NAVAIR Corrosion Program
Materials, Coatings and Corrosion

Project Success's

2011DOD Maintenance Symposium

Frederick Lancaster AIR 4.3.4 Materials Engineering

OUTLINE

Background – Cost of Corrosion/Impact
  - Naval Aviation Enterprise
- Drivers & Challenges
- Next Gen Materials
- Technology & Application Areas
- Efforts
- Summary

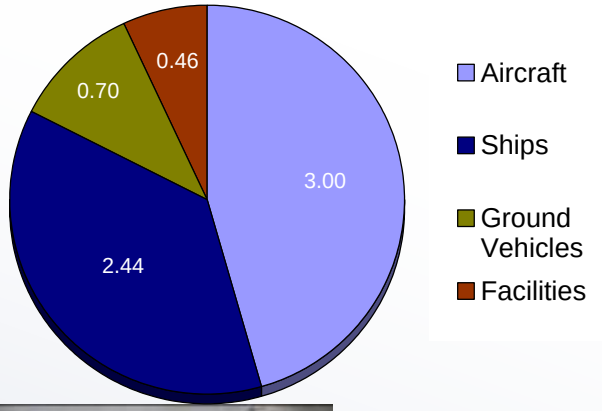
IMPACT OF CORROSION: NAVAIR

Acquire — Sustain — Retire

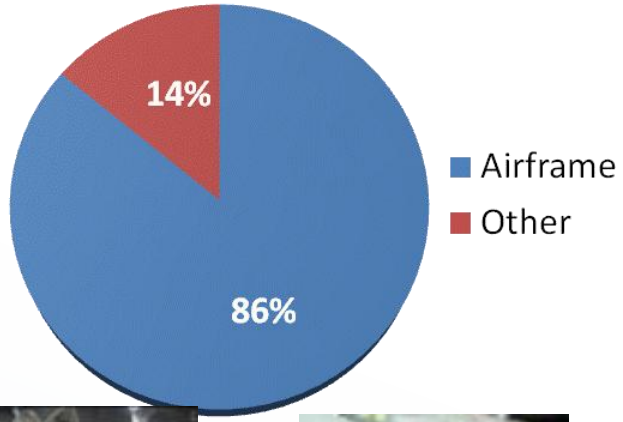
Total Annual Navy Cost, $6.6B

NAE Annual Cost, $2.6B avg

Corrosion Maintenance Costs, $B



$3B Corrosion Maintenance Cost



"death by a thousand cuts"

SUCCESS STORY: COLD SPRAY METALLIZATION REPAIRS

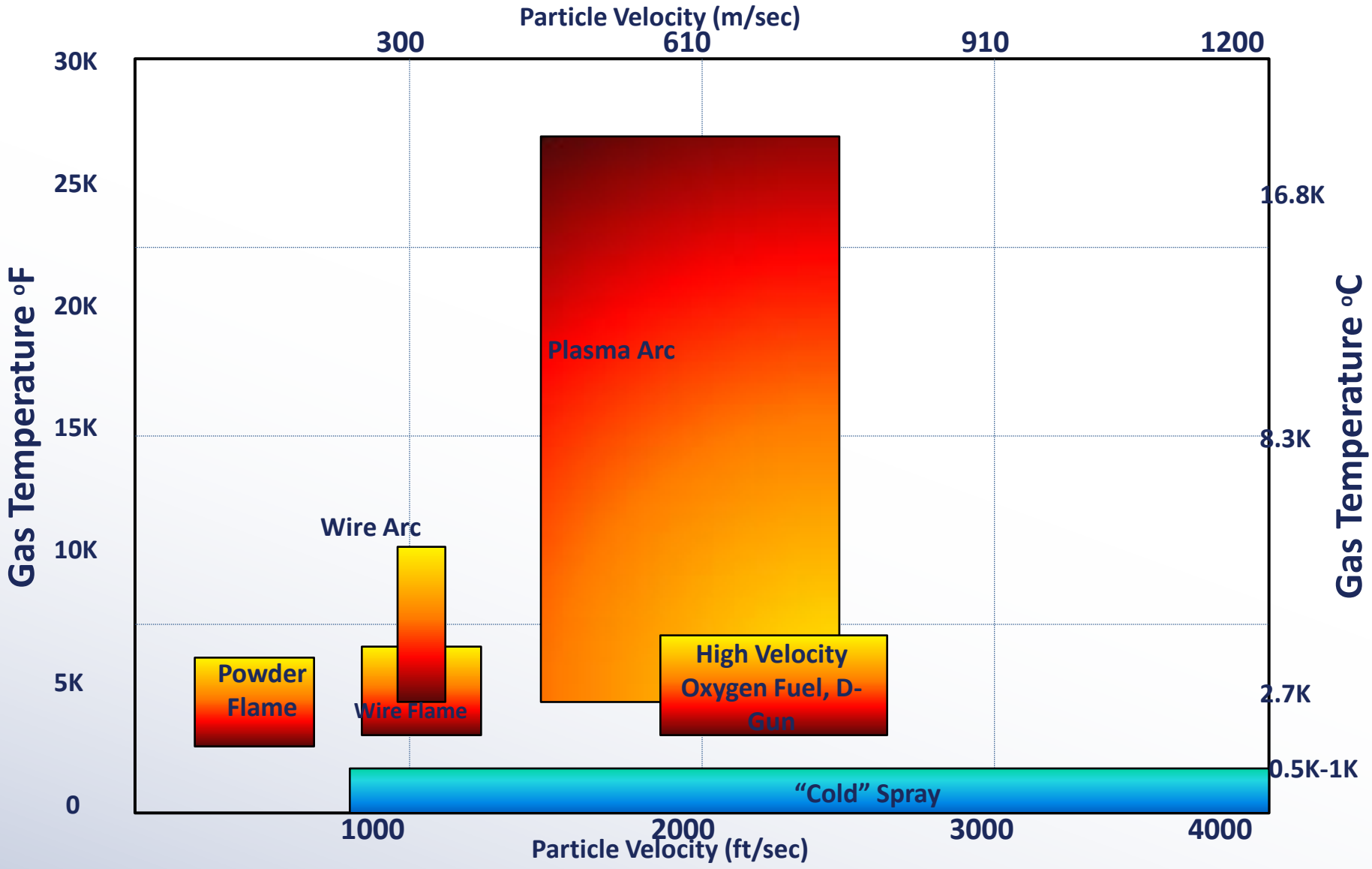
Cold Spray: What is it?

It is a lower temperature thermal spray process, where for the first time in aviation materials we now have the ability to put metal, (aluminum & magnesium in our case), back to the original or better material condition.

A disruptive, game changing technology for repairing corrosion, dimensional, & structural damage on and off aircraft

- Without additional effects such as heat.
- Ability to restore physical properties.
- Matches base material

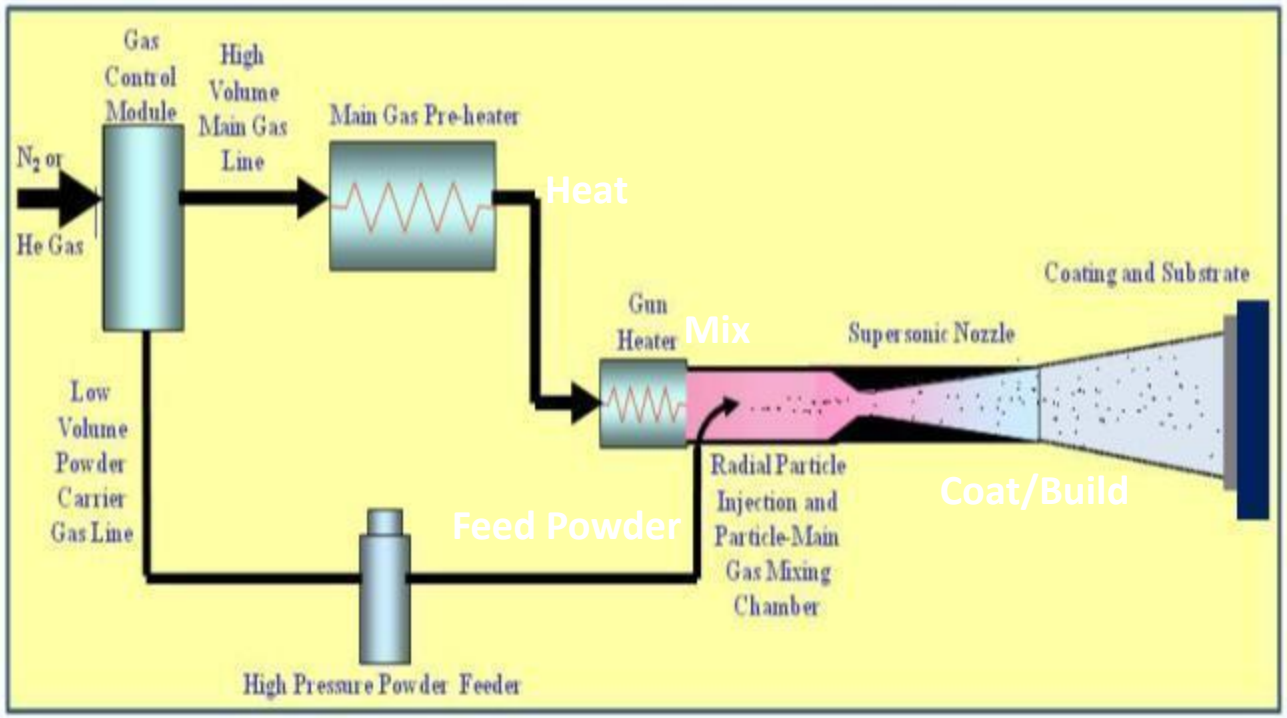
“Cold” Thermal Spray Process



Cold Spray Process

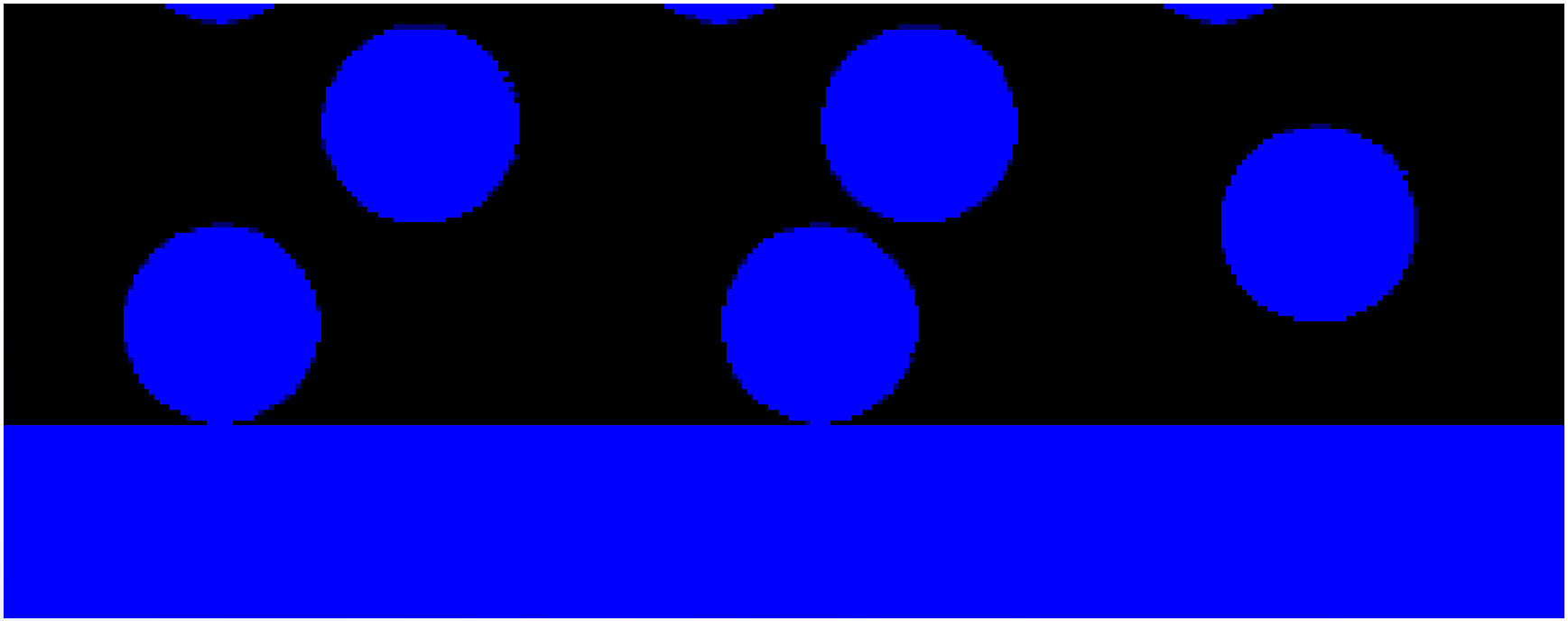
1. HEAT: Heated high-pressure gas such as He or N_2 or Air is introduced,
2. FEED: ***Particles of a metal*** (transition), ceramic and/or polymer are injected,
3. MIX: Both merge into a De Laval rocket nozzle, particles exit at supersonic velocities
4. COAT: Particles consolidate upon impact forming a coating or free-standing structure.

- **Gas temperature range from Room Temp to 800° C**
- **No melting of particles**
- **No decomposition or phase changes of deposited particles or substrate**
  - **Particles 1 to 50 µm diameter**
  - **Particle velocity400 to 1500 m/s**



Courtesy of ARL

Particle/Substrate Interaction*

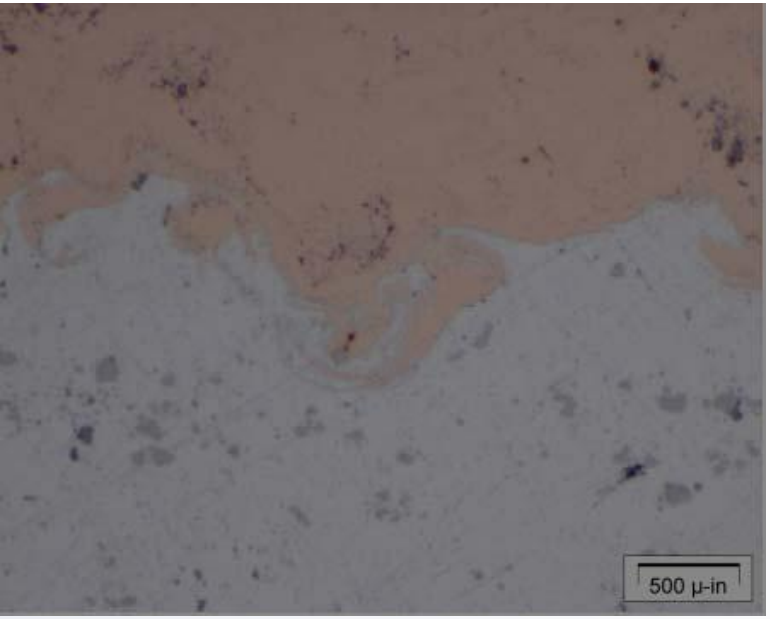


*from H. Assadi, www.modares.ac.ir/eng/ha10003/CGS.htm

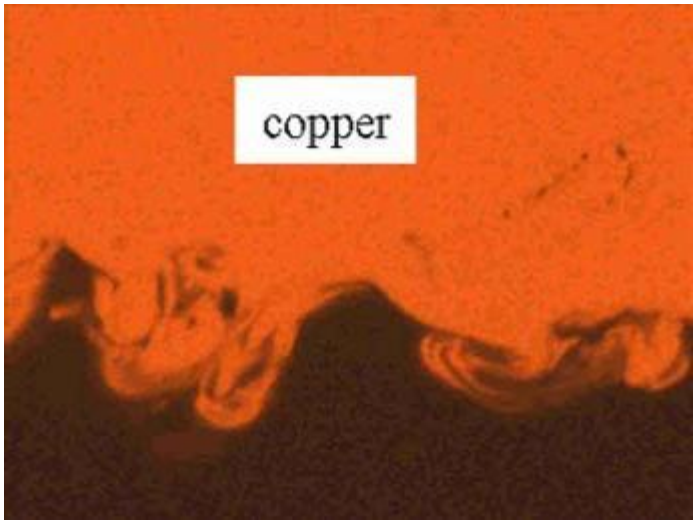
Courtesy of ARL

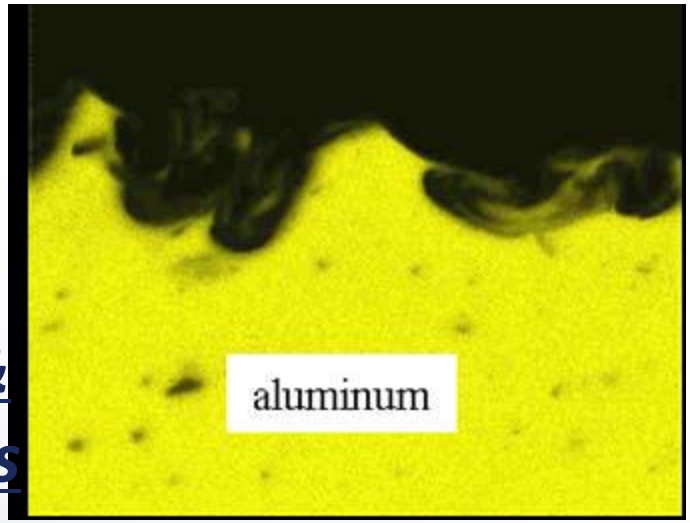
Advantage: No heat affected zone

Surface Intermixing Properties



Interface EDS X-ray Mapping showing mechanical mixing between coating material and substrate





Dense>10,000 psi adhesion

Innovation: An actual Metallurgical & Mechanical bond with the substrate is created

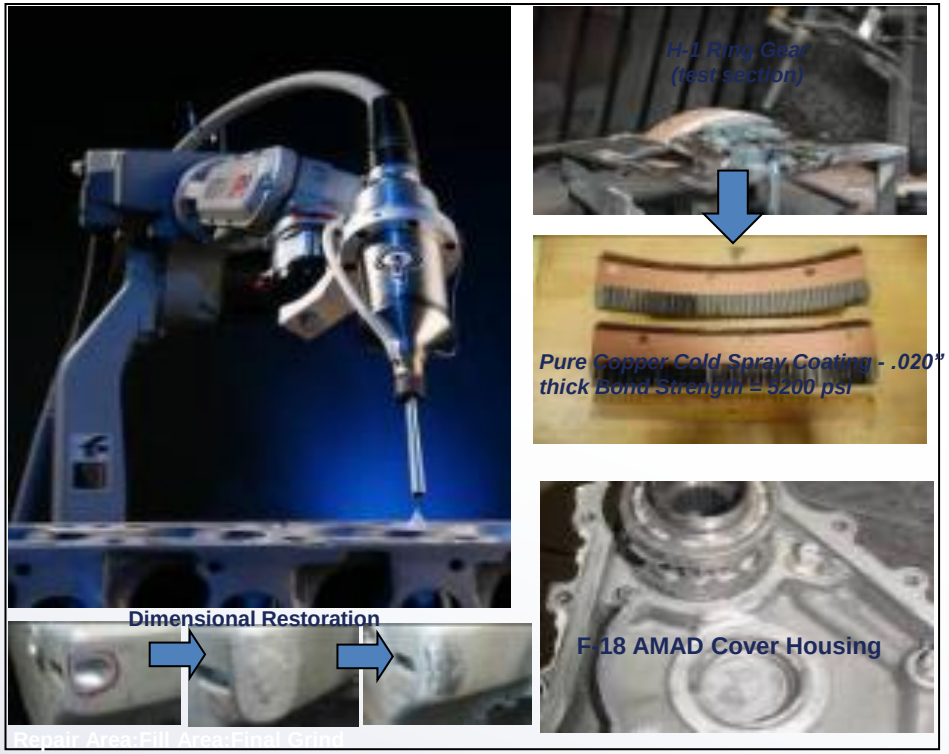
Courtesy of ARL

Low Pressure/High Pressure CS

•In Low-Pressure Cold Spray, air or nitrogen at relatively low pressure—80–140 psi/250psi—is also preheated, up to 550˚ C, then forced through a DeLaval nozzle ~ 600m/s.

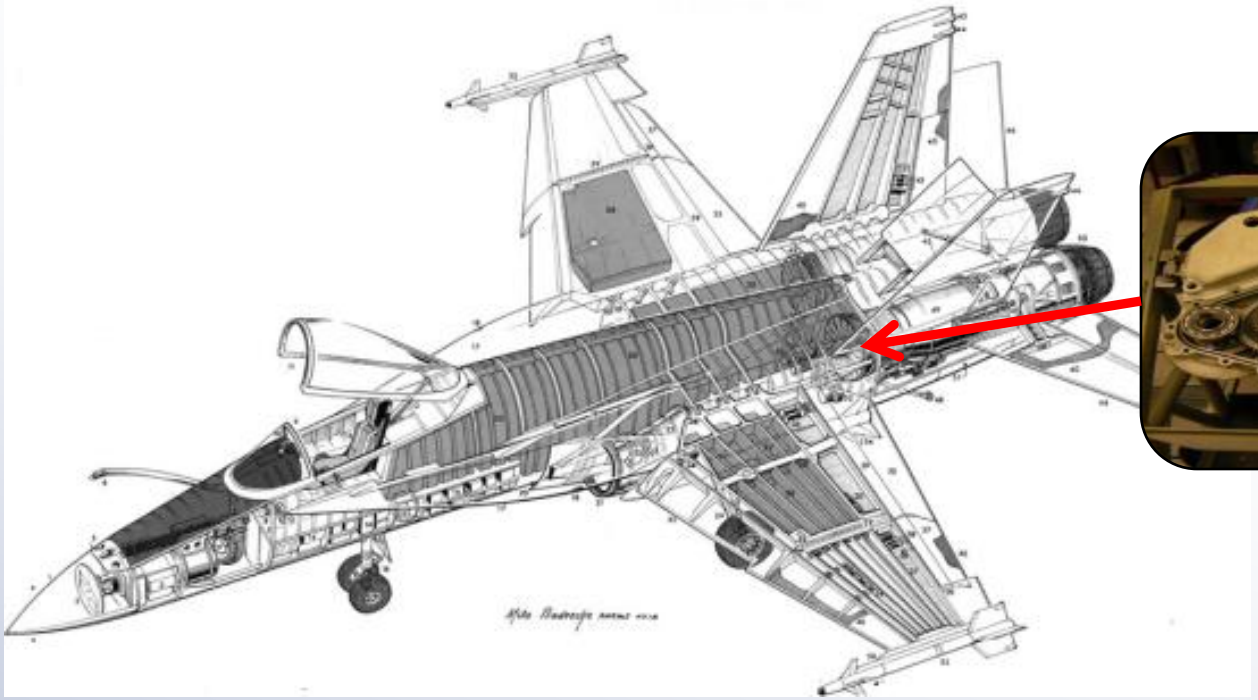
•In High-Pressure Cold Spray, helium, air or nitrogen at high pressure, up to 1,000 psi, is preheated--up to 1,000˚ C--and then forced through a converging-diverging DeLaval nozzle. (Robotic) ~ 1000m/s

Note: this part is portable



Objective

Objective: The objective is to develop the low & high pressure metallization process that can be used to facilitate dimensional repairs of gearboxes, specifically the F-18A AMAD Gearbox Cover Housing for metal that has been lost due to corrosion or dynamic wear damage



Impact/Motivation

Spare F-18 E/F/G Model AMAD Gearboxes purchased under original contract (not planned to be replaced)

3 Carrier Deployments

x 6 AMAD's per Deployment

18 needed per Deployment

~ 33 Spares Procured

- 27 used to date

- **6 spares remaining** ***= -12 net deficit***

- **$1,020,000 cost (12x$25K) per deployment to replace *if they could be replaced***

– AMAD Cost - $85,000, 14-18 Month Delivery Time from manufacturer

Replace all spare AMAD's

– Estimated at $1M for 33 spares, long lead.

– AMAD now classified as a short life replacement part.

Degraded readiness (continued cannibalization)

Degraded mission capability

F-18 AMAD Gearbox Repair I: Fretting Corrosion

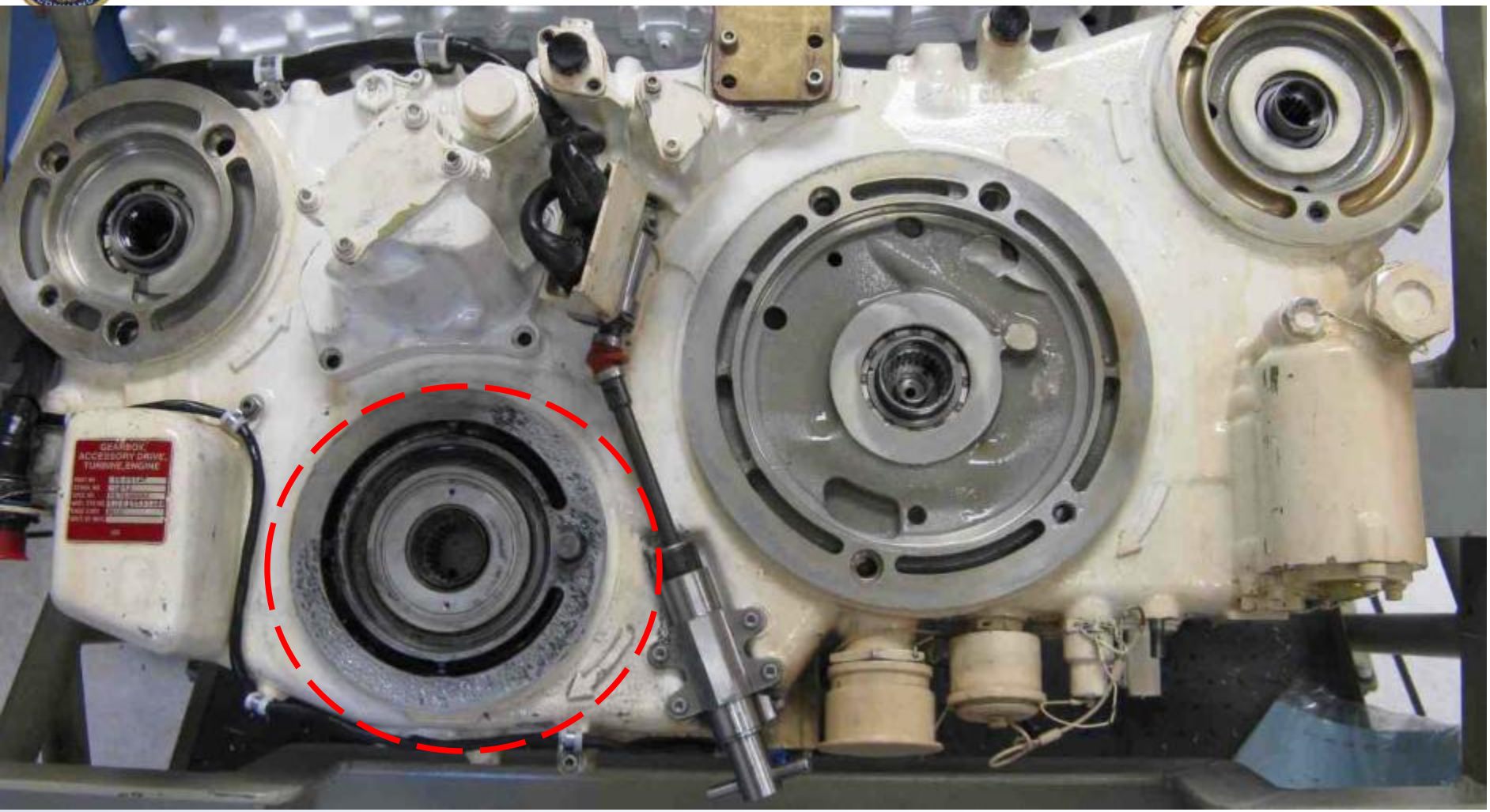
The need to perform dimensional structural restoration of cast aluminum A357 due to damage from fretting corrosion.

Corrosion degradation repaired to dimensional tolerances.

Material selection, process refinement, mechanical, thermal cycling tests performed to verify repair.

Six returned to fleet to date.

AMAD Fretting Repair Day 1

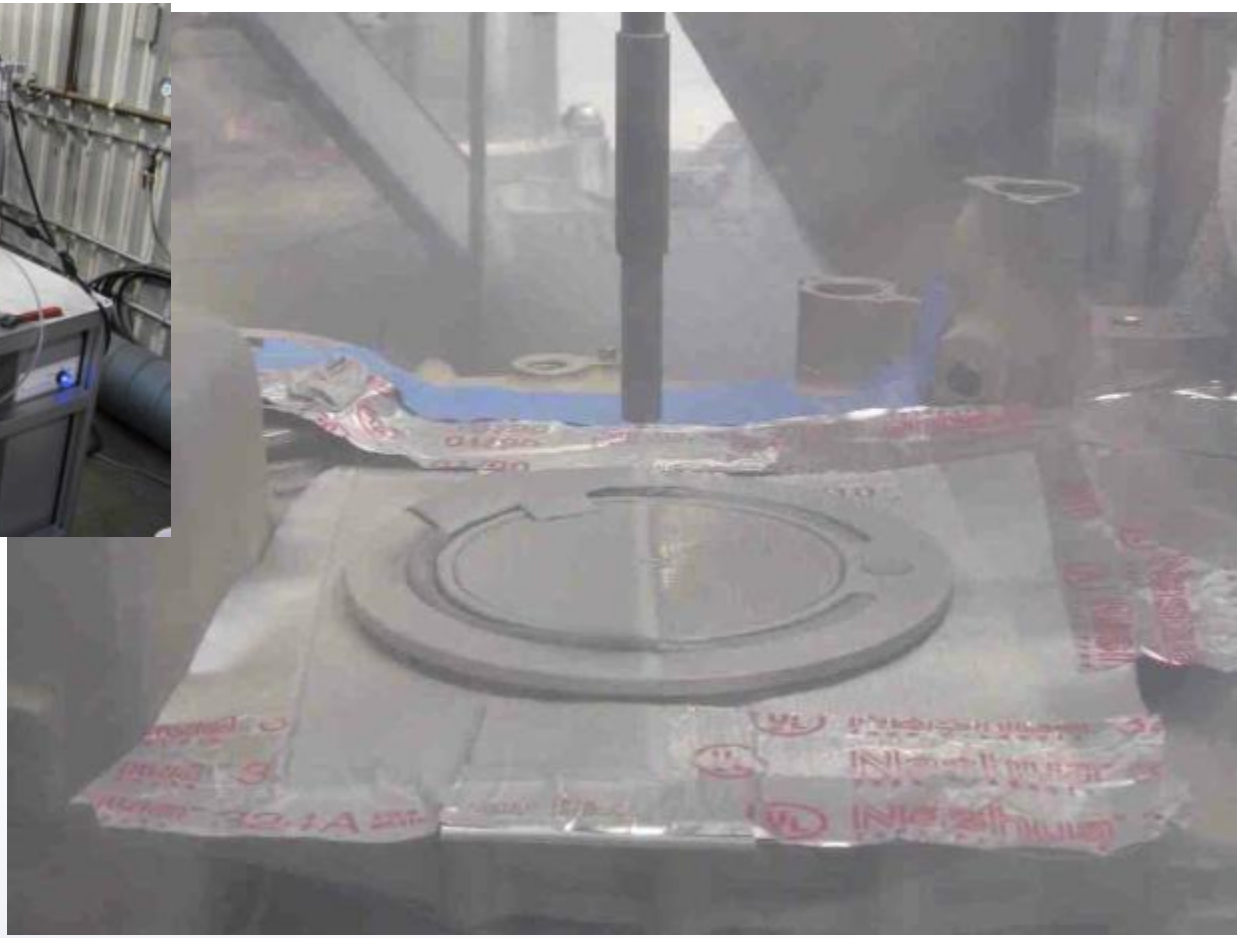


AMAD was returned to the Depot & inspected & found to have severe fretting on the hydraulic pad surface

AMAD Fretting Repair Day 2

Hydraulic pad was severely fretted. North Island removed the alignment pin and machined off the damaged areas (approx 0.008 deep)

AMAD Fretting Repair Day 3



AMAD was sprayed with 6061 Al alloy using the cold spray metallization process <8 hrs start to finish.

AMAD Fretting Repair Day 4

AMAD was finished machined back to the original dimensional tolerances at North Island (FRC-SW)

AMAD Fretting Repair Conclusion

AMAD was finished machined back to the original dimensional tolerances at North Island (FRC-SW). This housing has been returned to the fleet & is flying again. ***Estimated Savings Approximately $75,000/part.***

$10,000 repaired vs $85,000 new

SUCCESS STORY: OPERATIONAL MAINTENANCE PRODUCTS

Operational Maintenance Products

So much that we do in corrosion control relies on the tools that we are given, qualified maintenance products and reacting to changing times by keeping them up-to-date or developing new ones.

- Safe, from a human use/exposure point.
- Shelf Stable,
  - Preferably min year storage
  - Compatible with multiple environments
- Compatible with all substrates without inciting corrosion

Operational Maintenance Products

- **Ready to use MIL-PRF-85570 Type II Cleaner-(pre-diluted water based)**
- **MIL-PRF-85570 Type 1 in Aerosol & Pre-Moistened Wipes**
- **Micro-mesh Cloths for Canopy & Optics Cleaning**
- **MIL-DTL-81706 Type II Non-Chrome Pretreatment Applicator Pen**
- **MIL-PRF-29608 Class L CPC Electrical Contact Cleaner**
- **Non-Chrome pretreatments**
- **Advanced performing topcoats**
- **Cold Spray Metallization**
- **MIL-PRF-32295 Types I & II (PD-680 alternatives)**
- **Helicopter engine wash diverter**
- Hot-melt glue sticks for non-structural adhesives
- Waterless Aircraft Wash
- Portable dust containment
- Selectively strippable midcoats
- Non-chrome primers
- Canopy & windscreen restoration products

Driver: Environment

Non-Hexavalent Chrome Pretreatment Touch-up Pens

Portable Dust Containment – Portable glove box for composite repair adapted for surface prep & coating containment

Driver: Corrosion Prevention/Quality of Life

Aircraft Water Wash Diverter- Developed to keep engine wash water from interior of helicopter cabin, and additional cleanup.

Solvent Based MIL-PRF85570 Ty I Aerosol- Developed to provide an alternative to a non-qualified spray cleaner. Easy to use, convenient application.

Driver: Safety

Acrylic Canopy/Windscreen Restoration & Maintenance products

Microfiber cloths for waterless aircraft canopy/windscreen cleaning.

Driver: Mission Based

<u>Water Based Cleaners (MIL-PRF-85570 TyII)</u> packaged in pre-diluted form. Mission environment does not provide Fresh Water. Not readily available on ship or in the desert

<u>MIL-PRF-85570 TyI Solvent Cleaner Wipes</u> – Convenient packaging, reaction to commercial wipe use, also in a good form for RADCON cleanup.

SUMMARY

- Corrosion is a significant cost to the Navy
  - NAVAIR's total annual budget is ~$40B; annual corrosion cost is estimated at $3.0B
- The Naval Aviation Enterprise Corrosion
  - Prevention Team is attacking corrosion problem in all phases of aircraft life cycle
- Solutions lie in the areas of leadership,
  - training, policy, basing, materials, design, and documentation
- Key Outcome: Balanced approach to reduce impact of corrosion on NAE
- ***Reacting and being Proactive to the needs of the Aircraft Maintainers***

Thank You for supporting the Navy and Marine Corps Warfighter!