Cold Spray Applications for the *Australian Defence Department*

COLD SPRAY ACTION TEAM (CSAT) 2012

Presented by
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Chief Engineer Rosebank Engineering

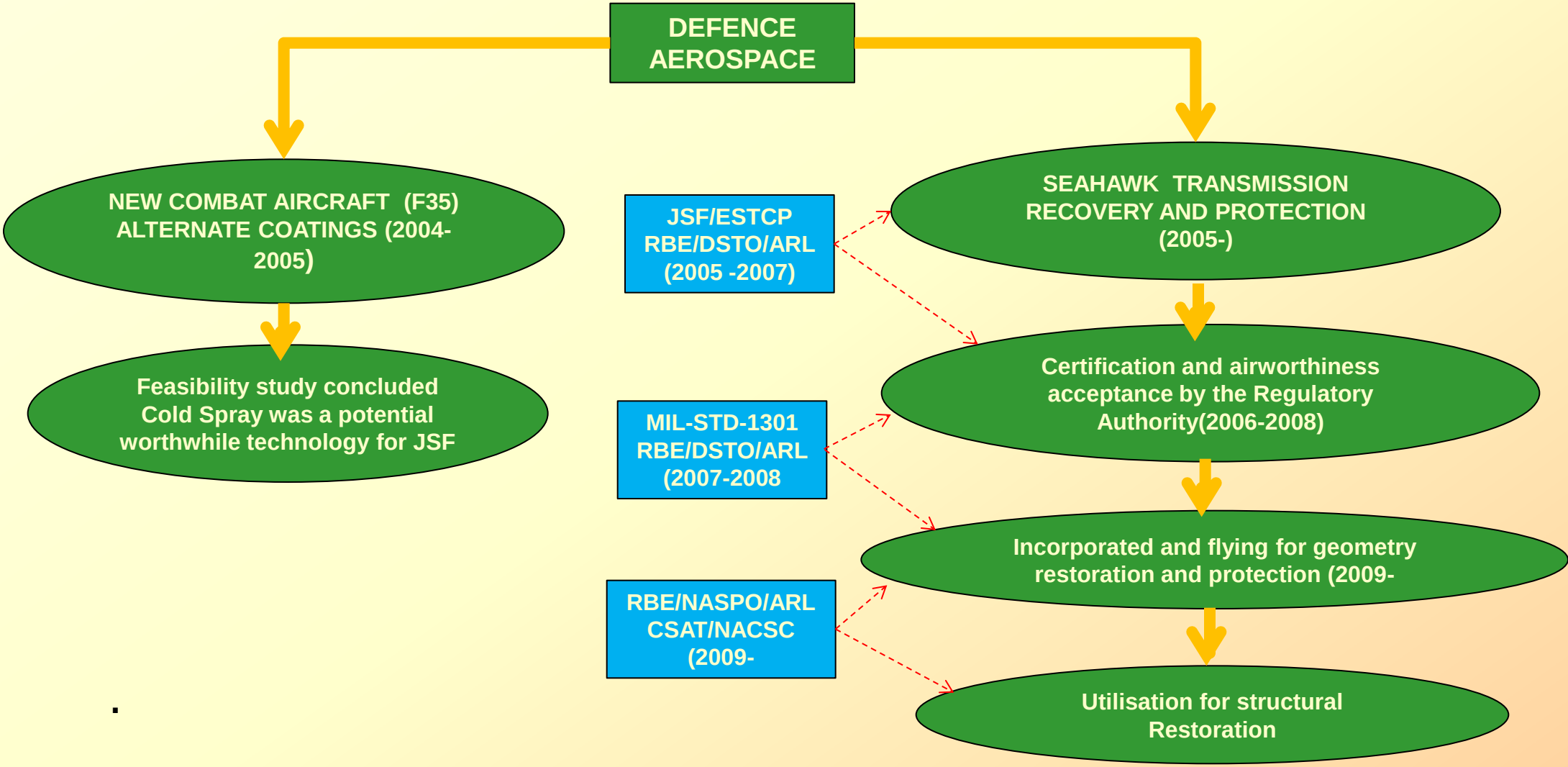
Presentation

- Introduction
- Cold Spray Engagement In Australia Defence Aerospace
- Acceptance of Cold Spray as an Approved Technology
- Cold Spray Applications In Defence Aerospace
- Cold Spray Structural Integrity Enhancement/Restoration
- CTD Portabilisation
- Closing Discussions/Questions

Introduction

- Rosebank Engineering is a major research centre for the development and application of Cold Spray for aerospace and Defence applications in Australia.
- This technology provides a number of exciting and cost benefit outcomes particularly in the corrosion protection and restoration of corroded/damaged metallic components/structure to an acceptable level of structural integrity and functionality.
- To this end the presentation outlines process of evolution of the technology in Australia through local and international collaboration, current Cold Spray application activity to date and the on- going development of this technology for structural repair and restoration.

Technology Engagement – Defence Aerospace



Acceptance of Cold Spray as an Approved Technology

- Cold Spray Technology is an approved is a Military Standard MIL-STD 3021_ Materials Deposition, Cold Spray (issued AUG 08)
- Rosebank Engineering developed and completed an Acceptance Protocol in conjunction with DSTO
- The Acceptance Protocol has been used to gain DAR acceptance of Cold Spray applications on numerous Seahawk Component.
- DGTA considers that sufficient evidence exists to support Technology Transition for Cold Spray within the aerospace community.
- DGTA has established a Technology Transition Working Group (TTWG) to transition the technology for all users and expand the Cold Spray application for structural restoration/enhancement

Benefits of Cold Spray

- Demonstrable cost saver in sustainment costs (RAN Seahawk transmission cost savings 35% – 50% ($4M +over three years)

  (US DOD 2009 Report on the Annual Cost of Corrosion as 24 % of maintenance cost –Air Force 31%)
- Can be applied to recover damaged geometry without adversely affecting the substrate
- Reusable for reclamation of eroded surfaces and application of wear resistant coating.
- Initial trails have shown that it can be used to enhance structural integrity
- Significant reduction in O H & S risks associated with a number of current in-service applied coatings on both legacy and newly acquired platform

Acceptance Strategy of Cold Spray as an Approved Technology

- Cold Spray(Cold Spray) Technology is an approved is a Military Standard Mil- STD 3021_ Materials Deposition, Cold Spray (issued AUG 08)
- Rosebank Engineering developed an Acceptance Protocol matrix and in conjunction with DSTO has completed a validation test program
- The aim of the Acceptance Protocol was to demonstrate that the application of Cold Spray was not deleterious to range of common used aerospace materials

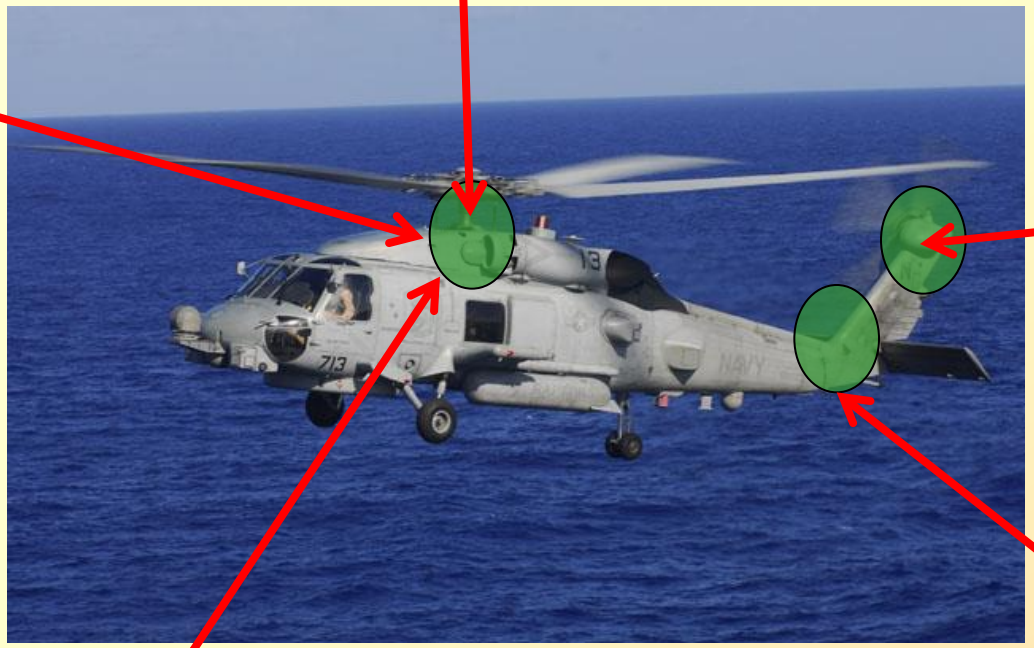
Acceptance Test Protocol

- Aluminum powder coatings (Pure Al and 6061)
- Four substrate material types (ZE41A Magnesium, 4130 Steel, Al Alloy 7075, Al Alloy 2024
- 9 test regime
  - Corrosion
  - Tensile
  - Compression/Bearing
  - Shear
  - Fatigue
  - Residual Stress
  - Impact
  - Hydrogen Embrittlement
  - Coating Tensile Strength

RBE Cold Spray Accepted Seahawk Applications

RBE has applied Cold Spray to Input module webs and mounting faces

RBE has applied Cold Spray to main module sump and Flight control pad

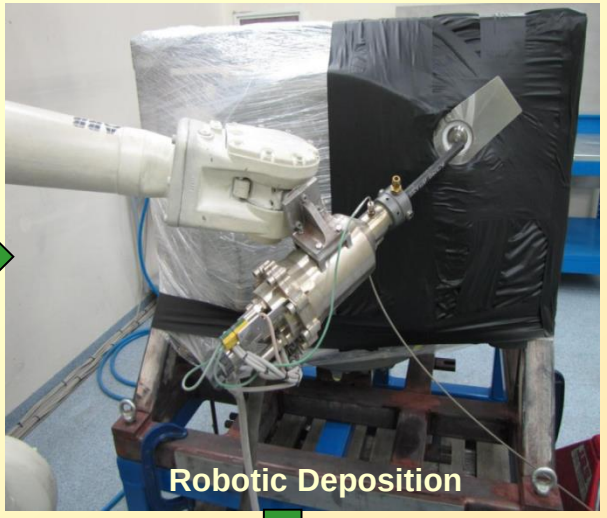


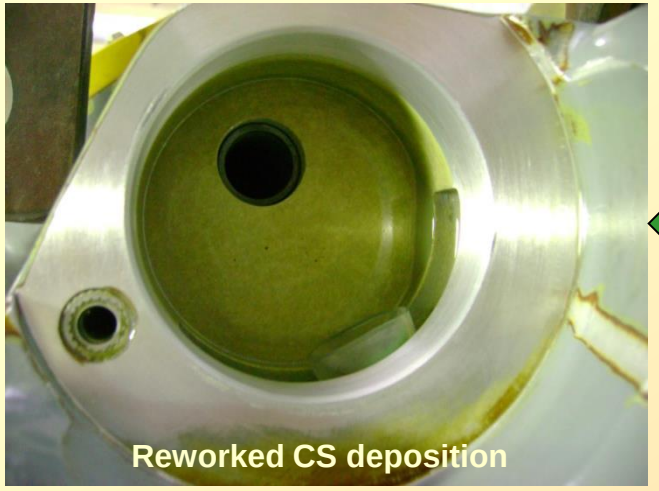
RBE has a applied Cold Spray to TRGB feet

RBE has applied Cold Spray to Accessory Module mounting faces for corrosion protection and geometry restoration

RBE has applied Cold Spray to IGB feet for corrosion protection and geometry restoration

RBE Cold Spray Seahawk Main Module

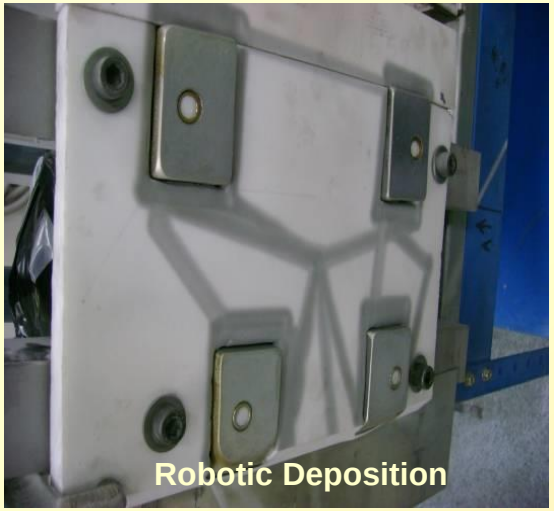




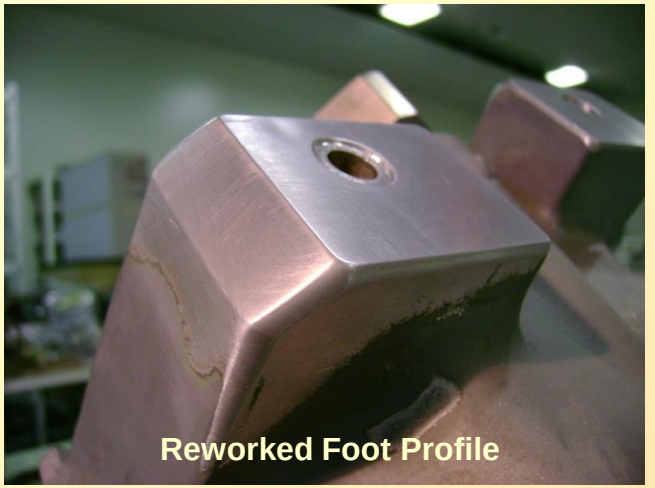
Seahawk Intermediate Gearbox (S/N A005-01595)

Before

During



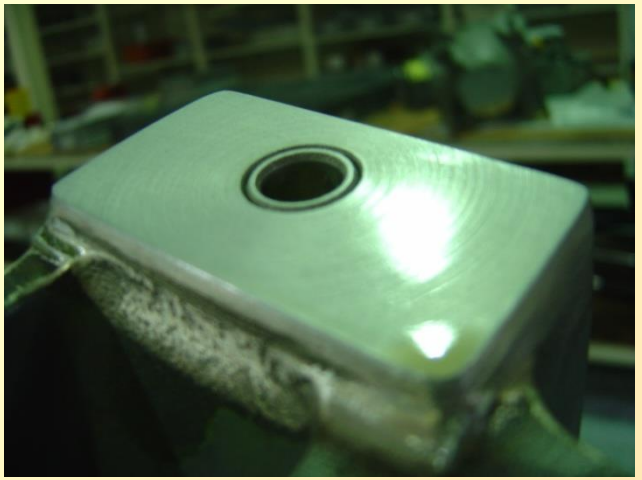
After

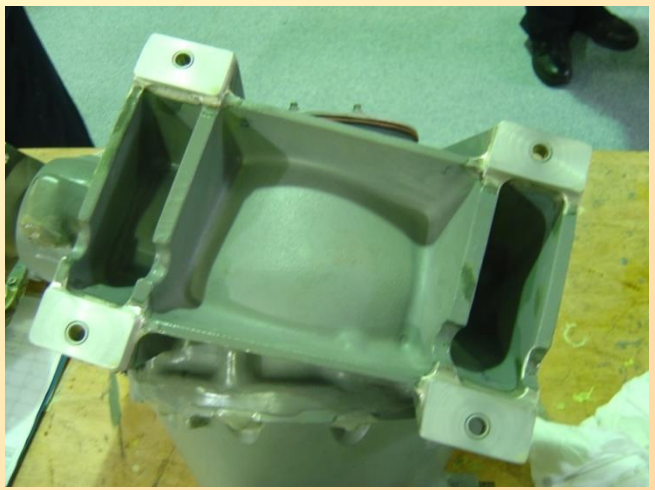


TAIL ROTOR GEAR BOX (S/N A232-00172)

During Application

After Machining





Input Module (S/N A264-02946)

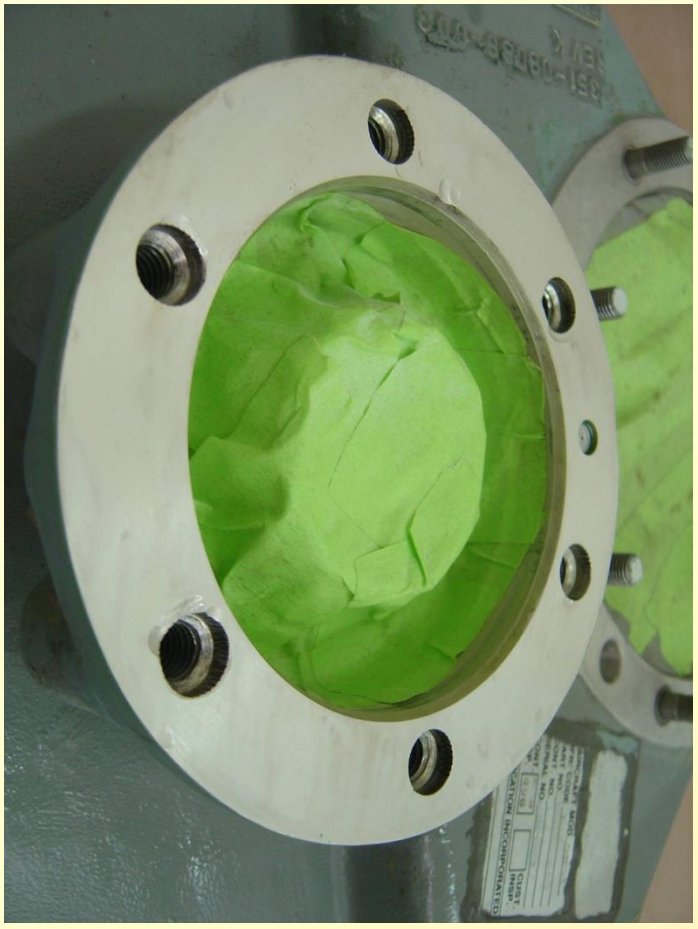
Before

During

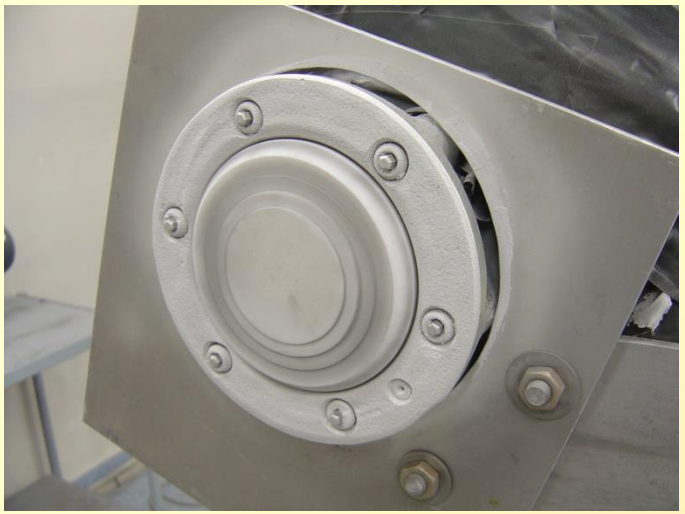
After

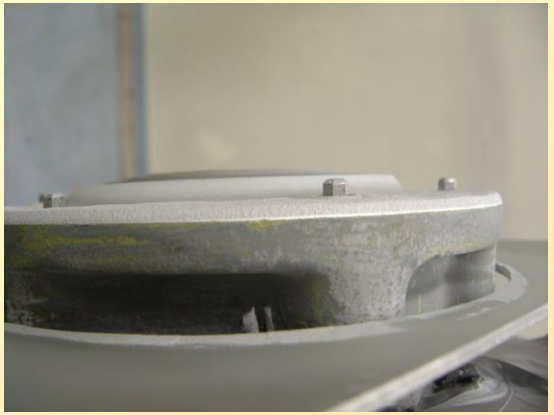
Accessory Module (S/N A258-003679)

Before

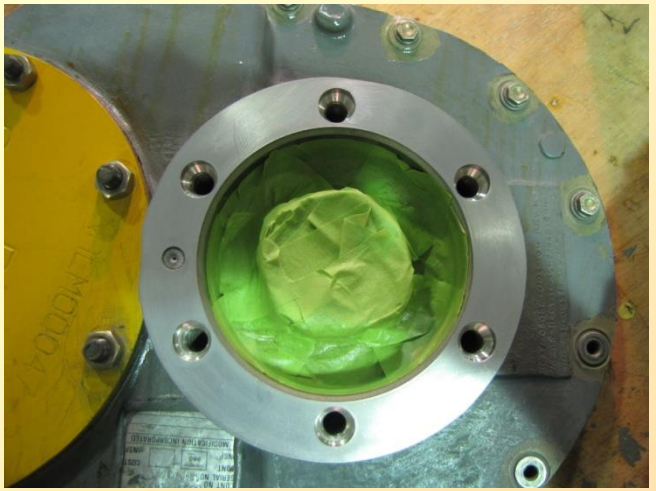


During





After

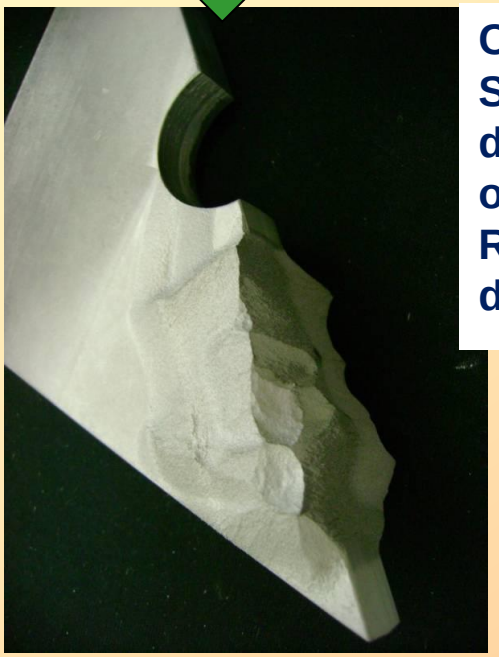


Trial Embedded Applications

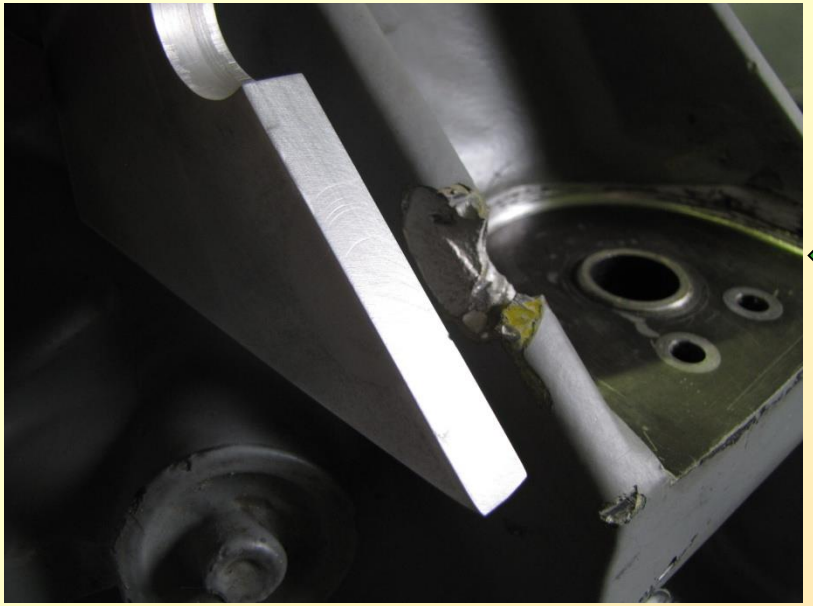
Damaged Main module

Replicated damage removal

Damaged Main Module

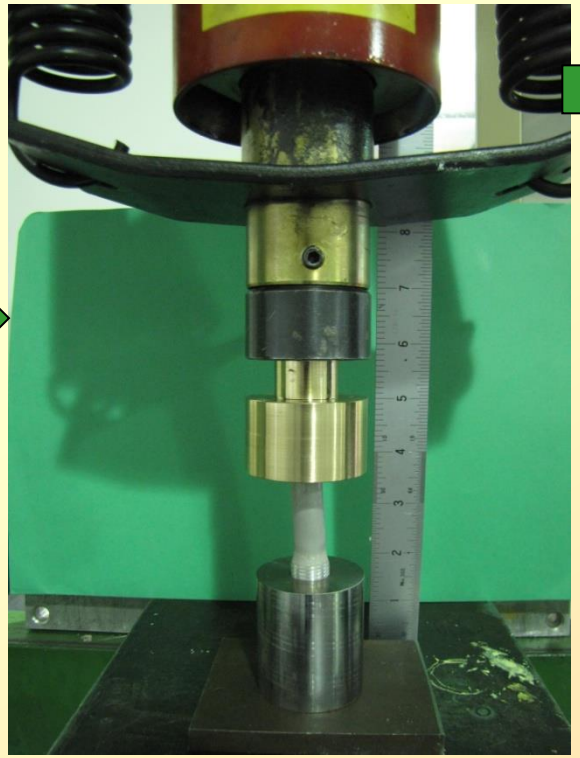


Cold Spray deposition on Replicated damage

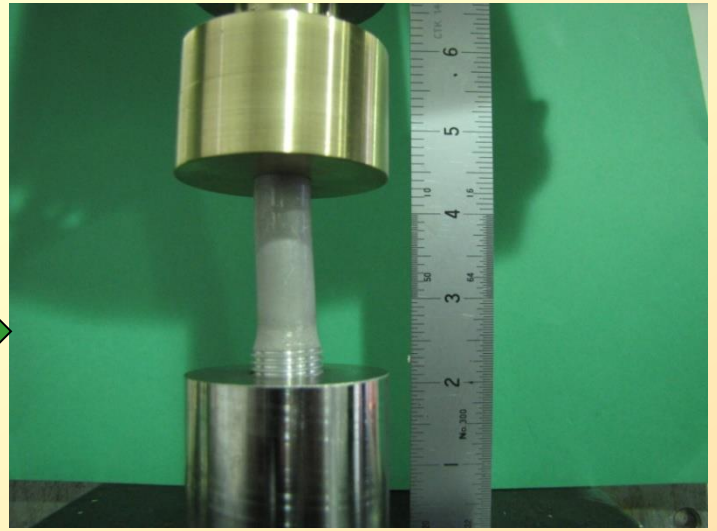


Trial Thread Applications

2024-T351 bar coated with 7075 powder with machined thread



Threaded bar under compressive load



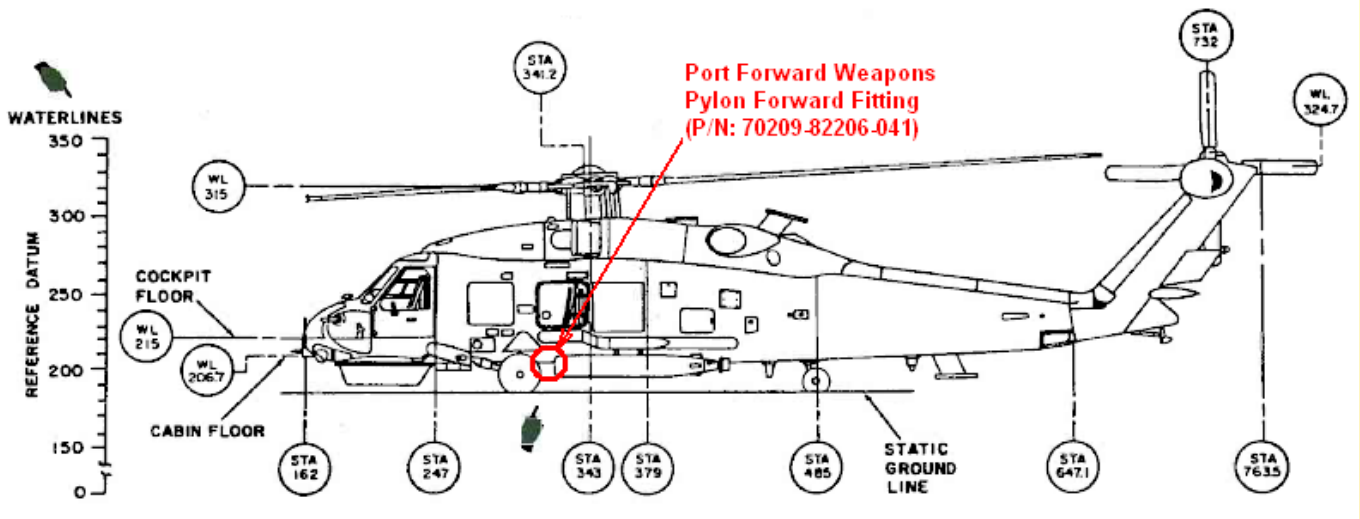
Buckled 2024 bar with minimal thread damage

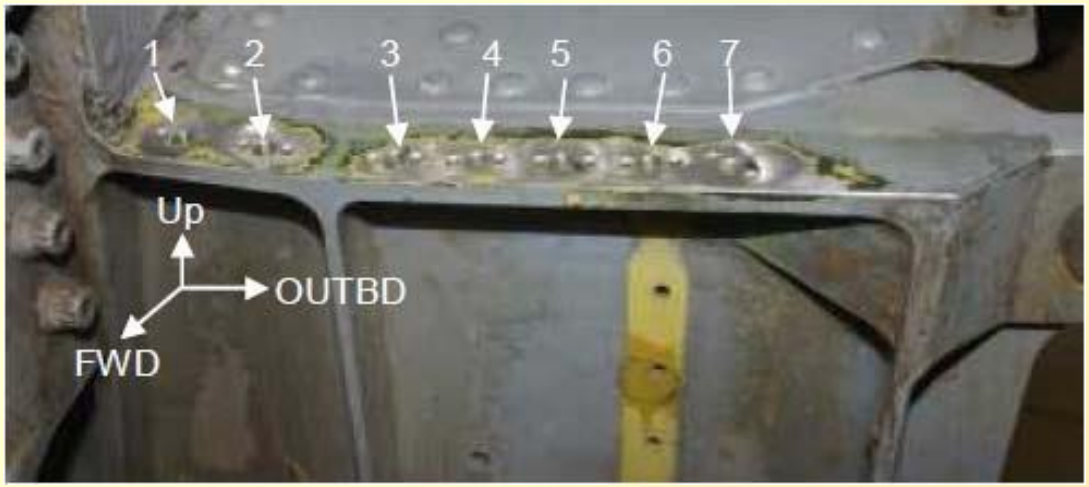
Structural Integrity Enhancement/Restoration

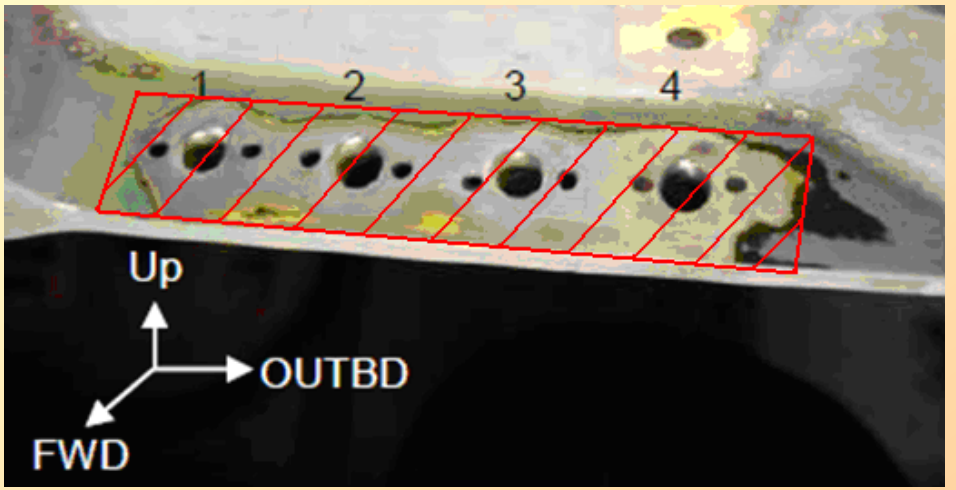
Question

Can Cold Spray be used to enhance/ensure structural integrity????

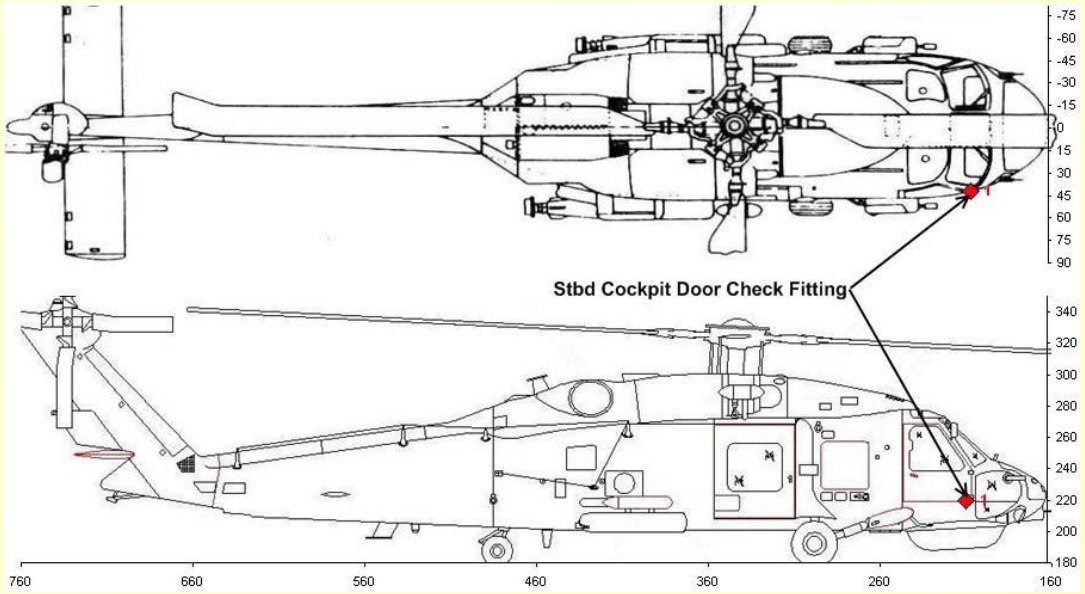
Potential Application on Seahawk Pylon Fairing

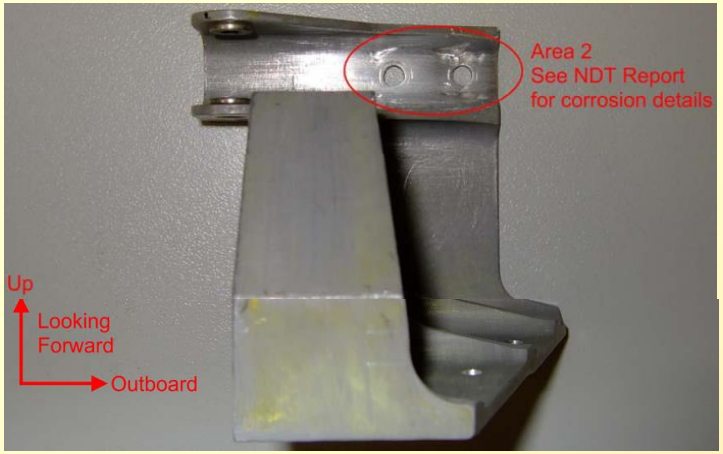


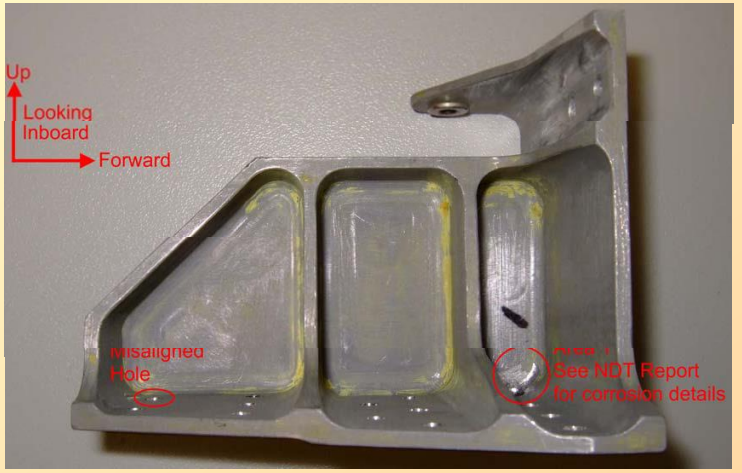




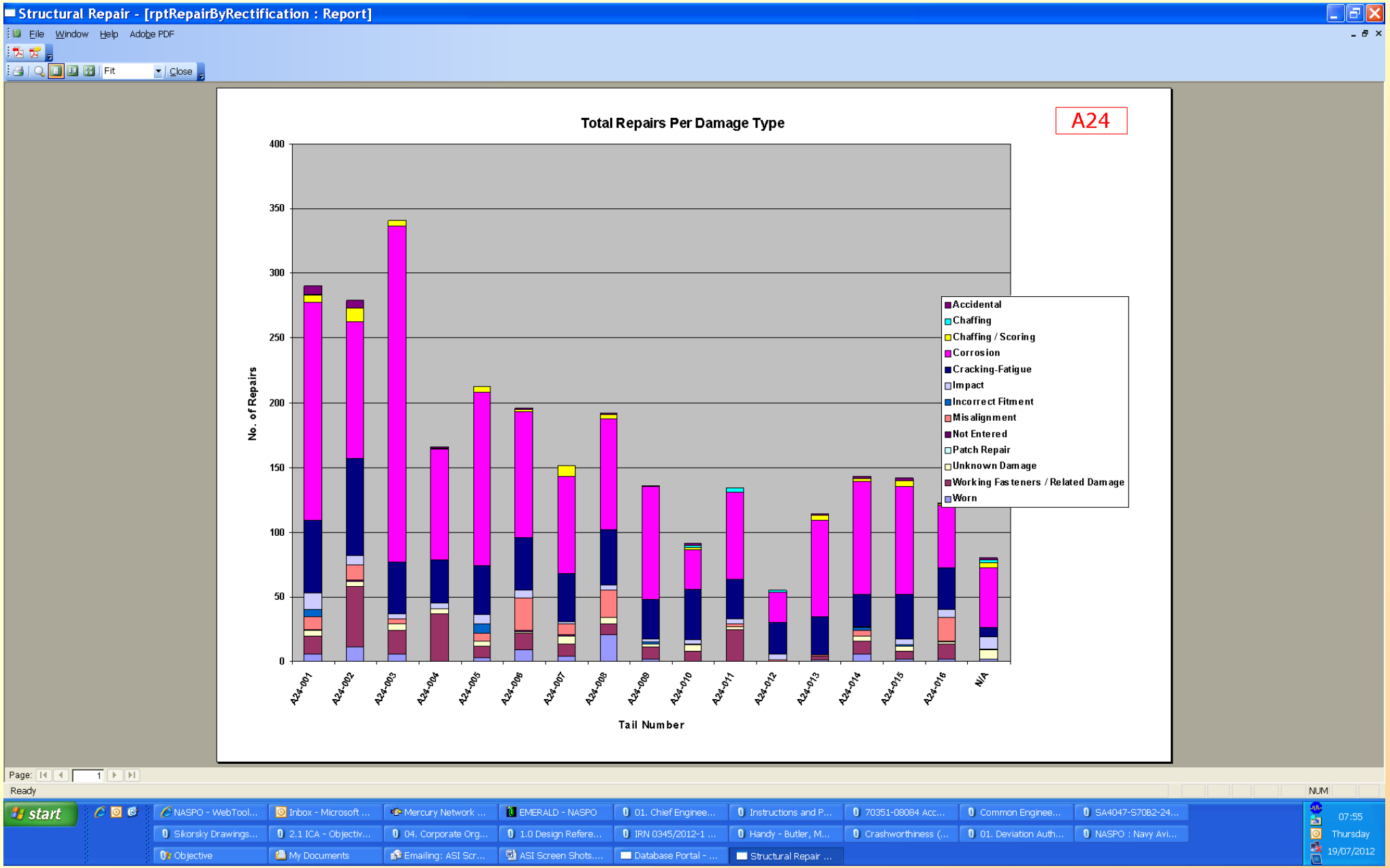
Potential Application on Seahawk Cockpit Fitting







Corrosion Impact



Structural Integrity Enhancement/Restoration

AUS DoD/FAA Damage Tolerance Requirements are as spelt out in the US Joint Services Structural Guidelines JSSG2006 and as such we consider that for cold spray certification we need

1. Experimental evidence that the technology can ensure/extend operational life and meet the stringent damage tolerance requirements.

2. A predictive capability that enables the effect of Cold Spray application on crack growth under operational load spectra to be quantified.

3. Non destructive inspection tools for examining the integrity of the Cold Spray mod/structure throughout its life.

Structural Integrity Enhancement/Restoration

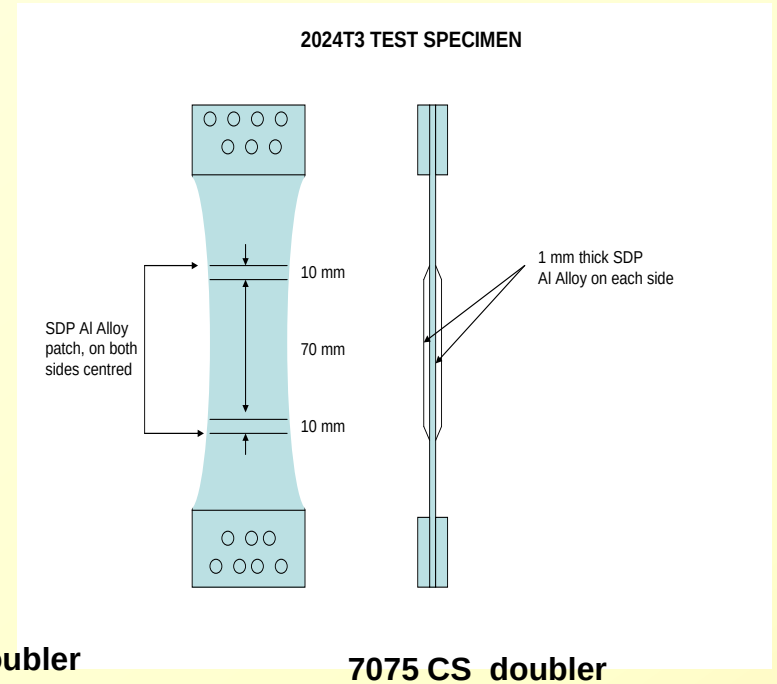
Rosebank Engineering along with its collaborative research partners are investigating the potential of Cold Spray research in two areas:

1. Application on thin Skins (PSE) – Monash University

2. Application on primary structure (SSI)- Defence Science and Technology Organisation.

Application on thin Skins

Experiment 1



7075 CS doubler
Applied peak stress
σ_{max} = 180 MPa, R = 0.1 MPa

OUTCOME

Baseline test specimen with notch and no Cold Spray Doubler - **Failure at 35,000 cycles**

For test specimen with notch and the Cold Spray Doubler - **There was no growth, or damage, after 60,000 cycles. Test stopped**

Experiment 2

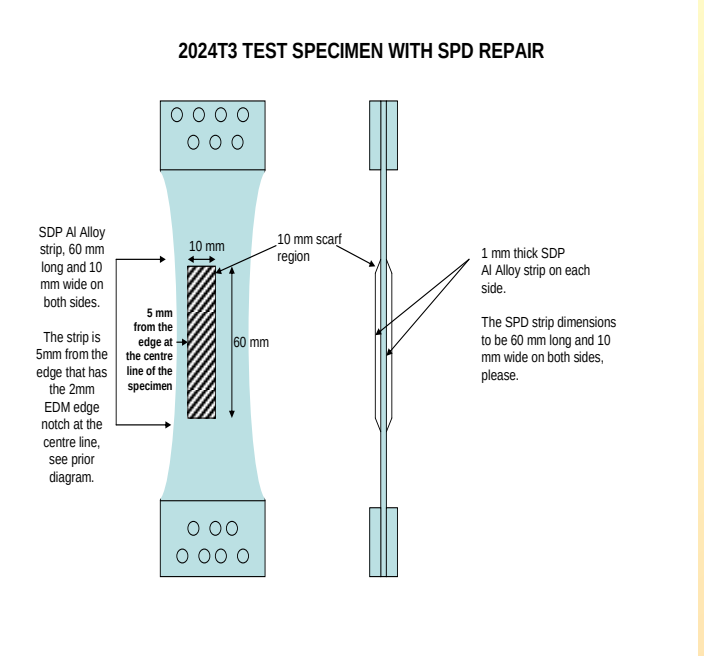
7075 CS doubler
Applied peak stress
σ_{max} = 270 MPa, R = 0.1 MPa

OUTCOME

Baseline test specimen with notch and no Cold Spray Doubler - **Failure at 1,800 cycles**

For test specimen with notch and the Cold Spray Doubler - **Test stopped 13,700 cycles with a crack of 3.7mm**

Experiment 3



7075 CS doubler
Applied peak stress
σ_{max} = 180 MPa, R = 0.1 MPa

OUTCOME

Baseline specimen (no Cold Spray) failed after **~ 40,000 cycles**

Specimen with Cold Spray - **This test was terminated after ~ 345,00 cycles *with no growth* from the edge crack *or damage in the Cold Spray*.**

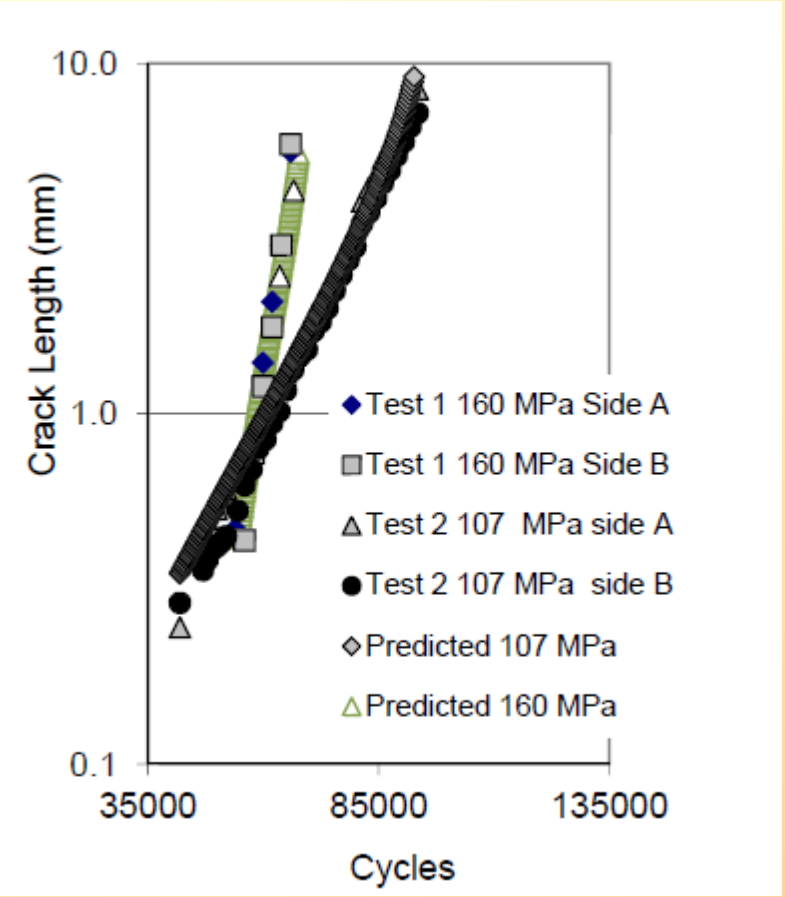
Predicting Crack Growth In Cold Spray Repaired Structures

A variant of the Hartman-Schijve crack growth equation was used to predict crack growth.

$$da/dN = D(\Delta K - \Delta K_{thr})^2/(1 - K_{max}/A$$

Test Program

Two 1.27 mm (thick) x 76 mm (wide) 2024-T3 Al alloy SENT (single edge notch tension) specimens with a 0.5 mm semi-circular notch were tested at 5 Hz, max stress 160 MPa and R=0.1 and 5 Hz, max stress 107 MPa and R=0.1 respectively.



Predicting Crack Growth In Cold Spray Repaired Structures

Having established the ability of Hartman-Schijve crack growth equation variant to predict crack growth in the baseline specimens the equation was used to predict Crack length in Experiment 2 specimen.

The predicted the crack length after 13,700 cycles for the Cold Spray repaired specimen tested at □max = 275 MPa and R = 0.1 including the length of the starter crack, of 3.1 mm which is in good agreement with the measured length of 3.7 mm

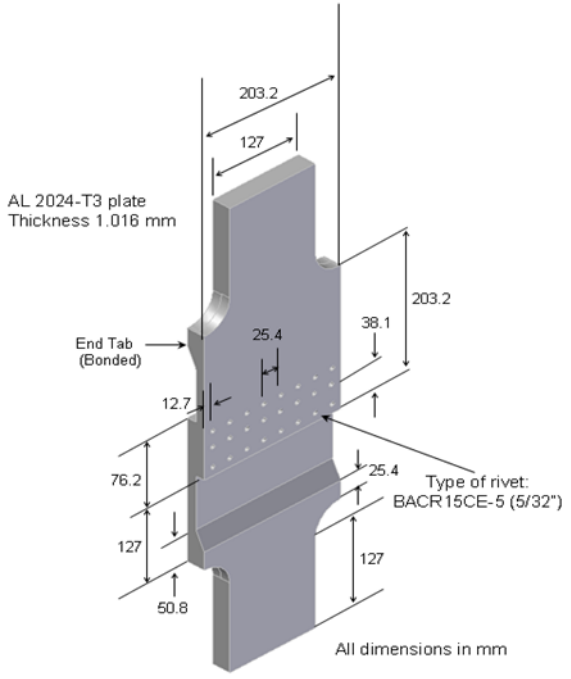
Application to Mechanically Fastened Joints

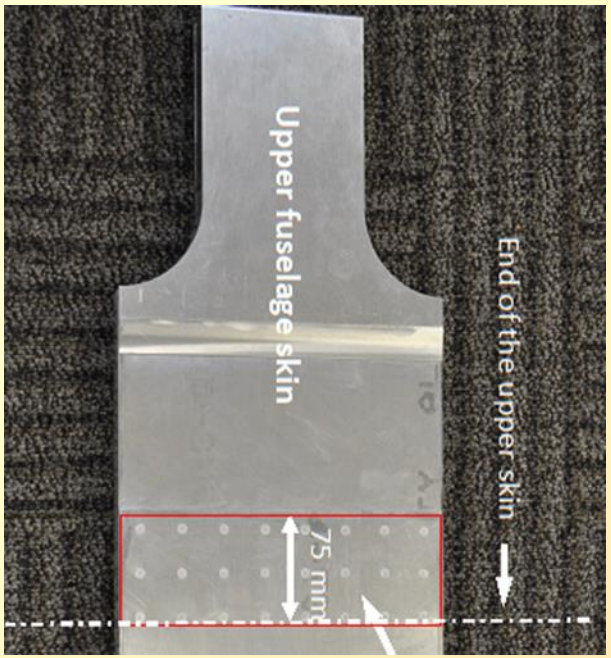
Multisite damage (MSD) around fasteners

Damage around fasteners due to corrosion

Application to Mechanically Fastened Joints

- Studies on the ability of Cold Spray to seal mechanical joints from the environment have now been undertaken using a specimen geometry developed as part of the FAA Aging aircraft program and patents lodged





Application to Mechanically Fastened Joints

OUTCOME

1. Cold Spray increased the Limit of Liability (LOV) of the joint by a factor of more than 3

1. Cold Spray has the potent to effectively seal the lap joint and thereby protect against the onset of corrosion damage.

Application on Primary Structure (SSI)

Application to of Cold Spray to an F/A-18 centre barrel undergoing full life cycle fatigue testing

Location Reference	Location Description	No Of Applications
1	Fuel tank area	1
2	Port Bulkhead Outer (Y470) - around bushed hole	1
3	Upper Skin Port - along fastener line -	4
4	Starboard Lower Bulkhead - across flat and webbing	1
5	Lower Bulkhead Starboard side and centre	2
6	Barrel Starboard Internal - across fasteners - 1 location	1
7	Starboard Lower Bulkhead (Y453) Lug	1
8	Starboard Mid Longeron Mounting	1

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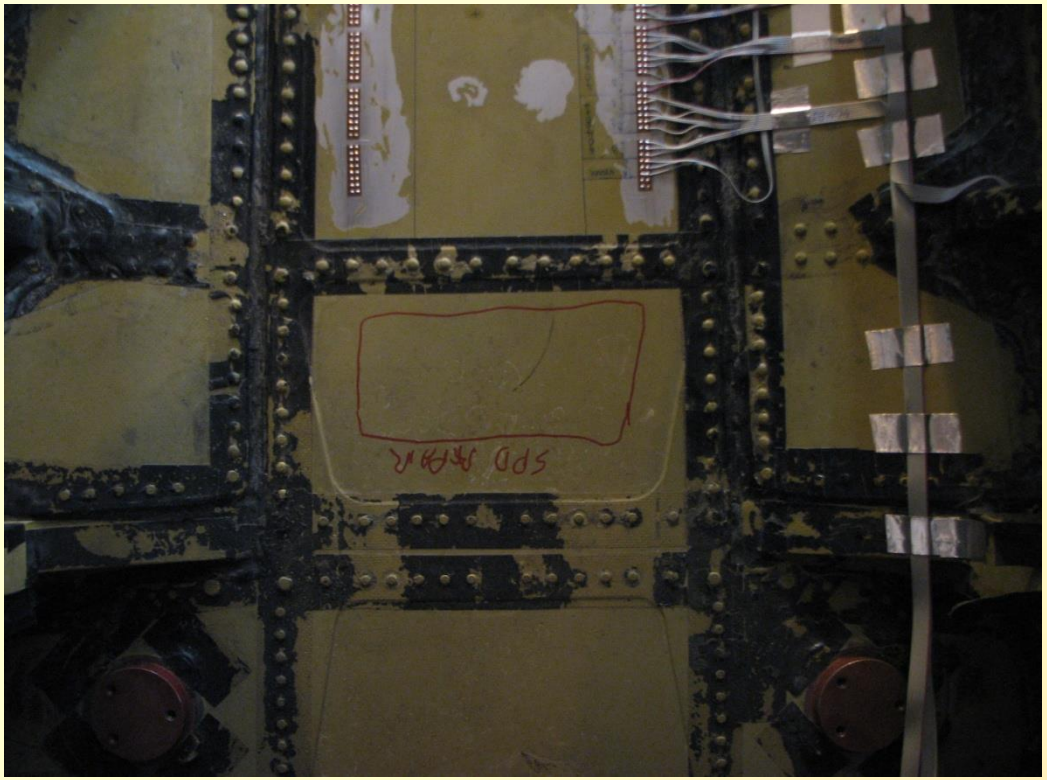
Fuel Tank Area (Internal)



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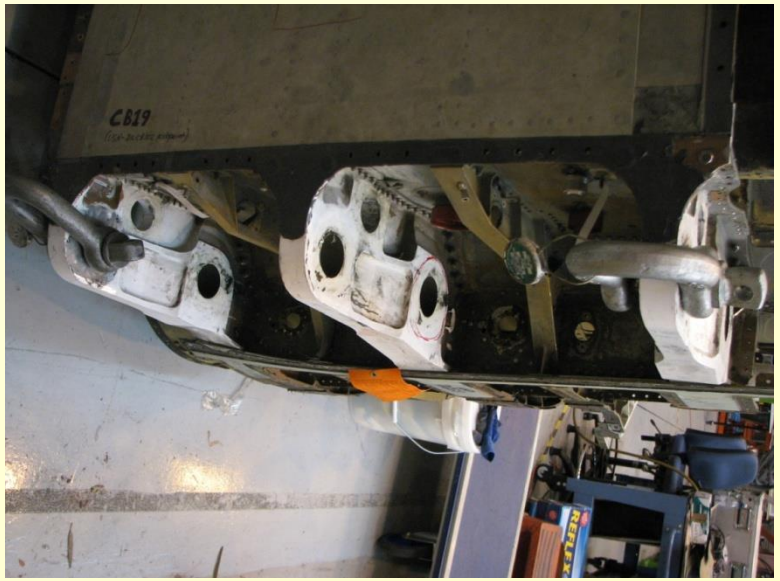
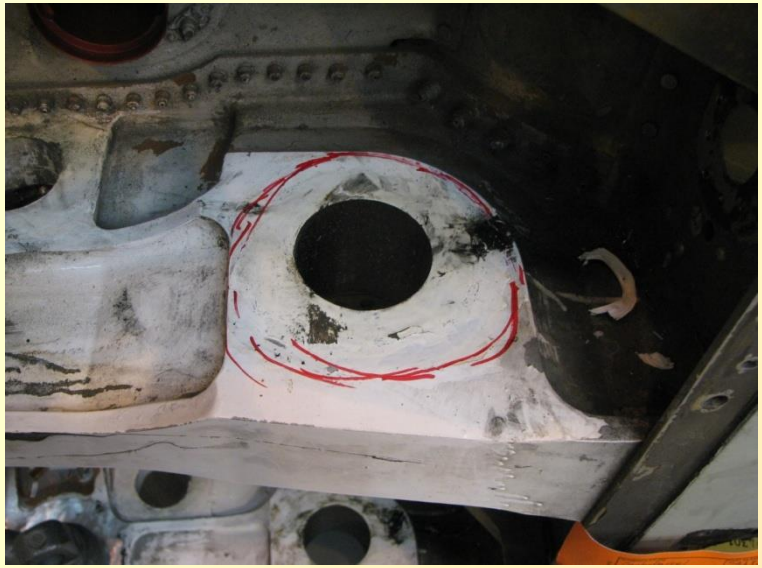
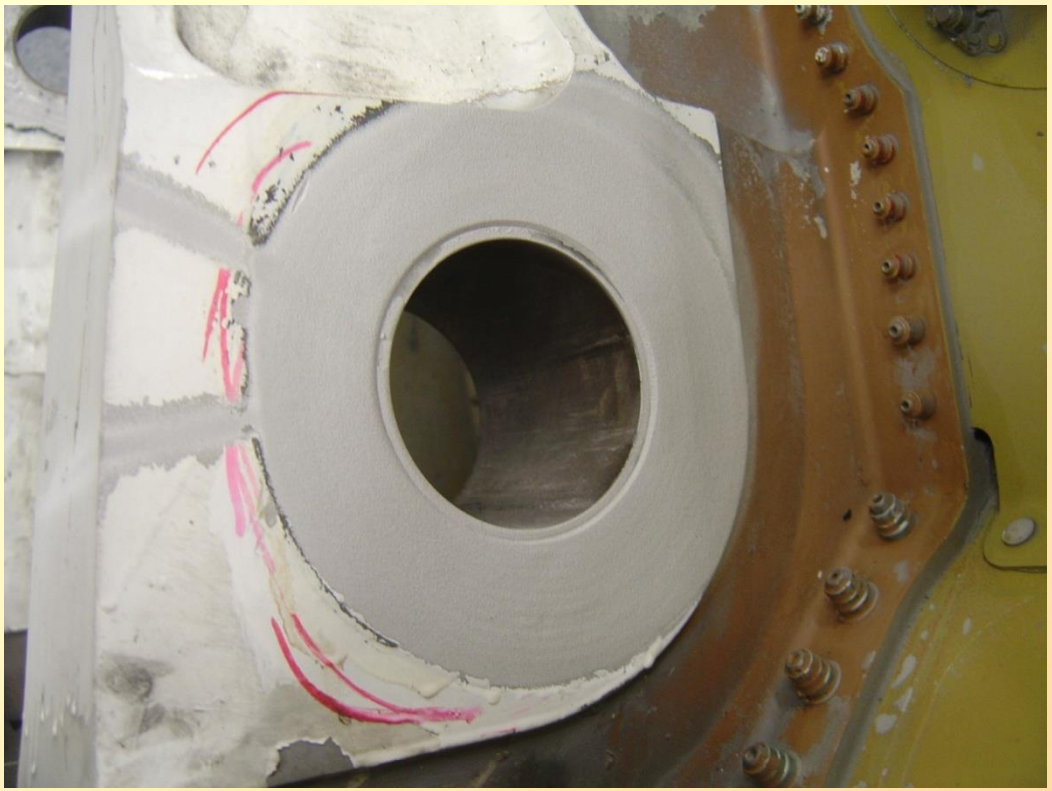
Port Bulkhead (Y470) Outer – Around Bushed Hole







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Upper Skin Portside - Along Fastener Line

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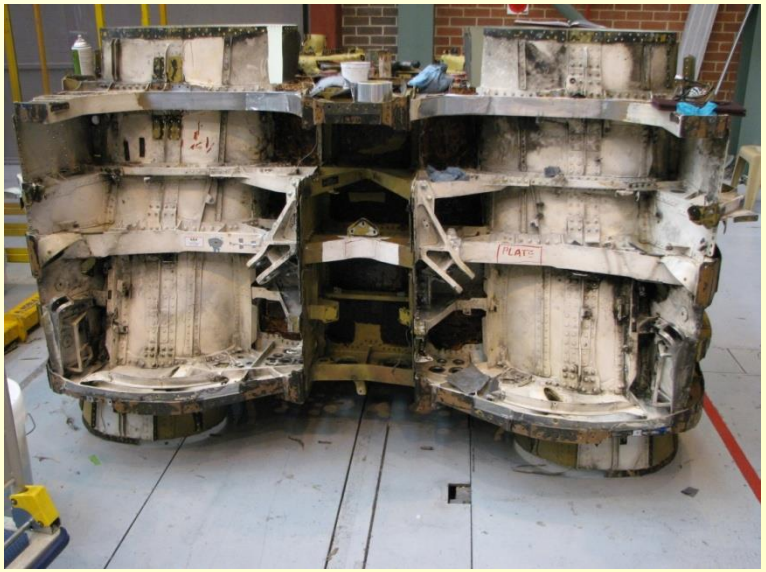
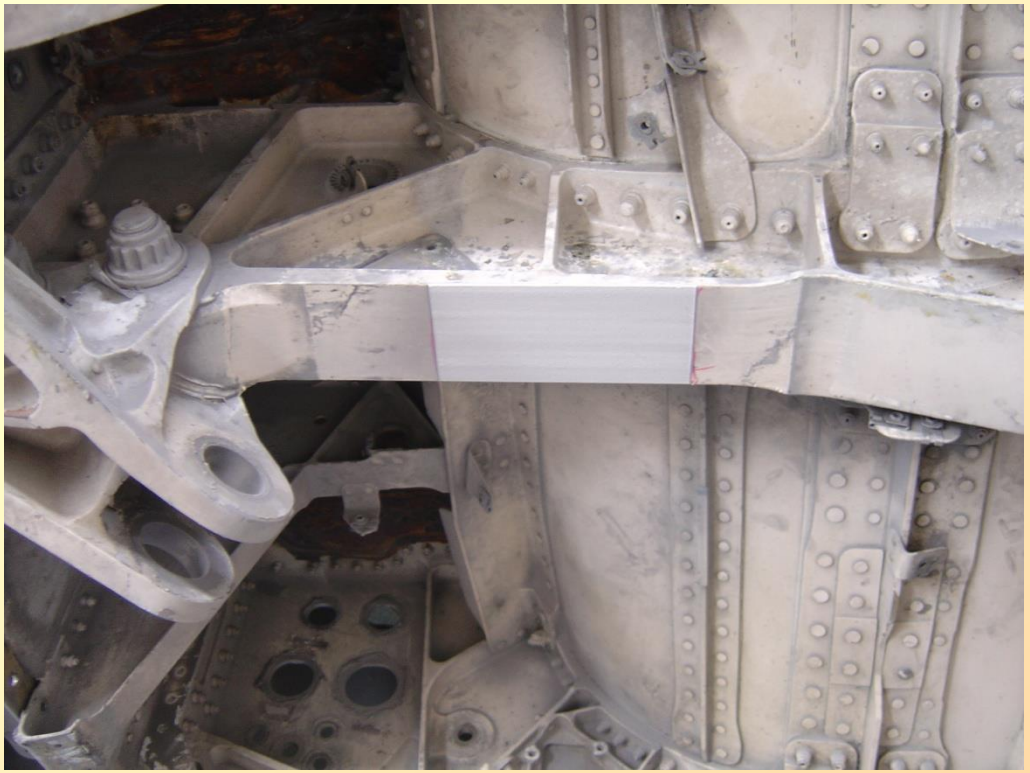
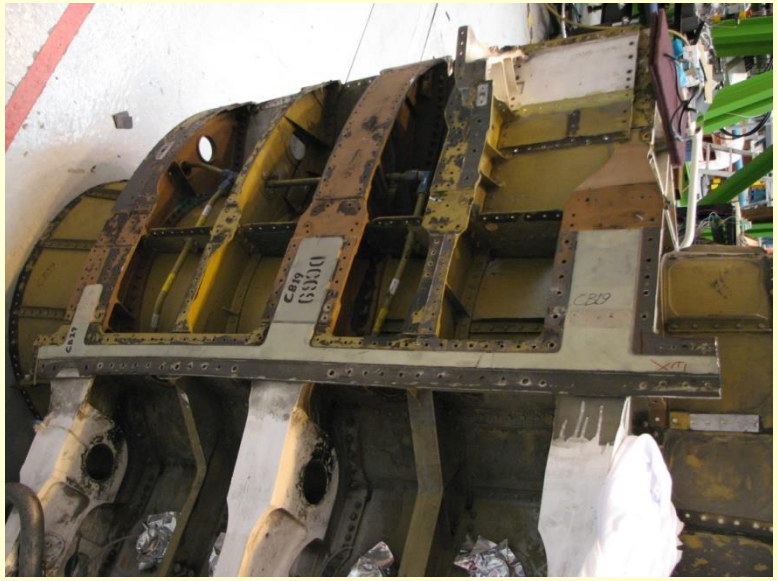
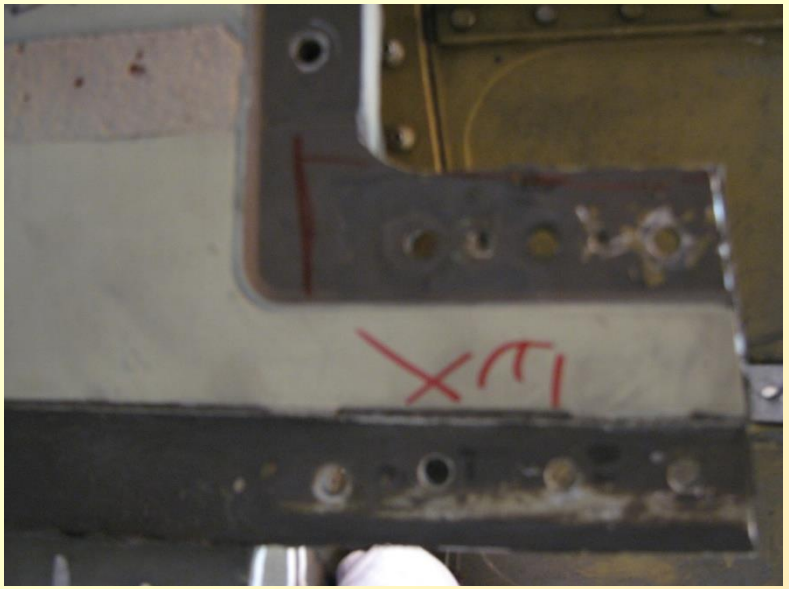
Lower Bulkhead Starboard Side





Starboard Mid Longeron





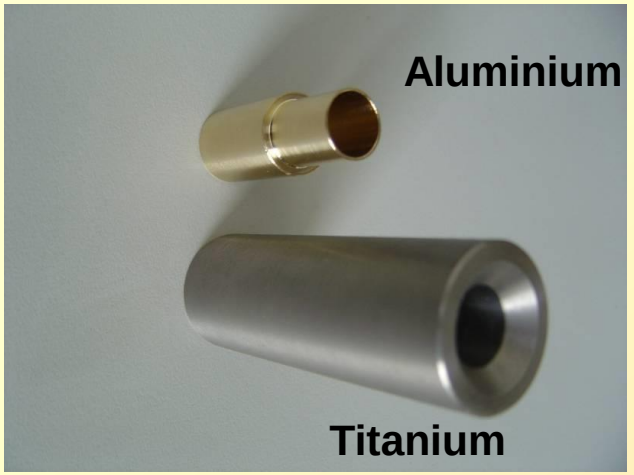
Cold Spray Portable Unit

- Rosebank awarded CTD program in Jul 2008 to the design and build a miniaturised field portable Cold Spray unit with the same capability as the large “fixed plant” Cold Spray capability
- Successful field demonstration held at HMAS Albatross on the 2 and 3 August 2010
- Hardware upgrades being implemented

Other Cold Spray/Powder Deposition Applications

- **Marine and Land Vehicle Applications**

- **Near Shape Production**



- **Integration as part of a Broad Powder Deposition Strategy e.g. Laser Cladding**

If all Else Fails

ACKNOWLEDGEMENTS

- US Army Research Laboratories (ARL)
- Defence Scientific and Technology Organisation
- Monash University
- Defence Materials Technology Centre
- Royal Australian Navy

THANK YOU