Emerging Materials | Nanomaterials (Nondisclosure) |
| | Munitions (Nondisclosure) |

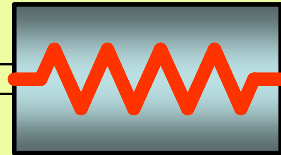
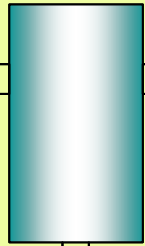


Cold Spray System Configuration

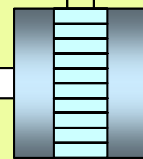
Gas Control Module

Electric Heater

N_2 or
He gas



Powder Feeder



Supersonic Nozzle

Particle Stream

Substrate

Deposit

- Main Gas Pressure 100-500 psi
- Gas Temperature 0-1300°F
- Main Gas Flow Rate 20-60 CFM
- Powder Feed Rate 1 to 10 pounds/hour
- Particle Velocity 300-1500 m/sec.



Stationary Cold Spray System at ARL



Robot-Controlled, High Pressure, He and N Gas

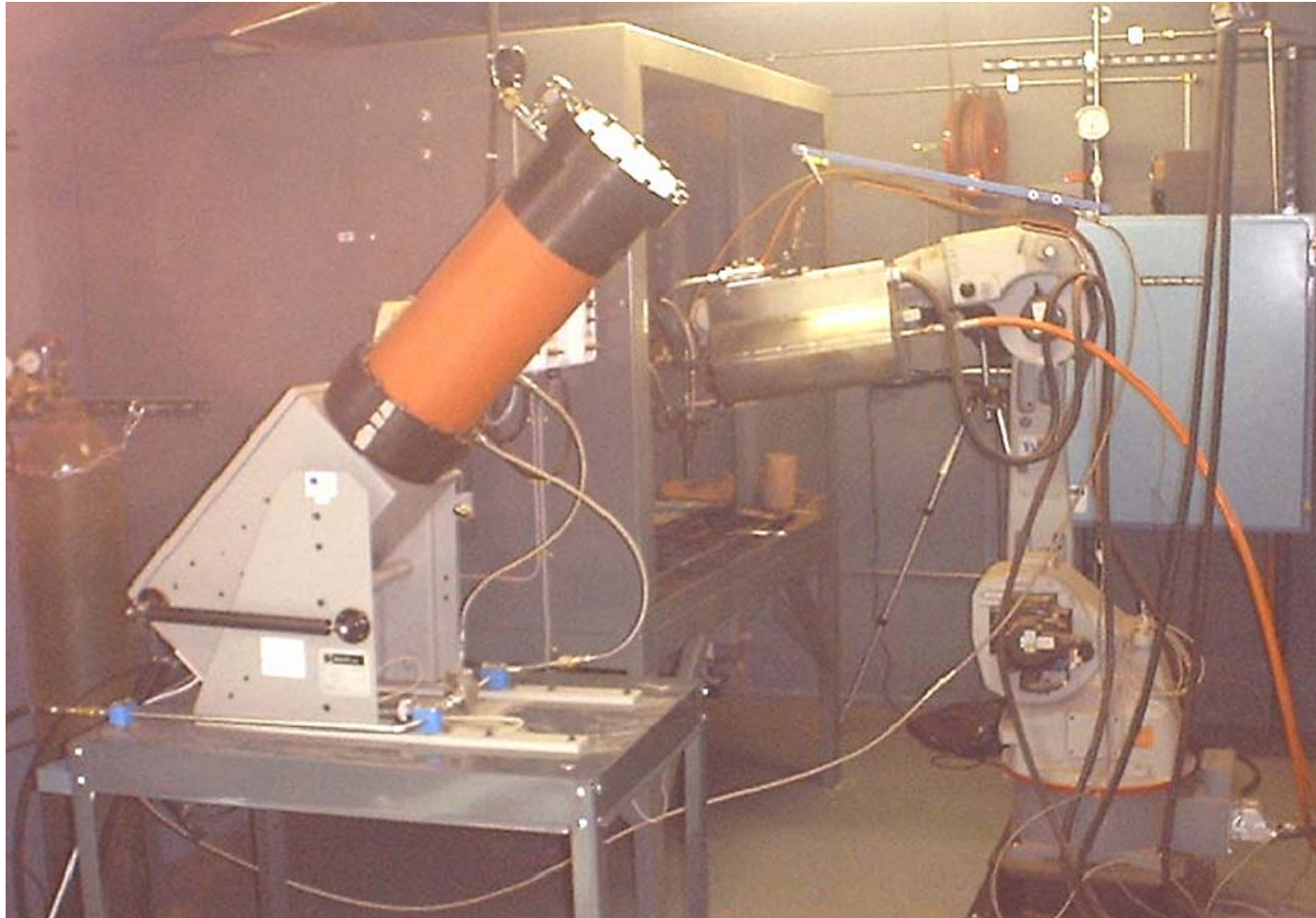


Main Gas Pressure 100-500 psi Gas Temperature 0-1300°F Main Gas Flow Rate 20-60 CFM

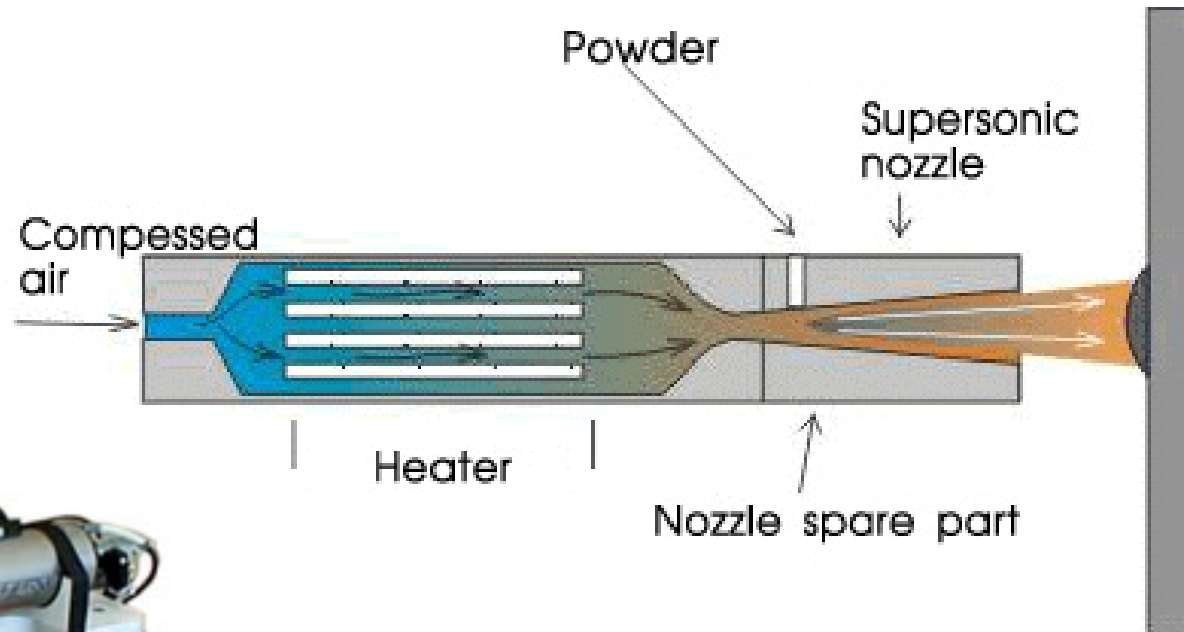
Powder Feed Rate 1 to 10 pounds/hour

Particle Velocity 300-1500 m/sec.

Army Research Laboratory SPD System



Portable Cold Spray Systems at ARL



- Hand-Held Heater-Nozzle
- Shop Compressed Air
- Particle Velocity 300-500 m/s



Cold Spray Advantages

Superplastic Particle Agglomerate Mixing (SPAM) bond

Plastic deformation may disrupt thin oxide surface films to permit bonding

Similar to explosive welding

Compressive residual stresses

Particles “peen” surface

Plasma and wire-arc thermal spray tend to be tensile

High density

Porosity: < 1 % - 10 %

Thick coatings

Free-form fabrication up to 1” thick.



EMI Shielding for HMMWV Shelter by Cold Spray

ARL Produces First Prototype Using Cold Spray Technology for the Terminal High Altitude Area Defense (THAAD) Project Office.

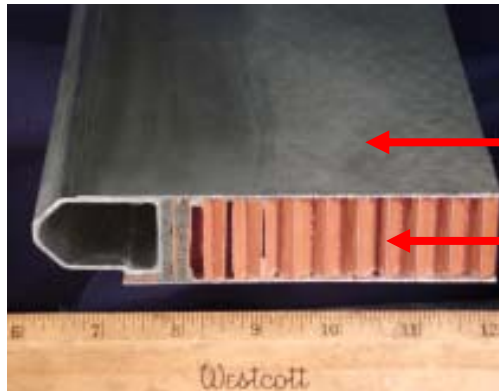


➤ HMMWV shelters require EMI shielding to prevent entrance/escape of electronic signals.

➤ The joints in al-composite walls must be sealed with a non-porous, conducting metal.

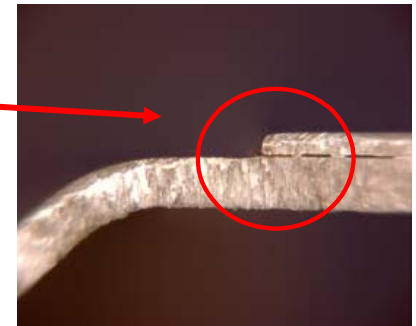
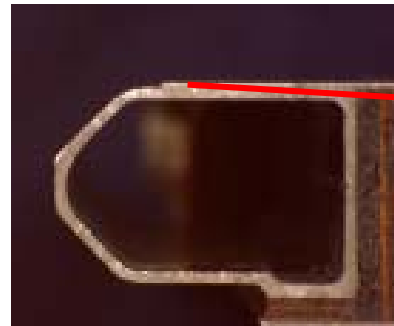
➤ The composite structure requires low-temperature application of sealer.

Conductive material needed to fill seams



← Aluminum

← Composite



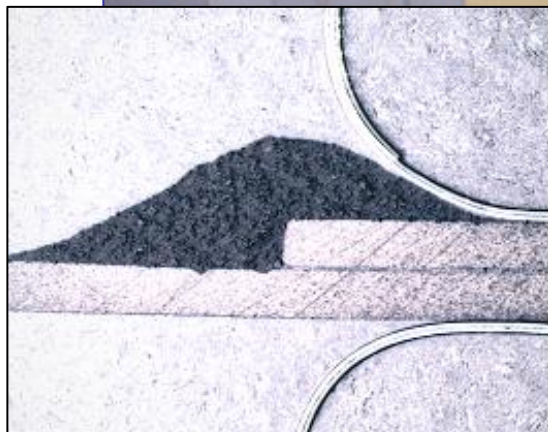


Applying EMI Shielding on the HMMWV Shelter

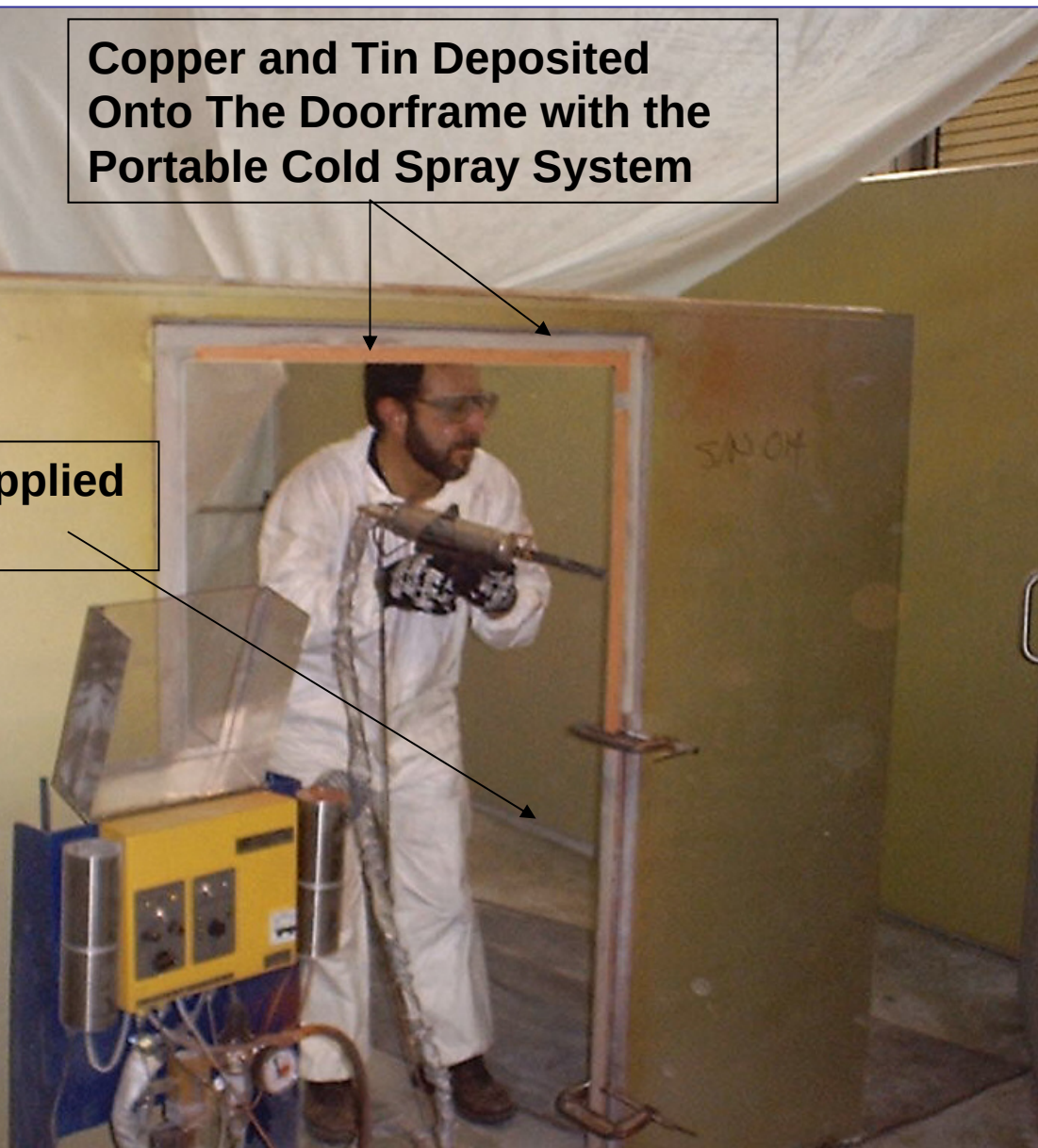


**Copper and Tin Deposited
Onto The Doorframe with the
Portable Cold Spray System**

**Aluminum/Zinc Applied
to Interior Seams**

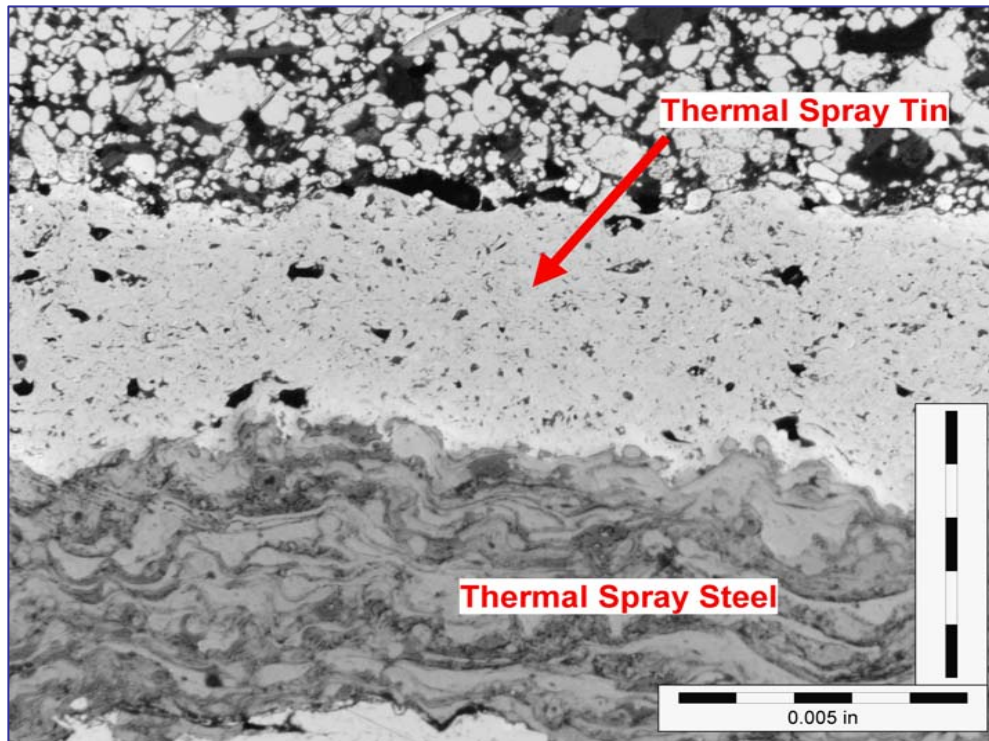


**Cross Section of Cold
Spray Coating**

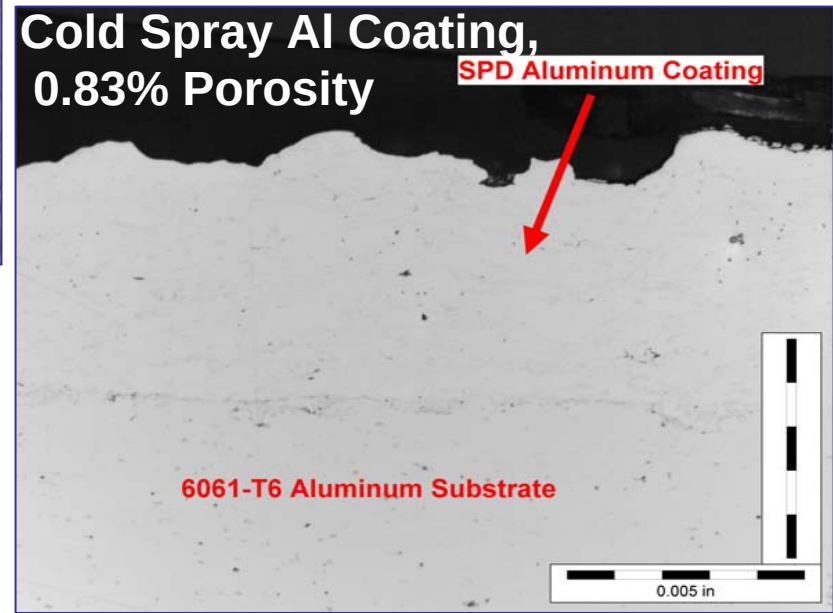
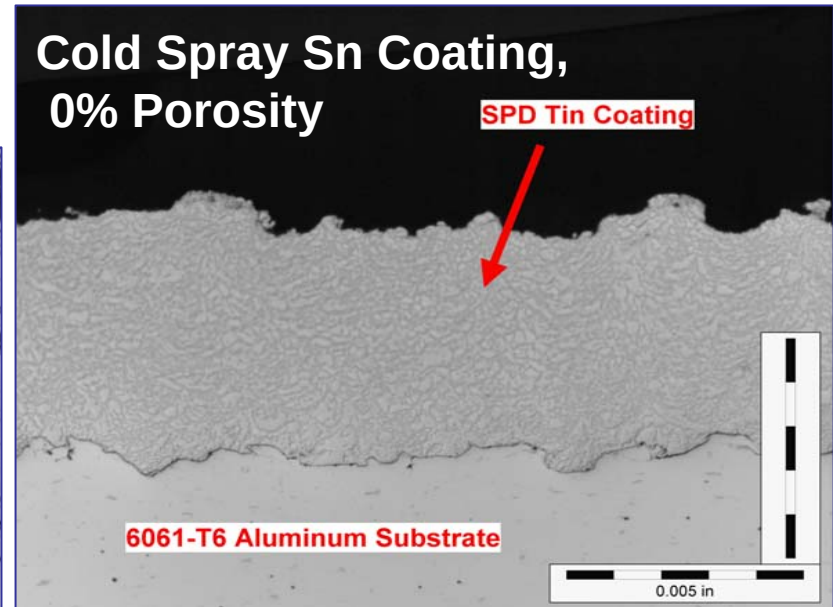




Comparison of Cold Spray and Thermal Spray



**Flame Spray Tin Coating
12.2% Porosity**





Cold Spray Technology for Repair of Magnesium Aircraft Components



ESTCP Proposal 06-E-PP3-031

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Use of Magnesium Alloys



- Magnesium alloys used throughout the aircraft industry for gearboxes on helicopter transmissions and gas turbine engines
- Use of magnesium alloys expected to increase due to favorable properties:
 - 40% lighter than steel and 20% lighter than aluminum on a like-for-like strength ratio
 - Good damping qualities, absorbing noise and vibration
 - Low density means easier, faster machining of components
 - High thermal conductivity and good EMI shielding
 - Ductile, with ideal casting properties; can be molded into large, thin-walled components at near net shape
- Current usage and future increased usage impacted by high reactivity and susceptibility to corrosion (especially galvanic corrosion); relatively soft and susceptible to scratching; adhesion problems of coatings



H-60 Transmission System Powertrain

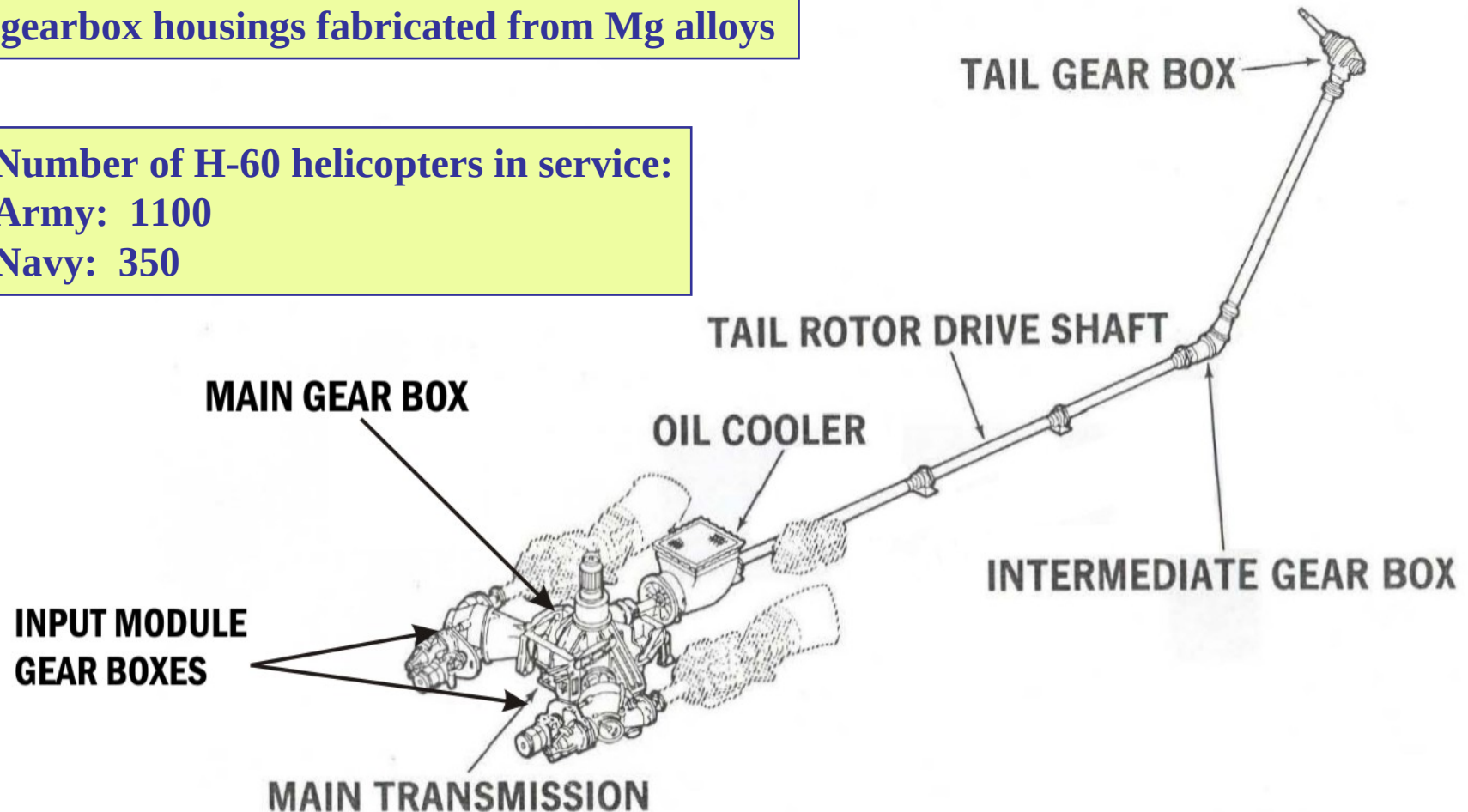


All gearbox housings fabricated from Mg alloys

Number of H-60 helicopters in service:

Army: 1100

Navy: 350





Magnesium Alloy Components on Joint Strike Fighter

- **Four Mg gearboxes in power system**
 - Two on engine generator
 - Two on the Integrated Power Package (which supplies all aircraft power when engine not running)
- Dow 17 would normally be used on these components but chromates are on JSF Restricted Materials List; therefore, JSF intends to investigate alternative surface protection processes



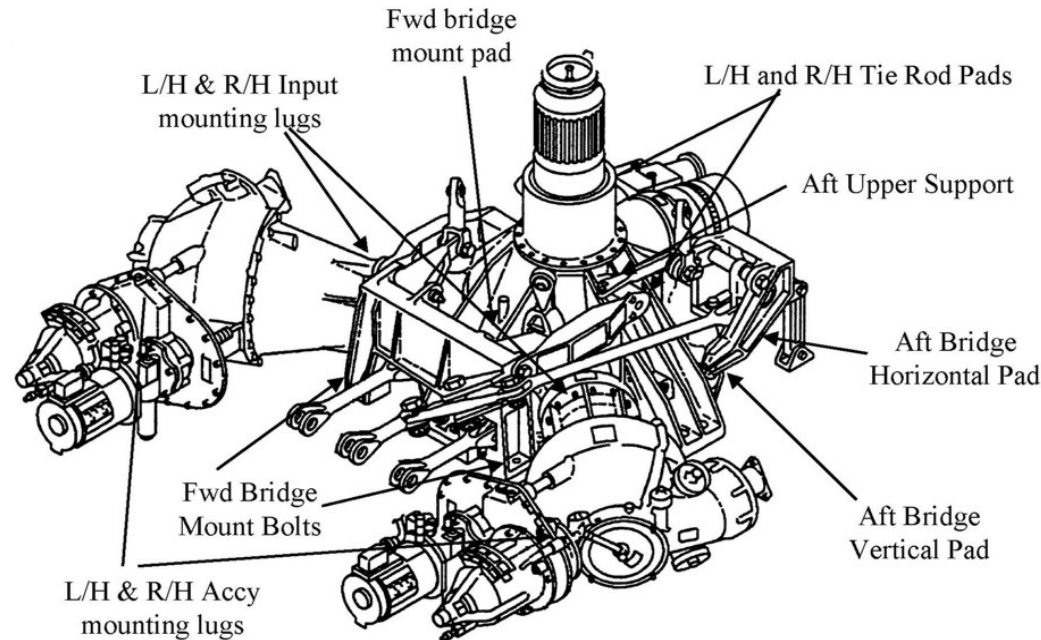
**Power and Thermal Management
System magnesium alloy
generator housing**



Performance Problems With Current Surface Treatment Methods



- Even with chromated surface treatments, Mg components suffer severe degradation in service
- Most corrosion occurs at mating pads, supports, and mounting lugs where dissimilar metal is in contact with Mg; damage is most likely to occur in those locations as well



H-60 Main Transmission Housing showing areas most susceptible to corrosion

Corrosion on H-53 Tail Gearbox Housing





Requirements for Mg Alloy Components to Address ESOH Issues & Improve Performance

Requirements:

- Alternative method that is ESOH benign for surface anodization of all surfaces to increase corrosion protection and scratch resistance
- ESOH-benign method for depositing aluminum coatings in critical areas to enhance corrosion protection and provide for restoration of severely corroded/damaged components; will enable restoration of components currently declared salvage

Solution:

- Plasma electrolytic oxidation (Tagnite or Keronite processes) for anodization is being qualified on components
- Cold Spray of aluminum coatings on critical areas, combined with PEO, will provide TOTAL solution to problem



Pure Al Applied by Cold Spray to ZE 41AMg

Cold Spray
Al Coating
0.015 inch

6,000 psi
adhesion





Expected DOD Benefit

Magnesium Gearbox Housing Repairs at Sikorsky Aircraft Overhaul and Repair Facility

Average Annual Figures

<u>Model</u>	<u>Main</u>	<u>Intermediate</u>	<u>Tail</u>
H-60	275	48	200
H-53	35	20	20

Total of 598 housings repaired

From Sikorsky data, approximately 33% (~ 200) of the housings that go through repair facility must be replaced due to severe corrosion/damage at average cost of \$20,000; total annual cost is \$4,000,000

Sikorsky engineers estimate that 60% of scrapped housings could be recovered using SPD; deposition of Al onto housings estimated to cost \$1500. Therefore, anticipated cost savings is $(\$20,000 - \$1500) \times 200 \times 0.6 = \$2,220,000$



ARL Introduces Novel Technology for the EM Gun

ARL completed coating the first two twelve foot long aluminum rails by the Cold Spray technique which tested successfully at IAP in Dayton, Ohio 7-8 June, 2005.

The results of the test indicate that this technology is a major breakthrough, since it is the first time that a coating/liner has been adhered to the rail without failing during actual test firing.

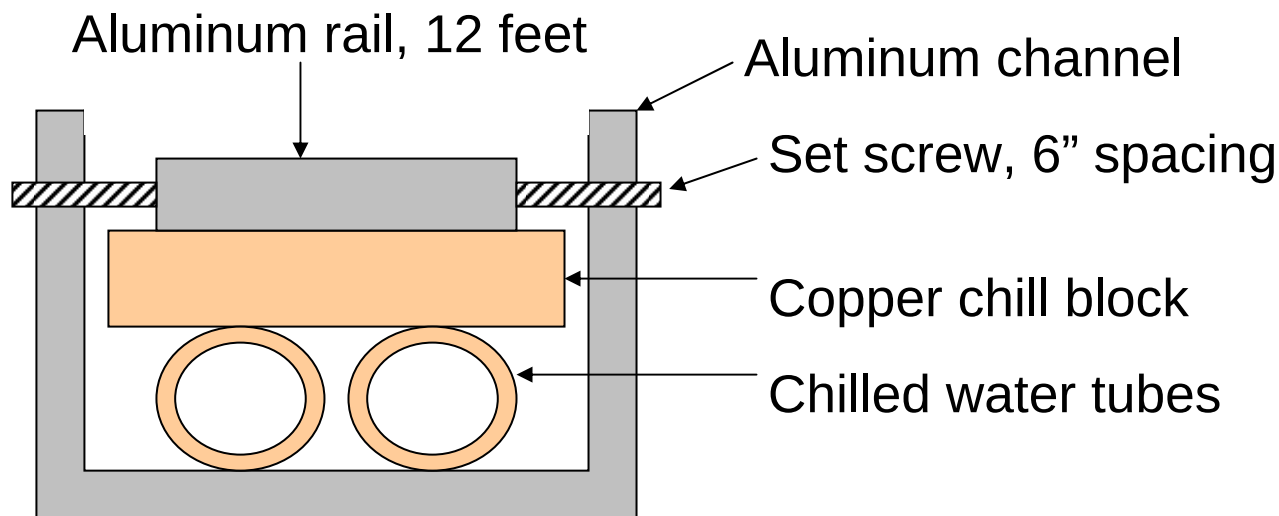
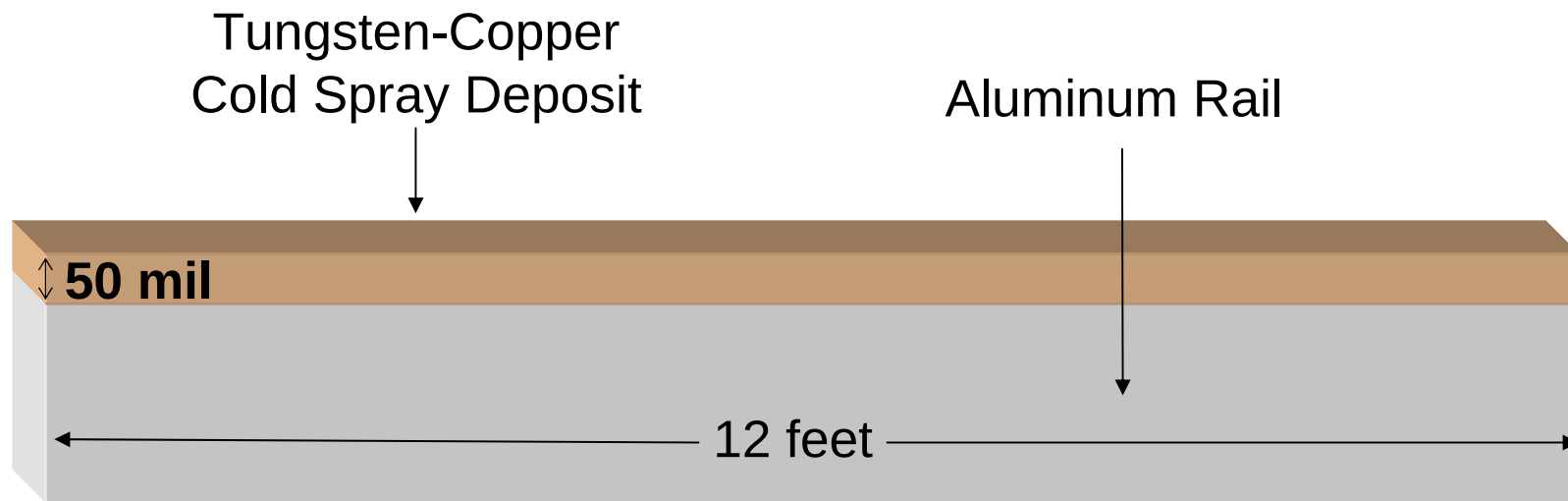
This technique utilizes micron sized particles of metal that are propelled at supersonic velocities onto a substrate to form a coating that becomes part of the substrate, analogous to explosive bonding.

ARL is the only DOD facility to have developed this technology for the EM Gun Rail application.

The coating consists of a high concentration of tungsten 70-80% and copper, which results in a hard, wear resistant but very conductive coating.

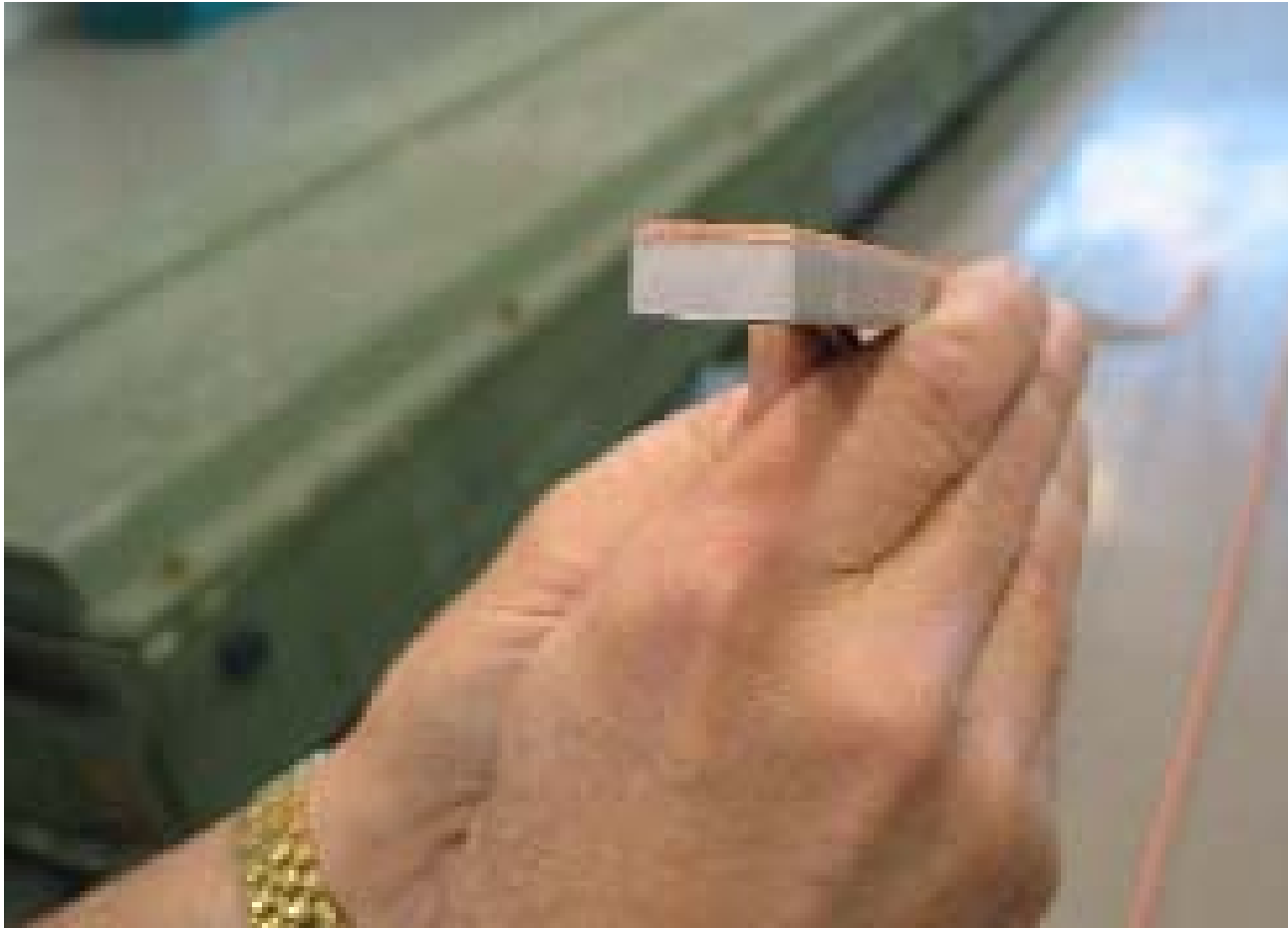


Apparatus used to Cold Spray W-Cu Coatings





Coated EM Gun Rail by SPD 70%W-30%Cu



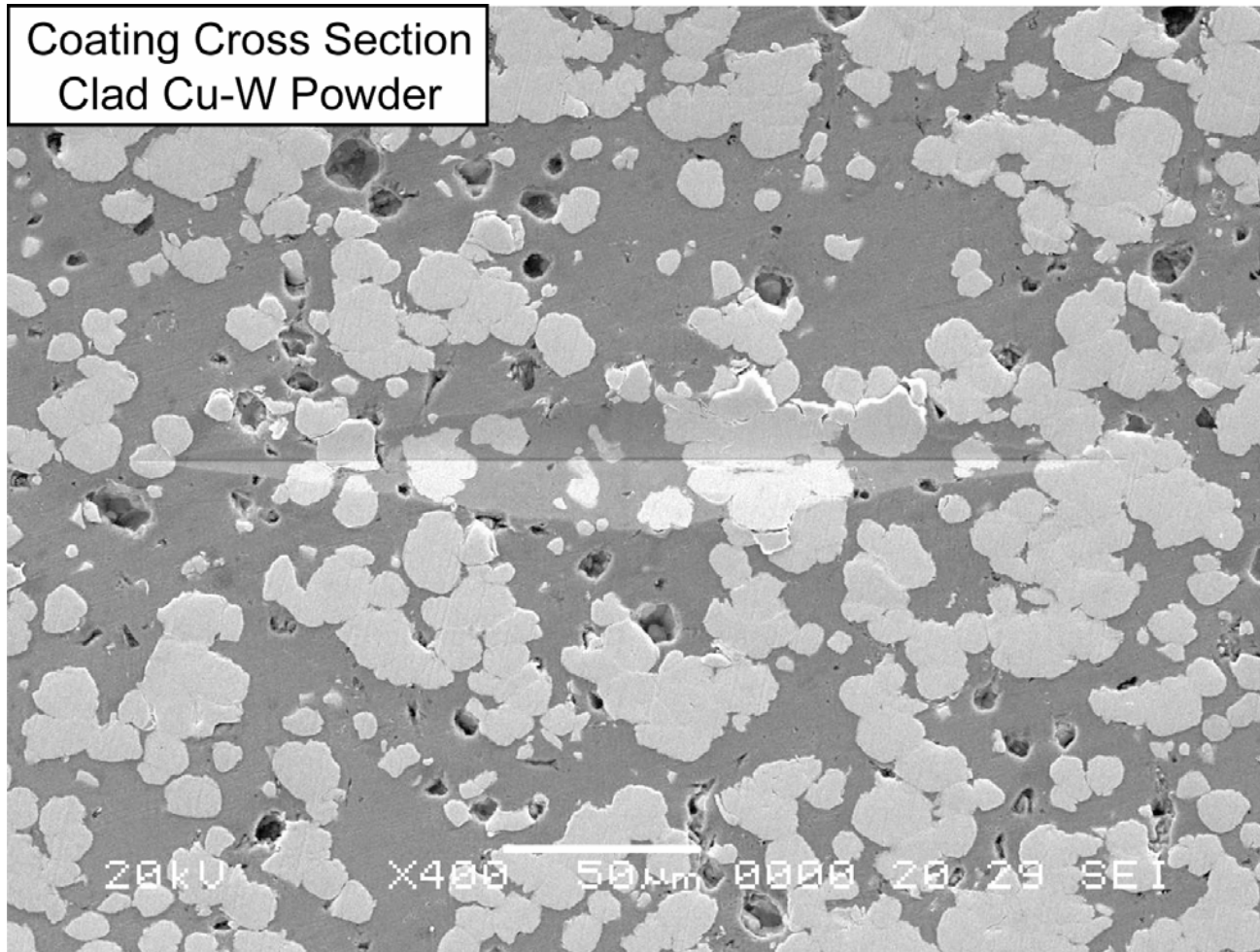
Close Up of Cold Coating on 6061-T6511 Aluminum



Front View of Coating

Hardness Indent of W-Cu Cold Spray Coating

Coating Cross Section
Clad Cu-W Powder



- Impression from the Knoop microindenter.
- Demonstrating the ductility of the Cu-W pseudoalloy.
- No cracking is evident.



“The progress of Cold Spray Coatings Technology indeed brought us one step closer for having EM rail guns as a tactical weapon” **Jerome Tzeng**



Ten shots were fired from a 4 meter long laboratory gun at a muzzle velocity range of 2.2 to 2.8 km/s.

The rails were charged up to 480k Amp of current that yielded to a current density of 45k Amp/mm, considered as a high performance rail gun.

The rail coatings were intact through the very intensive test schedule.



Hardness of Various Cold Spray Coatings



	Knoop Hardness	Equivalent HRB/HRC
Cold Spray Cu-W (powder mixture)	151	75-76 HRB
Cold Spray Cu-W (clad powder)	197	89-90 HRB
Cold Spray Ta	256	21 HRC
Cold Spray Ni	403	40-41 HRC



Cold Spray Coating of Nickel On 6061-T6 Al

Nickel
Coating



Hardness of HRC 41 and Adhesive Strength of 10,000 psi

NICKEL COATED EM GUN RAILS TO BE TEST FIRED FEBRUARY 2006



Video of Portable Cold Spray System

