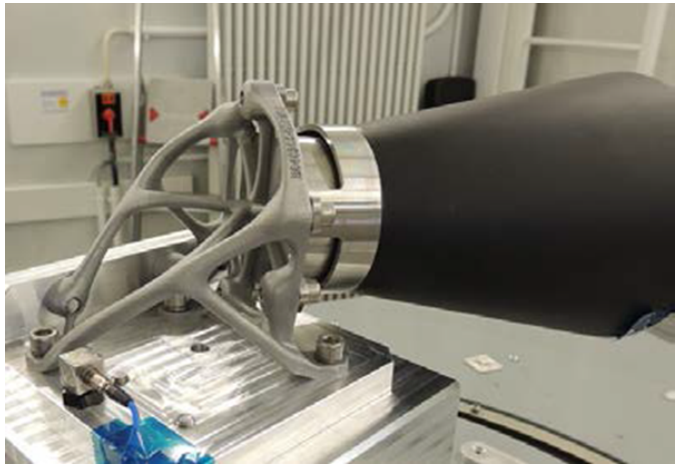
EDTAS Advanced Materials and Manufacturing

“Innovations in Manufacturing”



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Additive Manufacture & Materials

- Additive Manufacture (AM) is increasingly being referred to as the next industrial revolution and is fast approaching a “mainstream” technology status [1].
- In the aerospace industries companies that are expanding their 3-D manufacturing and production engagement are Boeing, Airbus , Lockheed Martin and General Electric (GE) [1].
- In more and more additive manufacturing parts are being introduced through the likes of NASA, Boeing and RUAG Space.
- Additive technologies such as SPD (Cold Spray) can also be used to generate new microstructures (material types) that cannot be achieved by conventional manufacturing approaches for specific combinations of properties.
- Part of the additive manufacturing family is additive metal technologies (AMT) and in aerospace AMT can be used for a range of sustainment applications up to including the creation of replacement parts and replacement of traditional metal coatings.

[1] D’Aveni R., The 3-D Printing Revolution, Harvard Business Review, May 2015 Issue

The Changing Nature of Our Business

Current

- Highly automated (low production costs)
- Build to print (Programming first article then away)
- Materials certainty (Supply and understanding)
- Subtractive processes much faster than additive processes
- Arguably additive processes currently exits
  - Castings
  - Forgings
  - Mouldings
  - Composites
- Well established supply networks

Future

- Efficiency when the total process is considered.
- Volume (high efficiency remains in extremely low volumes)
- Complexity. For any conventional fabrication process, high design complexity decreases efficiency Am avoids this.
- Flexibility Frequent changes and multiple revisions are inherently inefficient. With AM, they are encouraged.
- (Increased supply chain efficiencies (reduced warehousing/Shipping costs)
- Green manufacturing efficiencies

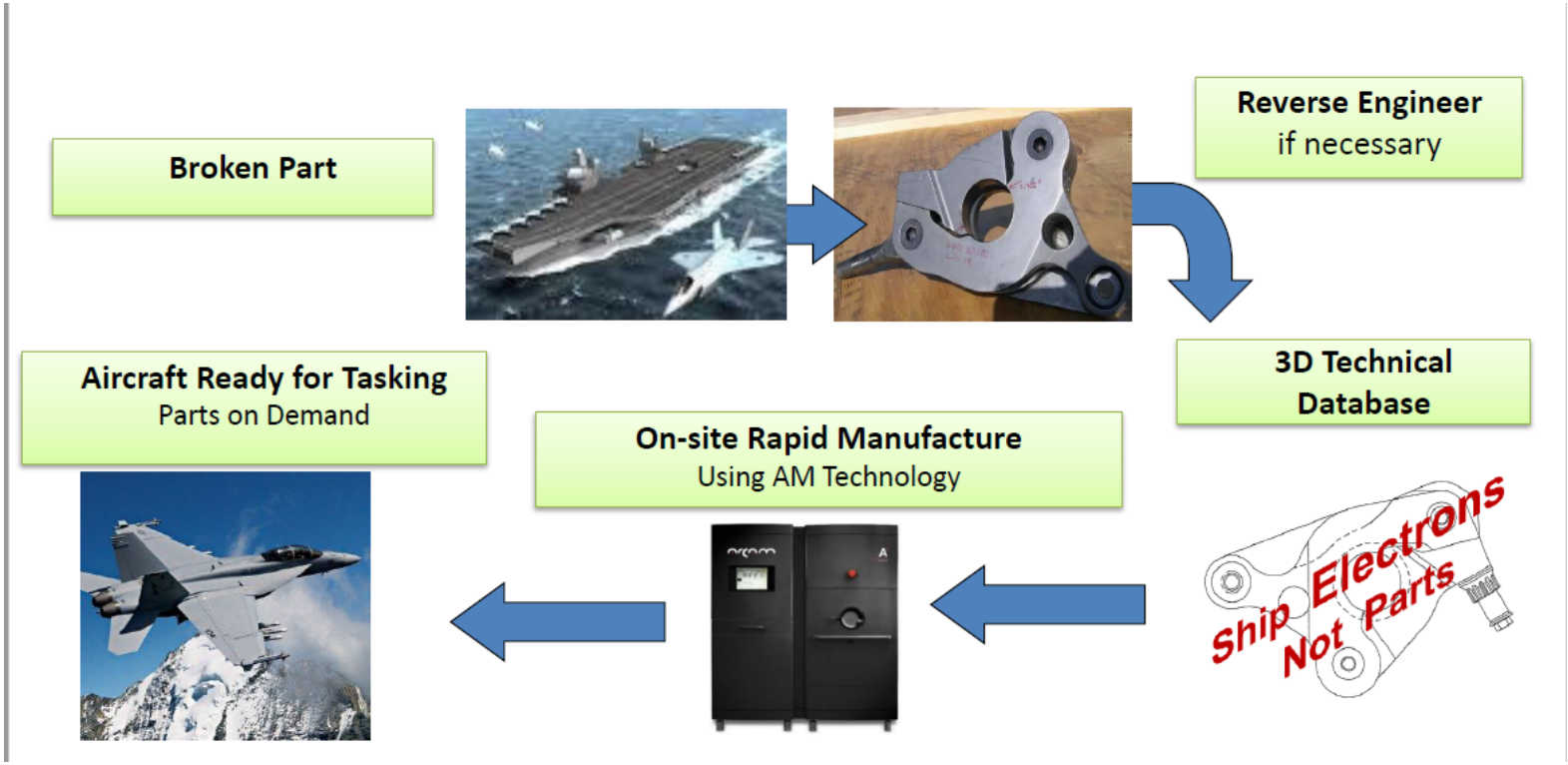
Linking AM to NAVAIR Imperatives

Readiness

- Parts on Demand
- Effective supply chain
- Local Repair

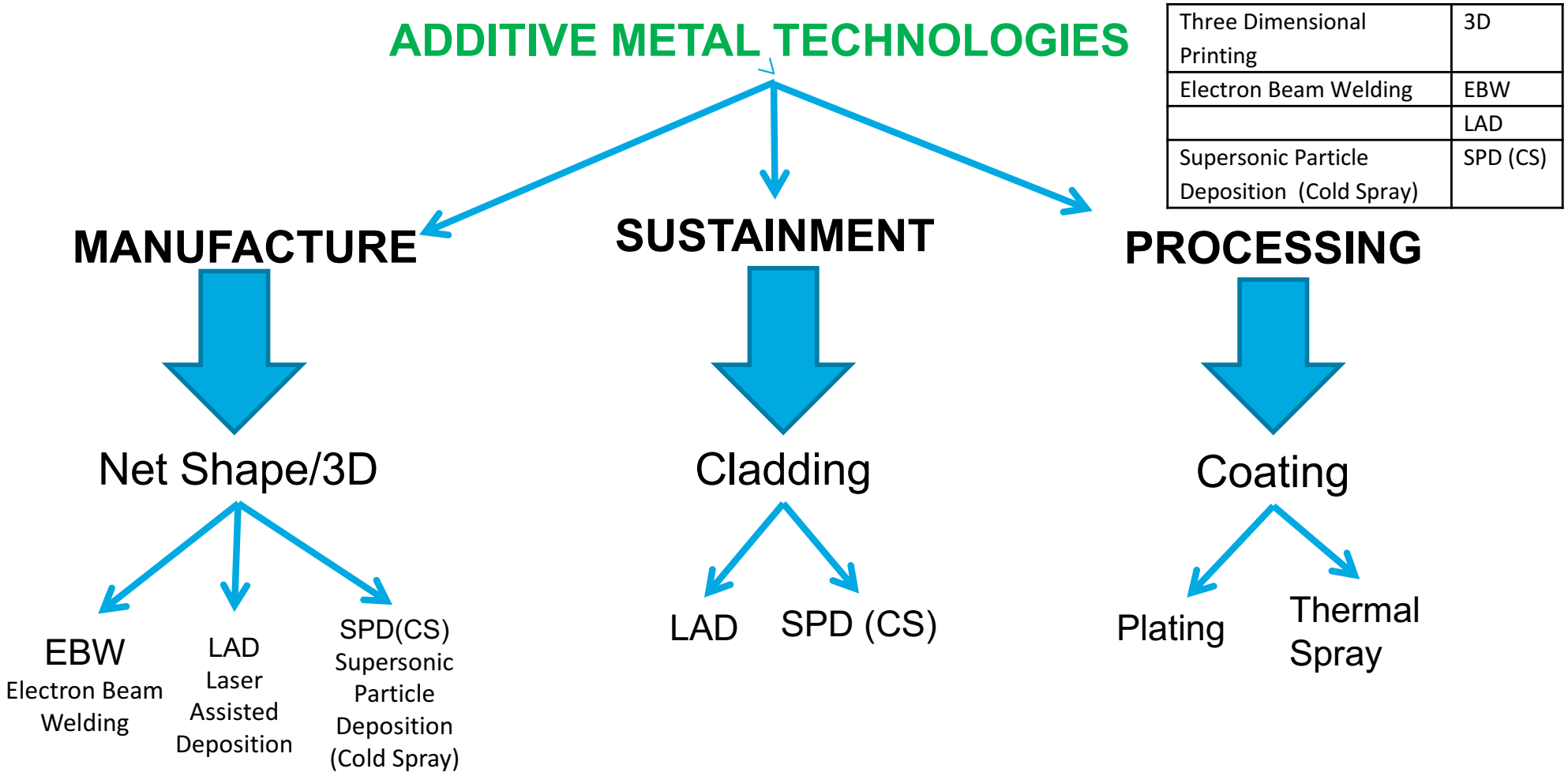
Increase Speed to Fleet

- Modifications for reliability enhancements
- Expanding capability
- Optimized &customized accelerated development and production solutions



Courtesy of NAVAIR - "NAVIAR AM Overview " Sea Air Space April 3, 2017

The AM Technologies - Part of Our Future



Three Dimensional Printing	3D
Electron Beam Welding	EBW
	LAD
Supersonic Particle Deposition (Cold Spray)	SPD (CS)

RUAG are well placed to be part of the change with achievements in R & T but need to transition into core business

AMT for MANUFACTURE - Current State Examples

- **Airbus to 3D Print Titanium Parts with EBAM 110 System from Sciaky (1.8mx1.2mx1.6m, 10Kg/hr)**
- **Arconic, Austin, Texas, has announced the installation of a 3-D printed titanium bracket on a series production Airbus A350**
- **Boeing will start using 3D-printed titanium parts in the construction of its 787 Dreamliner jet airliner. These are the first 3D-printed structural components to be approved by the Federal Aviation Authority, and could eventually save Boeing up to $3 million in construction costs on each jet built.**
- **GE (Sep 2016) agreed to buy two European 3D printing-machine manufacturers - Sweden's Arcam AB and Germany's Concept Laser. GE have also built a $50 million 3D printing factory in Alabama to make the parts in bulk for the new Advanced Turboprop (ATP) engine**
- **RUAG Space has been conducting intensive research and development work on how to "print" objects in three dimensions.**
- **US NAVY publish AM overview (road map). First flight critical AM part manufactured from 15-5PH steel to be flown in 2018 on V-22.**
- **The United States Air Force (USAF) is finalizing a strategic plan to integrate net shape (3D printing) technology in nearly every aspect of its airpower sustainment mission.**

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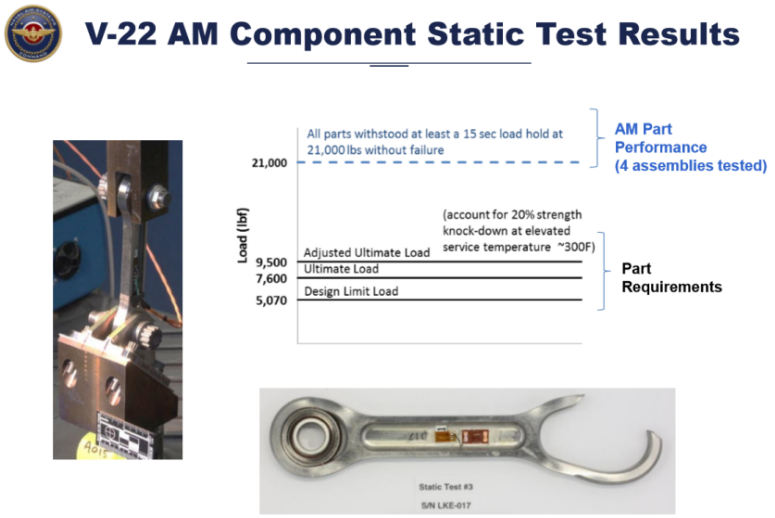
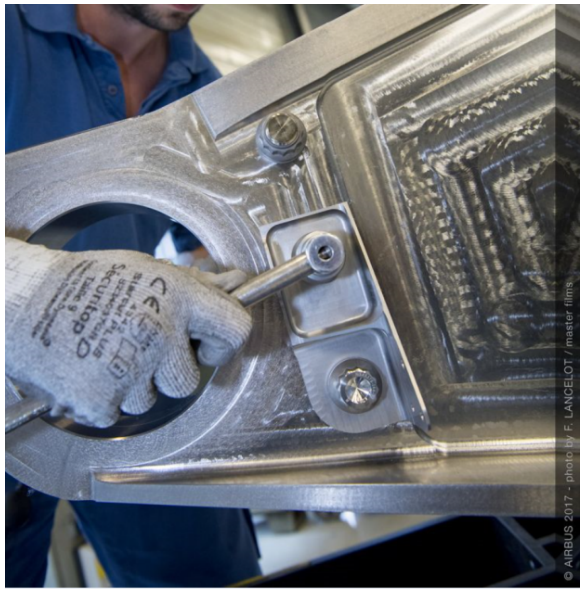
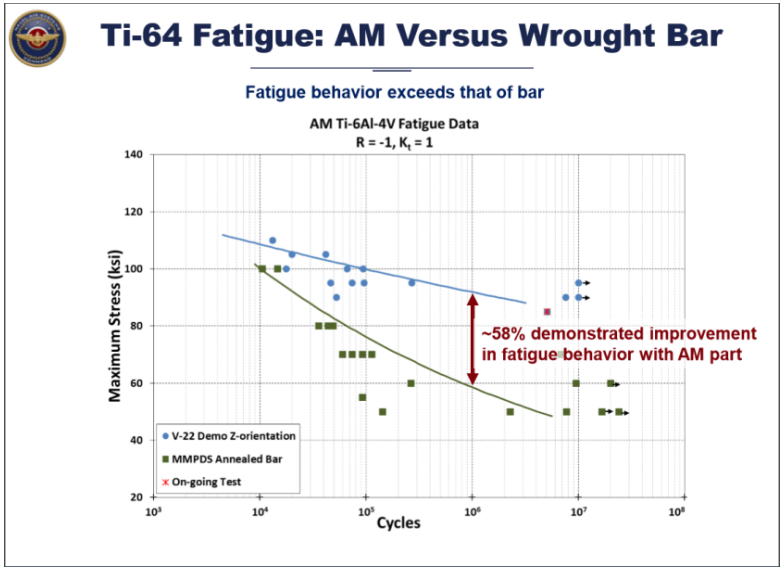
International activity re AMT for manufacture





3D printed bracket installed on A350 XWB pylon



3D printed bracket for Boeing 787 Dreamliner

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AMT for Sustainment - Now & For The Future

- Under Secretary DoD AT & L stated there is a need to research repair process that restore materials to an acceptable level of structural integrity *(US DOD 2009 he Annual Cost of Corrosion was between **$10 to 20 $Billon annually.** Cost of Australian Defence Force Aircraft **for Yr. 2103 was A$228M)***
- The United States Air Force (USAF) and USN is finalizing a strategic plan to integrate net shape (3D printing) technology in nearly every aspect of its airpower sustainment mission.
- For the new and next generation aircraft such as the F-35 optimised design process is that these new and next generation components will not be able to be repaired /recovered through the conventional subtractive processes.
- Australian F/A-18 continues to fund AM sustainment solutions.
- International interest gaining momentum from OEMs (Bombardier, BAE, Boeing)
- Australian Government award RUAG Australia $2M to develop laser repair technology

AM - FUTURE REPLACEMENT OF TRADITIONAL METAL COATINGS.

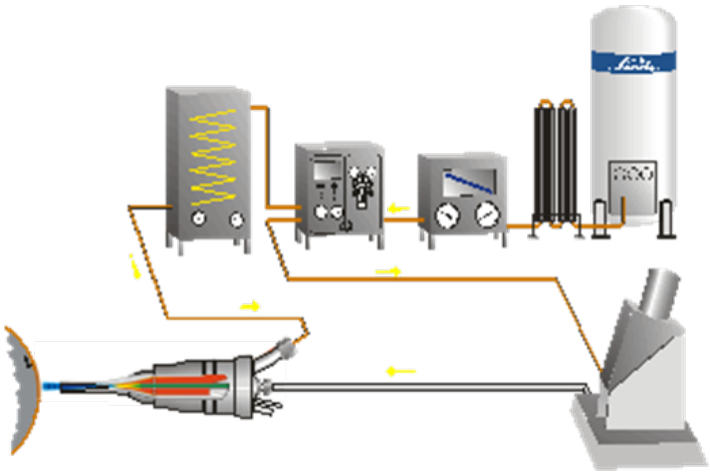
- **Traditional Metal Coatings**
  - Mainly chemically based resulting in both Environmental and Safety issues.

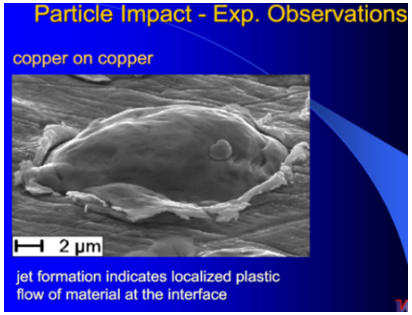
  21st September 2017 marks the official European Union sunset date for the use of Hexavalent Chrome, Cobalt and related substances "for which there is scientific evidence of probable serious effects to human health or the environment

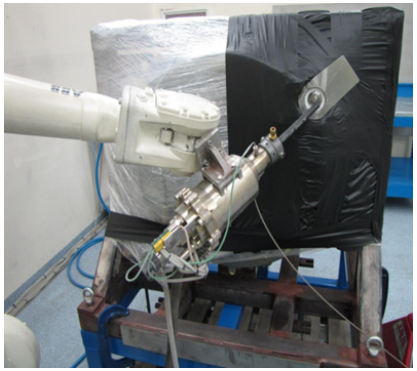
  - Large investment in establishment and running costs (electricity chemicals
  - Lengthy processing time due to masking, time in solution and quite often "baking"
- **AM Solutions**
  - Low environmental safety impact
  - Reduction in coating times by up to 75%
  - Restorations can be delivered in the field.
  - New coating opportunities.

Supersonic Particle Deposition (SPD) *(Cold Spray)*

- A technology in which Metal powder particles are injected into a supersonic gas flow and impact a solid surface with sufficient energy to cause plastic deformation and bonding with the underlying material.
- Bonding is a result of high strain rate deformation and adiabatic shear instabilities and the bond interface.
- No heat affected zone, no interface oxides, generation of surface compressive stresses, no thickness limitations.
- Various powder depositions (Aluminium, Nickel, Titanium, Inconel, Steel) on various Aerospace metal substrates.







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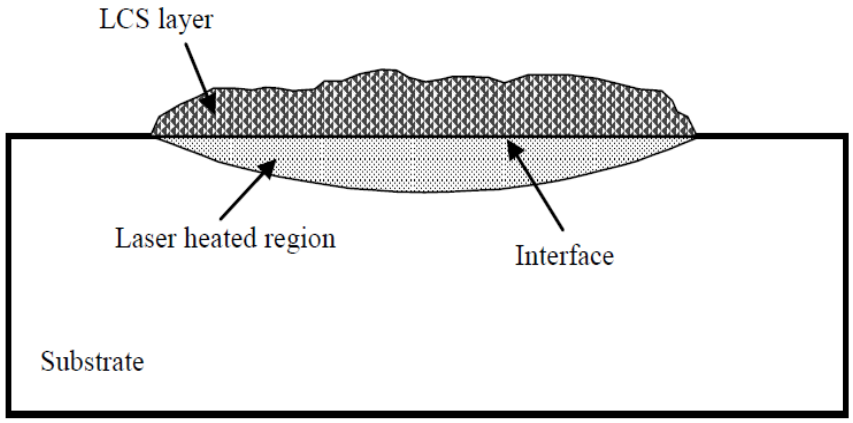
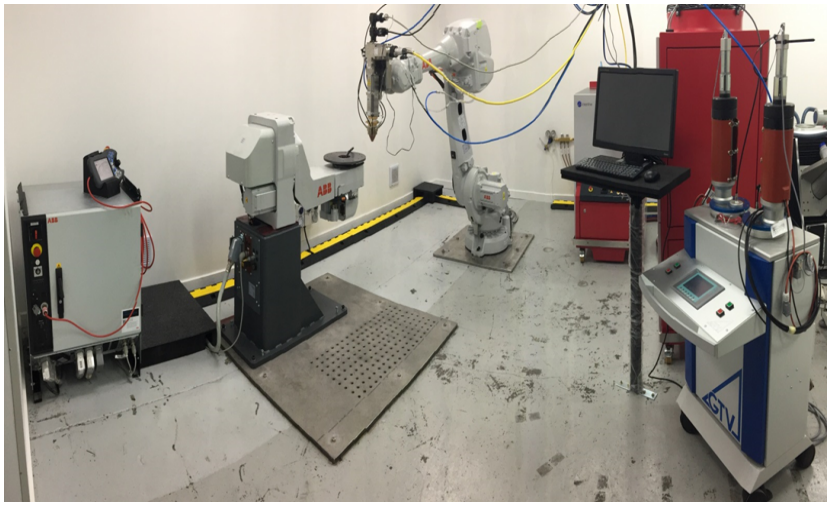
Laser Assisted Deposition (LAD)

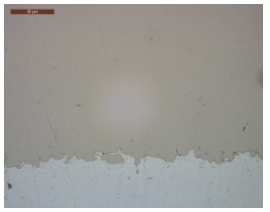
- **Laser Cladding** or **Laser Assisted Deposition** is a processing technique used for adding one material to the surface of another in a controlled manner.
- A stream of a desired powder/wire is fed onto a surface in front to a focused **laser** beam as it is scanned across the target surface, leaving behind a deposited coating of the feed stock material.
- High bond strength, quality of laser cladding deposits is very high (hard, dense with low level of dilution, surface finish can be smooth, heat input is localised, very rapid solidification, producing very fine wear resistant microstructures.

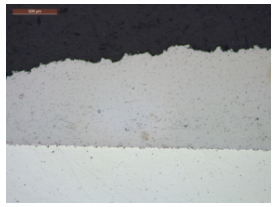




Successful Application Summary

- 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 (3 aircraft types, > 9000 accrued flight hours)
- RAN Seahawk transmission cost savings $5M over four years. Significant down time reduction (Seahawk Gear box TAT reduced by75%
- 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.





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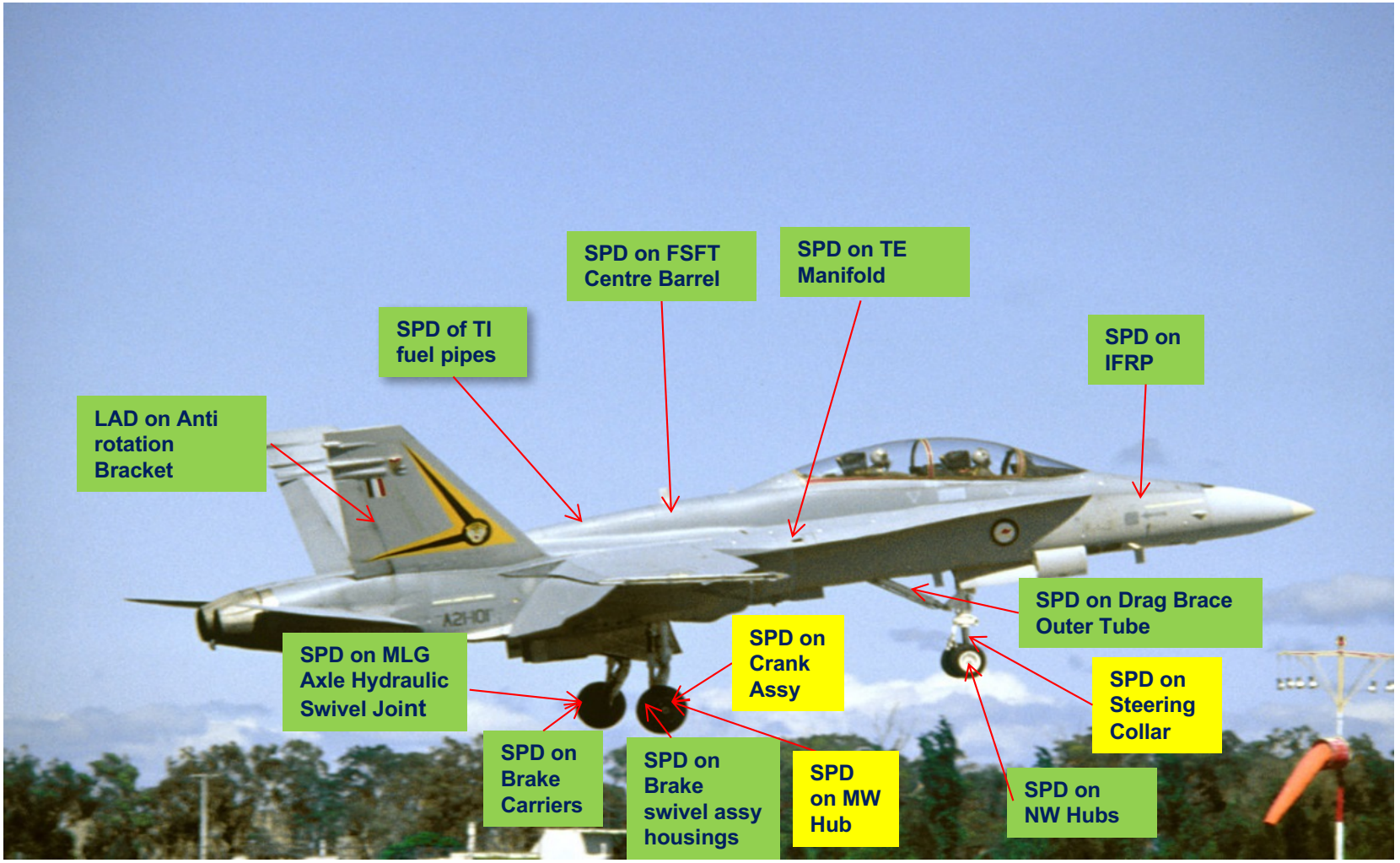
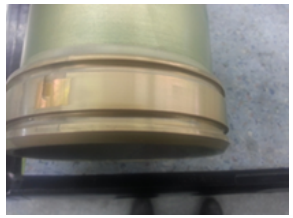
RUAG Additive Metal Successful Applications

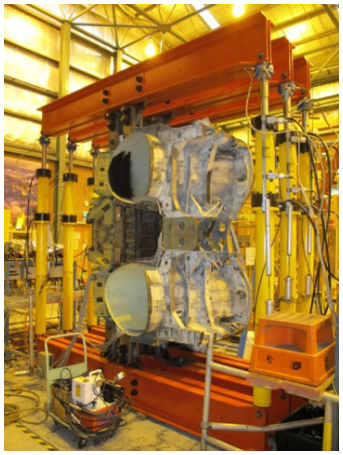


Brake Carrier Repair

Drag Brace Outer Tube Repair

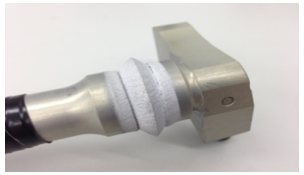


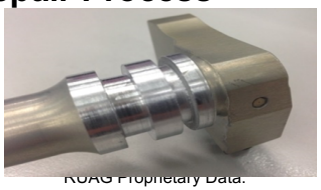
Full Scale Fatigue Test



Titanium Fuel Pipe Repair

Swivel Joint Repair Process





IFRP Repair

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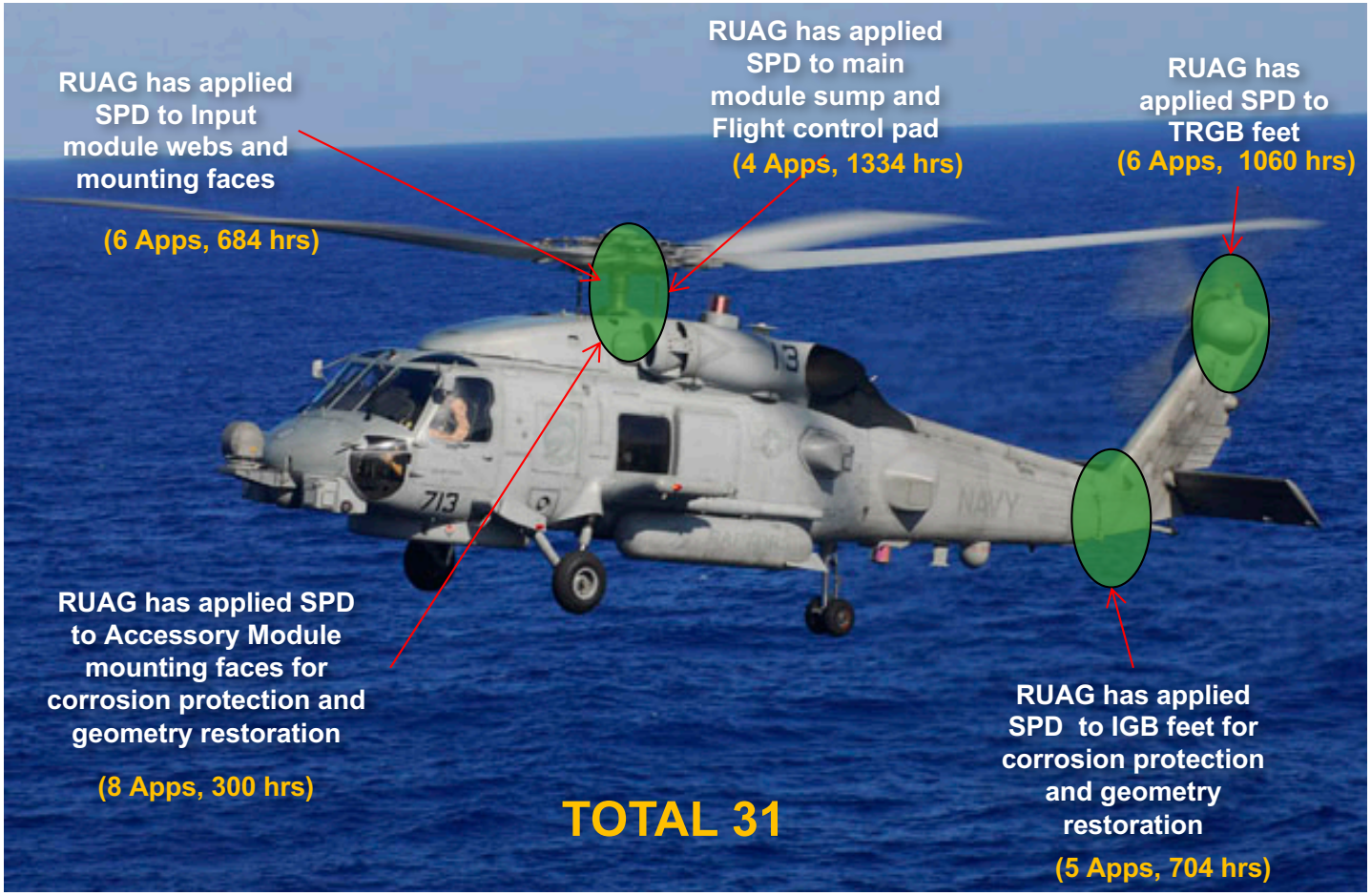
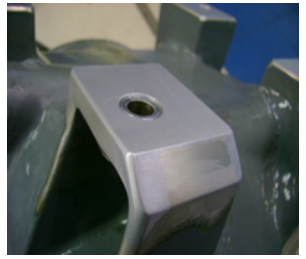
SPD Successful Applications

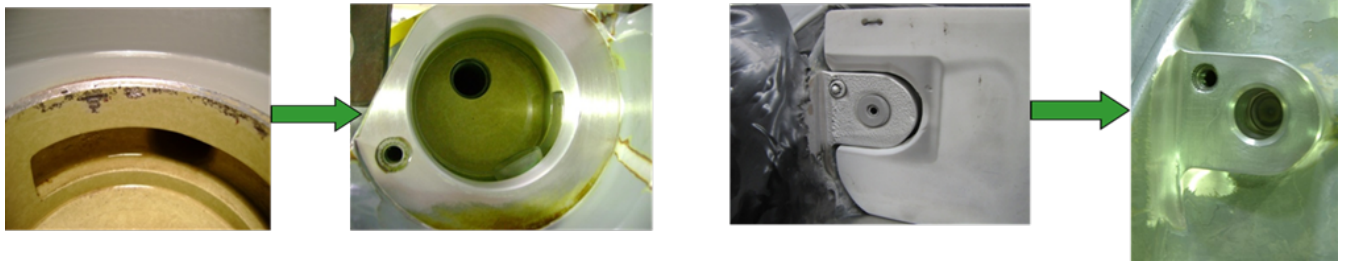


Input Module

Intermediate Gearbox



Main Module



RUAG Proprietary Data.

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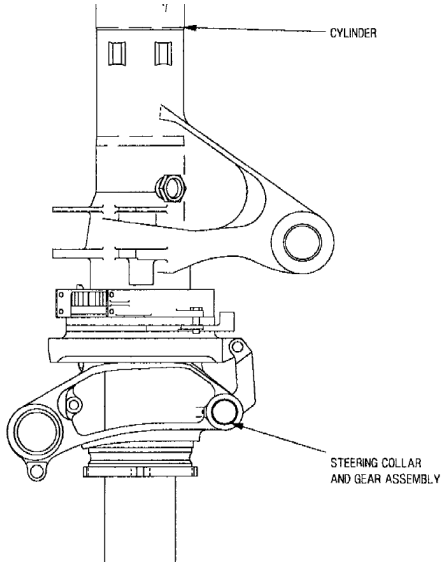
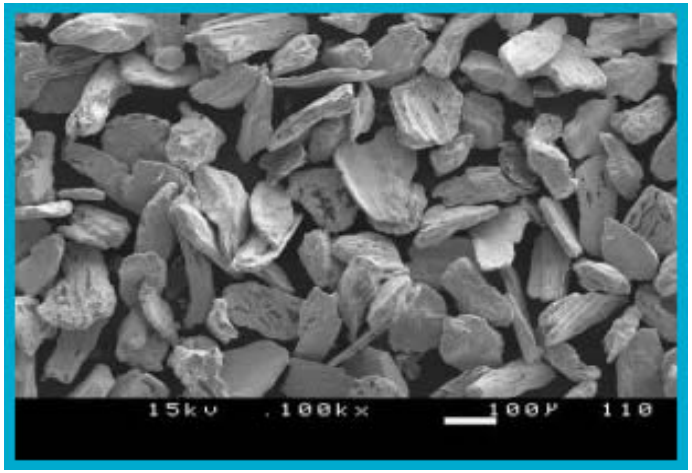
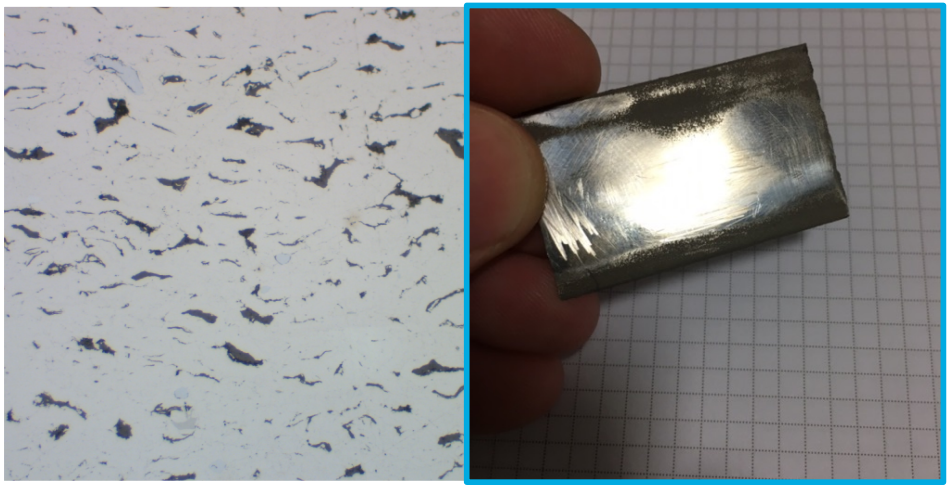
NLG Steering Collars

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







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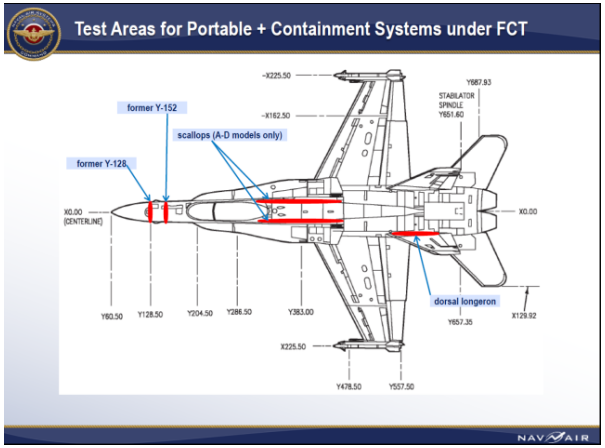
SPD *Field Application*



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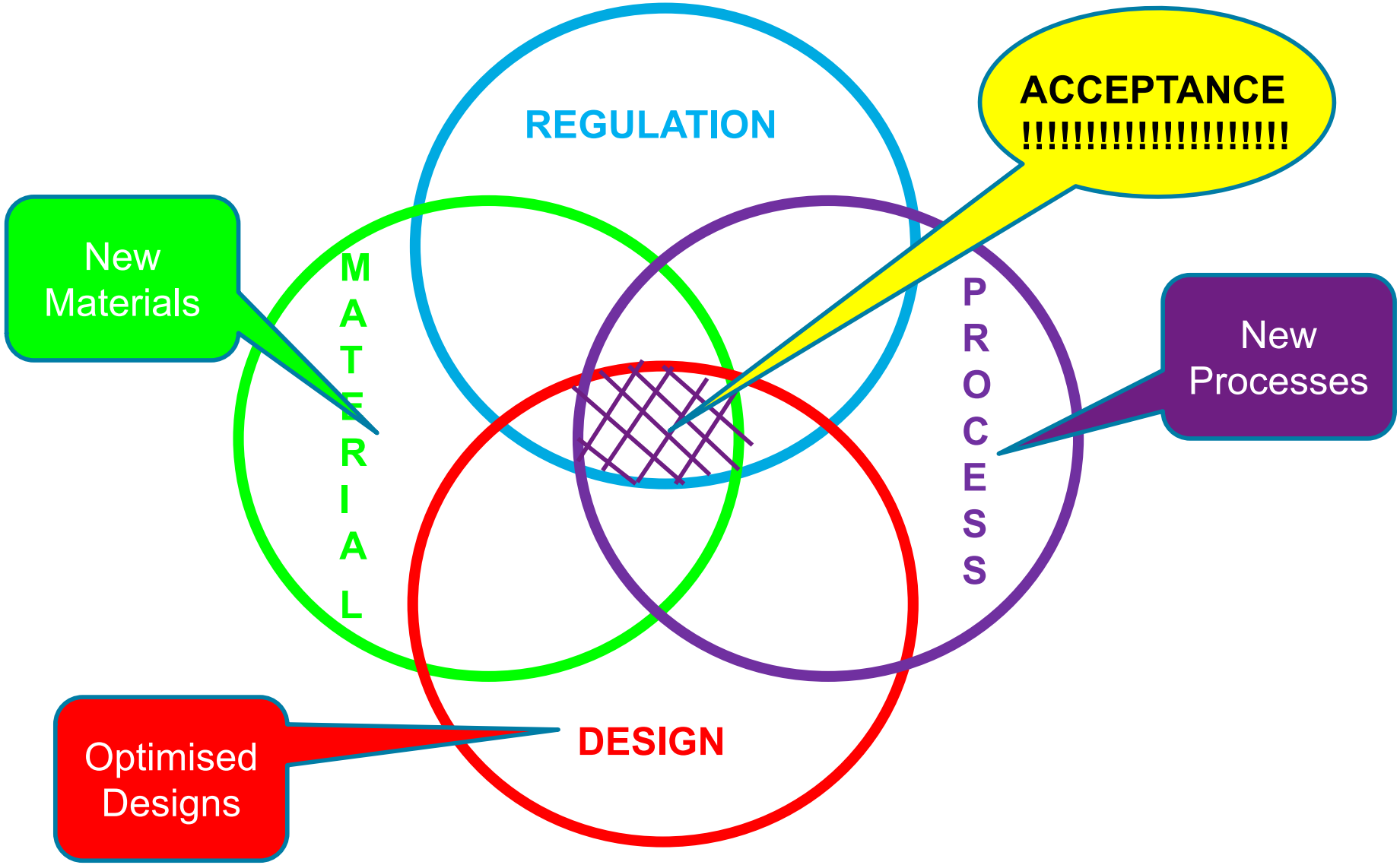
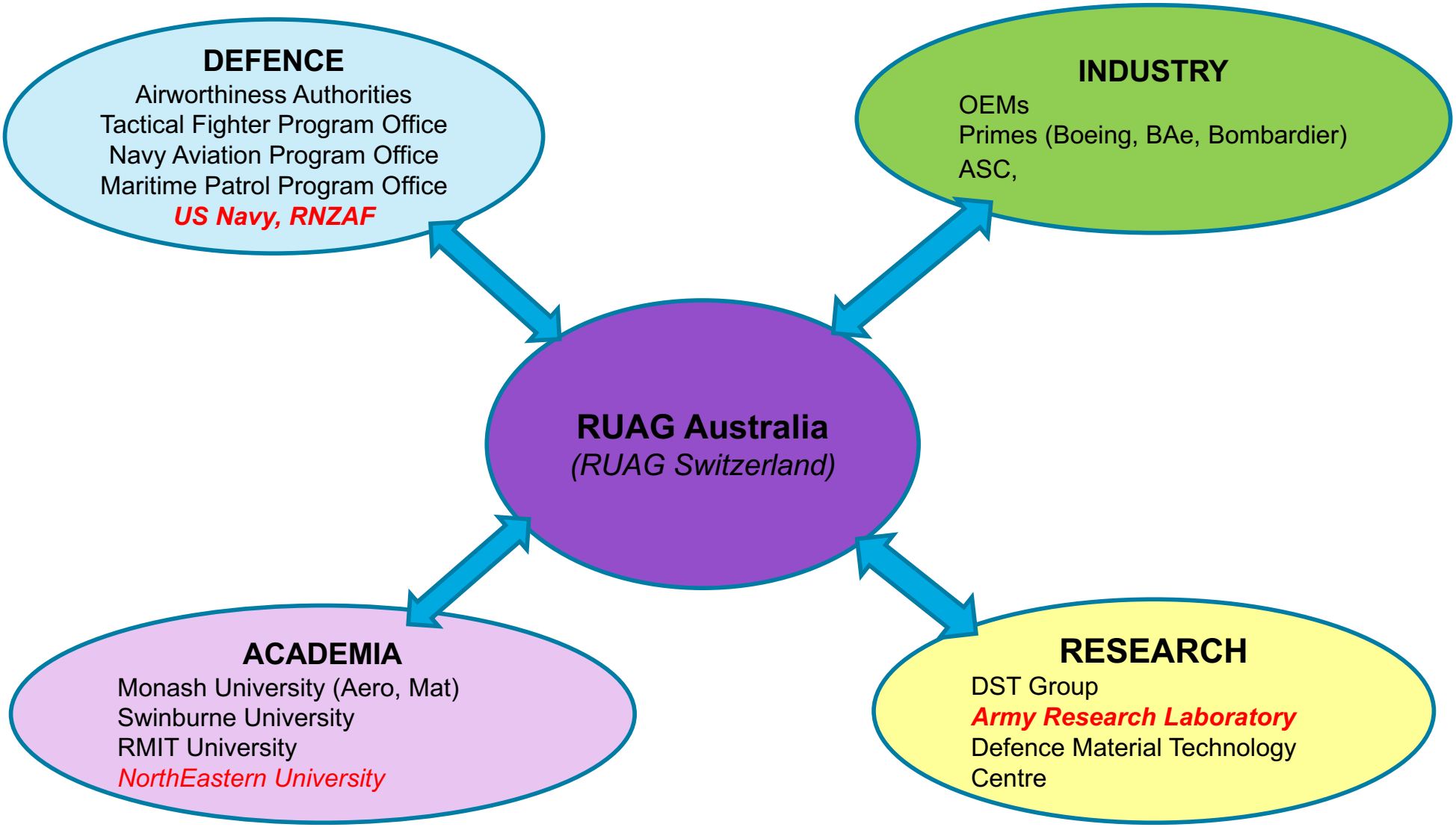
Acceptance of AM



Collaborative Partners



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System Specifications/Endorsements

- Cold Spray is an approved is a Military Standard, (MIL- STD 3021_ Materials Deposition, current issue Change 2 Mar 2015 – ***includes structure requirements***)
- The Director General of Technical Airworthiness (DGTA) stated that CS repairs for 'geometric restoration' presented no known detrimental airworthiness impacts..
- Swiss Defence Technical Airworthiness Authority (Armasuisse) Certification Office accepts CS is applicable for geometry restoration repairs for non-load bearing parts for the Swiss F/A-18's.
- OEMs are adopting/have adopted Cold Spray (SPD) in their approved repair processes
- US Army and Navy have approved SPD (Cold Spray) repairs
- FAA have accepted Cold Spray repairs for commercial aircraft application (components)

QUESTIONS ?????

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BACK UP SLIDES

Materials – The Status

Note Application's include both deposition on like material substrates and different material substrates

APPLICATION MATERIAL	Corrosion Resistance (CR)	Wear Resistance (WR)	Substrate Geometry Restoration (GR)	Structural Integrity (SI)	Structural Enhancement (SE)	Current coating Replacement (CCR)
6061 Al Alloy						
2024 Al Alloy						**N/A**
7075 Al Alloy						**N/A**
Titanium						**N/A**
Nickel				N/A	**N/A**	
Stainless Steel					**N/A**	**N/A**
High Strength Steel 4340						**N/A**
Tungsten Carbide			N/A	N/A	**N/A**	
Inconel	N/R				**N/A**	**N/A**

Verified/validated

Customer Acceptance

In Work

To Be Done

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SPD Nickel Application to F/A18 parts (CCR)

Nickle Application on M300 Substrate

- Geometry Bore Restoration
- Replaces Sulphamate Nickel
- Eliminates Hydrogen Embrittlement bake
- Reduces recovery time by 75%
- Reduces environmental exposure and cost associated with electroplating
- Meets required acceptance tests such as Corrosion test (Salt spray passed, Rating 10), Adhesion tests (Bend, scraping, ring shear, etc)
- Excellent properties (Porosity: ~0%, Hardness: >30 HRC
- Independently verified and validated (Australian Submarine Corporation)

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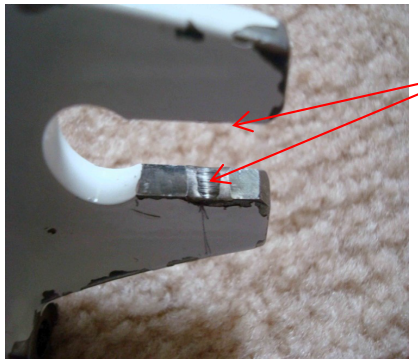
Customers Looking at AM Sustainment Solutions

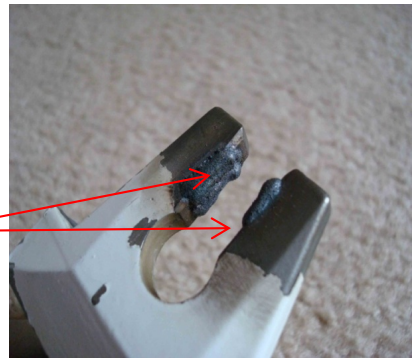
Customer	Application
AIRBUS GROUP ASIA PACIFIC GAP (AGAP)	Restoration of corroded helicopter truss frames and transmission housings . Repair of C130 components
BAE (Australia)	Restoration of corrode windscreen frames and engine intakes
BAE (UK)	SPD applications to repair fatigue damage on the Hawk Lead in Fighter
Bombardier	Resurfacing over fasteners on lipskin to improve airflow
US Army/Navy	Portable unit sales incorporating reliability performance enhancements.
Other International Organisations	RNZAF Restoration of damaged steel components. Finish Airforce for possible SPD restoration of missile launchers.
Other Industry applications including Marine, Land and mining	Restoration of damaged/corroded/worn components. Enhancement of ceramic designs

Laser Deposition Examples of Collaborative Research

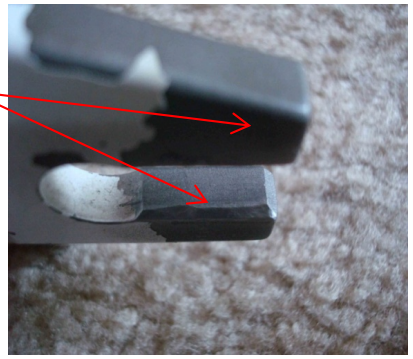


Damaged area

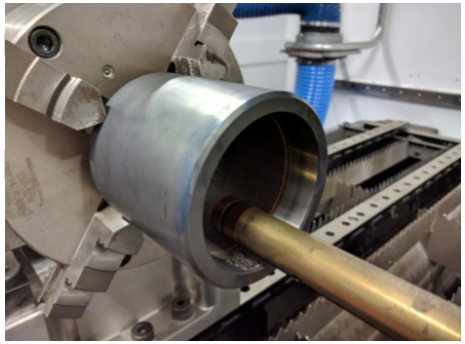
Clad areas



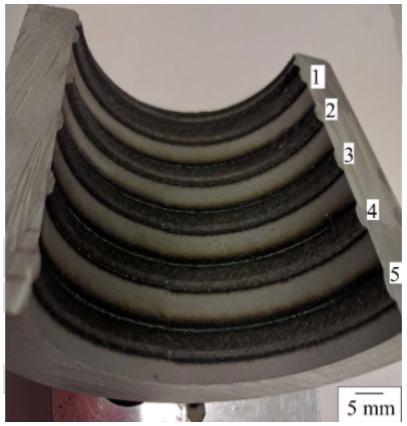
Repaired area



Repair F/ A -18 Hornet Bracket



Internal Bore Repair



Macro image of Multi track clad layers

RUAG successfully wins CTD for laser repair technology.

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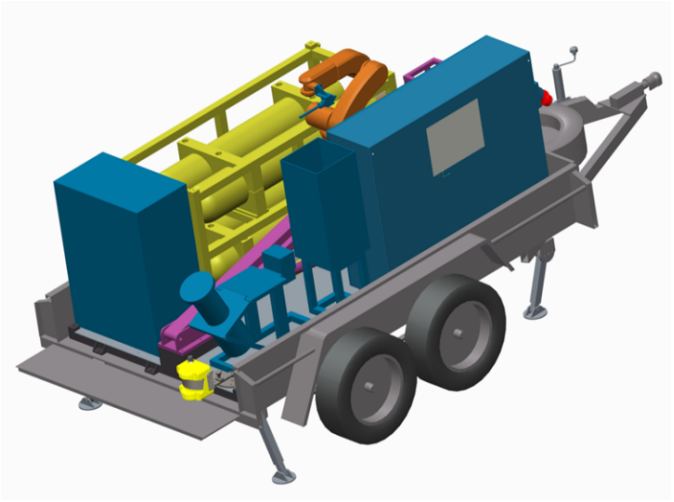
Technology to the Target



Hybrid

Portable

System

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ARL

HF WEBSTER ENGINEERING SERVICES

VRC METAL SYSTEMS

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