CSAT 19 -20 June 2018
Australia/US SPD/Cold Spray Collaborations

Neil Matthews
Head of Research and Technology
Senior Manager Advanced Manufacturing Solutions

Together ahead. RUAG

Introduction

- Update
  - Materials
  - Applications
- Australia/US Collaboration
  - History
  - Past Projects
  - Future Projects
  - Discussions/Questions

Together ahead. RUAG

Successful Application Summary

- **Successful deposition of the following metal powders; Aluminium alloys (2000, 6000 and 7000 series), Titanium, Nickel, Steels (stainless, low carbon, mild, invar etc), Inconel, tantalum.**
- **>50 certified SPD repaired products released back into service, approx 10,000 accrued flight hours)**
- **Military helicopter transmission cost savings $5M over four years. Significant down time reduction (TAT reduced by 75%)**
- **Components previously assessed as beyond economic repair can be returned to service**
- **Successful Commercial aerospace proof of concept applications Bombardier, Boeing , BAe, Messier Bugatti Dowty.**

Together ahead. RUAG

Together ahead. RUAG

Materials

Material	Applications
Al Alloy 6061	Geometry restoration standard repairs, **new proof of concept applications**
Al Alloy 2024	**Geometry restoration**, "structural applications"
Al Alloy 7075	Geometry restoration, **structural applications**
Nickel/Nickel Blend	Geometry restoration, **replacing electroplate nickel**
4340/M300 Steel	Geometry restoration, **load bearing**
Titanium	Geometry restoration, **load bearing**
Tungsten Carbide	Replace electroplate hard Chrome
Stainless Steel	**Geometry restoration** and corrosion protecting for mild steels

Together ahead. RUAG

F/A18 Primary Manifold

Item received with severe shear damage on lock-ring bore wall. All serrations appear to have damaged or stripped during Rosan plug removal.




Mock-ups were created to mimic the damage removal. Port bore was machined to oversize dimensions: 14.20mm dia.

The finished trial has proved this to be an ideal SPD repair in both terms of depostion accessability and machinability.

Together ahead. RUAG

NLG Wheel Hub

Item received with severe chatter marks and wear on the bearing surface of the hub. Largest damage depth recorded: 0.038 inch.




Bore coated with 2024 Al to a mimimum thickness of 0.075 inch

SPD Coating machined to acceptable limits and refininshed. Final coating thickness: ~0.020 inch



The SPD coating was tested for its ability to withstand shearing stress generated by the torque load. The coating can take 7 times more shearing (torque) load than the estimated design load at the bearing/bore interface due to interference fitting.

Together ahead. RUAG

SPD Wheel Hub Repair

Together ahead. RUAG

Oil Reservoir (T56)

Material: s/s 321;
Thickness: 0.7mm?
Defect: 35x5 mm,• Depth: 0.178mm

- ✓ **Cost of recovery including repair development < 15% of purchase price**
- ✓ **Turn around development and repair approx 8 weeks.**

Together ahead. RUAG

SPD nickel Application to F/A18 part -Approved application

- Corrosion test: Salt spray passed, Rating 10
- Series of test passed: Bend, scraping, ring shear, etc
- Porosity: ~0%
- Hardness: >30 HRC
- Quality Satisfactory confirmed by both RUAG Australia and ASC

MLG Crank Assy
P/N 74A410555-series

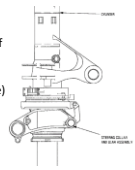
MLG Crank Assy
P/N 74A410549-series

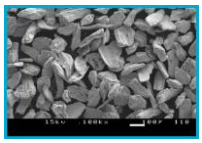
Planing Arm Assy
P/N 74A410538-series

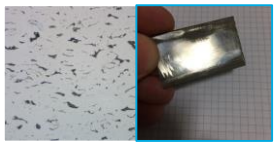
Together ahead. RUAG

NLG Steering Collars

Replacement of degraded Karon coating and repair of underlying corrosion with SPD lubricity metal deposition (Nickel graphite)



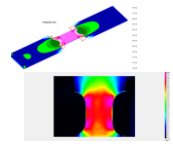




Together ahead. RUAG

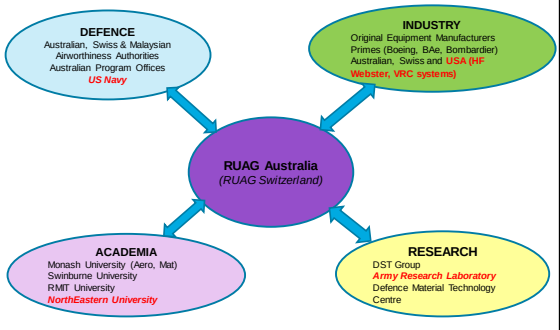
Structural Integrity

- Need to Quantify Cold Spray Performance on aircraft parts/structure
- Parts/structure be subject to both static and dynamic load conditions
- Measurements would be obtained from traditional strain gauging and thermography
- Current Opportunities
  - ➢ Swiss F/A-18 Door Frame structural enhancement to reduce peak stresses (underway)
  - ➢ Wing Structure dynamic tests (underway)
  - ➢ Fast Jet Full Fatigue Tests (Wing & Fuselage) (underway)



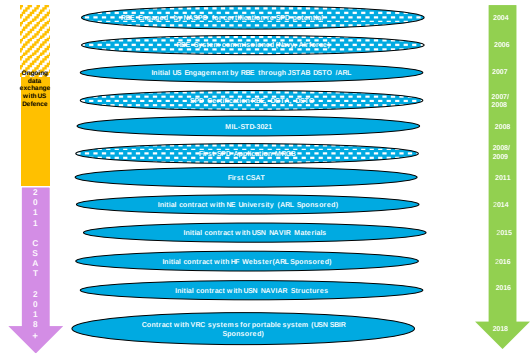
Together ahead. RUAG

Collaborative Partners



Together ahead. RUAG

SPD/Cold Spray - The Journey



Together ahead. RUAG

Together ahead. RUAG

SPD *Field Application*

Together ahead. RUAG

Collaborative Programs With ARL

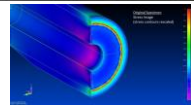
Agency	Activity	Status	Outcome
	Development of High Ductile/Strength Cold Spray Aluminium Aerospace Alloys for Mobile Applications	Complete (2014-2015)	Replicating RUAG's Field Portable SPD Unit achievable spray parameters on our fixed system has demonstrated that additional pressure/temperature enhancements are required to achieve optimum deposition outcomes for 7075 al alloy powder depositions.
	Development of Advanced Cold Spray Prototype for Mobile Applications	Complete 2015-2016	The assessment undertaken has identified a number of features on VRC Systems a Gen III High Pressure Hybrid Cold Spray System which have the potential to be incorporated into the FPSPDU to produce a highly effective "cold spray system" that could provide portable, robotically controlled deposition capability for numerous metal powders for a vast array of industries.
HF Webster	Develop a detailed specification for the integration of the provided VRC Gen II system into RUAG Australia's FPSPDU.	Complete 2017	Gen III System provided by ARL Specification completed Layout Modelled confirmed
HF Webster	Optimization of Advanced Cold Spray Mobile System through	In work	GEN II system operated and particle velocity measured under different parameters to optimum parameters to align with fixed plant operations. Revised nozzle design generated. Ruggardisation requirements identified.

Together ahead. RUAG

Development of High Ductile/Strength Cold Spray Aluminium For Mobile Applications

1. Dense, well adhered low porosity coating for all three powder types can be achieved through parameter optimisation.
2. The deposition of all three powder types under optimised parameters will satisfy geometry restoration requirements.
3. Replicating RUAG's Field Portable SPD Unit achievable spray parameters on our fixed system has demonstrated that additional pressure/temperature enhancements are required to achieve optimum deposition outcomes for 7075 al alloy powder depositions.
4. Modified axial tensile test coupons should be used to eliminate the possible impact of stress concentrations at the substrate coating edge.

Stand-off distance (mm)	Temperature\Pressure (C°/bar)	Label	Failure load (N)	Failure Stress (ksi)
35-40	295/25	7A-1	954	165
35-40	425/38	7B-1	7,020	213
35-40	425/38	7B-2	4,317	151
30	425/38	7C-1	4,934	159
30	425/38	7C-2	6,091	165
20	425/38	7D-1	6,543	193
20	425/38	7D-2	7,123	186



Together ahead. RUAG

Detailed Specification (modelled)

Hybrid

Portable

System

Together ahead. RUAG

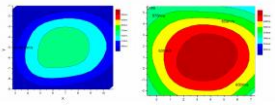
ARL

HF Webster

VRC METAL SYSTEMS

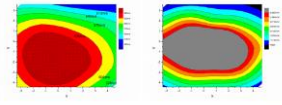
Together ahead. RUAG

Optimization of Advanced Cold Spray Mobile system

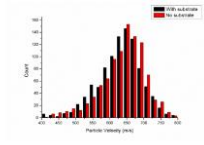


Velocity distribution in SPD jet sections at a standoff of 35mm using VRC NZZL0050 nozzle (left) and RUAG T5A26089-2/-50nozzle (Right).

3.2. Optimisation 2
Parameters: 600psi-440°C-50SLM-4rpm



Particle velocity (left) and particle flow (right) distribution at the selected optimum condition 2



Particle velocity distribution comparison of SPD with/without substrate

Together ahead. RUAG

Collaborative Programs With USN

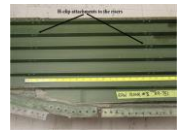
Agency	Activity	Status	Outcome
NAVAIR Structures.	Restoration of Load Carrying Capacity of Wing Skins and Structure FEA and Coupons	Complete	The analyses and validation testing outlined in this project demonstrated that SPD repairs are viable options to restore integrity
NAVAIR Structures	On going structural integrity evaluation of SPD coating on aircraft structures	In work	Test Plan complete. Aircraft wing segments prepared
NAVAIR Materials	Trial SPD coatings on aircraft component	Complete	Quality and fatigue of coated components assessed independently No issues.
VRC METAL SYSTEMS	Acquisition of Mobile cold spray FPSPDU for trials and evaluation in 2019	In work. Contact let	Ruggardistaion Specification finalised

Together ahead. RUAG

Assessment of Wing Integrity with Upper Surface Corrosion Subject to Compressive Loading

Baseline Model

- A 500 mm (long) by 250 mm (wide) rib stiffened 7075-T6 aluminium alloy panel where the skin and the risers were both 4.3 mm thick.
- The panel contained 5 ribs
- The length of the panel was taken so as to approximate the distance been the H-clips that are attached to the risers.
- The risers were 30 mm deep and 50 mm apart.
- The skin thickness analysed was 2.1 mm.
- The unloaded edges of the panel were assumed to be simply supported (other cases were analysed



.

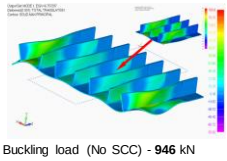
Model with Corrosion removal

- The corrosion was taken to be 40 mm in diameter with a depth of 1.05 mm. (50% of the total thickness of the skin)
- Centre of Panel for maximum Buckling stress

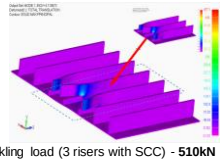
Together ahead. RUAG

On going structural integrity evaluation of SPD coating on aircraft structures

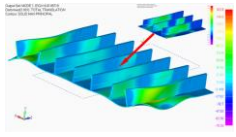
- Analysis was repeated for a 7 stiffener panel.



Buckling load (No SCC) - **946** kN



Buckling load (3 risers with SCC) - **510kN**

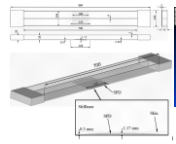


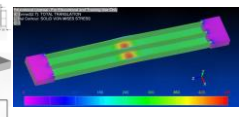
Application of 3 thin 0.2 mm thick, 10 mm wide, and 110 mm long SPD doublers essentially **restored** both the buckling load and the buckling mode.

Together ahead. RUAG

On going structural integrity evaluation of SPD coating on aircraft structures

- The overall program objective is to produce quantifiable structural enhancement outcomes using SPD.
- This program is a one year program to quantify the contribution of al alloy 7075 SPD to the structural integrity of a repaired aircraft 7075-T6 framed. Measurements will be obtained from traditional strain gauging and thermography both under static and dynamic load conditions. The results will be compared to analytical predictions.





Together ahead. RUAG

Demonstration of the Portable CS System @ RUAG Rosebank (Australia)

Courtesy of USN "In-Service Portable Dimensional Corrosion Repair for Aircraft April 2015, OSD Corrosion Office Project W14NA07, NAVAIR 4.3.4 4.4.3.3

Together ahead. RUAG

SPD *Field Application*

Together ahead. RUAG

USN Purchase Of Mobile Deposition Unit

Prime Contract: USN – VRC (Under existing SBIR No. N68335-17-C-0556:0 (sole source for 5 years)
VRC Contract with RUAG – VRC/RUAG/NAVY SBIR N6833517C0556/050818 executed 28 May 2018
Delivery: FEB 2019

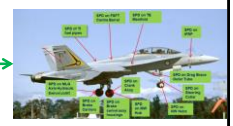
VRC METAL SYSTEMS

Together ahead. RUAG

Together ahead. RUAG

Australia US SPD/CS Collaboration

Oz Tasmanian Tiger



US Tasmanian Tiger

Together ahead. RUAG

QUESTIONS ?????

Together ahead. RUAG