17MIC-0045

2017 DoD Maintenance Innovation Challenge (MIC)

Abstract Form	
Innovation Title:	Expeditionary Hydraulic Fluid Analysis
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Abstract (300 – 500 words):

For over 30 years, the Department of Defense (DoD) has relied on the Joint Oil Analysis Program (JOAP) as the sole means to probe and assess the condition of the lubricants protecting the engines, transmissions, gearboxes, and flight control systems of DoD assets. Over this timespan, several new technologies (chip detectors, HUMS vibration sensors and fine filtration) have been integrated into many platforms to improve reliability and advance the condition based maintenance protocol. Arguably each of these additions has contributed to pursuing that goal; however, component degradation still occurs, often undetected until at an advanced stage, one or more of these active devices alarms the flight crew or maintainers. The root causes of component degradation varies widely from the introduction of a contaminant such as abrasive silica, water or fuel to accidental (wrong fluid added) maintenance error. In a down range environment where the nearest JOAP lab may be days or a flight away, oil analysis is often waived, exactly when it is needed the most.

Expeditionary Fluid Analysis Capabilities (EFAC) are available today that are able to assess the condition of the lubricant and mechanical integrity of each component on-site in under 10 minutes. Technology has been developed through a USAF SBIR program that puts comprehensive fluid analysis in the hands of the maintainer to assess the condition of the fluids in their aviation assets wherever and whenever the need arises. This technology comes in the form of a one-man portable, 33-pound battery operated oil analysis laboratory capable of performing the standard battery of tests conducted at a JOAP laboratory. This device would meet every requirement for aviation compliance provided it included the capability to conduct comprehensive hydraulic fluid assessment in accordance with the Army Engineering Directorate (AED) Hydraulic Oil Fluid Sampling doctrine AED-TTS 130751; a mandatory requirement. This Maintenance Innovation Challenge (MIC) offers to develop an enhanced hydraulic fluid analysis capability on a standardized EFAC platform that will provide aviation maintainers with a comprehensive hydraulic fluid analysis capability that most AOAP/NOAP/JOAP laboratories do not have.

The overall objective is to partner with the Office of the Secretary of Defense (OSD) to develop a comprehensive hydraulic fluid analysis capability on a common support equipment platform standardized across the DoD Joint Oil Analysis Program. Development of this capability will provide all branches of the services with the additional capability to analyze hydraulic fluid cleanliness, contamination and cross contamination of hydraulic fluids at platform in under seven minutes using the enhanced version of the Field Lab 58M (formerly Q5800). Accomplishing the full objective of this MIC has minimal risk isolated to the measurement of the elements chlorine and barium. A rough order of magnitude estimate to accomplish this objective in full should not exceed $325k over a 9-12 month program period.

Expeditionary Hydraulic Fluid Analysis

PROBLEM STATEMENT

Hydraulic fluids used in flight control systems of fixed and rotary wing aircraft can and do experience contamination from external sources as well as unintended maintenance error. Today, no expeditionary technology exists that can perform a comprehensive field test and evaluation of hydraulic fluids in accordance with mandatory Army Engineering Directorate AED-TTS 130751 doctrine for hydraulic fluid cleanliness.
This capability gap places aviation maintainers in an unsettling position of having to decide to release the aircraft for operations or placed it in maintenance status when an abnormal flight control condition is observed. An expeditionary capability that provides a laboratory quality analysis of hydraulic fluid cleanliness in <10 minutes will empower the maintainer with a confident GO-NOGO decision making capability.

BENEFITS

- Laboratory quality analysis of hydraulic fluids in an expeditionary environment in <10 minutes.
- Enhancement of the standardized expeditionary fluid analysis platform (Field Lab 58M) without changing form, fit or function
- Operation creates no hazmat or waste stream
- Particle Count (fluid cleanliness) down to 50 particles/ml
- Water detection down to 175 parts per million (ppm)
- Chlorine detection down to 100 parts per million (ppm)
- Barium detection down to 10 parts per million (ppm)

TECHNOLOGY SOLUTION

This capability gap can be filled through research and development of enhanced modules that currently exist in the man portable expeditionary fluid analysis laboratory, Field Lab 58M (formerly Q5800). Design enhancements in the particle counter module can reach limits of detection below AED standards. A novel design of a disposable fluid cell cuvette will enable water detection in hydraulic fluids to reach ultra low concentrations as specified in the AED standard. Additionally, a novel disposable hydraulic fluid holder design enables a fluid sample to be introduced into the X-ray Florescence (XRF) spectrometer for detection of chlorine and barium. These three enhancements will expand the capabilities of the EFAC platform (Field Lab 58M) and fill this capability gap for all branches of the DoD.

Field Lab 58M

17MIC-0059

2017 DoD Maintenance Innovation Challenge (MIC)

Abstract Form	
Innovation Title:	Small Unmanned Aerial System (sUAS) Maintenance Inspection Capability
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Abstract (300 – 500 words):

Small Unmanned Air System (sUAS) technology is being more widely used in the commercial sector but there are still areas that have yet to take advantage of the capability. The 412 Test Wing saw an opportunity to use sUAS for aircraft inspections for C-17 and B-52s. The sUASs are a natural inspection application for wing, fuselage, and outer edges of the aircraft that eliminate the need to send maintainers up on ladders and buckets to inspect. sUAS have the potential to reduce tripping and falling hazards for safety inspections and greatly reduce time spent on maintenance. The 412 Test Wings evaluated the use of sUAS for aircraft maintenance inspections and other tasks.

The Emerging Technologies Combined Test Force (ET-CTF) of the 412th Test Wing at Edwards Air Force Base, California, demonstrated sUAS inspection applications using a 3DR Solo quad-copter fitted with a video camera to inspect the exterior of a Boeing C-17 Globe Master III cargo jet on loan from Joint Base Lewis-McChord in Washington state. The test team, which included 412 MXG maintainers and ET-CTF operators, conducted three sorties with the sUAS to determine if the quality of its video was adequate for routine inspections and clear enough to see smaller details of the exterior such as structural abnormalities, rivets and cracks.

“It was the first time the ET-CTF flew a small unmanned aerial system on the flight line and the second time the ET-CTF has used a sUAS in a new application that shows promise.” The ET-CTF started testing a quadcopter to determine if a sUAS can be used to calibrate the 412th Range Squadron’s telemetry antennas on the base. Those tests produced positive results. The 412th Civil Engineering Squadron is also considering using sUAS for roof inspections, airfield inspections and “environmental-concern area” inspections.

Inspections of aircraft upper surfaces that normally can take up to 2-hours were done in 30 minutes with a quadcopter; in the case of the C-17 a sUAS would spare maintainers using a lift to inspect its tail. Maintainers at Edwards AFB were able to use the sUAS’ video to sign off their preflight external inspection -an Air Force first. This testing opens the aperture on flying a sUAS near the airfield, which has been frowned upon in the past. These initial missions are establishing baselines for how operations can be conducted safely at Edwards and other USAF installations.
With proper development this technology presents potential for multiple uses. In addition, to real time monitoring of inspections; capabilities exist to record the inspection as well as tracking aircraft condition over time. Further development of automatic flight patterns, self-contained lighting, and improved camera capability would only enhance the capability of the platform.

Small Unmanned Air System (sUAS)

PROBLEM STATEMENT

- Inspection of cargo aircraft upper surfaces cannot always be accomplished in wet or icy conditions by normal methods. Traditional methods expose personnel to potential mishaps due to tripping hazards associated with lanyard style fall protection systems or potential for aircraft damage if using self-propelled maintenance platforms
- Inherent risk, increasing costs, outmoded approaches and continuing to do 'business as usual' are indefensible in current and future fiscally constrained constructs.

BENEFITS

The benefit of using sUAS for aircraft, facilities, and other installation maintenance inspections are significant.

- Aircraft downtime for inspections are reduced from 2 hours to 30 minutes.
- Aircraft maintainers reduce the time and effort needed climbing ladders, and walking on wings to perform visual inspections.
- sUAS is a natural inspection application for wing, fuselage, and outer edge of aircraft.
- Civil engineering inspections of 216 miles of road; 4.82 million square yards of airfield pavement; 1.98 million square yards of paved parking's areas, and 2,500 building/facilities will minimize bi-annual expenditures on digital optometric aerial photography costs.
- Use of sUAS for aircraft incident recovery surveys by CE personnel could reduce/alleviate the hazard of initial response in crash scenarios.

TECHNOLOGY SOLUTION

- Implement standardized and control measures for sUAS inspections in and around a flight line and installation environment.
- Support the rapid integrating of sUAS base operations support and maintenance environment through a flexible test and logistical support process.
- Establish an installation sUAS training and operator certification program that could be replicated across the USAF and Department of Defense.
- Enable safe and timely operations and effective integration of unmanned systems for installation activities
- Lightning strike damage inspections after known or suspected damage
- Immediate cost savings and expanded tangible benefits to all these Installation support areas and more!

The small vertical take-off and landing (VTOL) unmanned aircraft system gives warfighters, first responders and others in small, cluttered, urban environments an eye-in-the-sky in just minutes. Indago features an extended hover, perch and stare capability that provides military, civil and commercial customers with aerial reconnaissance in crowded areas unreachable by fixed-wing unmanned aircraft systems. The VTOL's gimbal mount includes electro-optical and infrared sensors and a laser illuminator to provide continuous 360-degree panning capability.

17MIC-0062

2017 DoD Maintenance Innovation Challenge (MIC)

Abstract Form	
Innovation Title:	DRIFT Composite Heat Damage Evaluation of V-22 Wing
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Abstract (300 – 500 words):

Over the last 35 years, the Department of Defense has been flying aircraft that include flight critical components constructed of advanced composite materials. These materials reduce the weight of the aircraft, while maintaining superior strength characteristics and corrosion resistance when compared to previously utilize metallic materials; however, the composites used on DoD aircraft are less tolerant to extreme temperature than traditional metallic materials.
Issue: While physical damage due to extreme temperature such as charring and delamination can be detected using conventional non-destructive inspection techniques, chemical damage—often called incipient heat damage—may remain undetected. The uncertainty of undetected incipient heat damage in the composite after a high temperature event can lead to scrapped parts or scrapped aircraft, which may have otherwise been repairable.

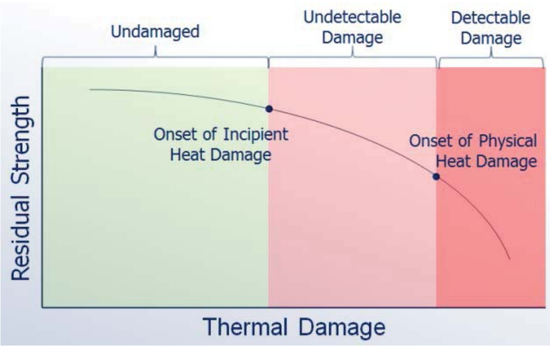
Diffuse Reflectance Infrared Fourier Transform (DRIFT) is a chemical analysis technique used for characterizing organic materials and can detect chemical changes such as those caused by incipient heat damage. The technique uses chemometric analysis to correlate the polymer chemistry of the composite to the chemistry of a standard with a known level of heat damage. In 2015, handheld DRIFT inspection was qualified by FRCSW to detect incipient heat damage in composites on F/A-18 aircraft using Agilent's portable Flexscan 4200. The DRIFT inspection technique is now regularly used for this purpose on F/A-18 composite aircraft. In 2016, a multisite team was formed by FRCSW, FRCSE, FRCE, and NAWCAD to transition the DRIFT inspection technique to other NAVAIR platforms, including the V-22. This team made standards, completed mechanical tests, and performed the required chemometric analysis to use the DRIFT inspection method on the composite material used on the V-22 wing skin.

In March 2017, an engine fire damaged a V-22 Nacelle located at MCAS New River. The Nacelle and all rotors components were scrapped because of obvious visual heat damage. Heat damage was also suspected in the wing tip, though no physical damage was detected using conventional non-destructive inspection. Without the DRIFT inspection method, suspicion of heat damage in the wing tip would have led to scrapping the entire wing at an estimated cost of $10M. A collaborative team from FRCSW and FRCE visited MCAS New River to perform a heat damage evaluation using the DRIFT inspection method developed by the multisite team. The team found no heat damage on the composite wing skin, enabling the wing to eventually be returned to service later. Work continues to develop the DRIFT inspection method to be used on other composite materials and on other aircraft.

DRIFT Composite Heat Damage Evaluation of V-22 Wing

PROBLEM STATEMENT

- Incipient heat damage in composites—damage to polymer chemistry—may go undetected.
- Traditional Non-destructive inspection techniques only detect physical heat damage.
- Without inspection method, repairable aircraft parts may be scrapped after high temperature events to ensure airworthiness.



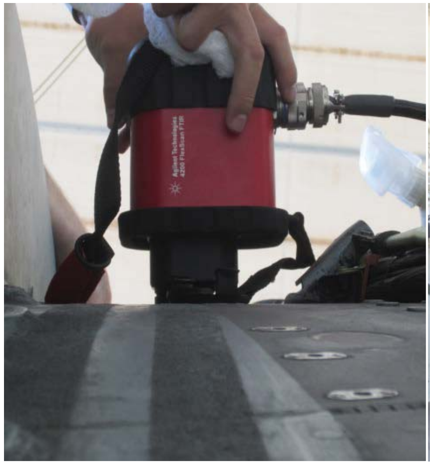
BENEFITS

- In March 2017, a V-22 Nacelle was damaged by an engine fire. The DRIFT inspection method was used to show there was no heat damage to the composite wing skin.
- Without this technique, the suspicion of heat damage would have led to scrapping the wing at an estimated cost of $10M.
- Use of this technique results in reduced cost, greater safety, and faster return of aircraft to the warfighter, improving readiness.
- The technique is being developed for more materials and aircraft.

TECHNOLOGY SOLUTION

- Diffuse Reflectance Infrared Fourier Transform (DRIFT) can detect chemical changes in composite from incipient heat damage.
- FRCSW has already qualified DRIFT inspection method for detecting incipient heat damage on F/A-18 using Agilent's portable Flexscan 4200.
- Uses chemometric analysis to correlate the polymer chemistry of the composite to the chemistry of a standard with a known level of heat damage.

Evaluation of Wing Skin



17MIC-0095

2017 DoD Maintenance Innovation Challenge (MIC)

Abstract Form	
Innovation Title:	Enhanced HUMS for Fixed-Wing Aircraft
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Abstract (300 – 500 words):

Over the past two decades, Health & Usage Monitoring Systems (HUMS) has been very successful in reducing maintenance costs while improving asset availability in the Department of Defense (DoD) rotorcraft fleet. Traditional HUMS accumulate accelerometer, acoustic emission, strain, and temperature data from various dynamic sources such as gearbox, shafts and rotors to provide structural health status, typically based on trends in peak operating frequencies. These systems deliver valuable diagnostic and prognostic information in a timely fashion to support condition-based maintenance (CBM) initiatives. While HUMS have been become an invaluable resource most rotorcraft fleets, no such analogous system is presently available for fixed-wing aircraft. The main reason being that the dynamic data that feeds traditional HUMS does not exist for fixed-wing aircraft. However, recent advances in the maturity of embeddable non-destructive inspection (NDI) methods—structural health monitoring (SHM)—enables the HUMS to accumulate meaningful data on quasi-static structures such as fuselage and wing skins and stiffened joints, even while they are on the ground.

Enhanced HUMS that incorporate SHM sensors are presently being validated on multiple DoD platforms. The USAF is funding a flight test demonstration on the C-5 aircraft monitoring the metallic troop deck panels for damage. Similarly, NAVAIR is funding the instrumentation of two full-scale fatigue test articles monitoring bonded composite joints for the Triton UAS and the CH-53K. In recent years, Army AATD has also evaluated this technology for impact damage monitoring on full-scale sub-components under multiple UH-60 efforts. Each of these programs is aimed at validation of enhanced HUMS platforms that incorporate ultrasonic based SHM sensors with a distributed data acquisition architecture. Low frequency (50-150 kHz) ultrasonic guided waves are used to scan large areas of structure (1-4 meters in diameter) to detect damage based on changes in reflected and transmitted acoustic energy as compared to a previously recorded baseline condition at the time of installation. These changes are related to local stiffness degradation affecting acoustic impedance, and can be caused by corrosion, fatigue cracks or dents in metals or delamination, disbond or microcracking in composite materials.

Introducing SHM enhanced HUMS into fixed-wing aircraft will enable advanced prognostics leading to practical CBM. Even when inspecting according to traditional fixed intervals, these systems will expedite inspections by eliminating the tear-down and build-up steps to access hidden structure. Ultrasonic methods in particular will offer general broad area coverage to detect damage in structure not normally inspected outside of incidental visual observations. Much of the saving, both in terms of cost and asset availability, would come from improved logistics, where tracking of damage can be used to more strategically plan maintenance actions without taking aircraft out of service unexpectedly or waiting for replacement parts. This same technology could be applied for assisting in service life extension, and “hot-spot” monitoring of fleet-wide issues without necessitating frequent manual inspections.

Enhanced HUMS for Fixed-Wing Aircraft

PROBLEM STATEMENT

- Presently damage tolerant approach used for maintenance on fixed-wing DoD aircraft
- Requires tear-down, manual inspection by highly specialized experts on a fixed interval
- This approach is safe, but very conservative, time-consuming and expensive
- Also, data is archived in a manner that is challenging to cross-reference for fleet-wide trends
- Susceptible to prolonged disruptions for damage discovered incidentally between inspection intervals
- Leads to large periods of asset unavailability

BENEFITS

NEAR TERM BENEFITS

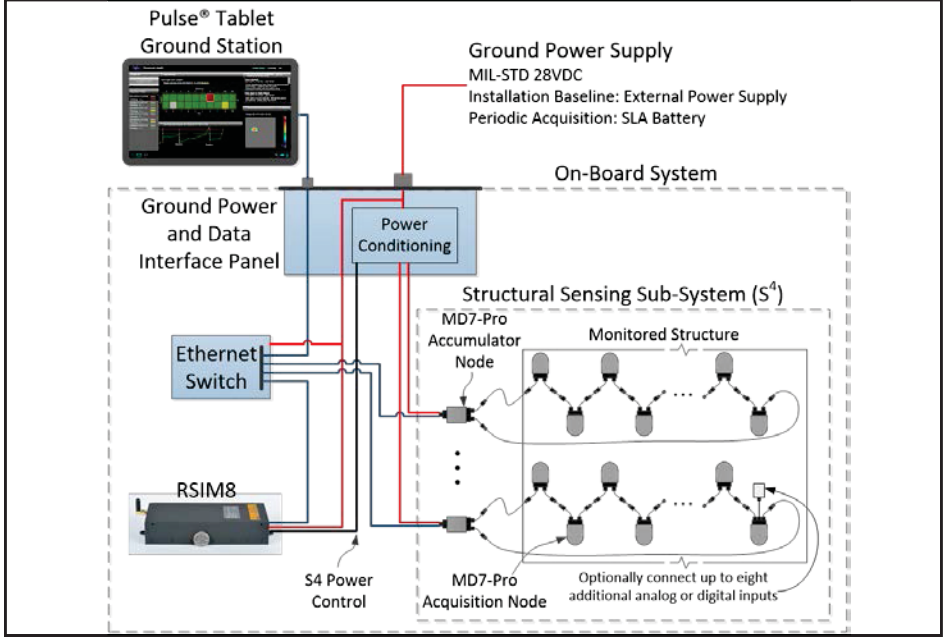
- Reduction in maintenance cost
- Reduction in inspection costs
- Improved asset availability
- Improved maintenance logistics
- Service life extension

LONG TERM BENEFITS

- Reduction in structural weight w/lower safety factors
- Improved performance w/real-time monitoring structural limits
- Better post-damage performance w/avionics feedback

TECHNOLOGY SOLUTION

- Health & Usage Monitoring Systems (HUMS) integrated into DoD rotorcraft fleet already provides useful CBM data
- HUMS can be enhanced with structural health monitoring (SHM) sensors to monitor quasi-static structure
- Provides a means to take advantage of mature HUMS on fixed-wing aircraft to improve logistics and asset availability
- Ultrasonic guided wave sensors can be used to monitor large areas of structure for multiple types of damage
- Distributed acquisition architecture reduces system mass
- Ultimate goal is to be able to use CBM to guide inspection and maintenance actions, as well as inform maintainers and suppliers to streamline logistics.
- Technology is being validated today by USAF, Navy and Army on C-5, Triton UAS, CH-53K and UH-60 platforms through static, fatigue and flight testing.



17MIC-0103

2017 DoD Maintenance Innovation Challenge (MIC)

Abstract Form	
Innovation Title:	Solid State Additive Repairs for Maintenance Applications
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Abstract (300 – 500 words):

Operational readiness is a priority across Department of Defense (DoD) platforms. A key logistics driver for readiness is low volume parts availability. Repair of existing parts through new technologies may support readiness for critical components. While there has been significant work in the application of cold spray technology at depot level maintenance facilities, much of this work has focused on dimensional restoration. Cold spray is a solid state technology that propels powder at high velocities to impact the surface and create a coating to restore critical dimensions. More recently, cold spray and other solid state repair technologies are being investigated for structural repairs, but there are key technology gaps that need to be addressed.

Cold spray is limited in the number of successfully deposited alloys, primarily aluminum alloys. Cold spray properties are also limited in elongation due to the amount of cold work imparted in the applied material. In order to increase the availability of materials for deposition and for successful build for structural components, additional development is required in the following areas:

- Powder processing for steel alloys of interest:
• Steel alloys have been challenging for deposition, but are commonly used materials for structural and dimensional repairs.
• Compatibility of base materials for steel cold spray powders for a wider application space could allow for a range of properties and application techniques.
• Powder processing before deposition has been shown to enhance elongation in aluminum alloys.
• May provide an alternative to welding for thin sections prone to distortion.

- Higher temperature deposition for increased adhesion:
• Higher temperatures may be needed for particle deformation in steels and other high temperature materials.
• This may require modification of existing COTS technologies and new nozzle designs.

- Coupled deposition technologies (i.e. laser assisted, friction stir welding, etc.):
• Cold spray may be used to deposit materials and subsequently processed for consolidation or end use.
• Laser assisted technology may be able to broaden the processing space for deposition.

These individual technologies are high TRL/MRL levels and commercially available, it is important to investigate DOD use of the coupled technologies for the targeted application. Modeling and simulation of new technology with design of experiments can provide targeted operational windows for maintenance and repair of components at the depot level. This has high interest across the services and platforms.

Solid State Additive Repairs for Maintenance Applications

PROBLEM STATEMENT

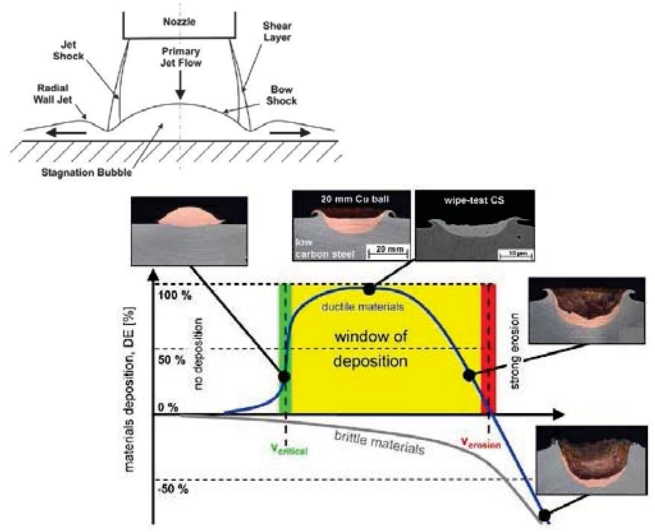
- Operational readiness is a priority across DoD platforms
- Structural repair of existing parts with additive technologies can reduce long-lead time items and current deficiencies with other repair techniques.
- New technologies, such as cold spray, are becoming available for structural repair, but materials are be limited for DOD applications. Current emphasis is on aluminum alloys, but there is a desire for solid state structural repair of steels.
- Previous research has focused on non-structural applications, such as dimensional restoration of corrosion pits, and technical challenges remain with achieving new solid state structural repair capabilities.

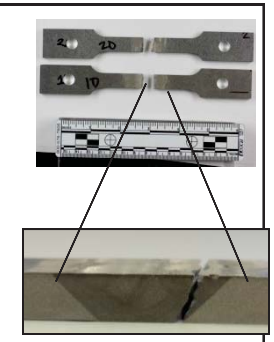
BENEFITS

- Cold spray is a solid state technology, currently used for coatings
- Does not approach welding temperatures
- Does not impose significant residual stress that may make structural repairs more likely to fail
- Infrastructure and equipment is already utilized for dimensional restoration.
- Return on investment is generally > 2:1 based on previous non-structural demonstrations.

TECHNOLOGY SOLUTION

- To advance cold spray capabilities for solid state additive repair, the following proposed technologies will be evaluated:
  - o Powder processing for steel alloys of interest to broaden the material deposition envelope
  - o Higher temperature cold spray deposition for increased adhesion for higher temperature materials through machine and nozzle modification
  - o Coupled deposition technologies (i.e. laser assisted, friction stir welding, etc) for consolidation and improved material properties and performance
  - o Enhanced hardness, ductility and other material attributes through integrated powered and process development





17MIC-0107

2017 DoD Maintenance Innovation Challenge (MIC)

Abstract Form	
Innovation Title:	Additive Manufacturing for Masking 76 PMXG Thermal Spray
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Abstract (300 – 500 words):

The thermal spray process is used frequently in the repair of engine parts to apply various coatings such as hard face coatings, thermal barrier coatings, abradable coatings, and coatings for material build up. Prior to applying these coatings, technicians are required to mask areas of the engine part that are not being sprayed. Historically, masking is accomplished through the tedious process of applying high temperature tape to the part and trimming the tape away from the spray area. This process requires significant time, materials and skill.

The 76 PMXG Tool Design and Process Engineering groups have been working to design and implement additively manufactured masking to replace this process on some parts. The use of 3D printed masks to replace old masking methods is challenging due to the requirement that the masking hold up to the high temperatures without warping to expose non-spray areas. The masking must also hold up to multiple spray cycles in order to make it an economical replacement for tape and other masking methods. This year, 3D printed masking has been developed and implemented on 8 separate parts, with an expected total savings of $164,334 and 1,844 labor hours.

Additive Manufacturing for Masking
76 PMXG Thermal Spray

PROBLEM STATEMENT

- Thermal spray process requires extensive masking, typically done with tape, to protect areas not to be sprayed.
- Taping leads to high labor and material costs.
- Some rework associated with inconsistency in masking.

BENEFITS

- Reduce labor hours and specialty skill requirements through replacement of tape methods with reusable masking.
- Provide consistent and accurate masking, reducing rework.
- Masking developed for 8 parts, resulting in an expected annual cost avoidance of $164,334.

TECHNOLOGY SOLUTION

- Additively manufacture reusable masking for engine parts.
- Masking must hold up to grit blasting and high temperatures in the thermal spray process.
- Masking designs must protect engine part from overspray where not acceptable.

F108 fan shaft with and without 3D printed masking for thermal spray of dia “U”