

MAINTENANCE INNOVATION CHALLENGE

DECEMBER 9-12, 2019
SPOKANE, WASHINGTON, USA





OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE

3500 DEFENSE PENTAGON
WASHINGTON, DC 20301-3500

SUSTAINMENT

NOV 01 2019

MEMORANDUM FOR 2019 DOD MAINTENANCE SYMPOSIUM PARTICIPANTS

The National Defense Strategy (NDS) requires the generation of a more lethal, resilient, and rapidly innovating Joint Force. As noted in the NDS, until recently, the United States has enjoyed a technological advantage, and operated in an uncontested or dominant environment in every operating domain. We are now challenged by near-peer adversaries and a changing character of war. We must retain the advantage that will allow us to fight and win conflicts now and in the future. Innovation and technology insertion, at scale, is critical to our success. Our Maintenance Innovation Challenge (MIC) aligns with our NDS objective of establishing an unmatched twenty-first century National Security Innovation Base that effectively supports Department operations and sustains security and solvency.

In keeping with the theme of the 2019 DoD Maintenance Symposium "Ready Systems @ the Speed of Relevance," we issued the 2019 Maintenance Innovation Challenge. The MIC aims to elevate and expand the call for maintenance innovation beyond solely novel technology; to include unique partnerships, resourcing strategies, and business practices or processes that promise to make maintenance more capable, effective, agile and affordable. I am pleased to announce that 80 outstanding submittals were received from the DoD, industry, and academia.

With assistance from the DoD Joint Technology Exchange Group, the submittals were thoroughly reviewed and six finalists were selected. The members from the Joint Group on Depot Maintenance and the Industrial Base Commanders group selected this year's MIC winner.

The six MIC finalists will be presenting their maintenance innovations during the Maintenance Innovation Challenge breakout on December 9, 2019, at 1:00-2:30 p.m. in the Spokane Convention Center. Based on the presentations, the audience present will select the MIC People's Choice Award winner. The MIC winner and the People's Choice Award winner will be announced and formally recognized during the DoD Maintenance Symposium's plenary session on the morning of December 10, 2019. I encourage your participation in this breakout session to engage with some of the most forward-thinking individuals in our community and to continue the dialogue throughout the Symposium and in Defense Maintenance and Logistics Exhibition.

Please join me in congratulating this year's MIC finalists, both winners, and all those who contributed their efforts to share the innovative ideas showcased in this Maintenance Innovation Challenge publication. Well done!

Sincerely,

Steven J. Morani
Deputy Assistant Secretary of Defense
Materiel Readiness

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THE MAINTENANCE INNOVATION CHALLENGE AIDS IN WARFIGHTER READINESS

Each day, DoD maintainers work hard to keep the U.S. military in peak readiness condition. And yet, there are inventive technologies already available on the market that could help make the maintainers' jobs easier. The Maintenance Innovation Challenge (MIC), that takes place at the annual DoD Maintenance Symposium, is a fun, and yes, competitive way to bring those technologies to the attention of high-level DoD maintenance decision makers.

The MIC aims to elevate and expand the call for maintenance innovation to include not only new technology, hardware and software but also unique partnerships, resourcing strategies, business practices or processes that promise to make maintenance more capable, agile and affordable.

The objectives for maintenance innovations are to showcase ideas that:

- Represent revolutionary or evolutionary maintenance and sustainment technology ideas
- Are already available (or available with modifications)
- Offer a real solution and value to the DOD Maintenance Community to help us meet the needs and expectations for the future facilitate logistics in an operational environment, or
- Demonstrate how to keep maintenance ahead of the curve in processes, testing, validation, finance, methodology, products, services, and/or workflows to the Symposium audience
- Are technical in nature
- Focus on current or potential maintenance operations or management
- Strictly avoid commercialism

But what exactly is innovation? According to the MIC Management Plan, an innovation must seek out concepts or technologies that improve maintenance effectiveness and efficiency. However, innovations need not depend on the development of a new technology or capability. The key is to pinpoint creative thinking and original concepts that assist maintenance and sustainment artisans perform their critical tasks.

"Through the Maintenance Innovation Challenge we seek to identify game-changing technologies that will enable the sustainment community to address warfighter readiness at best cost," says Greg Kilchenstein, director, Enterprise Maintenance Technology, ODASD, Materiel Readiness.

The MIC welcomes submissions from a myriad of sources that may include: industry, military personnel, and academic and research institutions. The submissions consist of a 500-word abstract and a quad chart. All applicants are on a level playing field.

Here are the criteria that the judges consider for each submission.

Evaluation Criteria:

- Maintenance Centric—Innovation’s impact on maintenance
- Original Contribution for the State of the Art—Originality of the idea
- Commercialism—focus on innovation rather than the company
- Technical Maturity—How ready is the technology/process?
- Cross-Service Application—How many Services is this applicable to?
- Potential to Benefit Maintenance—potential to improve the effectiveness and/or efficiency of maintenance
- Feasibility and Practical—assessment of how viable the invest is to transition to DoD maintenance

There are two separate grading phases. Once the submission opportunity closes, all applications are reviewed by the Joint Technology Exchange Group (JTEG), which is made up of principals representing each Service, and narrowed to six finalists. In the second phase, the finalists are evaluated by senior logistics managers, usually admirals, one to two-star general officers, and members of the Senior Executive Services, where a winner is selected.

Why submit? Yes, it takes a little time and effort to create the abstract and quad chart and your innovation may not be the chosen winner, but the results can’t be measured. Not only are all submissions read and reviewed by high-level decision makers from each Service, all submittals are posted on the JTEG website and published in this MIC booklet, which is distributed to the audience observing the MIC Finalists’ presentations. For a small investment in time, the rewards might be huge.

The judges juggle their busy schedules to evaluate each submittal, they enjoy the process because it allows them to see what new capabilities are out there. The MIC booklet of technologies and the JTEG website become reference publications used throughout the DoD enterprise. **All** submissions make an impact, and the visibility within the DoD maintenance and sustainment community is priceless.

JOINT TECHNOLOGY EXCHANGE GROUP (JTEG)

The purpose of the Joint Technology Exchange Group (JTEG) is to improve coordination in the introduction of new or improved technology, new processes, or new equipment into Department of Defense depot maintenance activities. The JTEG will seek ways to better leverage technology improvements in depot maintenance through collaboration to support the higher DoD goals of improving effectiveness and efficiency.

JTEG Mission:

- Provide a forum for the exchange of information on new technology, processes, and equipment developments within the DoD maintenance community
- Collect, analyze and disseminate relevant information on the Services' current and future maintenance technology insertion projects, initiatives, and depot maintenance technology needs
- Serve as an advocate for new technology or equipment with cross-service potential to increase efficiency

The JTEG community includes anyone in DoD or industry interested in exchanging information associated with DoD maintenance. The JTEG is overseen by a panel of representatives from each of the military services, the Defense Logistics Agency, the Joint Chiefs of Staff, and the Office of the Deputy Assistant Secretary of Defense for Materiel Readiness – (ODASD-MR).

The JTEG conducts virtual monthly technology forums that feature a different maintenance topic each month. The topics generally fall into one of three areas: 1) technology focus areas which feature a specific maintenance capability such as non-destructive inspection (NDI), additive repair, or intermittent fault detection; 2) maintenance processes such as improved business processes, training, or safety; and 3) organizational perspectives which describe maintenance capabilities and initiatives at specific DoD maintenance activities such as maintenance depots or research centers. These forums provide opportunities for the DoD maintenance community to exchange information and share ideas.

Industry and DoD personnel can use the JTEG website, jteg.ncms.org, to view and share information on new technology, processes, and equipment developments that have proven or potential applications involving depot maintenance. Visitors are welcome to review new and exciting technology projects posted on the website, or submit project ideas of their own. In addition, all JTEG technology forums are posted on the website.

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The Commercial Technologies for Maintenance Activities (CTMA) Program offers a unique contracting vehicle for industry, academia, and the DoD sustainment community to work in collaboration to demonstrate, evaluate, and validate new and innovative technologies which enhance warfighter readiness at best value and lowest risk.

Maintenance and sustainment challenges cost the DoD and taxpayers billions of dollars each year. The CTMA Program is the only DoD-approved avenue that focuses on maintenance and sustainment where the end-user gets the opportunity to try-it-before-you-buy-it to ensure maximum and immediate impact.

With its streamlined process and forward-facing approach, CTMA Program initiatives have helped make significant advances in the following *Maintenance Focus Areas*:

Autonomic Logistics

- Employing robotics and ergonomics to increase productivity in repetitive/unsafe work environments
 - » Gantry Hull Welding System
 - » Analysis of Innovative Container Operational Concepts and Expanded Use of Autonomous Logistics Platforms
 - » Mobile pRFID System to Support Depot Maintenance

Advanced/Additive Manufacturing

- Solving obsolescence and on-demand repair needs
 - » Adapting Blockchain Technology for Additive Manufacturing
 - » Naval Additive Manufacturing Knowledge Delivery System (NAMKDS)
 - » Direct Digital Manufacturing

Business Processes and Partnerships

- Utilizing cutting-edge technology to enhance efficiency and productivity
 - » Improving Supply Availability & Organic Industrial Base (OIB) Performance through Management
 - » F-35 Joint Program Office Digital Data Visualization
 - » Mission Analysis Readiness Resource Synchronization (MARRS)
 - » Naval Aviation Enterprise (NAE) Sustainment Vision 2020

DoD Wide Initiatives



Condition-Based Maintenance +

- Saving costs by conducting maintenance work only when needed
 - » Expeditionary Fluid Analysis Capability
 - » Vehicle Telematics & CBM Fleet Sustainability
 - » SmartSignal Digital Twin CBM+ Capability Evaluation
 - » Centralized Fleet Automated Management System
 - » Reducing Maintenance Costs Through Predictive Analytics



COST SHARE

Each project includes a cost share from project participants, so all parties have investment in a positive outcome.

A relentless focus on defense maintenance, sustainment, and logistics

Coating and Corrosion Prevention

- Elongating the life span of engines exposed to austere conditions
 - » Erosion/Corrosion Resistant Coating for Air Foil Compressor Blades, T56, T700, T55 & AGT 1500
 - » Degradation Prevention for Long-Term Tire Storage
 - » High-Temperature Coatings with Increased Adhesion and CARC Coating Development

The CTMA Program is a Cooperative Agreement in partnership with the Office of Deputy Assistant Secretary of Defense, Materiel Readiness (ODASD-MR).

Energy, Environment, Health and Safety

- Resource and condition awareness
 - » Joint Operational Energy Command and Control (JOEC2)
 - » Operational Energy
 - » Elimination of Hex-Cr/Cd for Sustainment
 - » ZeroG-Arm/Magnet Mount Systems
 - » Industrial Human Augmentation System

Enhanced Inspection

- Repairing/establishing source of circuitry faults
 - » Advanced Wiring Test System (AWTS)
 - » Intermittent Fault Detection Isolation System (IFDIS)
 - » Automated Process Inspection Guide
- Non-destructive inspection technology
 - » Large Area Standoff-Large Area Thermography
 - » Rapid & Agile 3D Scanner with Micron Accuracy
- Augmented reality allows point-of-need expertise
 - » Augmented Reality to Improve Maintenance Workforce Improvement

Reliability Improvement (Hardware)

- Ensuring equipment is ready
 - » Membrane Water Filtration System
 - » Highly Electrified Vehicles & Infrastructure Connectivity
 - » E-Drill
 - » Advanced Lithium-Ion Batteries for Forklifts

Training/Misc.

- Professional and skill upgrading to ensure maintenance proficiency
 - » Development of Computer-Based Training for Maintenance and Sustainment (GCSS-MC)
 - » Improved Training Curriculum for Maintenance Planning
 - » Ground Vehicle Maintenance Trainer



Through the CTMA Program, maintenance and sustainment productivity, safety, and cost issues are solved and cutting-edge commercial-off-the-shelf innovations are introduced. The streamlined CTMA contracting process allows demonstrations and evaluations to take place in an expedited manner supporting a seamless technology transition. Innovative technologies get into the hands of maintenance artisans resulting in enhanced warfighter readiness.



To learn more about the CTMA Program contact Debbie Lilu at debral@ncms.org, call 734-262-0758 or visit www.ncms.org

Aircraft Maintenance Unit weapons load crew member, inspects the AIM-9X missile. U.S. Air Force photo by Airman 1st Class Heather Leveille. Photo courtesy of DIVIDS.

CONGRATULATIONS TO OUR 2018 MAINTENANCE INNOVATION CHALLENGE WINNERS!

Only two presentations received awards—but all finalists had winning technologies

TECHNOLOGY AWARD:

2018: OC-ALC 76th CMXG REACT Metal AM Tooling and Testing Equipment – Martin Williams, US Air Force, Oklahoma City Air Logistics Complex, 76th Commodities Maintenance Group, REACT

Problem:

Sustainment of aging aircraft presents unique challenges with parts availability. Parts that were expected to last the life of the aircraft are failing, there is no tooling, or existing tooling has degraded with age and often there is no testing equipment to verify parts meet requirements. This leads to unnecessarily scrapping good parts or increasing risks by flying potentially bad parts.

Solution:

Use laser scanning and measurements to measure good parts and determine critical dimensions and then utilizing that data to design tooling specifically for Metal AM in CAD software. Metal additive manufacturing tooling and test equipment rapidly provides capabilities to manufacture and test parts.



PEOPLE'S CHOICE AWARD:

2018: Using Multi-Pole Magnetic Technology to Improve Productivity, Quality and Safety – Jim Michael, Maglogix, LLC

Problem:

DoD facilities are challenged with an aging workforce as well as a new generation of recruits unaccustomed to the physical demands required. Unfortunately, even with increased safety efforts, we anticipate frequent strains, sprains, and other crush injuries. Many DoD facilities have a multi-year backlog and struggle to meet date requirements. Robotics, while helpful are unable to be deployed rapidly in a highly fluid environment.

Solution:

When work performed in maintenance facilities involves steel or steel structures, a recent magnetic invention, “Phase cancelling Multi-Pole Performance Magnets”, is disrupting traditional steel manufacturing methods. MP magnet technology overcomes virtually all viability issues of previous magnet technologies. MP magnets have an unheard of performance to weight ratio exceeding 400 pounds holding force per 1 pound of magnet.



2019 MAINTENANCE INNOVATION CHALLENGE

Overview:

The Deputy Assistant Secretary of Defense for Materiel Readiness challenged individuals to submit their maintenance related innovations. An evaluation board comprised of maintenance subject matter experts selected six candidates to participate in the challenge during the 2019 DoD Maintenance Symposium.

Moderator:

Gregory J. Kilchenstein, Director, Enterprise Maintenance Technology ODASD (Materiel Readiness)

Finalists:

Atmospheric Plasma Coating Removal

Submitted by Glenn Astolfi, Atmospheric Plasma Solutions. Inc.

Fully Organic Repair of Air Force Assets via Cold Spray

Submitted by Julie Marasco and Glen Drebes, US Air Force, Oklahoma City ALC

Injection Procedure for Applying Radar Absorbent Material

Submitted by Andrew Kohl, Fleet Readiness Center-Southwest, Naval Air Systems Command (NAVAIR)

Joint Robotics Organization for Building Organic Technologies (JROBOT)

Submitted by Steve McKee, Naval Sea Systems Command (NAVSEA)

MELD: A Novel Solid-State Technology for Sustainment

Submitted by Chase D. Cox and Nanci Hardwick, MELD Manufacturing Corporation

Printed Circuit Board Reverse Engineering / Prototyping Suite

Submitted by Damon Brown, 402 Electronics Maintenance Group, Reverse Engineering, Avionics Redesign And Manufacturing (REARM) Innovation Center, Warner Robbins Air Logistics Complex

FINALISTS

ATMOSPHERIC PLASMA COATING REMOVAL

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As stated in the National Defense Strategy, “we cannot expect success fighting tomorrow’s conflicts with yesterday’s weapons or equipment.” For maintenance activities, the DOD has have been using antiquated technologies such as grit blasting and needle guns for over 50 years. Current coating removal techniques have serious shortcomings.

Atmospheric Plasma Coating Removal (APCR) is a media and chemical free process that can improve cycle time, lower cost, reduce injuries and increase environmental safety. Applicable to all service branches, APCR has demonstrated effectiveness while significantly reducing costs in labor, waste disposal, and personnel safety.

This advantageous approach to coating removal uses the fourth and most abundant state of matter PLASMA. Using only the inputs of compressed air and electricity the system produces a special form of non-thermal atmospheric pressure plasma. This species of plasma is fundamentally different than a plasma cutter or a laser.

The APCR process converts a significant portion of the removed organic coating into water vapor and carbon dioxide, leaving a small volume of solids to be safely collected with a HEPA vacuum. There is no requirement for containment or clean up. The existing profile of the substrate is revealed, not changed. Independent laboratory testing coordinated by NAVSEA 05 documented APCR doesn’t cause changes to the substrate metallurgy.

A 2018 National Ship Building Research project successfully demonstrated coating removal for ship-board applications including but not limited to MIL-PRF 24635, haze-grey silicone alkyd coatings, MIL-PRF-24647 anti-fouling, MIL-DTL-24441 epoxy primer on DH36 and HY steel. APCR process produced a surface with “near white metal blast cleanliness” (SP-10) at removal rates faster than a needle gun.

The TRL-8, field-deployable APCR PlasmaBlast® system weighs 34 pounds, uses only compressed air flowing at 90PSI at 3.0 CFM.

The next step for implementation is as a precision coating removal tool. Examples include, but are not limited to, non-destructive testing as coating is removed, but the substrate is unchanged. As plasma acts as a fluid, tight areas are quickly de-painted and revealed for inspection. Other applications include strip back around an area for welding. This work can be quickly completed with no need for containment. Rework areas can be easily addressed. This technology will support the objectives to address the backlog of deferred readiness and accelerate modernization programs while providing a new practices for greater performance and affordability.

PROBLEM STATEMENT

There is a need for lower cost, cleaner, environmentally safer coating removal solutions. Today removing coatings is a costly, multi-step, time and labor consuming process. Many coating removal methods can cause damage to the substrate and injury to the worker. Where grit and water blasting can’t be used, manual labor is often the only solution.

BENEFITS

- Significantly reduces job costs
- Reveals substrate without change to profile
- Safer for the operator and environmentally friendly
- Rugged, lightweight and portable for use in yards and depots
- Media and chemical free, minimal clean up
- Fast training, simple to operate and quick to mobilize

TECHNOLOGY SOLUTION

Atmospheric Plasma Coating Removal is a breakthrough de-painting technology that uses no media, requires no containment and does no damage to the substrate. Using only air and electricity the system converts organic components of most paints, sealants and protective coatings into carbon dioxide and water vapor. Inorganic constituents of the coatings, such as pigments are recovered as a fine dust.



FULLY ORGANIC REPAIR OF AIR FORCE ASSETS VIA COLD SPRAY

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As the Air Force extends the service life of legacy weapons systems beyond the original planned lifetime, certain components become scarce and irreplaceable. Air Force Materiel Command has struggled to be able to adequately sustain these weapons systems due to the combination of: (1) a lack of available new parts (due to retired manufacturing sources), (2) components being repaired more times than originally anticipated, and (3) technical data that uses only repair technologies that were available at the time of manufacture. This has led to constraints for certain parts, particularly cast magnesium housings.

The Air Force Sustainment Center, Air Force Lifecycle Management, and the Air Force Research Laboratory have worked together to test, develop, and publish technical data for cold spray repair of these housings, and to replace the outdated weld repairs that existed in the depot level technical orders.

The Oklahoma City Air Logistics Complex (OC-ALC) has retrofitted an existing thermal spray booth to have dual capability to include cold spray and has become a qualified source for cold spray repair of

these housings using entirely organic Air Force personnel. Cold spray can be used to add near net shape material, reducing the amount of post-machining required. In addition, cold spray reduces recycles and condemnation rates because it does not cause deformation and warping of the part as with welding.

Finally, the cold spray being conducted at the OC-ALC is entirely robotic controlled, reducing process variance compared to artisan welding processes. Technical data for the TF33-P100 engine (E-3 AWACS) has been published and the 76th Propulsion Maintenance Group (76 PMXG) has entered full scale production repair of the housings. Applications for the TF33-P103 engine (B-52), F-16, and B-1B have been approved through the combined change evaluation team and are in the process of being integrated into technical orders. In parallel, cold spray processes for these parts are being developed by 76 PMXG engineering.

Through the lessons learned at the OC-ALC, the Air Force Advanced Technology and Training Center has developed a high pressure cold spray

course that will be used to train and transition the technology to the other Air Force depots as equipment and applications become available. The OC-ALC is the first Air Force depot with organic cold spray capabilities and the cold spray repair on the TF33-P100 gearbox is the first to receive airworthiness for the Air Force.

PROBLEM STATEMENT

- Difficulty in procuring new magnesium casted parts for legacy weapon systems due to discontinued original manufacturing sources
- Current welding repair processes warp the parts and cause eventual condemnation due to process induced distortion

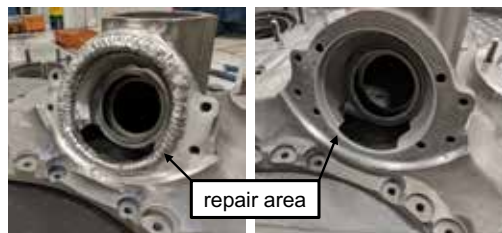
BENEFITS

- Cold spray does not induce distortion as compared to welding and does not require a post heat treatment for stress relief
- The cold spray process is more consistent and less likely to cause recycles or condemnations compared to weld repairs
- Sealing surfaces that were previously unable to be repaired can now be restored with cold spray due to its high accuracy

TECHNOLOGY SOLUTION

- Cold spray is a type of thermal spray technology with extremely low porosity and oxide content
- Aluminum 6061 was chosen as the material used to restore the castings due to its corrosion characteristics, wear properties, and ease of application
- Air Force Sustainment Center, Life Cycle Management, and Research Laboratory came together to develop and publish technical data and receive airworthiness certification for the first Air Force organic cold spray repair.

GRAPHIC OR IMAGE



Weld repair before
post-machining

Cold spray repair
before post-machining

INJECTION PROCEDURE FOR APPLYING RADAR ABSORBENT MATERIAL

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Application of Radar Absorbent Material (RAM) is a cumbersome process performed on several top readiness degraders at Fleet Readiness Center Southwest (FRCSW). The application method on a specific component utilizes a hybrid technique where an artisan first trowels on and then sprays RAM. This lengthy five-day process induces significant rework, and has a high rate of quality verification failures that result in delays averaging ten days in length.

To alleviate these issues, FRCSW Materials Engineering investigated an injection mold procedure, which is a more consistent method of applying RAM. To instill confidence in the injected coatings, Materials Engineering developed a quality verification technique using injectable witness panels. Immediately before applying RAM to the component, artisans inject RAM coating into the witness panel. Materials Engineering analyzes the injected coating's properties to confirm it meets the same quality metrics as sprayed coatings. The resultant injected coatings have lower porosity than sprayed coatings, thus achieving a much lower reject rate and eliminating rework delays.

Implementation of radical change to low observable coating processes typically necessitates near field range testing costing approximately \$250,000. By developing the injectable witness panels, Materials Engineering was able to eliminate this requirement and prove that the injected coatings had the critical characteristics necessary to meet the performance requirements. Materials engineering has completed investigation of the RAM injection process and FRCSW has already used it to apply RAM to aircraft components.

The injection molds used in this process cost approximately \$225,000 when purchased from the prime contractor. FRCSW owned two injection molds, but the original mold design had a history of poor reliability. FRCSW plans to 3D print these molds in-house to address the previous design flaw and prepare for future mold replacements. FRCSW created a 3D model of the existing mold and is now awaiting delivery of 3D printing equipment.

This RAM injection procedure decreased component turn-around time (TAT) by 2-3 days, and eliminated the ten-day delay

due to coatings failing quality verification. Development of the injection witness panel allowed for process implementation without the \$250,000 cost of near-field range testing, while still maintaining a high standard of quality. The 3D printing effort complements this by eliminating a recurring \$225,000 injection mold replacement cost, and increases the facility's agility by allowing quick replacement and development of injection equipment. Altogether, this effort will avoid costs exceeding \$850,000 in the first year and provide a faster more reliable process for returning a critical readiness degrader to grounded aircraft. Materials Engineering is looking to transition this capability to other components to improve coating application, decrease TAT, and reduce cost.

PROBLEM STATEMENT

- The RAM application method on a top readiness degrader utilizes a lengthy five-day hybrid technique where an artisan first trowels and then sprays RAM.
- This method has a high rate of coatings failing quality verification. When a coating fails quality verification, artisans must remove and reapply all RAM, resulting in delays averaging ten days in length.
- Implementation of change to low observable coating processes typically necessitates near field range testing costing approximately \$250,000.

BENEFITS

- The RAM injection procedure decreased TAT time on this top readiness degrader by 2-3 days, and eliminated ten-day delays due to coating failures.
- The injection witness panel allowed process implementation without the \$250,000 cost of near-field range testing.
- The 3D printing effort will eliminate a recurring \$225,000 injection mold replacement cost, and provide quick replacement, and development of injection equipment.
- Altogether, this effort will avoid costs exceeding \$850,000 in the first year and provide a faster, more reliable process for returning a critical readiness degrader to grounded aircraft.

TECHNOLOGY SOLUTION

- FRCSW Materials Engineering adopted an efficient and repeatable injection procedure for applying RAM to the component.
- To instill confidence in the injected coatings, Materials Engineering developed a quality verification technique using injectable witness panels.
- FRCSW plans to 3D print injection molds in-house to address a previous design flaw and prepare for future mold replacements.



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JOINT ROBOTICS ORGANIZATION FOR BUILDING ORGANIC TECHNOLOGIES (JROBOT)

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Issue:

Industry advances in robotics have largely not been harnessed by Department of Defense (DoD) maintainers with an impact directly affecting readiness. Similarly, robotic advancements made by the DoD's research institutes have not traditionally focused on maintenance as part of the operational continuum. Inputs from the maintainer community into both industry and the DoD research groups have not been coordinated providing isolated solutions for a few forward-thinking activities.

Background:

Accelerations in robotics capabilities and fielding world-wide (e.g., Made in China 2025) require appropriate focus to enable resilient and agile logistics for the DoD. Inter-agency and allied partners are also seeking maintenance solutions to meet similar requirements.

Solution:


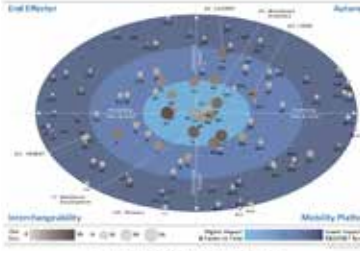


In March 2019 the inaugural "Joint Summit: Robotics in Sustainment" was held. The summit gleaned inputs from the maintainer and research communities within the federal

government (e.g., across the DoD, United States Coast Guard, National Aeronautical Space Administration, and the Department of Energy) and the United Kingdom's Ministry of Defense. The summit provided a roadmap for continued coordination and fielding for governmental agencies. Since the summit, on-going monthly discussions with the attendees have drafted a charter for approval, provided workforce development insight from various services, and also put form to the next summit that will include industry partners.

created to provide greater performance and affordability for both the Department and the National Security Innovation Base.

Next Steps/Benefits:

Resulting from the summit, the DoD's Advanced Robotics in Manufacturing (ARM) Institute offered to host a shark-tank style summit in February 2020 at their facility to award a new round of projects that specifically advance sustainment. The Joint Technology Exchange Group principals with their ManTech counterparts will finalize the plan for the February 2020 summit to ensure maximum engagement by all stakeholders. With a focus on fielding robotic solutions that affect sustainment across the DoD and other partners, the foundation has been

<p>PROBLEM STATEMENT</p> <p>The US government and allied partners do not have integrated or shared avenues to leverage investments in research and development to harness advancements in robotic technology for maintenance efforts.</p> 	<p>BENEFITS</p> <p>Provide a forum to develop and advance a series of deliverables across the Joint, Inter-Agency, and allied partners for maintainers.</p> 
<p>TECHNOLOGY SOLUTION</p> <p>Align current and future efforts:</p> <ul style="list-style-type: none"> ✓ Establish JROBOT group from the Organic Industrial Base (OIB) and existing R&D activities to collaborate and identify needs ✓ Develop and maintain roadmap for future capabilities that span common purposes ▶ Collaborate with DoD Advanced Robotics in Manufacturing (ARM) Institute existing structures with industry and academia to deliver coordinated solutions [~Feb 2020] <p>https://www.milsuite.mil/book/groups/robotics-in-sustainment/overview</p> 	<p>JROBOT Way Ahead</p> 

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FINALISTS

MELD: A NOVEL SOLID-STATE TECHNOLOGY FOR SUSTAINMENT

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Sustainment challenges continue to emerge in the dynamic environments in which we operate while engaging our adversaries. The ability for our Nation's war fighters to maintain and repair strategic assets in the field or at sea not only improves operational efficiency but also reduces overall cost and logistics overhead. There is a need to enable these types of sustainment activities for materials that are not compatible with traditional repair strategies, such as high-strength aluminum alloys used in aircraft landing gears, armor plating for light-weight ground vehicles, and structural components of LCS watercraft.

MELD is uniquely suited to provide both cost and time effective repairs in theater. MELD represents a portable process able to build, repair, and join metals, including non-fusion weldable materials.

The MELD process has unique benefits. It creates fully-dense products with little-to-no distortion at deposition rates orders of magnitude faster than other metal additive processes. MELD is a solid-state no-melt process, which yields near net shape parts with superior mechanical properties,

meaning there is potential for parts to go from the machine to the field. MELD is an open- atmosphere process and is not restricted to vacuum chambers or powder beds, allowing for extreme scalability to make or repair large structures. By the nature of the process, all depositions, repairs, and coatings are fully dense and do not require any additional processing for densification such as sintering or hot isostatic pressing.

Deposition rates are extremely high; for example, MELD currently exceeds 30 lbs per hour in Aluminum. Machines have a low operating cost (comparable to a CNC mill) and can be operated by traditional machinists. Special material is not required. MELD is compatible with a wide array of materials including, but not limited to, stainless steels, titanium alloys, nickel alloys, copper alloys, magnesium alloys, and aluminum alloys, including non-fusion weldable alloys such as 2XXX and 7XXX series. MELD machines work with solid bars of metal, removing the risk of explosion and health hazards inherent in metal powder.

Over the last decade this technology has been matured and repairs have been

demonstrated while working with partners, including ONR, NAVSEA, TARDEC, and AIR FORCE, and is now commercially available. Types of repairs demonstrated include cracks, simulated ballistics damage, and corrosion pitting. MELD offers a multifunction technology to those tasked with MRO activities within one piece of equipment, such as the ability to print near-net parts that are difficult or costly to procure, the ability to repair the unrepairable, and the ability to add corrosion/erosion resistant coatings to existing structures.

PROBLEM STATEMENT

Sustainment challenges continue to emerge in the dynamic environments in which we operate while engaging our adversaries. The ability for our Nation's war fighters to maintain and repair strategic assets in the field or at sea not only improves operational efficiency but also reduces overall cost and logistics overhead. There is a need to enable these types of sustainment activities for materials that are not compatible with traditional repair strategies, such as high-strength aluminum alloys used in aircraft landing gears, armor plating for light-weight ground vehicles, and structural components of LCS watercraft.

BENEFITS

- **Compatibility:** MELD is compatible with all metals, including non-fusion weldable high-strength aluminum alloys.
- **Throughput:** High deposition rates enabling rapid repairs (30 lbs/hr in Al).
- **Operation:** MELD systems are user friendly and field deployable.
- **Logistics:** No limitations on material source. Use the material you have on hand to perform the repairs
- **Safety:** No flammable or hazardous powders required.
- **Performance:** materials deposited during the repair operation possess wrought or better properties.

TECHNOLOGY SOLUTION

The MELD process is a solid-state additive technology enabling the repair of otherwise unrepairable assets due to the part's/component's inherent material limitations. MELD is a field deployable technology able to expeditiously repair, join, and build metal components, including non-fusion weldable materials such as high-strength aluminum alloys. This technology has been demonstrated on projects with numerous defense partners, including ONR, NAVSEA, TARDEC, DEVCOM, and AIR FORCE. MELD Machines and Services are commercially available and have a high TRL/MRL.



PRINTED CIRCUIT BOARD REVERSE ENGINEERING / PROTOTYPING SUITE

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Avionics repair is challenging when circuit card assemblies are no longer available from original equipment manufacturers, especially when no technical data exists. Current processes for reverse engineering and manufacture of printed circuit boards (PCBs) are time consuming and costly due to manual development of schematics, parts lists, Computer Aided Design/Manufacturing (CAD/CAM) data, and engineering drawings. Procurement delays and PCB manufacturing process time also increase flow time. Our innovation, PCB-REPS, addresses this problem by increasing the efficiency of reverse engineering and prototyping PCBs using software technology and additive manufacturing.

402 Electronics Maintenance Group's Reverse Engineering Avionics Redesign and Manufacturing (REARM) Innovation Center has assembled a suite of technology and processes to rapidly reverse engineer, document, and prototype circuit card assemblies (CCA) with little or no technical data available. The suite consists of four elements: a material removal system, a PCB scanning system, industry standard

PCB CAD software, and an additive PCB manufacturing system.

Facing a shortage of multiple two-layer CCA's necessary for the overhaul of the MHU-196 Munitions Handling Cart Main Control Unit, the REARM team developed Form-Fit-Function replacement circuit cards. First, the team used existing technical data to create a Bill of Materials. A DMSMS study was then performed to determine parts substitutions for long term sustainment. All components were then removed from the CCA, leaving a bare two sided board. Next, the team used the media blaster to clean the CCA's layers and scanned the copper traces into the reverse engineering software. Subsequently, the software converted the scanned photos into Gerber files and a schematic. This data was then imported into the CAD/EDA tool to develop the procurement level technical data package. Lastly, the CAD data was input into the additive PCB manufacturing system to build a prototype. The additively manufactured prototype PCB was verified against the original CCA to be functionally identical and the TDP could now be sent off to a board vendor for Mil-spec production. This process

is also being used to recreate PCB's for the A-10 Gun Control Unit, as well as the HH-60 Intercom Control Set CCAs.

In initial test and simulations, the team drastically reduced the development time to create a usable procurement level TDP and prototype by 75%. These initial tests were done using moderate complexity boards with two layers and the flow time was compared to the previous process of using a DMM to measure connectivity between traces and drawing schematics in a legacy PCB CAD tool, using separate drafting software to create the TDP and contracting with a PCB vendor to build prototypes. The greatest benefit is the ability to create a PCB that was otherwise unavailable, restoring capability to legacy systems that are carcass constrained.

402 EMXG REARM plans to streamline the process and develop a PCB-REPS framework and curriculum to be shared among the DoD maintenance community, effectively commoditizing this capability. With additional qualification and testing, future DoD Maintainers could potentially scan and then 3D print a mil-spec PCB for use in an avionics system.

PROBLEM STATEMENT

Avionics repair is often hindered when circuit card assemblies are no longer available from original equipment manufacturers, especially when no technical data exists. Current processes for reverse engineering and manufacture of printed circuit boards (PCBs) are time consuming and costly due to manual creation of Technical Data Packages (TDPs) and labor intensive PCB manufacturing processes.

Manually creating engineering TDPs and CAD/CAM data has historically taken 6-8 months, depending on the complexity of the PCB. The manual process is also prone to human error and must be validated prior to PCB production. Current PCB manufacturing techniques take at minimum 10 days production time to build a prototype board, not counting procurement times.

BENEFITS

Cost/Schedule

75% reduction in cost and schedule for production of TDPs and CAD/CAM data for circuit card assemblies (CCAs).
\$350k in capital investment will save \$488k in engineering labor over the first 8 planned projects.

Manpower

No draftsman required to produce TDP.
No procurement time for prototypes

Performance

Rapid prototyping of CCAs (2 days) for pre-production test.

Usability

Suite can be recreated and used by all branches of the military that require TDPs for previously developed CCAs.

TECHNOLOGY SOLUTION

Precision removal of PCB layers using a media blaster.

Digital scanning of every layer of a PCB through the use of a high resolution scanner and computer software.

Scanner software provides a user interface to manipulate the images and create CAD/CAM data and schematics.

PCB CAD software imports CAD/CAM data to create Technical Data Packages (TDPs) which contain all data needed to recreate and manufacture the Circuit Card Assembly (CCA) and is ready for JEDMICS submission.

Additive PCB printer 3D prints prototype PCB for testing without procurement, STINFO release, or contract manufacturing delays



REDESIGN ADDITIVE MANUFACTURING (AM) APPROACH

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The DOD (and other agencies) ground managed systems are in need of developing and implementing technical solutions for Obsolescence/Diminishing Manufacturing Sources and Material Shortages (DMSMS). The solutions need to be focused on improving readiness and modernization along with technical insertion. This will require material analysis/testing, disassembly, part scanning/measuring along with both physical and simulated part performance testing. It may also use various methodologies of creating a sample/prototype part, which could include traditional low or high volume manufacturing processes as well as additive manufacturing or a combination of both.

Since technology insertion is an objective, the redesign additive manufacturing (AM) approach will fill this requirement. AM enables the manufacturing of more weight effective parts compared to traditional manufacturing approaches, as the need for drafts, fillets, cores etc. are no longer required and AM virtually eliminates the need for conventional tooling. This allows the opportunity for more design freedom, enabling the part designers to focus more

on the requirements of the Warfighter. There are also various methods of utilizing AM within the product development cycle, for example, the part may be conventionally manufactured, but tooling could be additive manufactured. This will drastically improve the tooling lead time, resulting in parts getting to the Warfighter faster.

For the Warfighter, this translates into a lighter, more structurally efficient part, reducing power consumption and increasing payload. AM has logistical benefits as well. Spare parts warehousing is no longer required. Just in Time manufacturing at a designated manufacturing facility or depot is possible. The logistic footprint is drastically reduced, supplying a more cost effective infrastructure for the DOD.

The objective of the project will be as follows:


1. Define a detailed AM development work flow including strategic part selection and audit process, design optimization and both performance and manufacturing modeling and simulation.
2. Demonstrate AM efficiencies on a small scale and plan a broader based

implementation of a more efficient DMSMS approach to be used across all service branches.

This proposed research and development will provide benefits in supplying data in better understanding AM's technology readiness and its potential impact to DMSMS current approach, the Warfighter, and Engineering Teams:

- Develop deep understanding of conventional manufacturing approaches vs AM.
- Evaluate part weight efficiencies gained that lead to less power consumption and more payload.
- Understand AM cost implications compared to current manufacturing and engineering processes.
- Better understand logistic efficiencies and reduction of overall timing and infrastructure footprint.

AM technology coupled with AM design methodologies specifically developed to fully exploit AM capabilities.

PROBLEM STATEMENT	BENEFITS
A significant gap across all service branches is the availability of old and out dated spare parts. For many of these parts, TDP's are not available for a variety of reasons driving a considerable amount of re-investment to reverse engineer and re-tool for only a few parts. This approach equates to low value add to the warfighter and significant cost inefficiencies for the DOD.	<ul style="list-style-type: none"> • Defines an ideal opportunity for part/system re-design to optimize cost, weight and performance. • More cost effective approach in supplying spare parts by reducing tooling, manufacturing lead time and shortening engineering work flow. • Reduces logistical footprint by printing on/near point of need eliminating warehousing and excess inventory. • Develops a detailed work flow including how to strategically select a part for AM for broader adoption of approach across all service branches.
TECHNOLOGY SOLUTION	 <p>Old New – 50% Lighter</p>
<ul style="list-style-type: none"> - A commercially available DFAM software (Inspire) with proven topology optimization capability along with print simulation capability. - Proven DFAM processes that have been developed and refined in the automotive and aerospace industries: - Metrics defining a part pre-selection process gauging AM applicability. - A part audit process that generates data defining/ comparing opportunities focusing engineering resources. - Mature DFAM software tools in designing select parts 	

2D23D PILOT PROGRAM TO CONVERT LEGACY DRAWINGS TO DIGITAL FORMAT

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This effort will provide a way to quickly scan and digitize legacy drawings utilizing scanning and artificial intelligence technologies. This will contribute across the sustainment community to enhance DOD System capabilities by providing a quicker process to convert critical data into usable data for maintenance and sustainment.

In today's environment supporting the warfighter, systems across all services are being utilized much longer than originally anticipated. As a result, the manufacturers no longer exist or the procurement of replacement parts from the original manufacturer does not fit required schedules and financial budgets due to price gouging from OEM and surplus vendors. Parts are failing more frequently as they become older. Parts that were never in demand are now in demand and in many cases, drawings do not exist, are not available or are proprietary to the OEMs. Additionally, the drawings that are available and do exist many times are not usable in their current format. Many drawings are still in their original media consisting of paper, blueprints, Mylar and sepia original

drawings. In most cases, drawings like this are damaged, not readable, stained, ripped and cracked.

Utilizing newer manufacturing processes and additive manufacturing technologies in both thermoplastic and metals, we can eliminate the need to procure new parts with their original manufacturing processes which creates long lead times and costly tooling for low quantities. It is clear that there is a need for innovative solutions that are both logical and economical. Examples of conventional redesign parameters are component geometry characteristics, dimensional tolerances, shape volume, surface finish, material requirements, loading, and cost.

Imagine if there was a way to scan legacy drawings and use a combination of Artificial Intelligence (AI) and other newer scanning and digitizing technologies using cloud based technologies to capture and stitch the data to be able to convert these drawings into usable vectorized data that can then be used to validate the quality of the drawings, verify the accuracy of the dimensions and clean up the legacy data. There are literally hundreds of thousands if not millions of

legacy drawings that are not usable in their current form.

The concept for this submission is extremely innovative because a tool like this does not exist today. The purpose of this effort is to develop a proof-of-concept and notional architecture of software to Convert typical physical 2D engineering drawing to digital 2D engineering drawing and then to Convert digital 2D engineering Drawing to 50% accurate 3D engineering drawing and to Provide for manual conversion of remaining content (<50%) of 2D drawing while implementing block-chain technologies for security and provenance of the captured data.

<p>PROBLEM STATEMENT</p> <p>There are thousands upon thousands of drawings (paper, mylar, sepia, etc.) that have not been digitized or updated for many years that are now needed to support legacy weapon systems. There is also no viable tool or process to get these drawings into a digital manipulatable format for use. This effort will provide a mechanism to convert legacy drawings to digital formats and will contribute across the spectrum to enhance Military or DOD System capabilities by providing a quicker process to convert critical data into usable data for maintenance and sustainment.</p>	<p>BENEFITS</p> <p>Imagine if there was a way to scan the drawings and use a combination of Artificial Intelligence (AI) and other newer scanning and digitizing technologies utilizing the cloud to capture and stitch the data to be able to convert these drawings into usable vectorized data that can then be used to validate the quality of the drawings, verify the accuracy of the dimensions and clean up the legacy data that is required to support these vital assets. There are literally hundreds of thousands if not millions of legacy drawings that are not usable in their current form. There will still be the need for engineering to oversee and contribute to this effort but this technology will make the arduous process faster and easier to use.</p>
<p>TECHNOLOGY SOLUTION</p> <p>Develop proof-of-concept and notional architecture of scanning software to:</p> <p>Convert typical physical 2D engineering drawing to digital 2D engineering drawing (2D to 2D)</p> <p>Convert digital 2D engineering drawing to 50% accurate 3D engineering drawing (2D to 3D)</p> <p>Provide for manual conversion of remaining content (<50%) of 2-D drawing</p>	<p>Elevate Systems</p>

ADDITIVE MANUFACTURING OF CARBON NANOTUBE METAL MATRIX

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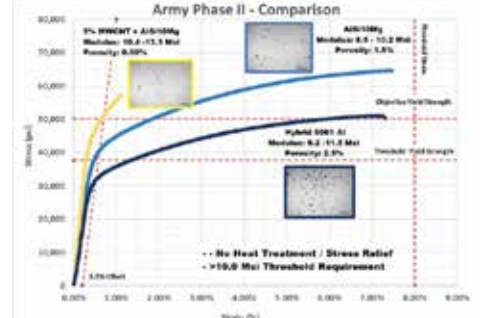
Additive Manufacturing (AM) of metals has been identified as a solution to address critical Mission Readiness (A0) challenges facing the Department of Defense with respect to maintenance and sustainment. However, even if AM is fully qualified for use and economically viable for implementation, it will still not be able to address a significant portion of the components and systems that drive Mission Readiness. These components are typically rated as flight critical, mission critical or even life critical in their use and application. As a result, they require use of high-performance titanium, aluminum and steel alloys with specialized post process mechanical and heat treatments to achieve a maximized combination of strength, stiffness and ductility in order to perform their mission. Unfortunately, the layer by layer melting of material inherent in the AM processes does not provide the thermomechanical processing capability available in conventional metal foundry processes required to achieve wrought (optimal) mechanical properties. While recent efforts have focused on the use of post processing approaches such as Hot Isostatic Pressing (HIP) and solution heat

treatments followed by annealing to improve mechanical properties these processes add further delays and costs. What is required is a material system for use in AM and other related powder metallurgy processes such as Cold Spray or Metal Injection Molding that achieves wrought mechanical properties without the use of significant post processing and is compatible with multiple metal alloy systems.

Recently, SHEPRA Inc. and its partner at the University of Dayton Chemical and Materials Engineering Department demonstrated the ability to create a carbon nanotube metal matrix composite via laser powder bed AM. While the research is still ongoing, SHEPRA has been able to show near wrought mechanical properties for 17-4 Stainless Steel through its Navy Phase II STTR program and mechanical properties comparable to wrought 6061-T6 aluminum using AISi10Mg as the base alloy.

Because the physical mechanism that improves the strength and stiffness of the overall metal matrix composite is based on mechanical load transfer between the stronger and stiffer carbon nanotubes and

metal comprising the matrix, this approach can be used with a variety of metal systems (e.g. Titanium, Aluminum, Steel, etc) and various alloys of these systems.

PROBLEM STATEMENT	BENEFITS
<p>Current metal Additive Manufacturing materials lack the required mechanical properties need to address critical Maintenance and Sustainment Mission Readiness requirements</p>	<p>Use of Carbon Nanotubes to create a metal matrix composite for use in Powder Based Additive Manufacturing based on mechanical load transfer to improve strength and stiffness</p>
TECHNOLOGY SOLUTION	
<ul style="list-style-type: none"> Achieve Wrought properties required to meet Mission Readiness requirements Applicable to multiple metal systems and alloys Technology utilizes existing supply chain for ease of commercialization of a system that is affordable and scalable 	

UTILIZATION OF ADDITIVE MANUFACTURING AND DIGITAL PART LIBRARIES FOR EQUIPMENT SUSTAINMENT

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EOS of North America would like to partner with a DoD organization(s) to formalize the method of utilizing Direct Metal Laser Sintering (DMLS) and Selective Laser Sintering (SLS) Powder bed technologies to establish robust processes that provide support to the unique and time sensitive sustainment needs of today's military. Proper utilization would require the use of industrialized technologies, a critical review of part-selection and the creation of a digital part library.


EOS DMLS and SLS Powder Bed technologies are state of the art, industrialized systems being utilized throughout the global marketplace to support a wide range of applications and production efforts. These machine systems are combined with advanced process methods and a broad spectrum of materials aimed to deliver a robust and repeatable capability. Such systems could be easily integrated into existing manufacturing centers and be supported by established workforces.

In combination with the powder bed technologies, EOS would suggest a part-selection review of critical components

that are currently cost-prohibitive and/or time-consuming to have produced by suppliers and/or are in near-depleted supply. This part-selection phase would be focused on defining the "recipe" of the component; material performance allowables, system process controls, and production conditions.

From this part-selection study, a digital part library could be established that details the "recipe" and sources for which a part could be produced. These production services could be transferred to civilian entities and/or through the use of military/DoD depots familiar with part production and equipment maintenance.

EOS is a global market leader in advanced, industrialized powder bed technologies, but has also become a leading partner in solving the digital problems associated with the implementation of Additive Manufacturing technologies. Through the use of EOS powder bed technologies, a critical review of part-selection and the establishment of a digital part library cost-effective solutions can be developed to address the difficult sustainment conditions that are suffocating our DoD branches today.

<p>PROBLEM STATEMENT</p> <p>Today's military is plagued with long wait times and high cost when it comes to managing the sustainment needs of both new and legacy technologies and equipment. If today's military is advancing their methods of defense and lethality, shouldn't they be advancing their process for sustainment.</p> <p>Furthermore, the military is often restricted by sole-source providers that stranglehold the DoD at high expense or long delay.</p> <p>Additionally, numerous DoD entities that have long supported manufacturing and sustainment efforts have been under utilized and are at threat of being shutdown.</p>	<p>BENEFITS</p> <ul style="list-style-type: none"> • EOS technologies are world renown for robust and repeatable build capabilities which utilize a wide range of industrialized materials that can be applied to various applications to support the diverse DoD sustainment requirements. • This principle of part selection would be utilized to identify critical parts that are either cost prohibitive to produce or suffering from debilitating lead times. It would define the part "recipe", material performance, system controls and production conditions. • Digital part libraries will allow for decentralized part access and global access.
<p>TECHNOLOGY SOLUTION</p> <p>EOS DMLS and SLS Powder Bed technologies are robust and industrialized systems capable of supporting a broad range of production needs.</p> <p>Through a history of partnership, EOS has developed well established processes for determining high risk, high reward part-selection.</p> <p>Digital part libraries allow for the securement of part "recipes" and decentralized access for production.</p>	<p>Today's sustainment needs tomorrow's technology!</p> 

USE OF ADDITIVE MANUFACTURING FOR OBSOLETE/DIMINISHING SOURCE PARTS

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The Issue & Challenge


- Problems sourcing obsolete parts, or those produced by diminishing sources, for legacy equipment/vehicles is significantly impacting DoD readiness
- Targeted application of Additive Manufacturing (AM) will be one element in a multi track strategy for the DoD to address readiness challenges
- One of the main challenges to expanding the application of AM to address readiness challenges is to identify the parts that are, or will be, obsolete or produced by a decreasing number of suppliers, and that are good candidates for AM. The focus would be on the highest priority parts with known demand that are affecting near-term readiness for equipment/weapon systems.

Identifying Parts for Additive Manufacture

- Industry-proven, Commercial Off-the-Shelf (Current TRL: 8) processes exist to down-select and qualify parts for AM from a larger pool of parts required for sustainment
- A multi-step parts screening process, combining trained personnel and

proprietary software, identifies and selects appropriate parts based on their technical attributes, and value, for AM production

- The first step determines a part's technical fit for AM by reviewing the part's size, dimensions, surface quality, usage, and other technical specifications.
- The next step determines the value for candidate parts, including the part's cost, quantity requirements, traditional manufacturing tooling cost and setup vs AM, lead-time, and other costs, in a variety of use/business cases. A scorecard is created to advise the user on the value of the part for production with AM.
- The analysis produces a fact-based decision on the suitability of each individual part for AM from technical and economic
- The third step, if the user chooses to proceed, is to design and build the prototype in AM and test it for functionality and suitability

<p>PROBLEM STATEMENT</p> <p>Problems sourcing parts, particularly obsolete parts or those produced by diminishing sources, for legacy vehicles/weapon systems is significantly impacting DoD equipment/weapon system readiness</p> <p>There is no standardized method, or tool, within DoD for targeted application of AM to address which obsolete parts are good candidates for AM (i.e. from a material, build size, complexity and value standpoint)</p>	<p>BENEFITS</p> <ul style="list-style-type: none"> - A qualified process/tool for identifying parts suitable for AM manufacture quickly and efficiently with limited manual effort or subjective criteria - Thousands of parts can be assessed quickly to produce potential AM candidates from a large sustainment pool that will have the most significant benefit to readiness, at the best value, for equipment/weapons systems - Allows for updates, as AM technology and materials improve and expand in the future - Can be employed remotely or on site
<p>TECHNOLOGY SOLUTION</p> <p>A multi-step parts screening process, combining trained personnel & proprietary software; identifies and selects appropriate parts based on their technical attributes, and value, for AM production (Current TRL 8). The first step determines a part's technical fit for AM by reviewing the part's size, dimensions, surface quality, usage, and other technical specifications. The next step determines the value for candidate parts, including the part's cost, quantity requirements, traditional manufacturing tooling cost and setup vs AM, lead-time, and other costs, in a variety of use/business cases. A scorecard is created to advise the user.</p>	<p>SAMPLE SCORECARD</p>  <p>The screenshot shows a 'SAMPLE SCORECARD' titled 'AM Part Score Card for Satellite Arm'. It is divided into two main sections: 'Technical Fit' and 'Economic Fit'. The 'Technical Fit' section includes criteria like Size, Material, and Complexity, with a 'Technical Evaluation' bar at the bottom. The 'Economic Fit' section includes criteria like Cost, Value Add, and Lead Time, with an 'Economic Evaluation' bar at the bottom. A central image of a satellite arm is shown. The Philips logo is in the bottom right corner.</p>

PRINTED CIRCUIT BOARD REVERSE ENGINEERING / PROTOTYPING SUITE

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Avionics repair is challenging when circuit card assemblies are no longer available from original equipment manufacturers, especially when no technical data exists. Current processes for reverse engineering and manufacture of printed circuit boards (PCBs) are time consuming and costly due to manual development of schematics, parts lists, Computer Aided Design/Manufacturing (CAD/CAM) data, and engineering drawings. Procurement delays and PCB manufacturing process time also increase flow time. Our innovation, PCB-REPS, addresses this problem by increasing the efficiency of reverse engineering and prototyping PCBs using software technology and additive manufacturing.

402 Electronics Maintenance Group's Reverse Engineering Avionics Redesign and Manufacturing (REARM) Innovation Center has assembled a suite of technology and processes to rapidly reverse engineer, document, and prototype circuit card assemblies (CCA) with little or no technical data available. The suite consists of four elements: a material removal system, a PCB scanning system, industry standard PCB CAD software, and an additive PCB manufacturing system.

Facing a shortage of multiple two-layer CCA's necessary for the overhaul of the MHU-196 Munitions Handling Cart Main Control Unit, the REARM team developed Form-Fit-Function replacement circuit cards. First, the team used existing technical data to create a Bill of Materials. A DMSMS study was then performed to determine parts substitutions for long term sustainment. All components were then removed from the CCA, leaving a bare two sided board. Next, the team used the media blaster to clean the CCA's layers and scanned the copper traces into the reverse engineering software. Subsequently, the software converted the scanned photos into Gerber files and a schematic. This data was then imported into the CAD/EDA tool to develop the procurement level technical data package. Lastly, the CAD data was input into the additive PCB manufacturing system to build a prototype. The additively manufactured prototype PCB was verified against the original CCA to be functionally identical and the TDP could now be sent off to a board vendor for Mil-spec production. This process is also being used to recreate PCB's for the A-10 Gun Control Unit, as well as the HH-60 Intercom Control Set CCAs.

In initial test and simulations, the team drastically reduced the development time to create a usable procurement level TDP and prototype by 75%. These initial tests were done using moderate complexity boards with two layers and the flow time was compared to the previous process of using a DMM to measure connectivity between traces and drawing schematics in a legacy PCB CAD tool, using separate drafting software to create the TDP and contracting with a PCB vendor to build prototypes. The greatest benefit is the ability to create a PCB that was otherwise unavailable, restoring capability to legacy systems that are carcass constrained.

402 EMXG REARM plans to streamline the process and develop a PCB-REPS framework and curriculum to be shared among the DoD maintenance community, effectively commoditizing this capability. With additional qualification and testing, future DoD Maintainers could potentially scan and then 3D print a mil-spec PCB for use in an avionics system.

PROBLEM STATEMENT	BENEFITS
<p>Avionics repair is often hindered when circuit card assemblies are no longer available from original equipment manufacturers, especially when no technical data exists. Current processes for reverse engineering and manufacture of printed circuit boards (PCBs) are time consuming and costly due to manual creation of Technical Data Packages (TDPs) and labor intensive PCB manufacturing processes.</p> <p>Manually creating engineering TDPs and CAD/CAM data has historically taken 6-8 months, depending on the complexity of the PCB. The manual process is also prone to human error and must be validated prior to PCB production. Current PCB manufacturing techniques take at minimum 10 days production time to build a prototype board, not counting procurement times.</p>	<p>Cost/Schedule 75% reduction in cost and schedule for production of TDPs and CAD/CAM data for circuit card assemblies (CCAs). \$350k in capital investment will save \$488k in engineering labor over the first 8 planned projects.</p> <p>Manpower No draftsman required to produce TDP. No procurement time for prototypes</p> <p>Performance Rapid prototyping of CCAs (2 days) for pre-production test.</p> <p>Usability Suite can be recreated and used by all branches of the military that require TDPs for previously developed CCAs.</p>
<p>TECHNOLOGY SOLUTION</p> <p>Precision removal of PCB layers using a media blaster.</p> <p>Digital scanning of every layer of a PCB through the use of a high resolution scanner and computer software.</p> <p>Scanner software provides a user interface to manipulate the images and create CAD/CAM data and schematics.</p> <p>PCB CAD software imports CAD/CAM data to create Technical Data Packages (TDPs) which contain all data needed to recreate and manufacture the Circuit Card Assembly (CCA) and is ready for JEDMICS submission.</p> <p>Additive PCB printer 3D prints prototype PCB for testing without procurement, STINFO release, or contract manufacturing delays</p>	 <p>Precision Material Removal System High Definition Printed Circuit Board Scanning System Printed Circuit Board CAD / Electronic Design Automation Software Additive Printed Circuit Board Manufacturing System</p>

BLOWN OPTICAL FIBER CLAMP

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As Aircraft Carriers have become more advanced there has been an expanded use of Blown Optical Fiber (BOF) cables for transmitting data and signals within the Ships. These cables are composed of hollow tubes into which maintenance activities blow thin glass fiber using a pressurized air source. Prior to banding down the BOF cable into the cableway, maintenance personnel place a metal u-shaped saddle between the BOF cable and the banding material. This prevents the banding material from crushing the BOF.

When working in cableways, saddles often fall out when banding is removed or modified. If this is not identified and corrected, BOF cables can be left unprotected. This results in cables being damaged. The cost to repair these cables and retest associated system is significant. Additionally, the timeline for repairs can increase the length of the maintenance availability, delaying the Aircraft Carrier from returning to the fleet.

In 2017, electricians at Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS&IMF) started working with

the Electrical Community of Practice and the NAVSEA Fiber Optics Program on strategies to prevent damage to BOF cables. Using additive manufacturing the team went through dozens of iterations, creating a new self-captivating design to replace the saddles. They worked across the Shipyards, in partnership with the Naval Surface Warfare Center Dahlgren Division and the NAVSEA Technical Warrant Holders to design, certify, and approve the additive manufactured component for shipboard use. The BOF Clamp was approved for use on Aircraft Carriers in May 2019.

This solution will prevent damage to BOF cables. A most recent Aircraft Carrier maintenance availability spent \$202K (336 Man Days) in labor and \$188K in material to repair three BOF cables totaling 2,500 feet in length. This magnitude of repair effort is typical for a longer in-port period. Cost and schedule risk associated with these repairs will be eliminated. The new clamp is easier to install and work with as well.

The current Aircraft Carrier availability at PSNS&IMF is utilizing these BOF clamps and has installed 65 of them to date. These

clamps are now permanently installed Shipboard components and represent the largest installation of additive manufactured items shipboard by PSNS&IMF to date.

These clamps were manufactured at the Shipyard. Now that they are approved for use, efforts are underway to get them added to the Naval Stock System in order to make them available to other commands and to reduce the cost of manufacturing them. These steps will allow the solution to be fully implemented across the naval maintenance community.

PROBLEM STATEMENT

- The current approved method of protecting Blown Optical Fiber (BOF) cables is with the use of a BOF saddle. This is a sheet-metal component in a U-shape that is designed to sit over a length of BOF cables resting on a cableway pan.
- BOF saddles are easily knocked out of cableways. BOF cables are hollow and made of soft plastic/rubber material making them prone to crushing and fiber damage.
- Cost for repair and retest of cables is significant.
- Timeline for repairs has the potential to increase length of maintenance availability and prevent Aircraft Carrier from returning to the fleet.

BENEFITS

- Prevents damage to BOF cables when saddles fall out of place. Eliminates repair and retesting of the systems when cables are damaged.
- Cost: Savings in repair and retest of damaged cables. The most recent Aircraft Carrier maintenance availability at PSNS&IMF spent \$202K (336 Mandays) in labor and \$188K in material to accomplish these repairs.
- Schedule: Prevents delay in Ship's delivery due to repair of late-identified cable damage.
- Quality: Clamps are easier to install and secure than previous BOF saddles.

TECHNOLOGY SOLUTION

- Using additive manufacturing technology a protective clamp was designed and manufactured to provide more robust protection for cables.
- The BOF clamp is composed of two identical units that lock together without additional fastening devices by use of a tongue and groove design. The pair of two units, when attached to each other, create a tubular-shaped, hard, rigid, protective sheath around a short length of BOF cables from fiber damage when it is banded in the cableway.
- Engagement with stakeholders to get approval for use of additive manufactured solution permanently installed shipboard.



Current method of protecting cable using metal saddle

New method of protecting cable using additive manufactured clamp

ULTEM 9085 FLCS CANOPY TRAINER

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Egress is one of the most important functions in aircraft functionality and pilot survivability. Every piece of hardware and software must work simultaneously and in perfect sequence to complete a successful ejection of the pilot. One of the key components is the Flexible Linear Shaped Charge, or det cord, that is used to remove the canopy from the aircraft before the pilot is ejected. This cord is installed during production with a service life of five years before it must be replaced. Currently the first LRIP jets are experiencing the expiration of this material, and the field is having to conduct maintenance to remove and replace this cord from these jets. An effort to re-train our maintainers is underway since most have not seen or executed this procedure since technician school. A total lack of training assets has made it difficult for units to get any training on the procedure before performing the operation on the jet. This makes the process difficult and prone to error.

The FLCS Canopy Trainer is a hybrid training asset with a additively manufactured frame that supports a scrapped transparency. This

training asset replicates the conditions on the jet and allows the maintainers to train and practice before approaching the aircraft. The 3D printed frame is printed into 10 separate sections using Ultem 9085 material. The trainer can be quickly assembled and fits onto the standard mil-spec canopy cart. It is lightweight and can easily be stored or shipped to another base. The 10 sections of the canopy trainer can be printed in 1 month utilizing only one Fortus 900 machine which was one tenth of the time quoted for a standard steel frame. This additively manufactured frame can be paired with scrap transparencies to create the necessary training assets for the units.

Today we have created a working prototype of the Canopy Trainer and are in the testing phase. An assembly test has been conducted with a cart fit check and functionality test to be conducted shortly. Once a scrap transparency has been procured, we will conduct a final buyoff of the asset at Luke AFB and receive recommendations and feedback from air force maintainers. After buyoff the next steps will be to productionize the design and get the asset certified for

training. Once deployed this device can act as an easily assembled training asset that can be transported easily from base to base. This will also serve as hands on experience for base personal on additive manufacturing using Ultem 9085 material.

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PROBLEM STATEMENT

Egress is one of the most important functions in aircraft functionality and pilot survivability. Every piece of hardware and software must work simultaneously and in perfect sequence to complete a successful ejection of the pilot. One of the key components is the Flexible Linear Shaped Charge, or det cord, that is used to remove the canopy from the aircraft before the pilot is ejected. This cord is installed during production with a service life of five years before it must be replaced. Currently the first LRIP jets are experiencing the expiration of this material, and the field is having to conduct maintenance to remove and replace this cord from these jets. An effort to re-train our maintainers is underway since most have not seen or executed this procedure since technician school. A total lack of training assets has made it difficult for units to get any training on the procedure before performing the operation on the jet. This makes the process difficult, lengthy, and prone to error.

TECHNOLOGY SOLUTION

The FLCS Canopy Trainer is a hybrid training asset with an additively manufactured frame that supports a scrapped transparency. This training asset replicates the conditions on the jet and allows the maintainers to train and practice before approaching the aircraft. The 3D printed frame is printed into 10 separate sections using Ultem 9085 material. The trainer can be quickly assembled and fits onto the standard mil-spec canopy cart. It is lightweight and can easily be stored or shipped to another base. The 10 sections of the canopy trainer can be printed in 1 month utilizing only one Fortus 900 machine which was one tenth of the time quoted for a standard steel frame. This additively manufactured frame can be paired with scrap transparencies to create the necessary training assets for the units.

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BENEFITS

- Reduce on-aircraft maintenance mistakes
- Low cost training asset
- Portable training asset
- Lightweight
- Easy to store
- Easy to assemble and install

PROTOTYPE



Functional and Strength Testing
Coming December 2019

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BOTFACTORY - DESKTOP ELECTRONICS PRINTING & ASSEMBLY

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A critical part of Electronic devices are Printed Circuit Board Assemblies (PCBAs), and fabricating them takes weeks, costs hundreds of USD, and needs to be outsourced, exposing the PCBA design to potential tampering and theft. Maintenance issues are made worse when dealing with legacy boards, as few US suppliers will still fabricate them.

BotFactory's SV2 is a desktop PCBA printer & assembly machine. It uses 3 interchangeable heads to create complete boards in a few hours for around \$20. It inkjet prints silver nanoparticle conductive ink and polymer insulating ink to create multilayered boards, before extruding micro-dots of conductive epoxy where electronic components will be placed. Finally, it assembles the components on the boards and cures the PCBA using heat and UV light.

The technology is portable and enables on-site or near-site electronics fabrication, saving significant time and costs. It guards manufacturing/repairs/maintenance operations from outside interference, greatly reducing risks of tampering or theft. Operational readiness is improved,

preventing a simple malfunction from compromising mission-critical operations.

It can also be used for Humanitarian Assistance & Disaster Relief, as well as Research & Development. PCBAs can be printed on a range of new materials, opening up new electronic applications.

BotFactory has been selling its technology since 2015, steadily adding new functionalities such as multi-layering, kapton substrates for flexible PCBAs, micro-dot dispensing, and tape assembly.

It participated in a JIFX exercise in November 2015 to demonstrate its potential for on-field repairs during a drone operation.

Laboratory experimentation have shown the SV2 PCBAs can operate with frequencies under 2 GHz. The electrical traces have a sheet resistance of 40 mOhms/square.

Its new model, SV2, is the achievement of 5 years of development. It is built to integrate seamlessly with existing operations, using the same files that a standard PCBA manufacturer uses.

BotFactory counts space agencies and many Fortune 500 companies among its customers, as well as every branch of the DoD. Most recently, the US Naval Academy installed an SV2 for on-site training of Naval Cadets.

While the current state of the technology is focused on the fabrication, the next steps include features such as automated board testing (visual and electrical) and automated head swapping.

PROBLEM STATEMENT

Any electronic device requires Printed Circuit Board Assemblies to function. Fabricating PCBAs takes weeks, costs hundreds/thousands of USD, and exposes the technology to potential tampering and theft

Fabrication lead time is delayed by months if the user is in a remote location

Legacy PCBAs are hard to manufacture, and there are very few US suppliers for them

BENEFITS

Secure on-site line of manufacturing/repairs/maintenance, including for legacy boards

Save time & cost: from weeks to 2 hours, \$20 per board

Reduce waste: no acid or any subtractive operations

Improve operational readiness: preventing a simple malfunction from compromising mission-critical operations

Humanitarian Assistance and Disaster Relief

Opens up new electronic applications on new materials

TECHNOLOGY SOLUTION

SV2 is a Desktop Electronics 3D Printer

It prints & assembles PCBAs in 2 hours for \$20 per board.

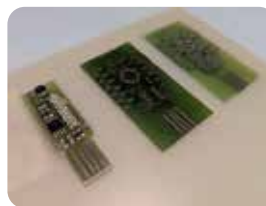
- **Inkjet prints** silver nanoparticle conductive inks and polymer insulating inks to build a multi-layered bare board
- **Extrudes** micro-dots of conductive epoxy or solder paste to attach electronic components
- **Pick-and-place** electronic components
- **Heat / UV cures** to finish the PCBA

Highly portable: 16.5" L x 14" W x 17.5" H, 25.5 lbs

More information on www.botfactory.co



SV2 machine



PCBA made by SV2

MACHINE LEARNING/ARTIFICIAL INTELLIGENCE IN CENTRALIZED ENTERPRISE LOGISTICS AND SUPPLY CHAIN SUPPORT

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The current challenge is leveraging the terabytes of data generated by deployed, monitored systems to provide actionable information for commanders, maintainers, logisticians, and program managers. The benefits of a cloud-based application performing data transactions, learning and predicting future states from current and past states in real-time, and communicating anticipated states is an appropriate solution to reduce latency and improve confidence in decisions. Decisions made from deep learning and artificial intelligence (AI) application will improve mission success and operational readiness, improving overall cost/effectiveness of any program. These improvements will accelerate process improvements at the Depot Level by filling the information gap between unit-level maintenance and depot-level maintenance efforts for each inducted vehicle or aircraft.

Systecon leverages automation to shorten the time associated with data ingestion and cleansing. Our team offers a flexible ingestion framework leveraging direct upload, Java Script Object Notation (JSON) code, or application programming interface (API) endpoints to analyze, cleanse, and

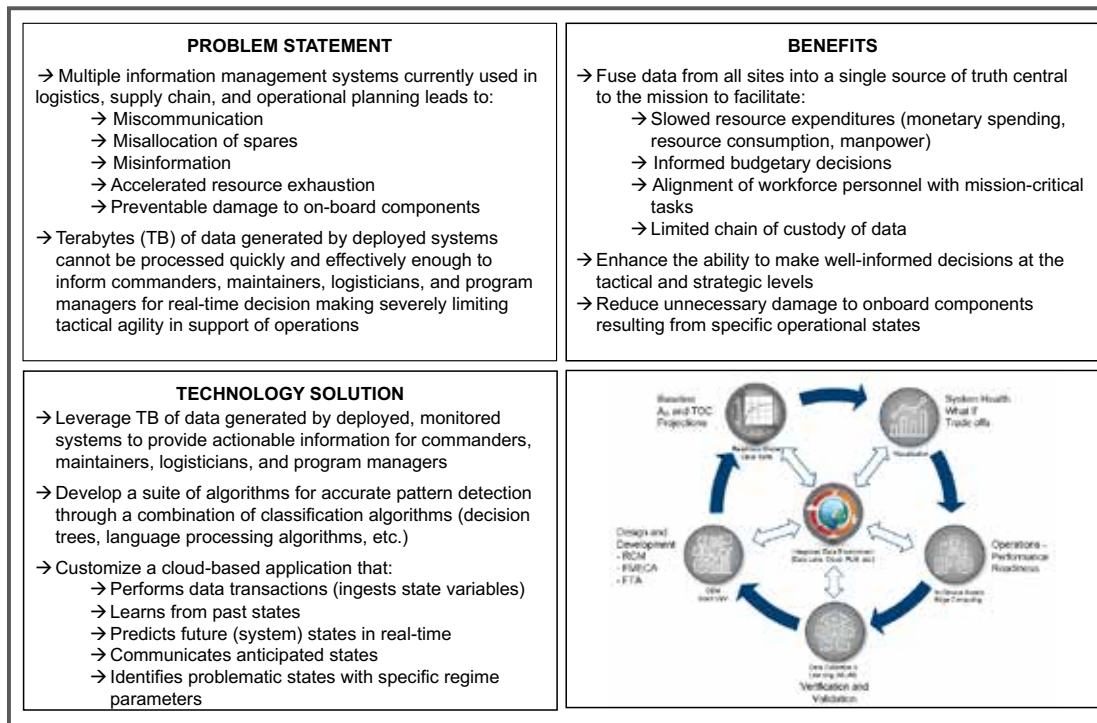
train machine learning (ML) models. The AI consumes multiple data types, structured or unstructured, from any platform without interrupting existing applications, adding hardware to platforms, or requiring complex integration across multiple “silos”.

Systecon’s solution utilizes proprietary, deep ML algorithms, created with the Defense Advanced Research Projects Agency, and leverages Topological Data Analysis to automatically present actionable information via a customized, user-friendly dashboard display. Views are designed to quickly provide the user with critical decision-making information necessary to maintain individual platforms and fleets on a day-to-day basis and through major maintenance events at the Depot level.

The vehicle agnostic algorithms correlate state variables such as kinematic data, system sensor data, external condition variables, and digital behavioral data to infer a system’s current state and digital maintenance information. Systecon’s AI optimizes both sensor-supported equipment and legacy systems absent supporting sensors or the capability to move data off

platform. Systecon’s solution identifies the prevailing trends, enabling state prediction at the system/component level. Our platform automates ongoing model tuning, reducing the cost and risk of running ML models long-term, while simultaneously improving their accuracy and performance.

The Systecon team constructs model-based, serialized digital twins across a system’s lifecycle and across logical/operational groupings of systems. This bi-directional data coupling enables tactical, operational, and strategic decision support, detachable and deployable logistics services, and configuration-based automated distribution of digital technical and product data to enhance supply and logistics operations.



THE ENHANCED MAINTENANCE & AIRCRAFT STATUS SYSTEM (EMASS)

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Aircraft maintenance has not changed for decades, but technology has. Most of the technology has been utilized in inspection methods, equipment upgrades, and currently all technical orders now being electrically accessed using eTools or eTablets to give the maintenance technicians 1000's of technical orders at the swipe of a finger. However, a process within the production effort has been stagnant for over 20 years. Production Superintendents have used pencil and paper to create, track, change, and highlight aircraft status. The information is then passed along to unit commanders through more paper and daily briefings.

Currently, the effort does utilize computers, spreadsheets, and PowerPoint slides to access data and to push updates throughout the maintenance complex to ensure all who need to know the vital information to make sound decisions have the information readily available. Once the information is received meetings are required to review the data, correct statuses, and plan ways forward to increase fleet availability and health to continue the mission. Meetings take valuable time away from the unit commanders, time

that can be utilized to keep the focus the maintenance units continued effectiveness.

The Enhanced Maintenance & Aircraft Status System idea will give the ability to enhance all aspects of communication from the ground up. The system will consist of a multi-application based program(s) that have are able to utilize the current hardware. Each application within EMASS will consist of one of the following: aircraft status, supply data, short and long term aircraft schedules, integrated data collection, and technical orders. This system will be connected to the wireless network and all data be stored in the EMASS server. From lowest level production staff to the group commander, inputs to each application are pushed to the server and then delivered to all users for real time information.

Commanders will have oversight on all statuses and issues concerning fleet health. Meetings that are required due to continual updates can be reduced by 1 ½ hrs each day for a total of 8 hrs per week, time that can be used to focus on other issues that could impact the maintenance effort. The system will enhance communication with

Production Superintendents and Expeditors as well as lateral support agencies for sound and educated maintenance decisions that directly affect sortie generation. Will insure accurate aircraft status reporting, to include in-depth breakdown of each aircraft, and down-time tracking. This tracking data will be used to evaluate time effectiveness for future improvements. Continued supply data updates and tracking for short-term parts removal feasibility to limit wasted cross-cannibalization to keep aircraft availability high. Finally, with the ability to update all information via wireless communication, supervision of aircraft maintenance operations is greatly increased.

PROBLEM STATEMENT

Limited ability for aircraft maintenance units to communicate real-time tracking of aircraft status throughout command utilizing current hardware and software to optimize all levels of aircraft maintenance for sortie generation.

Current methods of communication has not changed for over 20 years and has not taken advantage of new technology and wireless connectivity

BENEFITS

- Wireless communication w/real time status update
- Commanders have oversight of fleet health as it happens
- Reduce time spent at meetings (8hrs gained per week)
 - Allows more focus on unit internal issues
- Enhanced Production Superintendent/Expediter communication
 - Enables educated maintenance decisions
- Accurate aircraft status reporting
- In-Depth maintenance breakdown for each aircraft
- Aircraft maintenance down-time tracked
 - Evaluate time effectiveness for future issue
- Continually updated supply data & estimated delivery dates
- Increased flight line supervision.

TECHNOLOGY SOLUTION

Utilize multi-application based programs on current eTool and eTablet to provide the ability track current status of aircraft, supply data, scheduling, integrated data collection, and technical orders via wireless network.



TECH DATA VIDEO EXCERPTS

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Previous grounding of the B-1 Aircraft fleet, along with incoming airmen more adept to visual/kinesthetic learning, fuels this concept of videoing Technical Order (T.O.) tasks.

Web Access (WA) digital Technical Data used by our new AF Maintainers, is showing to have a lot of confusion in the steps by having to jump around in the tech data between steps. This is causing a loss in clarity since moving away from paper. Maintainers don't have the comfort of touching the paper T.O. and logical process they are used too. There is ambiguity in the wording and/or schematics with the tasks in this process.

Videoing T.O. tasks has been talked about for some time throughout the AF. Imbedding them in the T.O. would allow the Maintainer to have continuity and clarity while working. The concept of keeping things more clear to our Aircraft Maintainer in performing their tasks on multimillion dollar aircraft, along with ensuring the safety of lives, keeps with the AF values.

We recommend gathering ALL who have ideas on this concept, encouraging creativity

and innovation. By utilizing ideas spurred from situations encountered by individual Maintainers during the performance of a task, would improve the overall design of this concept. Not losing the individual, but including all. Also, eliminating duplication of time and wasted effort throughout the AF, but strengthening efforts.

Recommend a type of gatekeeper, without shutting down innovative ideas. AETC being the belly button for training, would be good start. Their expertise in creating training videos, are more technological in nature, and meet the needs of our airmen.

Keeping all videoing and efforts in a location known to the whole AF, is more efficient. Different bases stashing videos on Share Point, training sites, etc. would be counter-productive. Imbedding video in WA T.O.s minimizes and/or eliminates jumping around.

The following is an outline of the suggested process to implement:

1. Put word out to ALL Aircraft maintainers requesting input of T.O. tasks better suited in video format

2. Compile all data by aircraft, then by T.O. Determine and Prioritize task to video
3. Gather scheduled maintenance tasks. Determine if any base has scheduled maintenance that would include that particular task
4. Schedule videoing of the scheduled maintenance task to be performed. Filming done by AF personnel, which is more cost effective
5. If a task has no scheduled maintenance due, but is one that has caused downtime/issues in the past. Coordinate and schedule videoing of that task, possibly at the Technical Schools or Depots
6. Submit T.O. task performed to Equipment Specialist (E.S.) for verification of accuracy and clarity
7. Submit verified video to T.O. Home Office for embedding in WA T.O., which is authorized

<p>PROBLEM STATEMENT</p> <ul style="list-style-type: none"> ▪ Wording in Technical Order Data does not clearly convey certain individual repair steps to maintainers ▪ Lack of clarity on steps and procedures causes work to be done improperly possibly grounding aircraft or sub systems ▪ With incoming airmen being more adept to visual guidance and learning, textual documents/wording can cause confusion slowing down work which could cause incorrect maintenance being performed 	<p>BENEFITS</p> <ul style="list-style-type: none"> ▪ Assists the Aircraft Maintainer in performing repeatable maintenance actions ▪ Prevents lost man hours in rework ▪ Minimizes man hours spent in additional research on specific tasks ▪ Saves man hours on additional tasks for specific training ▪ Help resolve issues similar to those that grounded the B-1 fleet previously
<p>TECHNOLOGY SOLUTION</p> <ul style="list-style-type: none"> ▪ Add video steps on specific tasks for regular scheduled maintenance technical guidance <ul style="list-style-type: none"> ▪ Provides a cost savings in man hours ▪ Submit changes to Technical Order (T.O.) Home Office for Equipment Specialist (ES) review and verification <ul style="list-style-type: none"> ▪ Each T.O. has their own Home Office ▪ Upon verification/approval <ul style="list-style-type: none"> ▪ Add/Imbed video for particular steps within the T.O. <p>NOTE: Video's are an approved part of Web Access (WA) T.O.s</p>	<p>Graphic or Image</p>

HARNESSING THE POWER OF AMERICA MAKES TO INNOVATE

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In FY2015, the Air Force Research Laboratory (AFRL) initiated a program to accelerate additive manufacturing and advanced technologies in support of improved sustainment operations. The Maturation of Advanced Manufacturing for Low-cost Sustainment (MAMLS) is a public-private partnership executed through America Makes manufacturing institute. MAMLS teams visited sustainment centers to understand current capabilities and issues. An advisory council of sustainment personnel and a Gate Review Process ensured projects addressed important issues. Over a period of 5 years, the relationship between MAMLS teams, AFRL research personnel, and AF maintenance personnel has grown and many successful projects have resulted. Workforce development is required for all America Makes programs, and this allows unique training opportunities to accelerate implementations. Cost sharing from America Makes members is another value-added factor. MAMLS is now in its third Phase and has conducted nearly 50 projects. Examples demonstrating the collaboration of maintenance personnel with MAMLS teams follow.


A MAMLS team worked with F-16 maintenance personnel at Hill AFB to innovate a process to repair F-16 tooling. Fiberglass trim/drill fixtures are still used and many of these are currently unusable due to damage. To get them repaired requires a process can take up to a year and is very expensive. The MAMLS team utilized a laser scanner to obtain tool data on-site and then used additive manufacturing to print the repair area, as well as a positioning guide to install it. The process was devised to use available shop equipment for all other operations. The resulting repair took a total of 9 days; has an estimated ROI of 35 to 1; and is transferable to similar tools.

F-16 maintenance personnel also identified a group of battle-damaged parts that had been an F-16 tail. The tail was not repairable because all datums had been lost and traditional methods of repair would not meet tolerances. The MAMLS team used a combination of metrology technologies (laser scanning, faro arm, and photogrammetry) to establish a digital model of the tail. With this data, the tail could then be correctly fixtured and the attachment lugs machined within

tolerances. The result was a \$1.0 - \$1.5M asset returned to the AF inventory.

Another MAMLS team focused on creating increased agility and capacity in the domestic casting base to meet defense sustainment requirements. The team collaborated with various AF organizations to demonstrate advantages of using additive manufactured tooling, such as 3D Sand Printing, in the manufacturing of hard-to-procure cast aircraft components. One part demonstrated a 60% lead-time reduction.

The America Makes methodology has proven to be very effective for innovating maintenance processes.

<p>PROBLEM STATEMENT</p> <ul style="list-style-type: none"> How to utilize developments in additive manufacturing and other advanced technologies to improve sustainment operations and address problems such as: <ul style="list-style-type: none"> Replacement of low-volume produced parts Out of production spares (OOPS) Non-availability of required tooling, fixtures, etc. Needed advanced technology training Lack of digital data for new processes 	<p>BENEFITS</p> <ul style="list-style-type: none"> Reduction of cost and lead time to fabricate replacement components for AF systems Improved sustainment operations through new capabilities for tooling, fixtures, jigs, masks, and other support equipment Advanced technology training at the workforce level. Collaborations between government personnel (both research and maintenance) and America Makes teams increases transition potential
<p>TECHNOLOGY SOLUTION</p> <ul style="list-style-type: none"> Use the America Makes national manufacturing institute and the wide range of member technologies to provide technology solutions such as: <ul style="list-style-type: none"> Laser scanning & photogrammetry Fused deposition modeling (FDM) 3D Sand Printing (3DSP) Direct metal laser sintering (DMLS) Digital Light Processing (DLP) Advanced Data Collection (Grate System) Composite Based Additive Mfg (CBAM) Advanced Training Many others 	 <p>The collage includes four images: the top-left image shows a person in a white lab coat working with equipment; the top-right image is a close-up of a mechanical part with a circular opening; the bottom-left image shows a group of people in a classroom setting; the bottom-right image shows a close-up of a mechanical assembly.</p>

RAPID TDP ANALYSIS TO SUPPORT MAINTENANCE READINESS

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DoD products are complex, and the data driving their design and intended use is growing in both size and nuance. Acquisition data is the foundation of decision-making, management, and oversight of weapon-system maintenance portfolios for the DoD and must be fluid in revisions, engineering changes, operational upgrades, and lifecycle support. Upon delivery of technical data, programs have limited time to accept the data from vendors. Manual analysis of large data 2D/3D relationships, BOM, manufacturing, analysis, ECO reports are time consuming and fall short of allocated time and resources. Each delivery is a myriad of tools, drawing / document revisions, custom alternatives, effectivities, and file types linked conceptually through the PLM it was extracted from.

An assessment of existing program's TDP showed 306,084 CAD models across multiple CAD versions, 145,898 drawings, and over 70 file types. Embedded are mismatched revisions, vendor-based nomenclature, and legacy / corrupt file types requiring legacy software and hardware.

The TDP analysis tool will read as-delivered technical data to check the completeness, flag issues, and produce a TDP staging area that facilitates loading BOM related structure into PLM or data systems for maintenance operations. Leveraging existing capabilities in interoperability, the TDP analysis tool examines all files delivered into the TDP and extracts information about part numbers, effectivity, relationships, and revisions. The modules that extract data are expandable for future requirements.

This information is loaded into a TDP index that provides a relational structure mapped to the delivered TDP. The data is analyzed to support maintenance operations through:

- Quick analysis of TDP for completeness
- Quick analysis of files delivered and required software
- Identification of parts removed based on previous data
- Analysis into mismatched revisions on drawings
- Utilization of data based on part design, manufacturing, ECO, and configuration

- Grouping based on design type (additive, piping, electronics)
- Staging for downstream PLM and maintenance data loading
- Reduced cost, time, and error in data assumptions

Today, data is manually analyzed or assumed correct. Leveraging an analysis tool speeds up the availability and accuracy of data to make decisions and share across the DoD enterprise. The interoperability toolsets keep the complexity of the formats out of the equation to provide reports quickly and accurately. As new toolsets become available the system is flexible to support new and existing formats.

Incomplete data results in delays and reduces availability and readiness of weapon systems. It is crucial to bring tools to the maintenance portfolio that can help assist analyzing the growing amount of technical data. As manufacturing complexity increases it is crucial to build the tools necessary to optimize the quality and speed of data that helps maintain our weapons systems.

<p>PROBLEM STATEMENT</p> <p>Delivered technical data is the foundation of decision-making, management, and oversight of weapon-system maintenance portfolios for the DoD. MIL-STD-31000 provides guidance for Technical Data Packages (TDP) however data analysis for accuracy and completeness grows ever complex.</p> <p>Data analysis is time consuming and falls short of the allotted time and resources, leaving gaps in data and inability to trust information for downstream maintenance operations.</p> <p>As systems grow more complex with manufacturing technologies, the need for technical data increases in size and complexity making it harder and more costly to analyze.</p>	<p>BENEFITS</p> <p>The analysis tool uses interoperable tools to extract key information from technical 2D and 3D data. This provides a solution to the maintenance operation through:</p> <ul style="list-style-type: none"> • Quick analysis of TDP for completeness (missing files) • Quick analysis of files delivered and required software • Identification of parts removed based on previous data • Analysis into mismatched revisions on drawings • Utilization of data based on part design, manufacturing, ECO, configuration, subsystem, or system level • Grouping based on design type (additive, piping, electronics) • Staging for downstream PLM and maintenance data loading • Reduced cost, time, and error in data assumptions
<p>TECHNOLOGY SOLUTION</p> <p>Analysis tool which provides:</p> <ul style="list-style-type: none"> • Ability to extract part data including number, revision, effectivity, and more from native 2D/3D files delivered • Ability to pull relationship data from files which related file to file, part to part, subsystem to part, effectivity to part, etc. • Ability to compare 2D drawing PDF and standard files to raw versions to check completeness and revisions • Data index providing data intelligence to models to identify critical areas where more data is required • Ability to stage loading data for PLM and other associated Master Data Management plans 	<p>TDP Analysis Tool vs Traditional Processing</p>

SHARED DISTRIBUTION SYSTEM

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Recently the IDF Spare Parts Center (SPC) has adopted a shared economy approach called the Spare Parts Network.

- Lower air pollution and gas consumption.
- Fewer traffic jams and accidents.

The concept of the Spare Parts Network is based on shared inventory. Any item might be stored in any warehouse.


The main difficulty in the implementation of this concept is the distribution system. The resources of the distribution system are limited and significantly lower than the needs of the network.

On the other hand, each day tens of thousands of military vehicles, trucks and semi-trailers are driving between the units all over the country. While platforms like UBER and GETT are taking advantage of these resources, the military world is driven in a traditional way.

The solution is a shared distribution and transportation application.

This leads to:

- Higher availability of military supplies.
- Reduced transportation costs.

PROBLEM STATEMENT	BENEFITS
<p>Recently the IDF Spare Parts Center (SPC) has adopted a shared economy approach called the Spare Parts Network.</p> <p>The concept of Spare Parts Network is based on shared inventory. Any item might be stored in any warehouse, being a vertex of the network. This approach allows for higher parts availability, especially in low resources scenario.</p> <p>The main difficulty in the implementation of this concept is the distribution system. The resources of the distribution system are limited and significantly lower than the needs of the network.</p>	<ul style="list-style-type: none">• Higher availability of military supplies• Reduced transportation costs• Real-time location of transported assets• Reduced load over dedicated and special vehicles• Lower air pollution and gas consumption• Helps fight traffic jams and accidents
TECHNOLOGY SOLUTION	GRAPHIC OR IMAGE
<p>Each day, tens of thousands of military vehicles, trucks and semi-trailers are driving between the units all over the country. While platforms like UBER and GETT are taking advantage of these resources, the military world is driven in a traditional way.</p> <p>The solution is a shared distribution and transportation application. The application allows for opening transportation demand, real-time tracking after the location of the shipment, grading the quality of service and payment by virtual currency (called M-Coin)</p>	

NAVY ENTERPRISE SUST TECH TEAM (NESTT) & INITIAL NAVY SUSTAINMENT IPL

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Issue:

Increasing readiness and modernization demands challenge Navy platform maintainers. Historically new development and fielding efforts have been organizationally unique even though similar technologies (e.g., Cold Spray) and processes (e.g., training, cyber) are common. Additionally, platform-aligned resource sponsors contribute to these historical behaviors.

Background:

In late 2018, senior managers from Marine Corps Logistics Command, Commander Fleet Readiness Centers, and Naval Sea Systems Command's Industrial Operations agreed to collaborate on areas of common benefit. They recognized technology advancements and fielding could be greatly accelerated through coordinated efforts.

Solution:

Subject matter experts from these depot activities met in April to form an action team to identify areas of common focus. The Navy Enterprise Sustainment Technology Team (NESTT) is coordinating a number of pre-existing projects and identified a

prioritized list of capability gaps to transform the future of Navy maintenance. The initial Navy Sustainment Integrated Priority List (IPL) portrays dual-use benefit intending to garner increased industry participation to resolve capability gaps that can transform maintenance and modernization operations. An example of this is the 19-001 gap that attempts to develop and field an expeditionary (tele-operated) maintenance capability that would allow maintainers to conduct maintenance evolutions while platforms remain in the field as far forward as possible.

Next Steps/Benefits:

- Resulting from the NESTT discussions and the initial Sustainment IPL, the Office of Naval Research engaged with an accelerated FY20 Small Business Innovative Research initiative and a \$30M investment.
- Additional outreach is underway to industry and academia through Cooperative Agreements, DoD Institutes, and recently established Navy Tech Bridges to resolve these capability gaps to transform Navy maintenance.

- The NESTT is developing a process to continuously update the Sustainment IPL from inputs across the Navy depots and the Fleet stakeholders.
- Future expansion of the NESTT will incorporate other Navy depot activities to optimize use of investments to meet the Navy sustainment portion of the mission.

PROBLEM STATEMENT

Disparate technology advancement efforts across organic Navy depots are creating unnecessary duplication and slowed fielding of needed capabilities to meet maintenance and modernization requirements.



BENEFITS

- Structural, mechanical, electrical... repairs are very similar across the Navy depots; coordinated development provides more rapid fielding of solutions to affect mission readiness
- Common solutions between Navy depots allow for distributed logistics support of various Navy platforms
- Use of a Navy Sustainment Integrated Priority List (IPL) allows depots to communicate common gaps resolution saving fielding time and investment; additional benefits are expected for the Defense Industrial Base

The Department of Navy has accelerated SBIR efforts in FY20 to develop and field solutions that address the initial gaps.

TECHNOLOGY SOLUTION

- Established the Navy Enterprise Sustainment Technology Team (NESTT) to align current and future efforts
- Created an initial Navy Sustainment IPL; working with various agencies to address capability gaps; gaps crafted to address dual-use (e.g., public and private sector) challenges
- FUTURE STATE:
 - Develop repeatable Sustainment IPL process to allow greater inputs from depots and Fleet activities
 - Add other Navy depot activities and stakeholders

Initial Sustainment Integrated Priority List Topic Titles	
19-001	Expeditionary Depot Capability
19-002	Artificial Intelligence (AI) Generated Work Instructions
19-003	Self Healing Data Collection Using Artificial Intelligence
19-004	Robotic Material Handling
19-005	Integrated Global Logistics Network to Allow Model Based Enterprise
19-006	Global Parts Tracking System
19-007	Autonomous Facility Health Monitoring and Prioritization
19-008	Master Command and Control for Multiple Activity Visibility
19-009	Cold Spray Next Steps

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BUSINESS PROCESSES AND PARTNERSHIP

JOINT ROBOTICS ORGANIZATION FOR BUILDING ORGANIC TECHNOLOGIES (JROBOT)

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Issue:

Industry advances in robotics have largely not been harnessed by Department of Defense (DoD) maintainers with an impact directly affecting readiness. Similarly, robotic advancements made by the DoD's research institutes have not traditionally focused on maintenance as part of the operational continuum. Inputs from the maintainer community into both industry and the DoD research groups have not been coordinated providing isolated solutions for a few forward-thinking activities.

Background:

Accelerations in robotics capabilities and fielding world-wide (e.g., Made in China 2025) require appropriate focus to enable resilient and agile logistics for the DoD. Inter-agency and allied partners are also seeking maintenance solutions to meet similar requirements.

Solution:

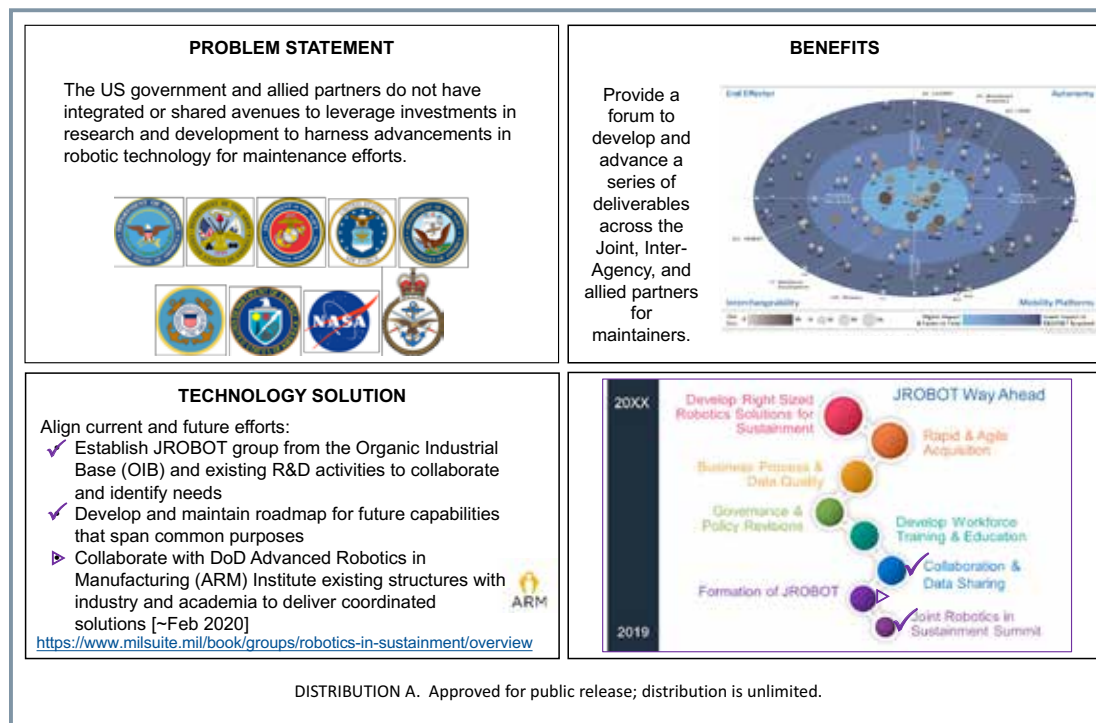
In March 2019 the inaugural "Joint Summit: Robotics in Sustainment" was held. The summit gleaned inputs from the maintainer and research communities within the federal government (e.g., across the DoD, United

States Coast Guard, National Aeronautical Space Administration, and the Department of Energy) and the United Kingdom's Ministry of Defense. The summit provided a roadmap for continued coordination and fielding for governmental agencies. Since the summit, on-going monthly discussions with the attendees have drafted a charter for approval, provided workforce development insight from various services, and also put form to the next summit that will include industry partners.

Next Steps/Benefits:

Resulting from the summit, the DoD's Advanced Robotics in Manufacturing (ARM) Institute offered to host a shark-tank style summit in February 2020 at their facility to award a new round of projects that specifically advance sustainment. The Joint Technology Exchange Group principals with their ManTech counterparts will finalize the plan for the February 2020 summit to ensure maximum engagement by all stakeholders. With a focus on fielding robotic solutions that affect sustainment across the DoD and other partners, the foundation has been created to provide greater performance and

affordability for both the Department and the National Security Innovation Base.



CLOUD BASED RISK ASSESSMENT

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The Cloud Based Risk Assessment platform is a Fifth-Generation auditing platform designed for Contracting Officer Representatives (CORs) and Contractors fulfilling contractual obligations to the U.S Government. It is designed to be used anywhere the U.S Government has Contractors performing work.

- It is based on the Aerospace Quality Management System (QMS) and the newest regulation, AS9100D. It is a web enabled audit platform with Amazon Web Services (AWS) capabilities over a secure network.
- It provides quantitative and qualitative data to enable Management to analyze supply chain operations, non-conformity issues, customer satisfaction, employee competence, employee training, management reviews, corrective and preventative actions maintenance shortfalls and other factors important to a functioning QMS.

It is capable of ensuring the customer is provided safe and reliable products and services that meet or exceed customer

and applicable statutory and regulatory requirements. It is focused on risk-based analysis, aimed at taking advantage of systemic opportunities and preventing undesirable results.

The QMS IT Solution is an electronic audit system that incorporates all the significant elements of a paper based surveillance plan and can be adapted to any industry.

The system documents and stores performance data. Stored information, can be instantly accessed by any QMS subject matter expert with appropriate access.

The system maintains records of all Contractor communication with the Government and Government replies to audit questions. It is not impacted by high turnover in either military or civilian personnel -The system monitors performance by contract number.

Additional features are aircraft readiness verification based on tail number, performing trend analysis, comparison reports, accessible from authorized civilian mobile devices and has a civilian application should the need

arise. By design, it reduces the number of repetitive maintenance tasks and reduces labor costs while increasing levels of productivity and efficiency. It has an intuitive user interface and requires minimal training prior to use. We are in the development phases of an Artificial Intelligence prediction model to anticipate areas of high risk and potential impact of these on the overall program. It is Patent Pending and Copyrighted.

PROBLEM STATEMENT

- ❑ Personnel turnover high in all military branches
- ❑ Both civilian and military positions are hard to fill
- ❑ Enormous amounts of data related to quality obtained but cannot be quantified or qualified
- ❑ Government has many contractors performing work, and cannot accurately verify delivery of products and services.
- ❑ Current verification systems and methodology outdated
- ❑ Cyber security in the Logistics and Maintenance chain, a significant but largely ignored threat
- ❑ Insufficient government personnel to verify contractor performance
- ❑ Warfighter not provided optimal products and services, readiness negatively impacted

BENEFITS

- ❑ Immediately able to provide a risk assessment on key processes throughout the Logistics and Maintenance departments
- ❑ Cloud based, over secure network. 24/7 access with mobile capability
- ❑ Reduce by 90%, the number of non conformities entering the supply chain and making it way to the maintenance departments
- ❑ Smart Machine Learning Technology, with predicative modeling to anticipate high risk processes. This allows for focusing resources to correct deficiencies
- ❑ Reduce maintenance time and rework
- ❑ Future blockchain capabilities to ensure a secure and centralized Logistics and Maintenance process
- ❑ Already provided demonstration to the F-35 Logistics/Maintenance folks. Ready for additional demonstrations.
- ❑ An example of the cost savings, by objectives estimates, the F-35 program will save about \$10m, per site, per month with this.

TECHNOLOGY SOLUTION

- ❑ World Technology U.S.A LLC developed a Cloud based Risk Assessment Platform. We recently briefed the platform and methodology at two Air Force based and are finalizing sale of the F-35 version to the Joint Strike Fighter program office. The platform is applicable to any process that involves government Logistics and Maintenance processes. It is designed to provide immediate Risk Assessments on specific key processes. It is Cloud Based and has the ability to store large amounts of data to allow any branch of service to make informed Logistics and Maintenance decisions. It filters out irrelevant data and ensures Management is provided a Smart view Risk Assessment Dashboard to immediately identify risk. This is imperative to a battlefield commander who needs to know where in his/her Logistics or Maintenance process, the most risk resides.



DEPOT DIAGNOSTIC AND FACTORYINTEL DASHBOARD

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The DoD's Depots face a complex challenge: they play a key role in driving increased readiness yet face increased annual carryover and diminishing technical capabilities. The DoD identified modernization, innovation, and cooperation as keys to restoring our nation's combat advantage. As the DoD transitions to Industry 4.0 standards, there is no "one answer" to increase the DoD's maintenance capabilities, but there is a risk of mis-investment in technology. The first step in the transition to the 'Smart Depot' is identifying the root causes impeding improvements in readiness.

The siloed nature of maintenance functions and data within Depots hinders leaderships' ability to identify root causes and prioritize investments. With 21 Depots, 17 of which perform complex Depot-level activities, the root cause is likely to be unique at each Depot. The unique missions, capabilities, and characteristics at each Depot makes identifying and prioritizing the most influential problems and targeting investment a potentially time-consuming process.

The Depot Diagnostic and FactoryIntel dashboard are the first steps toward

improving operations across the DoD's Depots. The Depot Diagnostic is intended to rapidly develop a comprehensive perspective of current state Depot operations. The FactoryIntel dashboard enables the DoD to consolidate and visualize disparate sources of quantitative and qualitative data to drive decision making.

The Diagnostic begins with an illumination of the Depots' governance construct, workforce, IT infrastructure, and processes to develop a baseline for improvement. The defined baseline is compared with the Advanced Manufacturing Maturity Model, identifying gaps between current performance, a commercial manufacturing baseline, and Industry 4.0 ('Smart Depot') standards. Once gaps have been identified, qualitative and quantitative data is collected to visualize performance.

The FactoryIntel tool digests data from a multitude of sources (ERP systems to paper processes), transforming information into a series of dashboard visualizations, granting leadership access to previously unavailable insights. A shared reality and increased transparency into the current

state of operations enables leadership to ask the targeted questions necessary in driving more efficient investments. The Depot Diagnostic approach pairs a holistic strategy with tactical solutions to transform maintenance operations.

PROBLEM STATEMENT

- DoD Depots play a key role in driving increases in readiness, yet face increased annual carryover and diminishing technical capabilities
- The siloed nature of maintenance functions and Depots' data hinders leaderships' ability to identify root causes and prioritize and target investment
- Through the emergence of innovative technologies the nature of warfare has been altered, and there is an increased urgency in tackling readiness related issues
- With the advance of Industry 4.0, there is likely not 'one solution' to improve maintenance capabilities, but there is a risk of mis-investment in technology

BENEFITS

- Rapidly develops a comprehensive understanding of the current state of maintenance operations
- Assists in the development of a future state vision for manufacturing operations and the transition to Industry 4.0 manufacturing standards
- Utilizes a proven methodical approach that pairs a holistic strategy with tactical solutions
- Breaks down data silos between disparate data sources, enabling data driven decisions and driving greater efficiency in prioritizing and targeting investments leading to increased readiness
- Enables a shared reality in decision making across decentralized MRO capabilities

TECHNOLOGY SOLUTION

- **The Depot Diagnostic:**
 - Consists of a questionnaire and the Advanced Manufacturing Maturity Model to assess the current state of operations and rapidly identify opportunities for improvement
 - Data is collected and uploaded into the FactoryIntel Tableau Dashboard to develop a scalable strategy, summarized in a strategic roadmap
- **The FactoryIntel Dashboard:**
 - Visualizes data collected from disparate data sources (ERP systems to paper processes) on single component processes, production lines, DoD Depots, or Depot Networks to enable increased transparency and a shared reality in decision making
 - Enables sensitivity analysis to estimate impact and a maturity assessment to visualize investment targets and track progress against KPIs to ensure investment drives increased readiness



OPTIMIZING MRO RESOURCING AND PROCESSES ACROSS THE NAE

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Performing maintenance, repairs, overhauls for the Naval Aviation Enterprise (NAE) involves navigating and managing an extremely complex network of Depots, Intermediate level land-based and ship-based locations. Depot Field Repair Teams also perform critical repairs to aircraft aboard Air Stations across the globe. Commander, Fleet Readiness Centers (COMFRC) is responsible for the planning, funding, and scheduling of maintenance activities at these sites in order to ensure that weapons systems are available capable to support the Warfighter. Andromeda Systems Inc. (ASI) has been working with COMFRC to develop an enterprise model that takes advantage of modern computing capabilities, advanced Operations Research techniques, modeling and simulation (M&S) tools, and in-depth understanding of the problems being faced to optimize resourcing strategies and business practices in order to maximize throughput and availability. The completion of this effort will greatly impact both production and maintenance practices as they apply to aircraft, engines, components, and other critical assets. While the current effort is focused on the Navy and

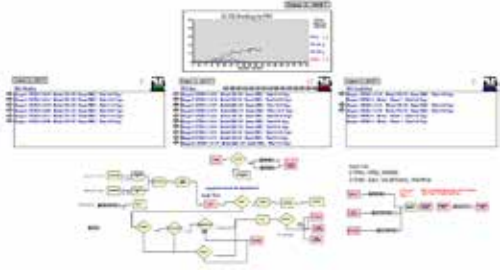
Marine Corps, it has implications across all the services throughout the DoD.

The model, currently in development, is a decision support and analysis tool that provides a holistic view of how all the sites are able to manage their current maintenance and production workloads. Key metrics are collected including throughput, Turnaround Time (TaT), resource utilization/availability, and backlog. Planned future workload can be evaluated and various scenarios can be analyzed in order to determine their impact. Some of these scenarios can include:

- Reallocating of resources (personnel, machinery, tools) to fill gaps in some locations and relieve excesses in other locations
- Intelligent routing of certain components/assets across the sites to gain efficiencies
- Prioritization of components/assets to meet the warfighter's needs
- Evaluating the ability to meet an increase in demand (surge) across the various sites

- Prioritization of Continuous Process Improvement efforts to reduce TAT and increase throughput

In addition to manually evaluating scenarios, the tool contains an Optimization capability that utilizes cutting edge Operations Research techniques to determine ideal enterprise wide solutions in a dynamic environment. The integrated nature of the model allows for COMFRC to react quickly to evolving situations, and continuously improve maintenance operations across the enterprise.

<p>PROBLEM STATEMENT</p> <p>COMFRC is responsible for the arduous task of managing a complex network of Depots, I-level locations, and field sites to provide maintenance, repairs, overhauls, and parts manufacturing for the NAE. An integrated approach is necessary to optimize business practices and resource allocations in order to maximize weapons systems availability to the Warfighter</p>	<p>BENEFITS</p> <ul style="list-style-type: none"> • Application provides one integrated solution that considers impact of decisions made at a particular site to the other sites, and the enterprise as a whole • Ability to run various scenarios to evaluate potential impact of any decisions or improvement initiatives • Optimization algorithms allow for intelligent resource allocations, routing of workload, personnel scheduling • Simple user interface allows stakeholders to make near real-time decisions to support enterprise operations in a dynamic environment
<p>TECHNOLOGY SOLUTION</p> <p>An enterprise wide modeling and simulation application is being developed that takes advantage of:</p> <ul style="list-style-type: none"> ▪ Advanced computing capabilities ▪ Operations Research (OR) techniques ▪ Near Real-time data collection and processing of current NAE data systems <p>The application will serve as a Decision Support System to be used both at the enterprise level, as well as the local sites to improve and optimize operations</p>	<p>GRAPHIC OR IMAGE</p> 

ROBOTICS AND INTELLIGENT AUTOMATION OF LIKE DOD MAINTENANCE PROCESSES

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Lean manufacturing and logistics layouts are a leading tool for cost saving. However, advancement of intelligent robotics and flexible work cells provides lean manufacturing with a new meaning. Combine these advancements with laser, non-destructive inspection, joining and paint technologies the operation throughput advances exponentially and yields tremendous cost savings. This technology reduces man- hours, materials, waste, consumables, manual logs, lost records and increases safety for workers.

The Automotive Industry with Industry Suppliers has perfected the Intelligent Robotic Work Cell and combining like processes. Cars are manufactured in 24/7 lights out operations, monitored intelligent systems that notify a technician when an exception occurs. The technician logs into the mobile system and views the analytics, determines next steps and implements go/ no go. All materials are marked with identification and tracked through the processing. 3D scanning and photographic equipment connects to PLC logic to verify coordinate positions communicating to the autonomous ground robotic movers the start position to implement the process.

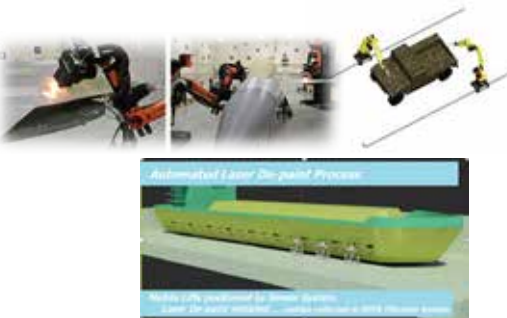
The USAF has implemented laser depaint on F-16 aircraft and are planning robotic painting. Commercial aircraft manufacturers have implemented robotic painting. The SurClean collaboration effort has identified Advanced Integration Technologies, a DoD security cleared vender as the System Integrator. Together we propose an advanced TRL 8/9 intelligent robotic dry dock maintenance solution. This solution would utilize FANUC Robotic Arms mounted on platforms. The platforms will be set up for each process: 3D scan, communicate coordinates and position autonomous robotic platforms, de-paint, non-destructive inspect, data capture, robotic weld repair, non-destructive inspect, data capture, profile validation and re-paint. This team would consist of AIT, FANUC, Coherent Lasers, API, a welding OEM, TruQC and SurClean.

The laser ablation process is proven and has been validated by an independent MRO shipyard provider that it will save their yard \$20,852,160 over 10 years providing 155% ROI. The cost calculations include manhours, materials, hazmat, PEF and reporting. A third party validated improved air quality in the work area that exceeds the

6% Navy goal. Laser ablation maintains the approved mil spec and cleanliness standard for paint. The Navy 5-Stack applied and validated by Sherwin Williams laboratory technicians, resulted in findings of improved adhesion characteristics (1400 psi). The sem particulate analysis was less than the standard specification and showed no thermal steel distortion.

The USAF has investigated laser ablation and implementation resulted in labor savings \$1,870,000, material cost savings \$323,000, maintenance cost avoidance \$106,000 and waste management cost avoidance \$3,600; total annual operating cost savings \$2,300,000.

This TRL 8/9 COTS modern solution transitions to other DoD assets.

PROBLEM STATEMENT	BENEFITS
<p>The US DoD maintenance facilities have been neglected due to budget constraints & demands to repair aging fleets.</p> <ul style="list-style-type: none"> National Security is at risk <ul style="list-style-type: none"> Other countries are expanding capabilities implementing new technologies Aging Fleet increases Demand on available facilities New assets also require maintenance of the facilities Infrastructure needs updating – Utilizing outdated, time consuming methods Implementation of Lean Manufacturing Principles needed to reduce manhours and increase throughput No commonality between repairs Manual paperwork impedes data management 	<ul style="list-style-type: none"> Increased Efficiency <ul style="list-style-type: none"> Optimize Current Capital, Turn Times & Labor Resources Cost <ul style="list-style-type: none"> Time, Materials, Consumables, All Processing, Material Movement considered not just cost of the equipment. <ul style="list-style-type: none"> Air Force RLCRS Savings \$7M -75% savings; Flow days were cut by over 50% Hazardous waste has been nearly eliminated Control <ul style="list-style-type: none"> Not dependent on coordinating multiple crews schedules Quality <ul style="list-style-type: none"> Repeatability, streamlined processing Viability <ul style="list-style-type: none"> Attracts the next generations workforce, retains control & improves quality of process, work life & asset
TECHNOLOGY SOLUTION	
<ul style="list-style-type: none"> Utilize lessons learned from the Automotive Industry Automate & combine like processes technology in cell Utilize Industry Experts who are experienced in: <ul style="list-style-type: none"> assessing current state conditions Recommend upgrades and Technologies Plan for future growth Capture maintenance data and implement predictive maintenance schedules Solution is adaptable across multiple assets <ul style="list-style-type: none"> Ships, Vessels, Submarines Airplanes, Jets, Helicopters Tanks, Trucks, Armored Vehicles Technology is proven, eliminates hazards & hazardous waste 	

ACCELERATE YOUR CBM+ PROGRAMS WITH THE IIOT AND AUGMENTED REALITY

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Pre-mission checks and inspections are a vital part in ensuring equipment is ready to perform. Mission Capable (MC) equipment can mean the difference between mission success or failure on the front line. With some machinery and systems running for up to 21 hours a day, it is crucial that the everything is running at optimal performance. This means there is less than 3 hours a day to not only identify potential problems, but to fix them. But in order to fix these problems, we need the right people in the right place with the right part, using accurate up to date, intuitive service instructions. How can we 'change the game' to make the products and the data we collect from these products work for us?

PTC's solution for condition based maintenance (CBM+), leverages its world beating Augmented Reality platform, Vuforia and Industrial Internet of Things (IIoT) platform ThingWorx to provide an interactive digital overlay to the real world, showing digital information in real time and in context on the physical asset. This is done using digital twins and 3D/Textual overlays. This visual aid allows technicians to run through a system check quicker, with both hands free,

using smart tools, and with more accuracy/confidence thanks to the improved cognitive retention afforded by visual augmentation.

PTC's ThingWorx Industrial Internet of Things (IIoT) Platform, allows technicians to view real-time and historical data from individual assets and systems. The ThingWorx platform is able to provide product insights by correlating data from an assets health monitoring system and linking that to the correct service/repair procedure. This data will also help them show which areas need to be addressed immediately. Combining both Augmented Reality and IIoT alongside traditional MRO and Service Parts Management Solutions creates a powerful tool suite which acts as a force multiplier for technicians and repair centers.

In addition to work instructions, Vuforia also can create a collaborative work environment with remote assistance via Chalk. This allows the technician to share their views with the support crew in the engineering operations center. This collaborative work environment allows both sides to draw on the screen, leave notes, pause the feed and even record the session.

PTC's Augmented Reality platform, Vuforia, has been a top performer and a leader in the industry for the past decade. With over 55,000 AR apps created across thousands of customers, PTC holds over 65% of the AR market share. PTC has assembled several Vuforia packages to create the perfect solution for any problem that maintainers may face.

ThingWorx Industrial Internet of Things (IIoT) Platform, has created new and unique opportunities across top MRO accounts, helping them take their business to the next level. The ThingWorx platform contains a broad set of features, including multiple connectivity options, application development tools, analytics, and AR – all built around the ThingWorx platform.

PROBLEM STATEMENT

Maintenance activities do not possess the capabilities to remotely access data from industrial machines, test equipment or storage locations. Lack of visibility results in machines operating in insulated environments without remotely monitored alerts, performance data or quality indicators. Additionally, workforce doesn't always have the skills to complete tasks safely, quickly and with quality. Lengthy training pipelines and increasingly complex machines, coupled with dwindling skilled workforce requires a new approach to learning, maintenance and operations.

BENEFITS

- § Reduce manual data entry and human decisions
- § Optimize machine performance
- § Access and analyses to stranded test stand data
- § Improve test scheduling and throughput
- § Increase response time and issue resolution
- § Improve access to data for engineering analysis
- § Reduce job completion time and error rates

TECHNOLOGY SOLUTION

ThingWorx: #1 Industrial Internet of Things (IIoT) software platform allowing users to source, contextualize, synthesize, orchestrate, and engage with data from their connected products, operations, and software.

Vuforia: Augmented Reality platform with more than 62% market share that provides the ability for users to experience digital information in the context of a physical product: in the field, on the shop floor, on the showroom floor, or on the cab of a machine. It can also bring the machine or the shop floor to the user wherever they might be.



A PREDICTIVE ANALYTICS FRAMEWORK TO IMPROVE READINESS AND CBM PRACTICE IN FLEET OPERATIONS

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Rapid deployment of predictive analytics applications plays a critical role in improving fleet readiness and condition-based maintenance (CBM) practices. In today's highly digital weapon systems, where increasingly large amounts of data are generated and collected by onboard and off-board systems, predictive analytics is essential. In DoD, predictive analytics can be used to enhance sustainment operations serving our military forces. For example, the Hornet Health and Readiness Tool (HhART) enhances aircraft maintenance and fleet operations by deploying predictive analytics to improve outcomes of CBM activities.

HhART is a framework that provides near real-time performance and health assessment of Navy F/A-18 aircraft to assist engineers and maintainers in identifying degraded components before failures occur. HhART implements data-driven maintenance tasks using big data from the fleet such as aircraft memory unit (MU) data, maintenance logs, and flight records to identify trends in system health (known as "features") that are indicative of occurring or impending failures which can degrade mission or pilot performance. The HhART

proactive advisories include a weekly report with details and performance trends, and automated Overwatch email alerts that go straight to engineering representatives for action. The HhART framework also includes weekly review sessions with engineers, maintainers, and data scientist to discuss degraded aircraft for actions. During this review sessions the team also identifies new system health indicator features to be vetted, iteratively improved, and ultimately recommend for the Feature Review Board (FRB) process. In the FRB, these features are thoroughly reviewed and documented so that maintenance recommendation can be automatically generated. This allows true agility in defining and evaluating system health degraders, while maintaining control and oversight over recommendations made to the fleet regarding maintenance and component replacements.

HhART grew out of the F/A-18 Physiological Episodes investigation and comprises contributions from the program office, data scientists and engineers from NAWCTSD, NSWCCD, Boeing, FST and NATEC. This multi-organization approach allows experts from both government and industry

to collaborate within a common F/A-18 condition-based maintenance operational framework that leverages both engineering and maintainer expertise using a structured process and a Government-developed AI/machine learning capability. Since its inception in late 2018, HhART has recommended dozens of replacements of critical components verified by engineering analyses. It has provided a testing ground and path to early deployment for future Maintenance Status Panel (MSP) codes. It has also helped engineers develop a fleet-level perspective of aircraft health parameters, allowing them to more readily identify potential anomalous flight conditions and improve overall readiness.

PROBLEM STATEMENT

Rapid deployment of Predictive Analytics applications is essential in order to sustain today's highly digital weapon systems, where increasingly large amounts of data are generated and collected by onboard and off-board systems.

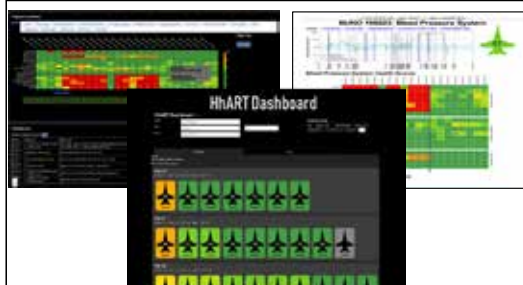
- Commercial, off-the-shelf solutions lack the agility to address the unique sustainment business processes and operational environment of the military.
- Using Predictive Analytics to optimize logistics processes, and drive weapon system readiness and outcomes of CBM activities requires close Government-industry collaboration, a structured CBM operational framework, and a certain level of Government-developed AI/machine learning capabilities.

BENEFITS

- Monitoring of system parameters enables health assessment and predictive maintenance of the F/A-18 platform.
- Near real-time assistance to engineers and maintainers aids in identifying degraded components before failures occur.
- Proactive issue identification and remediation reduces unscheduled maintenance and aircraft downtime.
- Agile and targeted intervention on degraded BUNOs allows maintainers insight prior to any apparent system advisory including Maintenance Status Panel (MSP) codes.
- A structured CBM operational framework with AI/ML capability leverages engineer, maintainer (NATEC) and data scientist expertise from both Industry and Government

TECHNOLOGY SOLUTION

- The Hornet Health and Readiness Tool (HhART) provides near real-time performance and health assessment of Navy F/A-18 aircraft.
- HhART provides data-driven maintenance recommendations using big data from the fleet such as aircraft memory unit (MU) data, maintenance logs, and flight records to identify trends in system health (known as "features") that are indicative of occurring or impending failures which can degrade mission or pilot performance.
- HhART proactive advisories include a weekly report with details and performance trends of the lowest-performing aircraft, and automated Overwatch email alerts that go straight to engineering representatives for action.



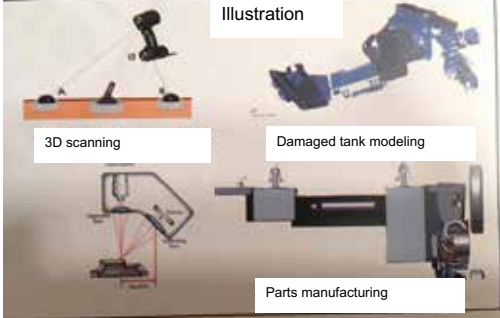
3D SCANNER APPLICATION FOR TANK REPAIR

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Portable 3D scanners and handheld 3D scanners, are able to capture thousands of points within seconds, thus creating surface data that are useful in inspection works. Wherever man can conduct inspection, these handheld devices are a valuable tool. In addition, 3D scanning technique can be used in areas that aren't easily accessible for human beings.

By using 3D scanning, measurements can be completed both faster and more accurately, which decreases the amount of time that that is required for maintenance.

<p>PROBLEM STATEMENT</p> <ul style="list-style-type: none"> • Battle damage to a tank caused severe deformation of right stretching mechanism. • The tank could not move. • The damage could not be repaired in field. • Technical examination advised that the module should be dismounted, delivered to assembly line and eventually fully assembled from scratch. 	<p>BENEFITS</p> <ul style="list-style-type: none"> • 3D scanning technology may be used in wide range of maintenance applications. • 3D scanning allows making only local minimal repairs instead of full disassembly and overall heavy repair. • The method reduces the need for physical work. • The tank was returned to service in only two weeks.
<p>TECHNOLOGY SOLUTION</p> <ul style="list-style-type: none"> • The module was scanned with a 3D scanner, operating in triangulation mode. • The scanner detected the location of the hit. • Scanned data was modeled in CAD software. • Damaged tank scanned model was compared to nominal model of the module. • Damaged parts were detected, manufactured and installed in tank. 	

MIXED REALITY INTEGRATION INTO ROBOTIC SYSTEMS FOR THROUGHPUT

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When properly integrated, a Mixed Reality environment using a HoloLens allows for increased versatility within robotic and automated systems. The HoloLens provides many benefits to include cost savings across depot operations and maintenance:

- Potential annual savings of \$141,000 per system, derived from part set-up time savings.
- Potential savings upwards of \$32,000 per custom part fixture plus NRE. HoloLens cost \$3000 each and can be interchanged with any system. CMXG processes 1000s of different parts.
- As systems are not co-located, multiple fixtures must be bought and stored. The potential savings for CMXG are \$10M+.
- Reduces footprint by creating location-agnostic part placement for the operators.
- Increases production output by decreasing the program creation time for new parts and eliminating the need for exact placement of parts that have been previously run.
- Increases flexibility by eliminating exact, custom fixtures per part and system,

allowing the operators to place parts in the work envelope as necessary.

Robins CMXG has tested alternative methods of part localization with processes such as LIDAR scanning of work cells. These other methods require dedicated systems on a larger scale and cost upwards of \$100,000.

Systems that can benefit from HoloLens Integration on Robins AFB

Current

Painting

Microwave Mapping

Borescope

FPI Blade Processing

Walnut Media Blasting

Glass Media Blasting

Aluminum Oxide Media Blasting

Plastic Media Blasting

Flash Jet

Low Plasticity Burnishing

HVOF Thermal Spray

Cold Spray

Belt Grinding

High Pressure Water Blasting

Shot Peen

Wing Defastening

Core Milling

Sanding

Grit Blasting for Bonding Prep

Laser Depaint

Mobile Wing Defastening

Mobile Core Milling

Future - Awarded

Mobile Structured Light Scanning

Composite (Radome) Repair

Collaborative Microwave Mapping

Future - Proposed

Welding

Chromic Acid Anodize / Acid Pickling

Stenciling

Ultrasonic Inspection

PROBLEM STATEMENT

Robotic tasks require operators to communicate the placement of parts within a work cell to the robot before processing. This task takes time away from processing due to 1) often-intricate fixturing for exact placement of a part or 2) programmatic changes were made requiring the robot to know the new location. This can be time consuming depending on the skill level of the operator and the process required to get the part placement correct. As robotic systems can not make real time changes during processing, this costs additional time for the operator since most robotic systems can not make real time changes during processing and decreases the throughput for the system.

BENEFITS

- Reduces time to set-up robotic processes
 - More time spent processing parts
 - Less touch time by operators
- Accurate Part Processing
 - Robot always knows the location of part
- Increased throughput
 - More parts processed due to less start up time
 - Saves \$141K/yr on C-130 prop blasting time
- Less Fixturing = Costs Savings
 - Saves money and floor space with generic fixtures
 - Each custom fixture costs \$30K+
- **Total Potential Savings: \$10M+**

TECHNOLOGY SOLUTION

- Using a Mixed Reality to identify the location of the part saves money on fixturing by eliminating the need for exact, single use fixtures each part. Generic fixtures can be utilized on a variety of part geometries
- HoloLens integration allows for more freedom when placing parts within a work cell
- The increased freedom and ease of use allows operators to spend more time processing parts and less time on set-up
- The HoloLens application connects directly to FANUC robots, which are standardized at 402d CMXG, thereby its use on any robotic system



SPARSELY DISTRIBUTED PHASED ARRAY-MODAL ACOUSTIC EMISSION

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Problem Statement:

With pressures on DOD to maintain our military advantage amid fierce global competition, the ability to monitor the structural integrity of weapon systems during extreme operational conditions is critical. A small footprint, low cost monitoring system for critical structures maintenance is needed to identify onset fracture development and flaw growth while delivering reliable real-time information.

Technology Description:

The sparsely distributed phased array-modal acoustic emission (SDPA-MAE) technology provides the above requirements for monitoring structures. By coupling the SDPA-MAE piezoelectric transducers to the structure and using the propagating wave energy released by flaw initiation and growth to detect and identify structural defects, SDPA-MAE is an ideal monitoring system – large area coverage with minimal access, high sensitivity, and accurate source location.

Current Development Status:

SDPA-MAE is used commercially for the requalification of 40' long, 42" diameter

high pressure composite tubes. The arrays are used to locate fiber tow fractures as the vessel is pressurized. The use of SDPA-MAE was vetted and approved by the DOT Pipeline and Hazardous Materials Safety Administration via DOT special permit 20396. To move the technology to even larger metallic structures used in the military, the number of array elements will need to be increased to increase the sensitivity and monitoring area. Hardening of the systems for military use will be required.

Test And Simulation Data Supporting Performance\ Claims:

As stated, composite pressure vessel monitoring is currently being performed with SDPA-MAE technology. Metallic fatigue crack growth monitoring using non-array MAE data was performed in the 1990's in aircraft structures, and in the 2000's in metallic pressure vessels. Phased array sensors will further increase the sensitivity, ensuring detectability. The following references provide data evidence. 1) DOT Special Permit 20396, 2) Article - Damage Detection Experiments and Analysis for the F-16 and 3) Cyclic Crack Growth Testing of an A.O. Smith Multilayer Pressure Vessel

with Modal Acoustic Emission Monitoring and Data Assessment

Next Steps – Potential Benefits:

SDPA-MAE monitoring is a technology that can be mobilized or built into large and difficult to inspect weapon system structures to provide actionable information about fault location and severity. It would be useful during shock testing to verify structural integrity and help limit the amount of insulation removal for follow-up inspections.

PROBLEM STATEMENT

Provide an inspection technique that addresses:

- The requirements of large structure inspections and difficult to inspect areas
- Remote structural integrity monitoring of unmanned systems, i.e., large drones
- Life cycle structural application for:
 - ✓ Prototype design monitoring
 - ✓ Acceptance testing
 - ✓ In-service real-time fault detection

BENEFITS

- Works with composite and metallic structures
- Increases readiness and availability
 - ✓ Early fault detection with continuous monitoring of flaw growth
 - ✓ Identifies fault locations and size for precise and efficient corrective action
 - ✓ Reduces risk of catastrophic failure
- Speeds inspections at lower cost with more thorough and accurate findings

TECHNOLOGY SOLUTION

Sparsely Distributed Phased Array (SDPA-MAE) Monitoring System

- Flaw growth energy release is used for detection, identification, severity, and location
- No energy input or signal radiation
- Real-time, low power, small footprint, distributed, non-invasive, remote capable
- DOT/NASA verified, validated and approved
- Commercially accepted with widespread use

USES



ADVANCED CORROSION PREVENTIVE COMPOUNDS FOR AEROSPACE APPLICATIONS

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It is well known that corrosion of metallic surfaces has a significant impact on the DoD assets. As aircraft age, corrosion often occurs in internal structures which are not easily inspected or treated. Corrosion is difficult to detect and correct; therefore, corrosion prevention is usually the most cost-effective treatment. However, due to limited performance, traditional CPCs require repeated applications during regular maintenance intervals. To address this problem, NAVAIR has developed an advanced corrosion preventive compound to reduce the cost of maintenance of aircraft systems, and extend the life of aircraft platforms. The new invention (Navguard IV) has exhibited superior corrosion resistance in laboratory testing and in the field test application on F-18 aircraft. Navguard IV has met the qualification requirements of MIL-PRF-81309H Type IV specification. NAVAIR is in the process of updating NAVAIR 01-1A-509 manual to incorporate Type IV product to make it available to DoD services.

Navguard products (I, II, III, and IV) have been authorized for use on DoD weapon systems and listed in NAVAIR 01-1A-509 manual. To protect the intellectual properties, two

patents have been awarded for Navguard (U. S. Patent Numbers: 7,776,233 B2 and 7,820,076 B2). For the past few years, Navguard CPC products have been used on several DoD platforms such as the Navy's F/A-18, the Army's Apache Attack Helicopter (APACE) Aircraft, and the U.S. Marine Corps' Expeditionary Fighting Vehicle (EFV) units.

Navguard I: Mildew growth on interior surfaces of rotary aircraft has been a chronic problem, especially when these aircraft are operated in humid climates. Mildew can cause corrosion, component damage, and accelerate the degradation of paint and decals. Navguard I (mildew-inhibiting CPC) product has enabled the capabilities to prevent corrosion and inhibit mildew growth on interior aircraft surfaces simultaneously. For the past six years, Navguard I has been used on H-57 Aircraft to prevent corrosion and inhibit mildew growth.

Navguard II and III are the first generation of developing Navguard series to improve the performance of corrosion preventive compounds (CPCs) for internal airframe application and to minimize the costs attributed to the aging aircraft. Navguard II is intended for

use on moving parts where some lubrication is required, such as hinges, bomb racks, and sliding parts. Navguard III is intended for use on avionics equipment, electrical connector plugs, and contact points.

Navguard IV: Navguard IV is a superior corrosion preventive compound for long-term protection on aging aircraft and any other weapon systems. Navguard IV can be reapplied once every one or two years instead of once every three to six months for the current products, depending on the application. The expected DoD benefits from the new technology include the following:

- Extend maintenance inspection intervals and reduce applications of CPCs (less material used and less VOC emissions).
- Decrease aircraft and other weapon systems down time due to fewer scheduled maintenance and inspection intervals.
- Achieve significant cost savings from the reduced work load
- Reduce the environmental pollution caused by VOCs
- Improve worker safety

PROBLEM STATEMENT

It is well known that corrosion of metallic surfaces has a significant impact on the DoD assets. Corrosion and corrosion prevention is extremely costly; military aircraft and support equipment are aging and corrosion, on both recent and older assets, is becoming a life-limiting factor. As aircraft age, corrosion often occurs in internal structures which are not easily inspected or treated. Corrosion is difficult to detect and correct; therefore, corrosion prevention is usually the most cost-effective treatment. However, due to limited performance, traditional CPCs require repeated applications during regular maintenance intervals. To address this problem, NAVAIR has developed an advanced corrosion preventive compound (Navguard IV) to reduce the cost of maintenance of aircraft systems, and extend the life of aircraft platforms.

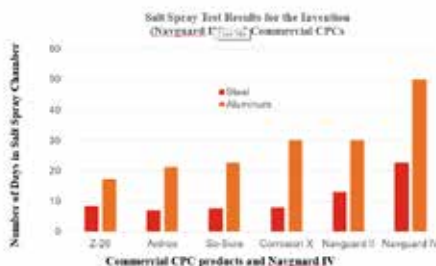
TECHNOLOGY SOLUTION

- Navguard IV has met the qualification requirements of MIL-PRF-81309H Type IV specification
- Navguard IV Laboratory testing has shown superior corrosion protection for aluminum and steel panels compared to commercial CPC products.
- MIL-PRF-81309H Specification has been updated to incorporate a new type IV for advanced CPCs; Navguard IV has been listed in the QPL for MIL-PRF-81309H specification
- DLA has issued National Stock Numbers (NSNs) for Navguard IV to make it available to DOD services
- Conducted one-year field test for Navguard IV on F-18 Aircraft at NAS Oceana, VA and NAS Whidbey Island, WA. In addition, a field test for Navguard IV on P-8A aircraft at FRC E, JAX, FL is in progress
- NAVAIR is in the process of updating NAV 01-1A-509 manual to incorporate Navguard IV

Navguard IV Benefits

It is anticipated that Navguard IV will be a significant contribution in the fight against corrosion and its application is expected to impact DOD in the following ways:

- Reduced work load resulting from frequent maintenance
- Improve the fleet readiness
- Cost savings from the reduced work load
- Reduced hazardous materials use
- Improved worker safety
- Reduced solvent emissions
- Elimination of a heavy metal in the use of CPC's
- **Patents:** Two US patents were issued on Navguard formulations for Types I and II (US 7,776,233 B2 and US 7,820,076 B2)
- Navguard IV patent application is pending



ENVIRONMENTALLY FRIENDLY CLEANERS FOR AEROSPACE APPLICATIONS

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Problem:

The current cleaner products for DoD services contain hazardous air pollutants (HAPs) and volatile organic compounds (VOCs), which cause health and environmental problems. Volatile Organic Compounds (VOCs) are released during cleaning operations, contributing to the formation of ground-level ozone (photochemical smog), which can damage lung tissue, cause respiratory illness, and damage vegetation. The South Coast Air Quality Management District (SCAQMD), CA, has imposed restrictions limiting the VOC content in solvents to no greater than 25 grams per liter for immersion cleaning processes, unless the solvent is used in an airtight cleaning system. The VOC content of the current solvent cleaners is 700-800 grams per liter. In addition, under Title III of the 1990 Clean Air Act (CAA) amendments, the U.S. Environmental Protection Agency (EPA) established emissions standards for categories and sub-categories of sources that emit or have the potential to emit listed HAPs. To address this issue, NAVAIR has developed low-VOC and hazardous air pollutant - free (HAP-free) solvent cleaners

known as Navsolve, Navwipe and NAVHFC to meet the current environmental regulations.

Navsolve: To meet the new environmental regulations, NAVAIR at Patuxent River has developed a new specification MIL-PRF-32295 entitled "Cleaner, Non-Aqueous, Low-VOC, HAP-Free" for cleaning aircraft components and ground support equipment. Navsolve has met the qualification requirements of MIL-PRF-32295B Type II specification. To protect the intellectual properties, two patents have been awarded for Navsolve (Patent Numbers: 7,897,558 B1, 8,273,698 B2). Navsolve has been used by DoD maintenance facilities for the past few years and listed in the NAVAIR 01-1A-509 manual. This product allows the DoD activities to continue their cleaning operations with environmentally compliant and superior performing materials.

Navwipe: Wipe solvents are essential for removing contaminants from parts and surfaces before it undergoes manufacturing operations that require clean surfaces, such as painting, sealing, bonding, welding, plating, and other applications. High VOC and hazardous solvents are currently utilized

for cleaning aircraft exteriors and parts applications. NAVAIR has developed an exempt and hazardous air pollutant - free (HAP-free) solvent known as Navwipe to meet the current environmental regulations (Patent # 9,920,280 B2). Navwipe has met the qualification testing requirements of the MIL-PRF-32295B Type III specification. The field test of Navwipe has shown successful results on wipe cleaning applications such as composite materials, and pre-paint metal surfaces. Currently, NAVAIR is in the process of updating NAVAIR 01-1A-509 maintenance manual to incorporate the new product.

NAVHFC: The current composite cleaners consist of hazardous chemicals with low flash points and must be used in a controlled environment in order to prevent worker exposure. NAVAIR has developed an environmentally friendly hydraulic fluid cleaner known as NAVHFC to remove hydraulic fluid from aircraft composite parts safely and effectively (Patent # 8,801,866 B1). The NAVHFC product has met the testing requirements of MIL-PRF-32597 Type II specification. Currently, NAVAIR is in the process of updating the technical manual to incorporate the new product.

PROBLEM STATEMENT

NAVAIR has developed environmentally friendly cleaners (Navsolve, Navwipe, and NAVHFC) to meet the current environmental regulations as shown below:

- Clean Air Act (CAA) Title III, NESHAP National Emission Standards for Hazardous Air Pollutants, described in 40CFR63 Subpart GG.
 - Vapor pressure restriction of less than 7 mm Hg for VOC containing solvents/cleaners
 - Must be Hazardous Air Pollutants (HAPs) free
- The South Coast Air Quality Management District Rule 1171: Limits VOC content of immersion cleaning solvents to 25 gm/L
 - Or requires air-tight cleaning systems.
- Similar regulations could propagate across the entire US

BENEFITS

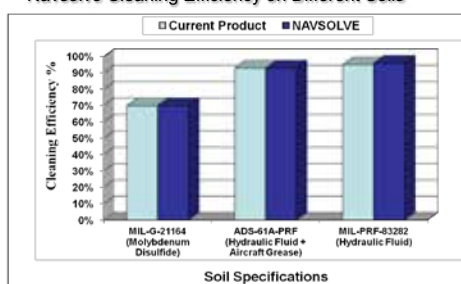
- Comply with EPA and the new environmental regulations
- Provide the fleet with a safer and environmentally friendly cleaner
- A new alternative to replace high VOC solvent (MIL-PRF-680) has been identified and validated
- Reduce VOC and HAPs emissions
- Provide a more efficient, cost effective, and environmentally acceptable means to clean critical composite weapons system components

Benefits: The main benefits of these inventions are the reduction in the use of volatile organic solvents for routine cleaning of aerospace equipment, improvements in worker safety, health, pollution prevention and compliance with the new environmental regulations.

Technology Solution

- Navsolve** (low-VOC/HAP-free cleaner) meets the environmental regulations of EPA and The South Coast Air Quality Management District. Navsolve meets the qualification requirements of MIL-PRF-32295B Type II and MIL-PRF-32597 Type I specifications.
- Navwipe** (low VOC and HAP-free wipe solvent cleaner) meets the environmental regulations in California and EPA. Navwipe meets the qualification requirements of MIL-PRF-32295B Type III specification.
- NAVHFC** (hydraulic fluid cleaner for composite materials) meets the fleet needs for non-hazardous, safe, more efficient, cost effective and environmentally friendly cleaner. NAVHFC replaces hazardous chemicals used for removing hydraulic fluid from composite structures. NAVHFC has met the qualification requirements of MIL-PRF-32597 Type II specification.

Navsolve Cleaning Efficiency on Different Soils



ATMOSPHERIC PLASMA COATING REMOVAL

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As stated in the National Defense Strategy, “we cannot expect success fighting tomorrow’s conflicts with yesterday’s weapons or equipment.” For maintenance activities, the DOD has have been using antiquated technologies such as grit blasting and needle guns for over 50 years. Current coating removal techniques have serious shortcomings.

Atmospheric Plasma Coating Removal (APCR) is a media and chemical free process that can improve cycle time, lower cost, reduce injuries and increase environmental safety. Applicable to all service branches, APCR has demonstrated effectiveness while significantly reducing costs in labor, waste disposal, and personnel safety.

This advantageous approach to coating removal uses the fourth and most abundant state of matter PLASMA. Using only the inputs of compressed air and electricity the system produces a special form of non-thermal atmospheric pressure plasma. This species of plasma is fundamentally different than a plasma cutter or a laser.

The APCR process converts a significant portion of the removed organic coating into water vapor and carbon dioxide, leaving a small volume of solids to be safely collected with a HEPA vacuum. There is no requirement for containment or clean up. The existing profile of the substrate is revealed, not changed. Independent laboratory testing coordinated by NAVSEA 05 documented APCR doesn’t cause changes to the substrate metallurgy.

A 2018 National Ship Building Research project successfully demonstrated coating removal for ship-board applications including but not limited to MIL-PRF 24635, haze-grey silicone alkyd coatings, MIL-PRF-24647 anti-fouling, MIL-DTL-24441 epoxy primer on DH36 and HY steel. APCR process produced a surface with “near white metal blast cleanliness” (SP-10) at removal rates faster than a needle gun.

The TRL-8, field-deployable APCR PlasmaBlast® system weighs 34 pounds, uses only compressed air flowing at 90PSI at 3.0 CFM.

The next step for implementation is as a precision coating removal tool. Examples include, but are not limited to, non-destructive testing as coating is removed, but the substrate is unchanged. As plasma acts as a fluid, tight areas are quickly de-painted and revealed for inspection. Other applications include strip back around an area for welding. This work can be quickly completed with no need for containment. Rework areas can be easily addressed. This technology will support the objectives to address the backlog of deferred readiness and accelerate modernization programs while providing a new practices for greater performance and affordability.

PROBLEM STATEMENT

There is a need for lower cost, cleaner, environmentally safer coating removal solutions. Today removing coatings is a costly, multi-step, time and labor consuming process. Many coating removal methods can cause damage to the substrate and injury to the worker. Where grit and water blasting can’t be used, manual labor is often the only solution.

BENEFITS

- Significantly reduces job costs
- Reveals substrate without change to profile
- Safer for the operator and environmentally friendly
- Rugged, lightweight and portable for use in yards and depots
- Media and chemical free, minimal clean up
- Fast training, simple to operate and quick to mobilize

TECHNOLOGY SOLUTION

Atmospheric Plasma Coating Removal is a breakthrough de-painting technology that uses no media, requires no containment and does no damage to the substrate. Using only air and electricity the system converts organic components of most paints, sealants and protective coatings into carbon dioxide and water vapor. Inorganic constituents of the coatings, such as pigments are recovered as a fine dust.



ARTIFICIAL INTELLIGENCE BASED SCHEDULING ENGINE FOR METALIZING PROCESSES

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This project is implementing a scheduling engine for metalizing aircraft parts for the U.S. military using artificial intelligence (AI). The shop in this effort requires hundreds of unique workflows to support over 8,000 unique parts, working approximately 2,500 total parts at a time, utilizing six ovens, 150 tanks with limited chemistry and amperage, 70 technicians, four lab personnel, twelve engineers, and ten maintenance support technicians. All personnel, ovens, tanks, chemistry, and amperage must be re-scheduled every day for all 2,500 parts, while ensuring each part's defined metalizing process is followed to precision. The shop currently employs a supervisor who manually schedules each activity performed by available personnel utilizing available resources. Case studies suggest that productivity, quality, and safety in the metalizing process can be greatly improved utilizing modern AI algorithms.


Mkinsey projects AI to be the heart of global economic value creation for the next 20 years with operations being the largest market, ahead of marketing and management. The construction industry, for example, limited by shortages in

skilled laborers, has employed drones for conducting site inspections, increasing productivity, efficiency, and safety according to Novotny. Additionally, modern drones utilizing AI programs preform inventory management with significant savings in time and costs. The power of AI in operations can be used to predict equipment failures before they occur, improve operational efficiency, identify and remove bottlenecks, improve quality of deliverables, improve safety, better predict supply chain completion dates, reduce negative impacts to the environment, reduce waste of natural resources including water and energy, and so forth.

This effort is being undertaken in three phases: 1) planning and design (current state); 2) installation of a real-time information system; and 3) AI engines for operational optimization. Planning and designing of the information system and the AI engines is being conducted in concert with the planning and designing of an overhaul of the entire metalizing shop. New computer systems, controls, sensors, and data storage systems along with new

metalizing tanks will provide the backbone for both subsequent phases.

The current system utilizes manual data collection, manual production mixing, antiquated reporting tools, lagging indicators, and manual prioritization of resource utilization resulting in current utilization rates hovering at or below 20%. The information system planned for phase 2 will provide real-time status, digital data collection and utilization, with on-demand reports that are estimated to raise utilization rates from 20% to above 90% based on a similar metalizing shop servicing commercial airplane parts in the U.S. Productivity is conservatively estimated to improve by 20% based on a similar metalizing shop servicing U.S. military parts. AI will then be used to predict equipment failures before they occur, improve operational efficiency, identify and remove bottlenecks, and improve the quality of deliverables.

<p>PROBLEM STATEMENT</p> <p>Manually scheduling complicated metalizing processes yield low utilization, productivity, and efficiency.</p>	<p>BENEFITS</p> <ul style="list-style-type: none"> • Optimizes process utilization, • Increases productivity • Improves efficiency • Safer • Maximizing warfighter readiness.
<p>TECHNOLOGY SOLUTION</p> <p>Artificial intelligence based scheduling for metalizing processes.</p> <ul style="list-style-type: none"> • Predict equipment failures • Improve operational efficiency • Identify and remove bottlenecks • Improve quality of deliverables 	

TEMPLE ALLEN'S PAINT STRIPPING TECHNOLOGY

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Problem Statement: Maintainers struggle to remove paint on decks, wings, and other horizontal surfaces using a hand-held tool requiring them to recline, kneel, or sit on the surfaces. To meet production times, aggressive removal of paint leads maintainers to tip the tool and risk damaging the surface. Due to the varying level of paint on surfaces, multiple sanding tools are used to feather as well as remove paint. This requires maintainers to utilize more than one tool and process to prepare the surface. Removing paint takes so long that maintainers incur injuries to muscles and soft-tissue as well as respiratory ailments due to paint-dust inhalation. Staffing issues impact asset availability schedules as injuries require downtime for surgery and rehabilitation.

Description of the Technology: The Temple Allen SAM (Standup Abrading Machine), outfitted with our Paint Stripping Technology, incorporates two random orbital sanders mounted on an ergonomic and vibration-dampening assembly, adding an integrated dust collection system and carry handle. The patent-pending technology includes a dual-mode circuitry that enables

the SAM's "two-in-one" capabilities. Maintainers quickly learn to take advantage of both the more aggressive enhanced sanding mode and the lighter feathering mode to generate the desired surface finish.

Current Development Status of the Technology: Multiple configurations of the SAM technology wielding various rotary and dual-action sanders, buffers, and grinders are available for sale as commercial products to government and private sector clients. The Paint Stripping configuration has been available for commercial sale since mid-2018.

Test Data Supporting Performance Claims: SAM technology has been in use at commercial and military locations since 2014. Feedback from our customers indicates that the equipment meets or exceeds internal targets for productivity, surface finish consistency and vibration exposure reduction.

Next Steps: While the technology is available for immediate purchase, trials at various locations are welcomed. Temple Allen will work with your team to configure the technology to address your needs.

Potential Benefits: Use of the SAM technology enables improved surface consistency and quality, eliminates injuries associated with manual operations, reduces exposure to toxic dust, and improves productivity.

Big Picture: Many critical-path maintenance processes still suffer from challenging environments, difficult ergonomics, and expensive asset downtime. This "Smart Augmentation" choice makes the current process better, safer, and faster without entailing dramatic infrastructure changes or requiring a massive training effort. User acceptance across multiple industries continues to grow.

PROBLEM STATEMENT

Aircraft paint is made to withstand dramatic temperature changes, unrelenting UV exposure, and Mach+ airflow. Such durable paint is difficult to remove during repaint operations.

Pneumatic random orbital sanders are moderately effective on aircraft paint, but all such tools are hard to use in ergonomically challenging environments, such as on hands and knees.

An effective tool is needed that allows for more productivity and addresses the ergonomic challenges that make tool use on many surfaces so difficult.

BENEFITS

In addition to eliminating injuries associated with manual use of sanding tools, Temple Allen's EMMA and SAM PS systems:

- Offer standard and enhanced sanding modes in one tool
- Generate more consistent results from each artisan
- Improve productivity by reducing micro-breaks
- Reduce fatigue levels, reduce errors, and improve morale

TECHNOLOGY SOLUTION

- Temple Allen's patent pending Paint Stripping End Effector can be deployed on both EMMA™ and SAM™ systems
- Systems feature dual mode sanding for aggressive paint removal and proper feathering into adjoining surfaces
- Removal rate improved via concentrated sanding pressure
- Systems are 100% pneumatic and require only 95 psi clean, dry air – no electricity, no complex infrastructure modification
- Artisans protected from vibration exposure and injuries
- Artisans operate from comfortable position, allowing for safer and more productive work

EMMA & SAM Paint Stripping Systems



SAM DECK SCALER

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Problem Statement: The popular Aurand MP6 surface scaler removes failing non-skid surface on carrier decks prior to reapplication. Injury rates among maintainers wielding the tool are high, and few other tools have been found that can successfully address the removal of the durable high-friction coating. Currently maintainers recline, kneel, or sit on the abrasive surface to use the scaler in an effort to complete their tasks and fight fatigue.

Based to the length of time required to remove the non-skid, maintainers incur injuries to muscles and soft-tissue as well as respiratory ailments due to dust inhalation. Staffing issues impact production schedules as injuries require downtime for surgery and rehabilitation.

Description of the Technology: The Temple Allen SAM (Standup Abrading Machine) Deck Scaling Tool takes the already-proven Aurand MP6, mounts it on an ergonomic and vibration-dampening control handle and adds an integrated dust collection system and carry handle. This configuration enables maintainers to confidently wield the MP6 while standing comfortably. In addition to

solving the immediate problem, the SAM Deck Scaling Tool also brings with it the benefit of not requiring any infrastructure changes or significant installation costs.

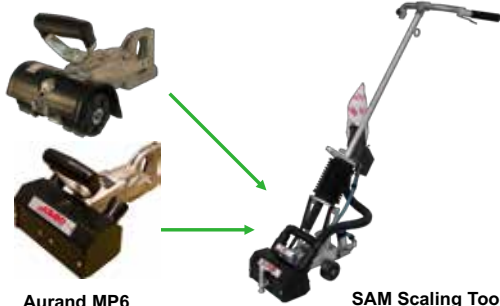
Current Development Status of the Technology: Multiple configurations of the SAM technology wielding various rotary and dual-action sanders, buffers, and grinders are available for sale as commercial products to government and private sector clients. The Deck Scaling configuration featuring the Aurand MP6 is available for commercial sale.

Test Data Supporting Performance Claims: The Aurand Tool has been in use since 1937 and the SAM technology has been in regular use at commercial and military locations since 2014. Customers report that this equipment is a “game changer” meeting or exceeding internal targets for productivity, consistency and vibration exposure reduction.

Next Steps: While the technology is available for immediate purchase, trials at various locations are welcome. Temple Allen will work with your team to configure the technology to address your needs.

Potential Benefits: Use of the SAM technology enables improved surface consistency and quality, eliminates injuries associated with manual operations, reduces exposure to toxic dust, and improves schedule reliability by maximizing “on surface” operations.

Big Picture: Many critical-path maintenance processes still suffer from challenging environments, difficult ergonomics, and expensive asset downtime. This “Smart Automation” choice makes the current process better, safer, and faster without entailing dramatic infrastructure changes or requiring a massive training effort. User acceptance across multiple industries continues to grow.

PROBLEM STATEMENT	BENEFITS
<p>Removing failing non-skid deck surfaces prior to resurfacing exposes artisans using the Aurand MP6 or other scaling tools to injury risks associated with vibration, poor postures, high grip forces, and repetitive stress.</p> <p>Injured artisans often require surgery, therapy, and retraining. Injured artisans lower net productivity, require training of replacements, and lower morale.</p> <p>The difficulty of recruiting new artisans for difficult and dirty jobs makes keeping existing artisans healthy especially important.</p>	<p>In addition to eliminating injuries associated with manual use of scaling tools, Temple Allen's SAM systems:</p> <ul style="list-style-type: none"> • Reduce fatigue levels, reduce errors, and improve morale • Generate more consistent results from each artisan • Improve productivity by decreasing micro-breaks • Make recruiting and retaining artisans easier • Improve dust and debris collection
TECHNOLOGY SOLUTION	
<ul style="list-style-type: none"> • Temple Allen's SAM (“Standup Abrading Machine”) Scaling System mounts the same approved Aurand MP6 tool now in common use on an ergonomic and vibration-reducing handle • Systems are 100% pneumatic and require only 95 psi clean, dry air – no electricity, no complicated infrastructure modifications • Artisans can carry systems up stairs and to work area • Pivoting handle accommodates height differences • Artisans operate from full standing position • Integrated vacuum and debris shroud 	 <p>Aurand MP6</p> <p>SAM Scaling Tool</p>

HARD ULTRA-LOW FRICTION SURFACE TREATMENT FOR GAS TURBINE AIRFOILS

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Thin film coatings are well known for wear-resistance and tribological properties. In addition to the physical properties some of these coatings can be optically matched to infrared glass to eliminate front surface reflections, which makes the coating ideally suited as a protective outer surface for lenses used in thermal sighting imaging systems deployed on military aircraft, land vehicles and weapons. Such lenses are mounted on the exterior of aircraft and can sustain adverse conditions without damage at supersonic speeds due to the physical properties of the coating specifically the hardness and very low coefficient of friction.

Our team has developed a system including a hydrogenated amorphous carbon coating called Diamond-Like Carbon (DLC), which has a very low coefficient of friction (more than 10X lower than Teflon), is very hard and exhibits a hydrophobic behavior. These physical properties enable it to act as an effective coating for gas turbine fan and compressor airfoils, which are susceptible to accumulation of fouling debris during flight/operation. In parallel we have developed a surface pre-treatment applied prior to coating to reduce surface roughness. The

combination of surface pre-treatment and coating results in a surface roughness of less than 5 nm.

Plasma Enhanced Chemical Vapor Deposition (PECVD) is an efficient process for depositing this optical grade DLC coating with the properties described above. It is also well suited for coating three dimensional shapes like that of jet engine airfoils because the process is conformal. When properly fixtured, the PECVD process will deposit the coating with high uniformity on intricately shaped three-dimensional parts without any compromise to aerodynamic geometry. The unique tribological properties will also result in improved performance because skin friction is directly proportional to aerodynamic losses.

During turbine engine operation, moisture particles and fouling debris migrate through the core of the engine and affect both the static and rotating surfaces. Adherence of moisture and debris to the flowpath surfaces, combined with repeated impingement will eventually form a surface buildup, which causes inefficiency in engine operation. This surface accumulation can also spall off

creating an opportunity for foreign object damage (FOD) to downstream components and the potential blowout of the combustor.

The surface roughness reduction enabled through the combination of our DLC coating and surface pre-treatment brings together pre-existing elements into a unique system to address both flowpath surface finish and skin friction as a tribological solution to minimize/eliminate the buildup of debris and the subsequent reduction in performance or loss of operation.

PROBLEM STATEMENT

During turbine engine operation, moisture particles and debris affect both the static and rotating component flowpath surfaces. Adherence of these contaminants to the surfaces, will buildup, causing aerodynamic inefficiencies in engine operation. This surface buildup can also manifest itself as ice. Ice accretion on aircraft turbomachinery flow surfaces and the resulting detrimental effects on engine performance, operability, and aeromechanics are well recognized as challenges for both legacy and advanced air breathing propulsion systems. This ice accumulation can also create an opportunity for foreign object damage (FOD) to downstream components and the potential blowout of the combustor.

BENEFITS

- Surface treatment and coating do not impact geometry as the resultant change in contour is only 1-2 microns.
- No impact to part weight.
- Tribological surface reduces skin friction.
- Aerodynamic performance deterioration minimized.
 - Reduces fuel burn.
 - Engine runs cooler over useful life
- Reduces cleaning maintenance (engine water wash)
- Eliminates ice build up.
 - FOD due to ice spallation eliminated.
 - Combustor blowout opportunity eliminated.
- Flight safety operation increased over current.
- Cost of ownership reduced.

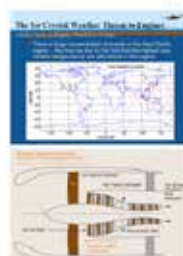
TECHNOLOGY SOLUTION

This inefficient and high risk surface condition can be eliminated through the combination of a unique hydrogenated amorphous carbon coating (diamond like carbon – DLC) and a surface pre-treatment that brings together pre-existing technology elements into a unique system to address both flowpath surface finish and skin friction as a tribological solution to minimize/eliminate the buildup of debris and the subsequent reduction in performance.

Each of these technologies are proven individually and have been in production on both aero and space flight systems.

Risk Prevention Through Hydrophobic Surface Treatments

Airfoil cleanliness applicable to both Aero and Industrial Gas Turbine Engines



In Production today in an optical application for the Infrared Night Vision Goggles for the F35

FULLY ORGANIC REPAIR OF AIR FORCE ASSETS VIA COLD SPRAY

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As the Air Force extends the service life of legacy weapons systems beyond the original planned lifetime, certain components become scarce and irreplaceable. Air Force Materiel Command has struggled to be able to adequately sustain these weapons systems due to the combination of: (1) a lack of available new parts (due to retired manufacturing sources), (2) components being repaired more times than originally anticipated, and (3) technical data that uses only repair technologies that were available at the time of manufacture. This has led to constraints for certain parts, particularly cast magnesium housings.

The Air Force Sustainment Center, Air Force Lifecycle Management, and the Air Force Research Laboratory have worked together to test, develop, and publish technical data for cold spray repair of these housings, and to replace the outdated weld repairs that existed in the depot level technical orders.

The Oklahoma City Air Logistics Complex (OC-ALC) has retrofitted an existing thermal spray booth to have dual capability to include cold spray and has become a qualified source for cold spray repair of

these housings using entirely organic Air Force personnel. Cold spray can be used to add near net shape material, reducing the amount of post-machining required. In addition, cold spray reduces recycles and condemnation rates because it does not cause deformation and warping of the part as with welding.

Finally, the cold spray being conducted at the OC-ALC is entirely robotic controlled, reducing process variance compared to artisan welding processes. Technical data for the TF33-P100 engine (E-3 AWACS) has been published and the 76th Propulsion Maintenance Group (76 PMXG) has entered full scale production repair of the housings. Applications for the TF33-P103 engine (B-52), F-16, and B-1B have been approved through the combined change evaluation team and are in the process of being integrated into technical orders. In parallel, cold spray processes for these parts are being developed by 76 PMXG engineering.

Through the lessons learned at the OC-ALC, the Air Force Advanced Technology and Training Center has developed a high pressure cold spray course that will be used

to train and transition the technology to the other Air Force depots as equipment and applications become available. The OC-ALC is the first Air Force depot with organic cold spray capabilities and the cold spray repair on the TF33-P100 gearbox is the first to receive airworthiness for the Air Force.

PROBLEM STATEMENT

- Difficulty in procuring new magnesium casted parts for legacy weapon systems due to discontinued original manufacturing sources
- Current welding repair processes warp the parts and cause eventual condemnation due to process induced distortion

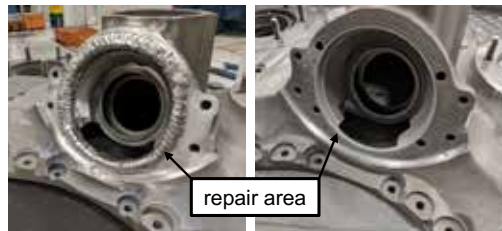
BENEFITS

- Cold spray does not induce distortion as compared to welding and does not require a post heat treatment for stress relief
- The cold spray process is more consistent and less likely to cause recycles or condemnations compared to weld repairs
- Sealing surfaces that were previously unable to be repaired can now be restored with cold spray due to its high accuracy

TECHNOLOGY SOLUTION

- Cold spray is a type of thermal spray technology with extremely low porosity and oxide content
- Aluminum 6061 was chosen as the material used to restore the castings due to its corrosion characteristics, wear properties, and ease of application
- Air Force Sustainment Center, Life Cycle Management, and Research Laboratory came together to develop and publish technical data and receive airworthiness certification for the first Air Force organic cold spray repair.

GRAPHIC OR IMAGE



Weld repair before
post-machining

Cold spray repair
before post-machining

INJECTION PROCEDURE FOR APPLYING RADAR ABSORBENT MATERIAL

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Application of Radar Absorbent Material (RAM) is a cumbersome process performed on several top readiness degraders at Fleet Readiness Center Southwest (FRCSW). The application method on a specific component utilizes a hybrid technique where an artisan first trowels on and then sprays RAM. This lengthy five-day process induces significant rework, and has a high rate of quality verification failures that result in delays averaging ten days in length.

To alleviate these issues, FRCSW Materials Engineering investigated an injection mold procedure, which is a more consistent method of applying RAM. To instill confidence in the injected coatings, Materials Engineering developed a quality verification technique using injectable witness panels. Immediately before applying RAM to the component, artisans inject RAM coating into the witness panel. Materials Engineering analyzes the injected coating's properties to confirm it meets the same quality metrics as sprayed coatings. The resultant injected coatings have lower porosity than sprayed coatings, thus achieving a much lower reject rate and eliminating rework delays.

Implementation of radical change to low observable coating processes typically necessitates near field range testing costing approximately \$250,000. By developing the injectable witness panels, Materials Engineering was able to eliminate this requirement and prove that the injected coatings had the critical characteristics necessary to meet the performance requirements. Materials engineering has completed investigation of the RAM injection process and FRCSW has already used it to apply RAM to aircraft components.

The injection molds used in this process cost approximately \$225,000 when purchased from the prime contractor. FRCSW owned two injection molds, but the original mold design had a history of poor reliability. FRCSW plans to 3D print these molds in-house to address the previous design flaw and prepare for future mold replacements. FRCSW created a 3D model of the existing mold and is now awaiting delivery of 3D printing equipment.

This RAM injection procedure decreased component turn-around time (TAT) by 2-3 days, and eliminated the ten-day delay

due to coatings failing quality verification. Development of the injection witness panel allowed for process implementation without the \$250,000 cost of near-field range testing, while still maintaining a high standard of quality. The 3D printing effort complements this by eliminating a recurring \$225,000 injection mold replacement cost, and increases the facility's agility by allowing quick replacement and development of injection equipment. Altogether, this effort will avoid costs exceeding \$850,000 in the first year and provide a faster more reliable process for returning a critical readiness degrader to grounded aircraft. Materials Engineering is looking to transition this capability to other components to improve coating application, decrease TAT, and reduce cost.

PROBLEM STATEMENT

- The RAM application method on a top readiness degrader utilizes a lengthy five-day hybrid technique where an artisan first trowels and then sprays RAM.
- This method has a high rate of coatings failing quality verification. When a coating fails quality verification, artisans must remove and reapply all RAM, resulting in delays averaging ten days in length.
- Implementation of change to low observable coating processes typically necessitates near field range testing costing approximately \$250,000.

BENEFITS

- The RAM injection procedure decreased TAT time on this top readiness degrader by 2-3 days, and eliminated ten-day delays due to coating failures.
- The injection witness panel allowed process implementation without the \$250,000 cost of near-field range testing.
- The 3D printing effort will eliminate a recurring \$225,000 injection mold replacement cost, and provide quick replacement, and development of injection equipment.
- Altogether, this effort will avoid costs exceeding \$850,000 in the first year and provide a faster, more reliable process for returning a critical readiness degrader to grounded aircraft.

TECHNOLOGY SOLUTION

- FRCSW Materials Engineering adopted an efficient and repeatable injection procedure for applying RAM to the component.
- To instill confidence in the injected coatings, Materials Engineering developed a quality verification technique using injectable witness panels.
- FRCSW plans to 3D print injection molds in-house to address a previous design flaw and prepare for future mold replacements.



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ENHANCED AIRCRAFT ENGINE WASH TECHNOLOGY

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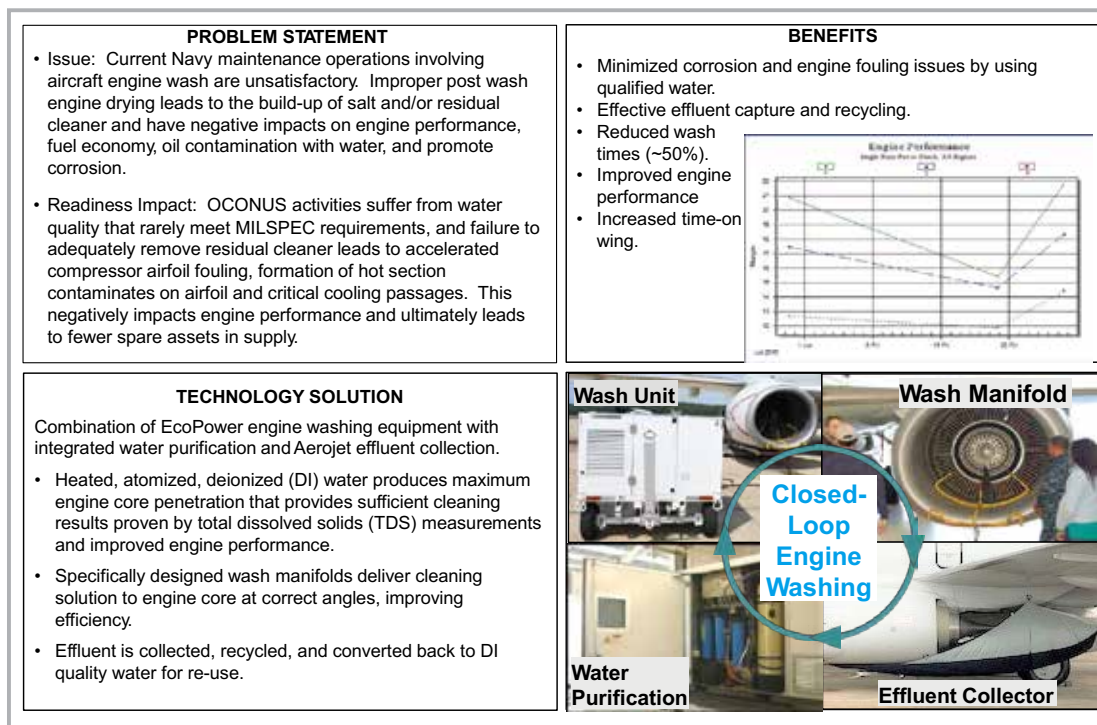
Current Navy maintenance operations involving aircraft engine washing are unsatisfactory for meeting performance objectives. Field-level activities suffer from corrosion issues from ionized salts introduced into an engine due to poor quality water followed by inadequate rinsing. Improper post-wash engine drying leads to the build-up salts and residual contaminants, having negative impacts on engine performance and fuel economy. Additionally, current wash systems do not address the containment of effluent and deionized water generating system which has negative environmental impacts.

An evaluation of a new engine wash technology with potential to improve cleaning efficiency while reducing environmental impacts was sponsored by the Naval Environmental Sustainability Development to Integration (NESDI) program and Non-Program Related Engineering (NPRE) in a collaborative effort between Fleet Readiness Center East (FRC-E) and Fleet Readiness Center Southeast (FRC-SE). The performance criteria evaluated for this new technology include: 1.) qualified initial water, 2.) sufficient wash performance, 3.)

decrease in corrosion risk, 4.) water conservation, 5.) enhanced readiness, 6.) improved engine performance, 7.) recycle effluent, and 8.) man-hour savings. EcoPower wash systems were chosen for evaluation and demonstration washes of AV8, C-130, H-53, P-8A, T-34, and V-22 were conducted. Performance improvements over the current process were further realized with an additional 90-day trial with the P-8A aircraft, which have reported corrosion issues with a commercially produced engine executing the mission of a naval aircraft. Additional commercial engine cleaning systems and effluent containment systems were evaluated by the P-8A platform to determine the best fit for their operations. Not only did the existing wash procedure fall short of efficiency, the current containment mat failed during service due to durability issues. Performance data was consolidated into a scoring matrix and identified the EcoPower wash system and the AeroJet effluent containment system as the best collective solution.

The evaluations showed improvement in all performance categories over the current engine wash process/equipment. Total dissolved solid (TDS) measurements found

that the initial water quality met ASTM D1193 Deionized (DI) water requirements. Washing with DI water proved to minimize corrosion. Improved water delivery effectively cleaned hard-to-reach compressors. The demonstration wash successfully dropped TDS up to 435 ppm after wash. Approximately 70% water conservation was measured. Processing time was reduced to 50-75% of the current processes for all tested aircraft. Engine Diagnostics System showed that the motor strength was the strongest and 1% increase from the strongest during the wash cycle after the wash. Improved engine performance directly correlates to longer time-on-wing, which improves readiness by keeping spare engines in supply.



LASER ABLATION – THROUGHPUT, QUALITY, ERGONOMICS & SAFETY

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Laser ablation is proven technology impacting lifecycle costs in two distinct areas—Asset Manufacturing and Maintenance. Pre-weld cleaning improves weld bonding. Laser de-paint improves coating adhesion while reducing corrosion development.

Time is key to achieve a high ROI. Laser technology challenges the norms. Culture change takes time and education. Laser ablation testing results prove the differences between handheld systems. The combination of optics and laser output power determine the quality and rate of removal. The Air Force and NAVSEA continue making significant strides validating the technology. VDOT is ready to implement. DoD desires to purchase COTS items. Industry improves laser source technology rapidly, while optical design is slower. Most laser ablation companies focus on the laser source. The optical system is an afterthought, hindering a COTS one-machine-fits-all validation.

The optical system is SurClean focus and tests are performed on COTS laser sources. There are four types of beam delivery optics—Galvo, Polygon, Risley and SurClean's patent pending Disc (TRL 6-7).

The optic integrates with the patented LPC Sensor technology application programing which regulates the COTS laser source output power. These components form the laser machine tool. Applications determine the source—Fiber delivered, CW or Pulsed at a specified kW output power.

Power equates to removal rate and throughput. The optic will not use all the output power. It is “dumped” during the optic reset. Power determines the laser source price. Automation improves quality and repeatability. Automation requires culture change, validation and time.

SurClean utilizes a COTS laser source, COTS LPC sensor, TRL 6-7 Disc optic and COTS flex track modified with an X-Y-Z slide with COTS magnets to the steel surface. The flex track system operator controls indexing and the asset position. They move the Disc optic slide mount. The LPC controls the output power preventing surface damage. The optic connects to the laser source via an umbilical housing. The fiber, exhaust, air and other control devices run through this umbilical. The source and other equipment mount to a frame. The frame allows for multiple means

to transport. The unit is optioned with a generator for total mobility. This is the Laser Ablation Semi Automated Machine Tool.

The flex track hand-held system has many military and commercial applications. It is easily maintained and available for source upgrades when available. The system addresses many concerns – Repeatability, Safety, Ergonomics, Throughput, COTS support, spare parts.

PROBLEM STATEMENT

DoD unplanned maintenance costs and the onboarding of new assets impact:

- Asset availability reduced – National Security
- Cost – unplanned negatively impacts strained budgets
- Scheduling – over-crowded MRO processes and equipment
- Safety concerns – planned maintenance is put on hold and outdoor use of laser requires light tight conditions
- Environmental impact – Hazardous waste, airborne particulates, water contamination, eco system is dwindling
- Ergonomics – wear n tear on worker's joints, requires more breaks; lifting and constantly moving light tight barrier
- Existing capabilities unable to meet Navy demands
- Need cost effective solution to implement and expand upon

BENEFITS

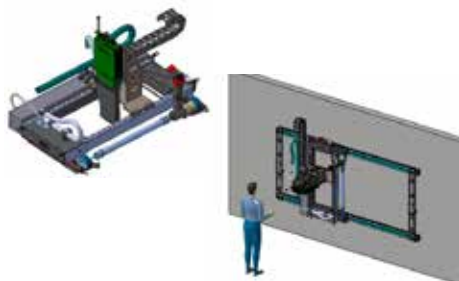
Laser Ablation is safe, precise, cost-effective, energy efficient and environmentally friendly. The technology is in use at the US Air Force with documented savings.

- Semi Automation will provide repeatable results over a straight handheld utilizing a larger, more robust optic.
- Reduces repetitive tasks that are injurious to the work force
- Reduces the need for large enclosures
- Simplifies the installation
- Eliminates Hazardous Waste – Environmentally Compliant
- Reduced Air Particulate – No PFE required for worker and eliminates surrounding area exposure

TECHNOLOGY SOLUTION

Handheld Laser Ablation Machine Tool with Magnetic Flexible Rail X,Y, Z Motion System

- Provides benefits of using a robot
 - Consistent stand-off
 - Consistent movement range
 - Repeatability from location to location
 - More use of laser output power increased removal rate
- Eliminates
 - Work force fatigue
 - Injurious wear to work force
 - Hazardous Waste & Airborne Particulates
 - Need for light tight enclosures



ROBOTS AS A SERVICE FOR AIRCRAFT WASHING

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The Air Force spends \$12 billion annually on organic and commercial depot-level maintenance, a significant portion of which is spent washing aircraft by hand. The current process is extremely labor-intensive and ergonomically challenging. Manual washing is frequently conducted by skilled mechanics which prevents them from performing other critical tasks to get aircraft back into service. Skilled aerospace labor is increasingly constrained in key aerospace manufacturing and maintenance markets like the Mid Continent states of Kansas, Oklahoma and Texas. In these regions, robotic systems have been adopted in the private sector to perform similar repetitive manual tasks, reducing costs and cycle times. Wilder Systems, a robotics company focused on automated aircraft manufacturing and maintenance, has developed a conceptual robotic aircraft washing cell. This in turn will increase sortie generation without adding planes to the flight-line for every class of operator in the United States.

The major components of the proposed washing system are standard for all industrial robot systems which generally comprise a robotic arm, end effector, fixed or mobile

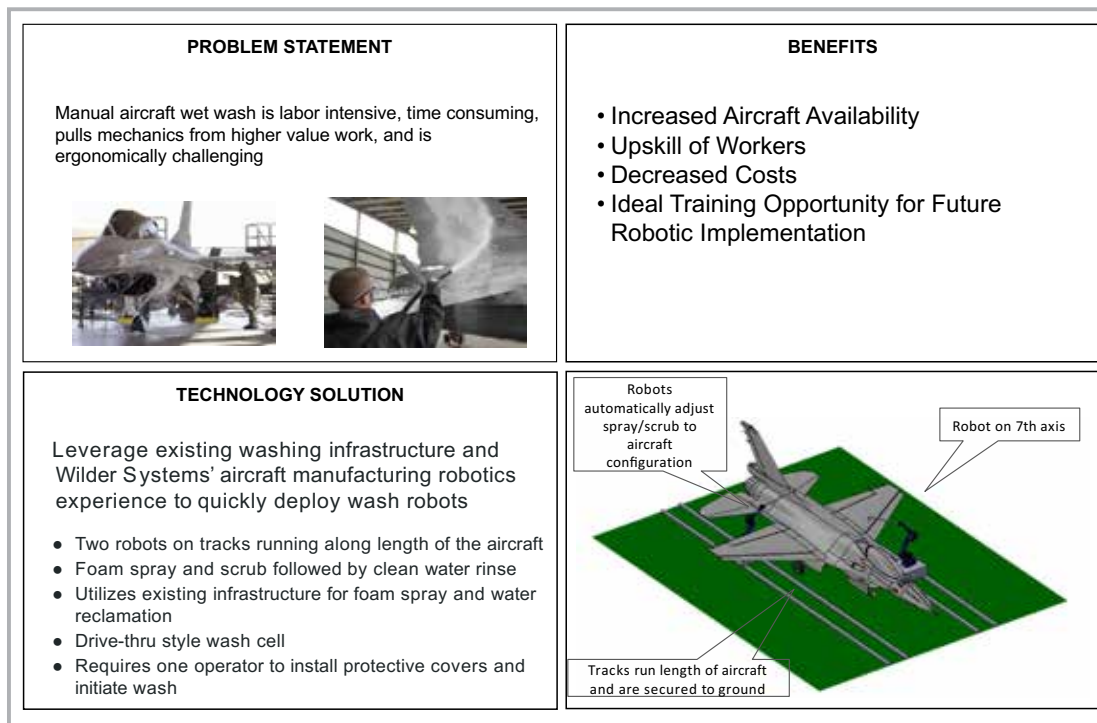
platform, power systems, and guidance software. The aircraft washing cell is "of a type" which will allow efficient deployment across the Air Force enterprise to process aircraft including the F-16, F-35, T-6, T-38, CH-47, etc. Adaptations for commercial and defense automated aircraft washing applications will be identical and will include:

- Cell reconfiguration to integrate with designated wash rack, such as at Lackland AFB
- Invert the robot configuration so the workpiece (F-16 jet) sits between the robots
- Application engineering to integrate:
 - Foam soap spraying robot tools
 - Water preparation equipment including filters, pumps, valves, and water heaters
 - Off the shelf Robot Armor® to make the robots waterproof

While this proposal is to build a fixed system into an existing wash rack, a modular system capable of washing several different airframes and equipped with water recirculation that folds out of a 40' conex can easily be envisaged. WS sees a technical

path to modularizing our system to enable deployment to austere environments such as forward operating bases, to serve temporary wash needs for large-scale exercises, and to supplement wash capabilities during times of limited labor or contractor supply. This will be the topic of further R&D enhancement in the future.

Through automation of maintenance tasks, we seek to enable the Air Force to fly more sorties with their existing fleet of aircraft in support of US foreign policy directives. The proposed robotic aircraft washing cell will provide an opportunity to reduce operating costs and improve operator ergonomics. One of the principal challenges facing robotics implementation in the Air Force may be limited knowledge of how to operate and maintain robotic systems. This skills gap parallels the private sector adoption of robotics.



SUBMERSIBLE REMOTE OPERATED VEHICLE FOR TANK INSPECTIONS

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Periodic maintenance requirements for tanks on Aircraft Carriers require manned entry for inspection to evaluate the condition of each tank and if repairs are needed. Criteria are based on inspections performed during manned tank entries. Conditions in these tanks require extensive mitigations for safe personnel entry. Water removal and ventilation systems are required and detailed training and practice are accomplished prior to execution of work. The cost of preparing for and executing this work is significant. Due to complexity of this work, the sequence of tasks for cleaning/inspecting a group of tanks is often the critical path for a maintenance availability, representing the longest string of work to be completed prior to returning the Ship to the fleet.

To address tank maintenance safety, cost, and schedule, the Nuclear Engineering team at Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) developed a strategy for use of a remote operate vehicle (ROV) to accomplish tank inspections. This approach uses the Pro 4 Plus BASE ROV system developed by a company named VideoRay. The ROV will perform video inspections that will be

transmitted to a viewing station for real time evaluation. In addition to visual inspection, the ROV can be equipped with several different tools developed at PSNS&IMF to evaluate tank conditions and has the capability to retrieve items from tanks for evaluation.

Use of the ROV will allow inspecting the tanks without manned entry. If no significant deficiencies are identified manned entries will not be required. If significant deficiencies are identified, only the tanks affected will require manned entry. Remote inspection will remove the need to put workers in spaces that expose them to unnecessary safety risks. Significant cost reductions will be met using this process. Additionally, the schedule for tank inspections will be significantly reduced, thereby removing a significant risk to completing the availability on time.

The ROV inspection process has been developed and is currently being tested using an in-shop scale model of the shipboard tanks. ROV inspection is scheduled on the next Aircraft Carrier maintenance availability requiring tank inspections. The anticipated savings is

approx. \$1.2 million (2,000 Man-Days) in labor and \$400,000 in material costs.

In addition to the safety, cost, and schedule benefits of this project a significant benefit is the engagement with the technical experts in the naval maintenance community. Beginning with a requirement that is based on a decades-old approach to tank inspection a new inspection criteria has been developed, based on techniques made possible through the use of new technologies that is safer, faster, and less expensive, without sacrificing quality. Finding better ways to meet maintenance requirements using new technologies and adjusting the requirements to parallel technology is a continued goal in the naval maintenance community.

PROBLEM STATEMENT

- Periodic maintenance for Aircraft Carrier tanks require manned entry for inspection to evaluate condition of each tank and make repairs.
- Conditions in tanks require extensive mitigations for safe personnel entry. Cost is significant and includes complex ventilation and dewatering systems as well as training and practice prior to shipboard execution.
- Due to complexity of tank maintenance the sequence of tasks for cleaning/inspecting a group of tanks is often the critical path for a maintenance availability, representing the longest string of work to be completed prior to returning the Ship to the fleet.
- Even with mitigations, workers are still exposed to safety hazards

BENEFITS

- Safety: Eliminates manned entry into confined spaces with multiple industrial hygiene risks for tank inspections. If entry for repairs is required it will be limited to areas with deficiencies.
- Cost: Reduction in cost by eliminating manned tank entries and all of the associated mitigations and efforts.
- Schedule: Significant time reduction to accomplish tank inspections.
- Quality: Inspection criteria engineered to ensure inspection will accurately assess condition of tank using new strategy
- Engagement with technical community in development of inspection criteria

TECHNOLOGY SOLUTION

Development of tank inspection process that does not rely on manned entry into tanks.

- Use of submersible remote operated vehicle (ROV) for inspections.
- Utilize commercial off-the-shelf technology solutions that are readily available at low cost and have a proven track record of reliability.
- Engagement with technical stakeholders to define maintenance requirement criteria to align with using the ROV to accomplish inspections.
- Evaluation and proving of plan for use of ROV in shop environment prior to shipboard execution.



PSNS&IMF testing ROV at NASA Neutral Buoyancy Lab, Houston Texas

CLEANMASTER: CLEANING AND SURFACE PREPARATION

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Millions of man-hours are spent every year on MRO tasks related to surface finishing of fabricated metals operations. The majority of these operations are still done manually. Tools used include rotary sanders, grinders, orbital and rotary tools and blast systems. These power tools are designed to help the worker be more productive, but in-fact due to their size, weight and vibration may actually increase worker dissatisfaction and risk of injury. Jobs of this sort are messy, noisy, dangerous yet completely necessary. In many cases, gearing up a worker with protective clothing, goggles, respirators, weld aprons, smocks, vests and coveralls can cause other issues such as overheating.

In recent years, labor and hiring , workman's comp claims from repetitive motion injuries combined with rising wages are all having an impact on our productivity.

- Manual, abrasive based
- Rotary, Orbital grinders and sanders
- Abrasive blasting (sand, grit, media)
- Abrasive brush, wire brush or wheel
- Scotchbright pad
- Wheel

Surface preparation: (includes material removal, de-burring, weld prep, weld dressing, de-painting, grinding, abrasive sanding and application of an adhesive promoter, bond agent or adhesives.

Surface cleaning. Even after following proper surface prep a surface may have to be cleaned of remaining, dust, grinding or sanding particles. Cleaning guidelines ensures quality.

PROBLEM STATEMENT

Millions of man hours are spent every year on MRO tasks related to labor intensive surface finishing of fabricated metals operations and clean up. The majority are still done manually. Tools used include sanders, grinders, orbital and rotary tools, and blast systems. Jobs of this sort are messy, noisy, dangerous, yet completely necessary and will never go away. In many cases, gearing up a worker with protective clothing, goggles, respirators, weld aprons, smocks, vests and coveralls can cause health issues from fatigue and overheating in addition to their joint muscle strain.

BENEFITS

- Collaborative robots Increase job satisfaction
- Labor reduction replace low demand jobs with high demand jobs
- Minimize risk from labor and hiring shortages
- Reduce or eliminate workman's comp claims from repetitive motion injuries
- Automation counters rising wages while having positive impact on productivity

TECHNOLOGY SOLUTION

Collaborative robot technologies allow industrial robots to work side by side with humans. Programmers have been replaced by game style joysticks and hand teaching. New compliance and sensitive rotary abrasive tools allow robots to accomplish these tasks by mimicking the human ability to sense and respond. New sensor packages can make a work area safe by sensing humans and adapting robot motion paths to eliminate human contact and/or harm to the workers CO2 based cleaning heads fight friction and heat while eliminating traditional cleaning with water wash and dry or dangerous solvents



Robot finishing of truck bodies and tool detail

NOVEL ENABLING TECHNOLOGIES TO INSERT LASER ABLATION INTO REPAIR AND PRODUCTION FACILITIES

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In the last 5-10 years, advancements in the laser industry have made laser ablation a viable method for depainting of large aerospace components & full aircraft. Key progress includes the introduction of higher efficiency, higher power (kW) lasers that are user-friendly, robust, & available at a cost that continues to come down over time. However, there are still significant challenges in using these high power lasers in aerospace production & maintenance facilities on substrates that are very sensitive to surface condition, creating a need for targeted innovations that enable the use of lasers in these environments.

Laser ablation as an advanced repair technology can replace current methods used for removal of paints, sealants, & corrosion products which are labor intensive processes that promote poor ergonomic conditions, utilize hazardous chemicals, & have long flow times. Laser ablation occurs when a material absorbs laser light & molecules are excited into the plasma state, vaporizing the material in a clean & efficient manner. Laser depainting has several advantages over traditional paint removal methods, including more than a 90%

reduction in hazardous waste, significant reduction in touch time, & improvements in ergonomics and quality. As far back as the early 1990s(1) the Air Force has significantly investigated laser depainting, pioneering the way for others in aerospace to follow & add to the advancements that have taken place in this arena.

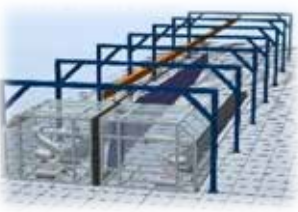
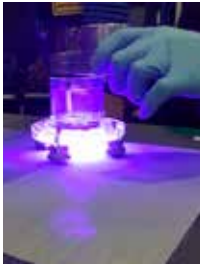
Navy, for example is investigating laser ablation for a variety of applications such as aircraft carriers(2) where confined spaces can be especially challenging. The traditionally used sand blasting method & a common occurrence of only one point of entry, which produces a lack of ventilation, can quickly cloud the vision of operators performing the work. In contrast, laser ablation's minimal waste production and co-located waste removal keep the areas free from debris & parallels the waste removal process.

One of the biggest challenges with implementing laser ablation is that often where it is needed most is in crowded facilities already operating at full capacity. Two strategic innovations that Boeing has added to laser ablation systems planned for implementation

starting in 4Q2019 are localized containment of the laser light & closed loop feedback for quality control. These two developments are key to reducing the footprint & impact to current operations while protecting underlying substrates with precise control by adapting & combining these technologies with commercial off-the-shelf-products, laser depainting can be readily inserted either as a fully automated or a handheld system that is compatible with both metallic and polymer composite substrates in current manufacturing facilities with minimal impact.

References:

1. Report No. 93-086; "Air Force Study on Paint Stripping Technology"
2. competition.ncms.org/submission/052-laser-ablation-and-naval-maintenance-applications

<p>PROBLEM STATEMENT</p> <ul style="list-style-type: none"> Removal processes for paints, sealants, and corrosion products are labor intensive, have poor ergonomic conditions, utilize hazardous chemicals and have long flow times. Inserting new technologies into fully operational manufacturing facilities with little to no impact is challenging. High energy lasers pose some unique challenges to enable safe operation around humans and to prevent damage to aerospace substrate surfaces 	<p>BENEFITS</p> <ul style="list-style-type: none"> Laser technologies can be used to efficiently remove paint, sealant, and corrosion products. Precise control of laser energy reduces damage to surface by approximately 20% and improves quality by up to 50% over mechanical and chemical alternatives. Reduces potential worker exposure to hazardous chemicals and airborne particulates. Eliminates chemical paint strippers (1000s of gallons), reducing hazardous waste by more than 90%. Reduces or eliminates ergonomic injuries. Reduces flow time up to 65% (fully automated system).
<p>TECHNOLOGY SOLUTION</p> <ul style="list-style-type: none"> Combine innovations of localized containment and closed-loop feedback to insert laser ablation into facilities already crowded and operating at full capacity. Localized containment reduces implementation cost, improves hazardous waste collection, and minimizes impacts to current production facilities and the environment. Laser ablation implemented with closed-loop feedback offers improved precision and control of the laser to protect underlying substrates. 	<div data-bbox="662 1627 958 1837">  <p>Localized laser containment system</p> </div> <div data-bbox="971 1606 1169 1869">  <p>Closed loop feedback for QC</p> </div>

BR-1, A SAFER SOLVENT FOR THE FUTURE OF MAINTENANCE

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Problem:

The solvents that are commonly implemented in the maintenance and preparation of parts for aircraft and heavy equipment are highly dangerous causing serious health and safety issues. Some of these solvents require the use of specialized person protection equipment (PPE) including but not limited to gloves, goggles, face masks, and respirators. The use of PPE incurs additional cost and time when maintenance is conducted. In addition, flammable chemical cleaners have risks associated with them when being transported, stored, used, or disposed of. Even milder solvents that are used in maintenance settings are risky; irritating and drying out skin when exposed and causing headaches with their harsh scents.

Technology:

TriboTEX BR-1, a nanosized oil-like solvent that was modeled for its jet fuel performance, shows promise as a safe cleaning solvent. This solvent is made from sustainable materials that are approved for human consumption, making it extremely safe for defense maintenance shops. BR-1 has a chemical structure similar to kerosene with a boiling point over 200 °C

and an accelerated rancimat test over 90 hours, meaning the solvent will be safe to store for many years. The electrochemistry of the solvent has a light plasticizer effect that easily and quickly breaks up organic contaminants. Additionally, BR-1 is unfreezable, making the solvent a good choice for the harshest conditions. BR-1 has received an AFWERX STTR Phase I Award.

Solution:

Common, harsh cleaning solvents are utilized to clean and maintain parts that can be replaced with BR-1. BR-1 is a gentle but effective solvent that has a similar or better cleaning capacity than competitors while also improving shop safety, reducing costs and improving the overall work environment. Since BR-1 has a high flashpoint, it is extremely safe to store and transport. Similarly, BR-1 is a non-toxic solvent that requires minimal to no PPE and thus reduces the cost and time needed when using the solvent. Furthermore, BR-1 is a pleasant solvent to work with due to its nice aroma with no added scents which is unlike most other solvents. BR-1 is also agreeable because it doesn't irritate the user's skin and may actually soothe dry skin. Not only

is BR-1 an easy solvent to use, but it is also highly efficient. It is a strong organic cleaner that can easily be recoverable and reused many times without a loss in performance. The molecules are thermally stable and can survive heated oxygen-rich environments without polymerization. BR-1 is very efficient when burned in waste oil burners, with the added benefit of cleaning the injection nozzles and improving lubricity on the fuel pump system. There is also little to no soot production when BR-1 is burned as a lantern fuel, which shows potential for reduced maintenance on shop heaters that run on waste solvents. Overall, BR-1 is the solvent of choice for the future of maintenance for both its properties in safety and efficiency.

PROBLEM STATEMENT

Common solvents used to maintain or prepare parts present in aircrafts and heavy equipment cause **serious health and safety issues**.

Often these toxic chemical cleaners require special PPE and when used which incurs **additional cost and time**.

Flammable chemical cleaners are **hazardous** when transporting, storing, utilizing, and disposing.

Milder solvents can **dry skin** and harsh smells cause **irritation and headaches** when used without PPE.

BENEFITS

- **Safe**
 - Non-Toxic
 - Non-Flammable, Very High Flashpoint
 - Minimal to no PPE needed
- **Pleasant**
 - Nice Aroma, No Added Scents
 - Doesn't Irritate, Soothes Dry Skin
- **Effective**
 - Strong Organic Cleaner
 - Creeping Decarbonizer
 - Room Temperature Performance
 - Dries Clean without Excessive Wiping

TECHNOLOGY SOLUTION

Technology

Nanosized oil-like solvent developed for jet fuel performance shows promise as a safer cleaner in defense maintenance shops. BR-1 is made from sustainable materials. The kerosene-like molecules are safe for human consumption, making it extremely safe. With a boiling point above 200°C and accelerated rancimat test over 90 hours, this solvent will be safe to store for many years. Electrochemistry causes a light plasticizer effect that breaks up organic contaminants easily, and this unfreezable solvent can endure the harshest conditions. **AFWERX STTR Phase I** awarded technology.

Solution

Replace common solvents used to clean and maintain parts with BR-1; a gentle but effective cleaner that significantly improves shop safety, reduces costs, improves working environment, while cleaning significantly better than competitors. Potential Phase II **4:1 matched funding** from DOD branches (3600 research funds).



ELIMINATING EXPOSURE TO HEXAVALENT CHROMIUM IN ABRASIVE BLASTING

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Corrosion is a major degrader of Air Force weapon system availability. The DoD has relied on hexavalent chromium (Cr6+) paints to protect sensitive assets. During the overhaul process, abrasive blasting removes these paints. Studies show this Cr6+ primer residue is extremely hazardous.

Occupational exposure to Cr6+ is 8 times more carcinogenic than asbestos. Numerous DoD abrasive blasting facilities have received OSHA citations for this. Facilities struggle to find commercial dust control equipment capable of reducing exposure to operators and preventing migration of hazardous dusts into adjacent areas to expose unprotected workers.

Unplanned ventilation costs are a leading cause of funding issues in new facility construction. Simply increasing airflow to reduce exposure is an expensive proposition; energy costs increase exponentially, and poor design can even worsen dust migration. To address this, Figure Engineering partnered with Hill AFB to develop the following SBIR and Rapid Innovation Fund technologies:

ACTAV is a suite of sensors that continuously monitor system parameters and dynamically control ventilation to minimize operator exposure to airborne toxins. With ACTAV, the blast system monitors airborne dust concentration and composition to increase or decrease airflow in response to actual need to optimize energy use.

CHEM directly monitors chromium levels at the operator's location in real time. A remote attachment samples dust near the operator's helmet, analyzes dust composition, then feeds results to ACTAV to adjust ventilation to lower concentrations around the operator. This eliminates operators wearing heavy measuring equipment and delays in sending samples to outside labs. CHEM can be used independent of

ACTAV to support plant maintenance and process improvement.

Dust Migration Mapping (DMM) is a method that samples dust throughout a shop. It produces a map to locate sources, leaks, accumulation points, and migration pattern. DMM directs equipment repair, work

practices, housekeeping, and hygiene to where they are most impactful.

The blasting facility in Building 844, Hill AFB was chosen to demonstrate these technologies. The prototype systems target chromium and cadmium. A system targeting methylene chloride paint strippers will be installed in Building 507, Hill AFB. Operational testing showed ACTAV and CHEM reduced chromium exposure inside the booth by a factor of 6. DMM showed leaks and migration from the booth were effectively eliminated with a 90% reduction in Cr6+ outside the booth.

These technologies provide an OSHA-compliant solution to eliminate much of the Cr6+ hazard to personnel and the environment. Additionally, they reduce operating costs by intelligently increasing ventilation only when needed. Maintenance costs are reduced through continuous system monitoring to trend and forecast preventive maintenance. Equipment uptime will increase, and unscheduled shutdowns decrease, translating to fewer flow-days per asset.

PROBLEM STATEMENT

- Toxic dusts such as hexavalent chrome, cadmium, lead, beryllium, and methylene chloride are released as a product of many maintenance processes
- Poor equipment design results in leakage to surrounding areas contaminating unprotected workers
- Cost and readiness issues from personnel training, equipment downtime and OSHA citations
- Even if chromated coatings stopped being applied today, in service assets returning for scheduled depo cycle will continue to contribute to problem for next 20-30 years.

BENEFITS

- Worker exposures to airborne toxins are reduced
- Leakage into adjacent areas has been eliminated
- The responsiveness of the system enables energy efficiency
- Engineers and safety groups have been given a new tool for process optimization with rapid feedback of operator exposures.
- Data can be used for compliance monitoring
- Airborne toxin thresholds can be changed in the software, thus future-proofing the system's compliance capability in the event of OSHA regulation changes.

TECHNOLOGY SOLUTION

- Provide sensors that monitor and mitigate exposures to toxic dusts in industrial environments
- Measurements are taken directly from the operator with minimal burden
- Airborne dusts are rapidly characterized for levels of toxic components
- Ventilation is automatically adjusted to compensate
- Maps are created of workshops that reveal sources and migration pathways of hazardous dust
- Validated at NIOSH. Technology is inserted at Hill AFB.

GRAPHIC OR IMAGE



HARDLINE COMMUNICATION SYSTEM ENSURING SAFETY IN CONFINED SPACES

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SAVOX Communications Inc manufactures the SAVOX – Con-Space Hardline Communications System, an intrinsically safe, ruggedized, and proven audio communications system that significantly improves safety while minimizing fatal confined space incidents.


According to the Office of Occupational Health and Safety (OH&S), over 2.1 million workers enter a confined space environment each year. A confined space environment is defined as a space with restricted means of entry and exit large enough for an adult to enter that is not designed or configured as a continuous work environment. The most common hazards that confront operators in confined spaces are insufficient oxygen levels and the presence of toxic gases or flammable materials.

The office of OH&S has recorded an average of 92 fatalities per year in confined space incidents, regrettably investigations have also revealed that 60% of those casualties were first responders or co-workers attempting to rescue the initial entrant. The Dept of Labor in their 2015 report on Confined Spaces in the Construction industry estimated a

statistical monetary value for preventing a fatality at \$8.7M. With no known fatalities having occurred when entrants and rescuers use the Con-Space Hardline System, its implementation into Dept of Defense work place regulations would minimize incidents while also being cost effective.

SAVOX developed the Con-Space Hardline Communications System for the confined space operator. The Con-Space Hardline Communications System exceeds all current OH&S regulations by providing the operator with an intrinsically safe, ruggedized and reliable hardwired audio communications system scalable for all confined space operations. The Hardline Communications System is currently used by FEMA Task Forces and Urban Search and Rescue Teams who have demonstrated that with the use of the Hardline System the ability of an attendant to continuously monitor the safety of operators both inside and outside a confined space is increased, and fatalities in confined space incidents are minimized. In a confined space, radio frequency signals are intermittent and unreliable, Hardline is not. The Con-Space Hardline System employs an easy to assemble modular and scalable

communications system tethered by heavy duty communications cabling. Employing a phone-like, hands free, full duplex communications system allows for uninterrupted two-way conversation. Its unique modular configuration supports from a basic one operator/two attendants system to multiple operators and attendants operations. The main control box is battery powered to allow for operation in remote locations. Should the confined space environment be noxious, explosive, or oxygen rich, the whole system is certified to rigid Intrinsically Safe standards. Should the confined space entrant be required to use a Self-Contained Breathing Apparatus (SCBA) facemask and have the means to transmit and receive audio, the Con-Space Hardline system uses the latest in throat microphone technology to ensure clear speech and compatibility with all types of SCBA's. Outside the confined space, the control box operator is equipped with a headset rated for a high noise environment. All cabling is shielded and has an external coating of hard thermal plastic to help protect it against harsh chemicals and mechanical damage. All connectors in the system are Military Standard.

<p>PROBLEM STATEMENT</p> <ul style="list-style-type: none"> • Confined spaces can be found in utility tunnels, underground electrical vaults, on ships, shipyards, structural collapses, rescues. • Over 2.1M workers enter these confined spaces each year for survey, maintenance, calibration, damage control • Confined spaces can contain toxic or flammable material or lack sufficient oxygen levels • Normal wireless communications in these confined spaces is notoriously unreliable 	<p>BENEFITS</p> <ul style="list-style-type: none"> • Approved by FEMA • Supported by approved US Govt Vendors • Improved Safety, no known fatalities when using SAVOX Hardline in combined spaces • Rapid deployment decreases downtime, increases survival chances in rescue operations • Compatible with all types of SCBA's • Can be used for emergency communications in a damage control situation • Training available at FEMA approved colleges
<p>TECHNOLOGY SOLUTION</p> <ul style="list-style-type: none"> • SAVOX has developed a proven hardwired communications system to OSHA Regulations • The SAVOX Hardline system is ruggedized, using a tethered cabling solution to ensure reliable and scalable communications • Hardline system is compatible with SCBA masks and rated hearing protection for high noise areas • With the possibility of an explosive environment, Hardline is Intrinsically Safe Certified. 	 <p>Typical General Industry Hardline Communications Kit</p> <p>Typical Urban Search and Rescue Hardline Communications Kit</p>

GUARDIAN XO (EXOSKELETON) ROBOT

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USAF aircraft maintenance personnel experienced over 4,300 injuries in FY 2009-2018 with a total injury cost of about \$22.5M. Of that, over \$12.5M were injuries from lifting heavy or bulk items, exertions, strenuous and repetitive movements. 25% of these injuries also resulted in lost work hours and caused profiles or disabilities.

The Sarcos' Guardian™ XO® exoskeleton system combines human intelligence with robotic strength, endurance, and precision to augment worker performance and reduce injury. The XO® robot consists of actuated arms, torso, and legs designed to transmit most of the load to the ground and is capable of 100% load relief. This allows the XO® robot to improve human strength and endurance without restricting the operator's freedom of movement. Thus, the XO® robot increases the maintainer's efficiency and effectiveness during logistics tasks and maintenance practices.

The Guardian™ XO® robot can support USAF maintenance and sustainment ops as observed by Sarcos and AFRL at the 412 Maintenance Group. They identified many use cases where the exoskeleton could reduce


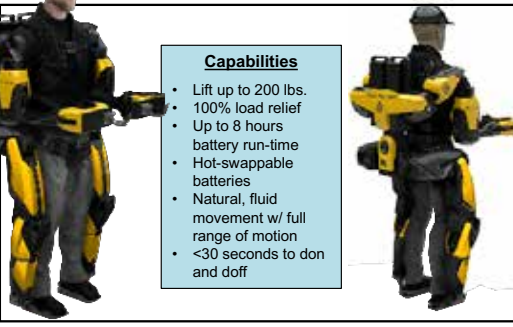
associated injuries for aircraft maintenance work areas, such as:

- Back Shops (EW, armament, wheel and tire, fuel, hydraulic, engines)
- Heavy and bomber support (C17, B-1, B-52)
- AMU support (T-38, F-16, F-22, and F-35)
- Weapon loading and munitions handling

Based on this analysis, the Guardian™ XO® robot could reduce lifting and movement injuries by up to 50%. The Guardian™ XO® could support aircraft maintainers while they lift and lower heavy objects to and from various heights – from the floor, trailers/carts (1-2 ft high), work benches (3 ft high), and storage areas (up to 6 ft high). The XO® system can also lift and lock loads in place, which supports maintainers lifting equipment from the ground to above their heads for hangar and flight line ops. The XO® robot makes lifting and lowering objects nearly effortless for AF maintainers. It can be used for pushing/pulling support carts, material handling, and torquing tasks for every platform (especially heavy lift/bombers). The exoskeleton can assist the operator with maintenance, cleaning, parts replacement,

inspection, pylons/pods/weapons loading, and off-loading various sizes weighing from 5 lbs. to 600+ lbs. The range of tasks can be expanded such as munitions loading with two Guardian XO robot (exoskeleton) working in tandem. The Guardian™ XO® robot technology also has potential use cases for Contingency Response Group (CRG) Base of Support (BOS) operations, where many tasks require heavy lifting and access to transport equipment is limited.

The Guardian™ XO® system is currently at TRL 6, having successfully demonstrated a system prototype in a relevant ops environments – including lifting pelican cases, boxes, ammunition cans, tires, and other objects varying from 5 lbs. to 175 lbs. during untethered, battery-operated maneuvers. Sarcos and AFRL plan to demonstrate the XO in AF ops in 2019.

<p>PROBLEM STATEMENT</p> <ul style="list-style-type: none"> • USAF aircraft maintenance personnel experienced over 4,300 injuries between FY 2009-2018, with ~50% associated with lifting heavy or bulk items, exertions, strenuous and repetitive movements • ~\$22.5 million in estimated injury cost • Thousands of lost work hours with >25% of these injuries causing profiles or disabilities • USAF maintainers routinely move equipment for inventorying, cleaning, maintenance, and other regular operations with equipment of varied sizes, shapes, and weights (5-600+ lbs.) 	<p>BENEFITS</p> <p>The benefits of using the exoskeleton technology for the USAF's Aircraft Maintenance Community are:</p> <ul style="list-style-type: none"> • Increase maintainer safety, mobility, and strength, thereby acting as a force-multiplier • Reduce fatigue and improve endurance – the operator feels a fraction of the effort the XO® robot makes • Multiply productivity: 1 worker and 1 XO® robot could accomplish the work load of 4-10 workers • Reduce injuries related to overexertion, ergonomically challenging movement, strains and sprains, objects dropped onto feet and hands • Reduce \$12.5M injury costs by up to 25% related to heavy lifting and other movement tasks
<p>TECHNOLOGY SOLUTION</p> <ul style="list-style-type: none"> • The Guardian™ XO® robot is a powered, untethered full-body exoskeleton that improves the strength and stamina of its operator without restricting freedom of movement • The XO® robot could assist high stress/high fatigue tasks and reduce injury with robotic strength, endurance, and precision <ul style="list-style-type: none"> - Moving heavy objects with minimal effort: parts replacement, pylons/pods/weapons loading and off-loading, maintenance support - Repetitive lifting, lowering, or holding of parts, equipment, and tools; tedious over-head inspections, material handling, supply support - Pushing and pulling support carts, heavy-duty platforms, fuel tanks, AGE - Torquing tasks for every platform (especially heavy lift/bombers) - Multiple XO® robots can also be used together to further expand the use case opportunities 	 <div data-bbox="824 1654 998 1900"> <p>Capabilities</p> <ul style="list-style-type: none"> • Lift up to 200 lbs. • 100% load relief • Up to 8 hours battery run-time • Hot-swappable batteries • Natural, fluid movement w/ full range of motion • <30 seconds to don and doff </div>

ENVIRONMENTALLY RESPONSIBLE CLEANING WITH DRY ICE

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While traditional cleaning solutions can be time-consuming, costly and ineffective, dry ice cleaning provides a completely dry solution that cleans faster and more efficiently, while reducing downtime and supporting environmental initiatives. This presentation will discuss the basic concepts of dry ice cleaning, as well as, recent developments in regards to dry ice blasting as a surface preparation and coating and corrosion removal method. Participants will learn the benefits of the process, as well as, how it can benefit their production by increasing efficiencies and improving quality.

Dry ice cleaning utilizes recycled solid CO as the cleaning media, which provides a non-abrasive cleaning solution that allows equipment to be cleaned without dismantling. Due to the gentle cleaning capabilities of dry ice, there is no risk of damage to electrical or sensitive equipment. Dry ice cleaning also provides a faster and more effective cleaning solution. The pre-setup, speed of cleaning, and post-cleanup reduces production downtime while cleaning performance enhances efficiencies and increases asset lifespan. The dry ice cleaning process is also safer in comparison to other blasting


methods. The dry ice turns into gas upon contact with the substrate, making dry ice cleaning a completely dry, with no generation of secondary waste stream. This helps minimize cleanup time, reduces disposal costs and eliminates foreign grit contamination to sensitive moving parts.

Dry ice cleaning capabilities allow us to be delicate enough to clean heat exchanger fins or aggressive enough to remove burnt on hydrocarbon and paraffin off of surfaces without damage.

However, Cold Jet is now developing an abrasive blast solution has the potential to offer all of the benefits of traditional abrasive blasting, but with significant reduction in overall abrasive waste stream, without residual moisture on the surface, or a need for drying time. Surface tolerant coatings now have the clean, dry, profile ready surface they were meant to be applied to, which results in longer lifespan of the coating. Painting contractors are immediately able to recoat the application after blasting.

Traditional sand blasting, is frequently not feasible or permitted for one or more

of the following reasons: contamination of machinery, damage, dust pollution or environmental regulations. As well, the use of too much sand may also present a hazard from silica dust inhalation. Cold Jet's abrasive blast solution is achieving a 2-6 mil surface profile and SP 10/SA 2.5/NACE 2 cleanliness level at similar production rates to traditional sand blasting and at an 80-95% reduction in abrasive media consumption.

<p>PROBLEM STATEMENT</p> <p>Cold Jet dry ice blast cleaning equipment is a tool used across multiple industries for cleaning, surface preparation, or parts finishing. As an alternative to more traditional methods, dry ice cleaning provides a completely dry cleaning solution that cleans faster and more efficiently, while reducing downtime and supporting environmental initiatives.</p>	<p>BENEFITS</p> <ul style="list-style-type: none"> • No secondary waste stream • Non-abrasive • Non-toxic • Non-conductive • Dry • Can clean sensitive, delicate material without causing damage
<p>TECHNOLOGY SOLUTION</p> <p>Dry ice cleaning utilizes recycled solid CO₂ as the cleaning media, which provides a non-abrasive cleaning solution that allows equipment to be cleaned without dismantling. Dry ice cleaning provides a faster and more effective cleaning solution with no risk of damage to electrical or sensitive equipment. The dry ice cleaning process is also safer in comparison to other blasting methods. The dry ice turns into gas upon contact with the substrate, making dry ice cleaning a completely dry, with no generation of secondary waste stream.</p>	

RAPID APPLICATION DEVELOPMENT FOR MAINTENANCE

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Problem Statement:

The Engineering Technical Assistance Request (ETAR) offers the perfect application to prove out the technology by working at the point of use and positively affecting thousands of people. The USAF works ~22,500 ETARs annually for the organically maintained aircraft. Additionally, the USAF has multiple, stand-alone legacy systems for Engineering to review & disposition ETARs. These disparate systems and disparate data drive additional work for initiators, reviewers, and dispositions of ETARs because there is no synchronization or linkage from one system to the next or between the data. Each ETAR is "hand-jammed" by maintainers, increasing errors causing rejections and re-work. Some weapon system Engineers are still using email to initiate, review, and disposition ETARs.

There are ~2,250 repeat ETARs annually, these alone drive field/depot maintainers to spend ~5,625 hours per year tearing down and setting up a work bench to request technical assistance on a situation that has already been answered in a previously dispositioned ETAR. The number of rejected and re-worked ETARs and the number of hours spent re-working these ETARs is unknown at this

point. Assuming rejected/re-worked ETARs was like repeat ETARs, the USAF is spending over 10,000 hours per year on this fruitless work. There are more than 10 legacy systems in use today to support the ETAR process.

Description of the Technology:

We put forward two significant technology concepts – High Productivity Application Platform-as-a-Service (hpaPaaS) and Enterprise Knowledge Graph (EKG) for the first time. The significance of the opportunity is to fundamentally change how maintenance and engineering collaborate with an agile, enterprise approach. The philosophy must change to understand it's more about psychology than technology, rapidly prototype business processes and test different solutions to ensure we can start turning ideas into scalable, working solutions.

Current development Status of the Technology; Test/simulation data supporting performance claims

- Application Platform as a Service - TRL 9
 - fully enterprise ready solution, being used today in over 500 world class

companies around the globe, proof: **mendix.com**


- Product Innovation Platform – TRL 9
 - Open source, digital transformation platform that Anautics has rebranded for DoD use
 - Transforms business processes and connects team to product information across the enterprise
 - Proof: **aras.com**
- CTMA - TRL 2
 - Assistance Request app connected to Enterprise Knowledge Graph (EKG)
 - configured on Microsoft Data Lake
 - Components for platform
 - Connectors for Product Innovation Platform

Next steps:

- Task 1: Setup environment and discovery
- Task 2: Development of the Knowledge Graph
- Task 3: Rapid Application Development

Potential Benefits

- Reduction of flow days in organic PDM, mis-routes, repeats, duplication, re-work, and creating metrics
- Increase responsiveness and aircraft availability

<p>PROBLEM STATEMENT</p> <ul style="list-style-type: none"> • USAF works ~22,500 ETARs annually for the organically maintained aircraft • High number of repeats, rejects & re-work of assistance requests • Disparate systems and disparate data drive additional work for initiators, reviewers, and dispositions • No synchronization/linkage between systems or between the data, "hand-jammed" errors cause rejections and re-work • ~2,250 repeat ETARs annually, drives maintainers to spend ~5,625 hours per year tearing down and setting up a work bench to request technical assistance on a situation that has already been answered in a previously dispositioned ETAR. 	<p>BENEFITS</p> <ul style="list-style-type: none"> • Reduction of assistance request repeats, rejections, and re-work • Reduction of flow days in organic PDM and improve aircraft availability • Reduction of mis-routed assistance requests • Reduce time spent creating metrics • Increase responsiveness
<p>TECHNOLOGY SOLUTION</p> <ul style="list-style-type: none"> • Open source, digital transformation platforms that Anautics has rebranded for DoD use • Transforms business processes and connects team to product information across the enterprise • Components can be configured while developing apps • Anautics will be connectors • Enterprise Knowledge Graph (EKG) – configured on Microsoft Data Lake • Anautics has partnerships with all proposed technologies and managed all code in a shared "secure" Github repository for collaboration, testing and release 	<p>GRAPHIC</p> 

TMDE CALIBRATION SOFTWARE INITIATIVE

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The repair and certification of Test, Measurement, and Diagnostic Equipment (TMDE) has become increasingly difficult over the years as technologies improve. This increases turnaround times and error rates as we task fewer and fewer technicians to perform increasingly complex tasks. The commercial solution to this problem often focuses on contracted manufacturer support plans, but the same digital automation tools they use are often available for purchase. Due to funding limitations and limited AFMETCAL Engineer manning, automation of AF calibrations has been limited to in-house software solutions with very limited utility.

However, by developing a local process to validate that the available commercial calibration software meets our Technical Order requirements, we can realize substantial multiplier benefits. Automated calibrations for Radio Frequency generation and analysis TMDE averages a 70% man-hr reduction in touch time, by rapidly making multiple measurements far faster than humanly possible. This not only frees up the technician to perform concurrent manual calibration of TMDE that cannot be

automated, it reduces the amount of time that one-deep TMDE standards are tied up. Additionally, commercial calibration systems routinely provide ongoing reduction of calibration labor as new software is reviewed and approved.

Another added benefit is 100% elimination of human-based errors in calibration process, as well as the associated Root Cause Analysis investigations and reports. By authorizing and performing the initial software validation, we concurrently reduce the turnaround time, free up the technician to perform other maintenance, increase availability of our own equipment for use in other calibrations, and eliminate sources of human error in measurements and report documentation.

<p>PROBLEM STATEMENT</p> <ul style="list-style-type: none"> Extremely limited availability of authorized calibration software solutions, in spite of multiple highly successful Commercial Off The Shelf (COTS) products from competing vendors AFMETCAL approved, and developed software that is limited by engineer availability, and funding 	<p>BENEFITS</p> <ul style="list-style-type: none"> Achieved 70% man-Hour reduction per automated calibration Increases time available for manual calibrations that cannot be automated Simultaneous automated and manual calibration capability Continuous Reduction of calibration labor effort as new software is reviewed and approved 100% Elimination of human-based errors in calibration process and associated Root Cause Analysis investigations
<p>TECHNOLOGY SOLUTION</p> <ul style="list-style-type: none"> Develop local process and tracking method to validate commercial calibration software meets TO Calibration requirements Quantify potential labor savings to prioritize software purchase with greatest return on investment (length and complexity of calibration) <p>* TMDE = Test, Measurement, and Diagnostic Equipment</p>	

ASCT - ACCURACY SAFETY CALIBRATION TE

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Verifying the accuracy of MLRS launchers in real time.

In the MLRS battalion the only way to make sure that the launchers are accurate is by aligning the NFS (north finding system) and the mirror of the SRP (launcher navigation and aiming system that reflects the azimuth line of fire) and measuring the difference (error) between both.

The procedure is done in the field by a qualified officer and takes about 3 hours for the first launcher and about 1 hour for any other launcher. The procedure requires placing the NFS system on a leveling ground.

The test is not reliable, causes false alarms, and requires the launcher to be sent back to depot level for verification. For these reasons the IDF cancelled the test and relies solely on tests performed at depot level once every 3 years.

The proposed solution is a reliable, easy to use and inexpensive device called ASCT - Accuracy Safety Calibration TE

By installing an independent device (ASCT) that shows the azimuth angle of the firing line and comparing it to the actual azimuth angle of the launcher. If the result falls within a 3 mils tolerance, the user can state that launcher is accurate and ready for combat.


An ASCT prototype was manufactured and analyzed for mechanical failures, and was tested on 12 different launchers.

In order to prove the ASCT performance we compared the azimuth angle of the ASCT with the depot level verification check procedure of the MLRS launchers.

The results met the success criteria (3 mils tolerance).

In conclusion, the ASCT system significantly shortens the procedure time to about 15 minutes. The ease of operation allows the technician to perform the test in the field whenever needed.

ASCT allows the battalion commander to reliably verify the accuracy of the MLRS launchers in the field.

PROBLEM STATEMENT	BENEFITS
<ul style="list-style-type: none"> There's a need to verify that the MLRS launchers are calibrated and accurate at any given time and place. The current procedure in the field (NFS checkup) takes a long time (hours), and the results are not reliable. The depot level check uses the SRP mirror which is no longer calibrated. 	<ul style="list-style-type: none"> This is the only way to get a reliable result in the field at any given time. The ASCT allows the verification and calibration process to take less than 15 minutes. The device is easy and cheap to manufacture and has no obsolescence issues.
TECHNOLOGY SOLUTION	
<ul style="list-style-type: none"> ASCT – an independent instrument that can be simply installed on MLRS launchers behind the SRP on a built-in rail. The ASCT matches an NFM (North Find Machine) azimuth reading to the launcher's own positioning system to verify the launcher laying accuracy. 	

LEICA ABSOLUTE TRACKER ATS600

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The Leica Absolute Tracker ATS600 is the ultimate in high-speed inspection for large parts and surfaces. Representing the next level of 3D inspection, it combines traditional laser tracker reflector measurement functionality with the pioneering technology of metrology-grade contactless measurement direct from the laser tracker. No accessories such as reflectors, targets or handheld scanners are required to mediate the measurement – this is the world's first ever-direct scanning laser tracker. Intelligently combining this ground-breaking technology with traditional reflector measurement delivers significant reductions in inspection process times and opens entirely new applications to the world of metrological quality control, in areas that have never before been practical. This is high-accuracy measurement, alignment and analysis on a whole new scale.

The first-ever direct scanning laser tracker will bridge the gap between point-by-point reflector and probe measurements and the advanced scanning functionality of a handheld 3D laser scanner. With its unique direct scanning functionality, the Leica Absolute Tracker ATS600 delivers several

unmatched benefits across a range of large-scale applications.

The range of the ATS600 is fundamentally different to any comparable metrology system, with direct scanning guaranteed at up to 60 meters distance with metrology grade accuracy of to within 300 microns. Parts that are challenging, impractical or uneconomical to digitize with traditional scanning tools are now fair game for accurate measurement.

Measurement is an easy one-user process with the ATS600. Targets are easily identified, either on the tracker or in the software, and results are delivered and processed efficiently through established workflows. Minimal training, minimal mistakes, minimal effort.

The ATS600 is ideal for automated installations – it was designed with automation in mind. With minimal user intervention required, it can be set up to independently perform many repetitive measurements independently and without station relocations.

A key benefit of the ATS600 is its ability to integrate direct scanning within a completely metrology-oriented workflow. All measurement data collected, whether non-contact or reflector, is directly delivered to metrology software with a data rate of up to 1000 Hertz, making it possible to bring quality inspection to entirely new parts of the manufacturing world.

With the ATS600, reflector-based and reflector, less measurement can be intelligently combined, with simple reflector alignment and direct scanning working together to quickly deliver a complete picture of a target part.

The ATS600 is uniquely fast throughout the measurement process, and data point-density is fully configurable, allowing users to tailor measurement process rate and accuracy level to their application – from a quick check at less than 10 seconds per square meter or a high-accuracy scan at 2:15 min per square meter.

PROBLEM STATEMENT

Large scale scanning and inspection of parts made easy and quickly with metrology grade accuracy.

Reduces inspection process times considerably for large parts. Terrestrial Laser Scanners are quite fast to take a full dome scan, but take significant time to import the point cloud into an application software package. The ATS 600 combines the speed of the scan along quick processing of the point cloud data into the software.

Opens entirely new applications to the world of metrological quality control.

BENEFITS

Large scale laser scanning, from up to 60 meters away, without having to relocate the tracker system.

Direct scanning makes alignment and adjustment processes simpler than ever – simple reflector alignment and direct measurement of the part with no need to install a large constellation of individual reflectors, no matter how big the part

TECHNOLOGY SOLUTION

Delivering a pioneering form of direct scanning measurement, the Leica Absolute Tracker ATS600 is a game changer for the inspection of large parts and surfaces. This change is based on a form of technology previously unexploited by dedicated metrological systems – Wave Form Digitization.

While Wave Form Digitization technology has been in use in geospatial measurement equipment for some time, it is only now that, for the first time, the accuracy of this technology has been refined to metrological levels.



HEXAGON COMPOSITE INSPECTION SYSTEM

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Aircraft composite repairs are labor intensive and time consuming. The repairs are often performed by hand. The damaged area is scarfed by hand, mylar sheets are laid over damaged area and curves are traced out by hand. The plies are cut by hand. Repair patches are laid up on scarf in the field. Hot bonder is applied, and the patch is cured. This introduces the current repair process to be prone to errors and inaccuracies.

There is often little to no digital history of the structure needing repair. Therefore, no 3D record of damaged area exists. Also, during the repair, no 3D record of the scarfed area is captured and there is no 3D record of the post repaired area. At best, there may be photographic records. To speed up this cumbersome process, often times "template" plies are used. Standard circle, oval, and other various shapes are used. However, one size does not fit all! Sometimes repairs must be redone, which equates to grounded aircraft for longer periods of time, which negatively affects aircraft availability.

To improve the repair process, more accuracy is needed. A patch that better fits the damaged area is stronger as a result. A

more thorough analytical analysis is needed during the repair process...Is the scarf right? Does it meet OEM specifications for repair? Faster turnaround times are required to make availability numbers. Also repair history with digital traceability needs to be injected into the process, to ensure consistency and repeatability. With digital models, anyone can look at repair histories and processes can be standardized throughout an enterprise. A method is needed that can be applied in the shop or in the field, because it's not always possible to get aircraft back to a repair depot.

The first ever system dedicated to carbon-fiber part applications, the Composite Inspection System from Hexagon Manufacturing Intelligence is set to revolutionize portable composite part inspection and analysis. The system comprises the custom-built Apodius Explorer 3D software solution combined with HP-C-V3D Apodius Vision Sensor hardware that has been designed to combine perfectly with a ROMER Absolute Arm with Integrated Scanner. With its advanced camera-based vision system and software designed specifically

for composite component analysis, the Composite Inspection System delivers unmatched defect detection and full-part digitization for carbon-fiber components.

The arm serves as a global reference system for the data collected by the HP-C-V3D Apodius Vision Sensor, becoming a vital component of the full-part digitization and analysis process. With the total system certification that comes as standard with every ROMER Absolute Arm, confidence in the accuracy of captured data is guaranteed. The combined system is portable, lightweight, highly accurate, able to scan large areas quickly, and can be placed on a stand for in-shop and field use.

The system is portable with minimal training required.

PROBLEM STATEMENT

- Composite repairs are labor intensive and time consuming, making them prone to errors.
- There is also a lack of 3D data needed of the damaged composite area, both before and after the repair. Repairs sometimes have to be redone, due to irregularities of applying standard templates to the damaged area.

TECHNOLOGY SOLUTION

The Composite Inspection System from Hexagon Manufacturing Intelligence combines Apodius Explorer 3D software solution with HP-C-V3D Apodius Vision Sensor hardware that has been designed to combine perfectly with a ROMER Absolute Arm with Integrated Scanner. This solution provides accurate 3D data of the damaged area and composite fiber analysis of the scarfed area, as well as analysis of correct fiber orientation of the plies during the repair and 3D scan post repair

BENEFITS

- Lightweight portable system, with minimal training
- Provides accurate 3D records of composite repairs, before, during, and after.
- Provides data analytics regarding fiber orientation and angles
- Ensures repair patches are geometrically correct, without folds, wrinkles or tears



HOW TO PINPOINT THE ABSOLUTE POSITIONING OF FLAWS USING PORTABLE AND MODULAR NDT

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Portable measuring arms are widely known for providing accuracy, usability and productivity enhancements into the manufacturing environment. However, the ability to instantly adapt and be ready to measure without recalibration is what sets them apart. Hexagon has started to move into industry partnerships to create new solutions by converting the Absolute Arm into a multipurpose sensor carrier

Recently, PRAGMA non-destructive testing (NDT) has utilized the flexible, portable and modular design of the Hexagon Absolute Arm to develop a unique and fully integrated NDT sensor that is shattering expectations. This ongoing development will meet a vital need of the NDT industry of being able to pinpoint the absolute positioning of flaws and defects, allowing the user to monitor their growth overtime.

PROBLEM STATEMENT

- Relative positioning has been problematic in NDT inspections
 - No encoding at all or mini-wheel relative encoders
 - If the probe or encoder are lifted, then exact position is lost
 - Skidding of the wheel encoder due to the couplant
- Key questions still remain...
 - Did we really scan the whole part?
 - Was the liquid couplant good at all time?
 - Where is the flaw exactly?
 - How long/wide is the flaw?
 - How has the flaw grown since the last inspection?
 - Are the results technician-dependent?
 - What is the confidence level to make a tough decision?

BENEFITS

- Absolute positioning over relative positioning
- Provides accurate 3D records of flaws and their exact location for monitoring
- Provides traceability of real surface shape with obstructions via laser scan
- Provides traceability on ultrasonic probe, scan passes and lifting
- Point-like Ultrasonic monitoring of layer thicknesses
- Future modular NDT sensors, (i.e. eddy current) combined with metrology for exact flaw location.

TECHNOLOGY SOLUTION

PRAGMA NDT has utilized the flexible, portable and modular design of the Hexagon Absolute Arm to develop a unique and fully integrated NDT sensor that is shattering expectations. This ongoing development will meet a vital need of the NDT industry of being able to pinpoint the absolute positioning of flaws and defects, allowing the user to monitor their growth overtime.

Developing an Absolute Positioning NDT Solution
First Product Offering: Inspection of CFRP



ALL-PURPOSE FOD DETECTION AND RETRIEVAL DEVICE

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Foreign Object Debris (FOD) is a major concern on every aircraft. It can damage or down an aircraft if not detected and removed or encapsulated. On every airframe there are difficult-to-reach areas where FOD can hide when cleaning up after maintenance tasks. Current methods to 1) find, then 2) remove or 3) encapsulate this FOD involve using multiple tools at the same time. It can be tricky, and it can sometimes require multiple people. Having one tool to perform all three tasks can simplify the process significantly.

The All-purpose FOD Detection and Retrieval Device is a high-resolution borescope with a multi-purpose channel built in that can either pull vacuum, fit a mechanical or magnetic grabber, or fit a tube to apply sealant. It allows simultaneous detection and retrieval of FOD, or encapsulation if retrieval is not possible. The tip of the borescope can articulate (bend) in multiple directions to make it easier to guide to the target area. Using this tool allows a single user to quickly and efficiently find and deal with any FOD that may be present in an aircraft, even way back in the nooks and crannies.

This technology is currently in the refinement stage. A Lockheed Martin engineer made a workable prototype in 2018 to prove the concept and do initial testing and user feedback. The borescope worked well, and the integrated vacuum was able to collect many types of FOD. The testing and feedback spawned additional requirements that are currently being addressed in another round of design, including the integrated sealant dispense channel and overall reduction in probe size. By November 2019 there will be a new prototype for additional testing.

The next steps will be to productionize the design and get the device certified for a flight line environment. Once deployed this device has the potential improve FOD prevention across multiple airframes and throughout the fleet.

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PROBLEM STATEMENT

Foreign Object Debris (FOD) is a major concern on every aircraft. It can damage or down an aircraft if not detected and removed or encapsulated. On every airframe there are difficult-to-reach areas where FOD can hide when cleaning up after maintenance tasks. Current methods to 1) find, then 2) remove or 3) encapsulate this FOD involve using multiple tools at the same time. It can be tricky and it can sometimes require multiple people. Having one tool to perform all three tasks can simplify the process significantly.

BENEFITS

- Reduce FOD risk
- Single tool for FOD detection, retrieval, and encapsulation
- Faster retrieval
- Capable of recording proof of proper encapsulation with pictures or videos

TECHNOLOGY SOLUTION

The BoreVac is a high-resolution borescope with a multi-purpose channel built in that can either pull vacuum, fit a mechanical or magnetic grabber, or fit a tube to apply sealant. It allows simultaneous detection and retrieval of FOD, or encapsulation if retrieval is not possible. The tip of the borescope can articulate (bend) in multiple directions to make it easier to guide to the target area. Using this tool allows a single user to quickly and efficiently find and deal with any FOD that may be present in an aircraft, even way back in the nooks and crannies.

Prototype Coming Oct 2019

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AUGMENTED REALITY MONITORING SYSTEM FOR AIRCRAFT WIRING

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Problem Statement

Maintenance activities across the aviation industry have a great concern with the reduction and management of operator workload where humans are required to make quick accurate decisions. UAT is aware of the problems of information overload and is developing a solution presented in a system for monitoring the aircraft wiring through Smart Clamps equipped with sensors and AR. The system uses a user-centric interface that would replace the old, metal clamps and associated hardware that hold wire bundles today. The old clamps often deform and the rubber coating wears off exposing the metal band, cutting through the insulation, and causing an electrical short. The Smart Clamp greatly reduces aircraft weight, which is extremely valuable to the military and commercial airlines.

Technology Description

The Smart Clamps have sensors embedded that can read the voltage and amperage flow in a bundle of cables. When used with AR, is capable of visualizing faults in wire bundles and can isolate a single wire. The Smart Clamp simplifies installation, reduces maintainer fatigue, minimizes associated

repetitive strain injuries, and dramatically reduces fly-weight. The system is wireless and is powered by harvesting the energy from the aircraft vibrations. The data would be gathered and stored every time a scan is done. The continued data collection of an entire program of recorded data would enable predictive failures, preventing unnecessary down time, and increasing equipment readiness.

Status

This technology is currently in a Technology Readiness Level 4. UAT is working with the AFRL in a technology transfer and acquisition program. The software is already in an MVP stage. Sikorsky/Lockheed Martin and BAE Systems bring unparalleled aircraft image-guided expertise and resources to facilitate studies of characterization of how trust affects human performance using AR hardware and software.

Next Steps

Benet Laboratories (a Department of the Army R&D facility) is performing the FEA analysis and preliminary static and dynamic testing. UAT has also obtained the support of Lectromec's President and

Chairman of SAE Wiring System Installation Subcommittee (AE-8A). UAT will be certifying our product through Lectromec and once it meets MIL-SPECS, a pilot should start in January of 2020 with Sikorsky (rotorcraft) and BAE Systems (ground and naval vehicles). Although this technology is initially focused on rotary wing aircraft, this system could be used in fixed wing, spacecraft, ships and boats of all sizes, vehicles, etc. Recently, all major US airlines voluntarily committed to mitigate climate change. They have the opportunity to adopt technologies that help reduce greenhouse emissions from all sectors. In its plan to support the US commitment to climate mitigation, if implemented with integrity, UAT could prevent up to 1,500 tons of carbon dioxide emissions per aircraft in one year. That is 200 times what U.S. households emit per year.

PROBLEM STATEMENT

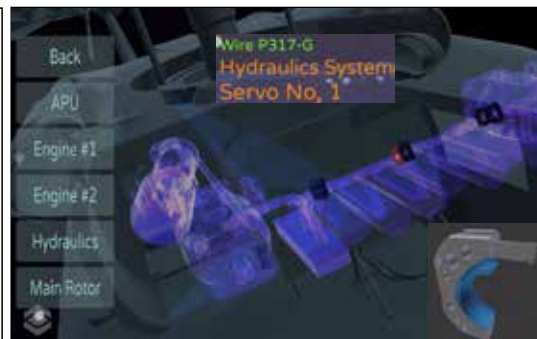
- Maintenance activities on aircraft systems across the aviation industry have a great concern with the reduction and management of operator workload. United Aircraft Technologies (UAT), is developing a smart aircraft Inter-Connecting Clamp (ICC) solution with an Augmented Reality Monitoring System (ARMS) for aircraft wiring that improves fuel economy (overall weight reduction of the aircraft), decreases the occurrence of Repetitive Strain Injuries (RSI) among the workforce, simplifies maintenance through 3D fault location and visualization, and reduces the environmental impact of CO2 emissions.

BENEFITS

- Our smart clamp saves weight, an average of 60-65% from current metal clamps, improving fuel economy. In addition, maintenance is reduced in half due to easy assembly and disassembly. Workers compensation expenses is decreased up to 30% due to its ergonomic design. The ICC provides maintenance crews greater confidence, minimizing complexity, shortening procedure times, reducing time loss, and helps expand the utilization of Augmented Reality to beyond all electrical wiring maintenance. The anticipated benefits will apply equally to weight savings, reduction of RSI, and reduction of CO2 emissions given that the world needs to achieve net-zero emissions by 2050.

TECHNOLOGY SOLUTION

- The smart Inter-Connecting Clamp (ICC) is unique. It does not use standard metallic installation hardware (screws, washers, and nuts). The ICC, has sensors embedded that can read the voltage and amperage flow in a bundle of cables. When used in conjunction with Augmented Reality, is capable of visualizing hidden faults in wire bundles and has the capability of isolating a single wire. The ICC greatly simplifies installation, reduces maintainer fatigue and man-hours, minimizing associated repetitive strain injuries, and dramatically reducing fly-weight.



MACHINE LEARNING FOR NON-DESTRUCTIVE TESTING

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Problem Statement:

Radiographic inspection is a crucial component of non-destructive testing (NDT) and predictive maintenance, whether during production or while conducting special investigations such as root cause failure analysis. Traditionally, image data captured from x-ray, n-ray, or computed tomography (CT) must be evaluated by trained radiographers to determine if defects are present. Despite time-consuming training for radiographers, there is often high variability in radiographical analysis. Two radiographers may look at the same image and disagree about whether a component is defective. This inconsistency can prove to be costly, as some defective components are determined compliant while other compliant components are determined to be defective.

Technology Description:


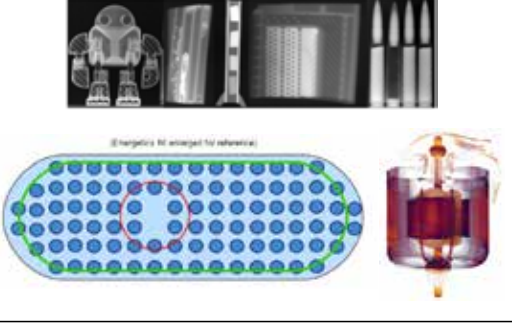
AURA proposes the use of machine learning (ML) algorithms to analyze NDT image data. Recently, deep learning algorithms are showing great promise for identifying anomalies in images. For example, the medical field is utilizing deep learning for automated tumor identification. Intuitively, these algorithms work by inherently

identifying features in an image that indicate a tumor, such as dark spots in unexpected areas. In the same way, AURA intends to diagnose failure modes in a component by identifying key features in a radiographic image. This technology is currently estimated to be at a Technology Readiness Level (TRL) of 3 to 4 since the adoption of ML into maintenance procedures is still in its infancy.

Automating the image processing and recognition phase will not only make the NDT process more effective but also more affordable. Benefits include decreased evaluation time, increased evaluation consistency, a reduced need for corrective operations, automated improvement of algorithms over time (i.e., machine learning), and unsupervised operation. The intent is to better utilize experienced NDT personnel to investigate root causes and mitigate known defects rather than to waste their time in redundant image analysis. As of the writing of this abstract, test/simulation data to demonstrate these benefits is unavailable due to the distribution restrictions on such data. If selected for further progress, AURA will work with the government to release this data for more general use.

Next Steps:

Machine learning algorithms are a game-changing innovation for maintenance operations. Automated image processing for NDT is a key factor in the shift from costly reactive maintenance to predictive, condition-based maintenance processes. Due to higher demand and increasing mission requirements, maintenance teams cannot afford to continue using traditional practices. The US Navy has been investing in predictive maintenance for decades while the US Army has likewise been investigating how to utilize machine learning to augment their own NDT procedures. As the amount of maintenance data inevitably increases, process automation using ML will be the only option for meeting the high demand.

<div data-bbox="110 1264 272 1333">  </div> <div data-bbox="272 1264 641 1281"> PROBLEM STATEMENT </div> <ul style="list-style-type: none"> Traditionally, image data captured from x-ray, n-ray, or computed tomography (CT) must be evaluated by trained radiography personnel. Despite time-consuming training, there is often high variability in radiographical analysis. Two radiographers may look at the same image and disagree about whether a component is defective. This inconsistency can prove costly as some defective components are determined compliant while other compliant components are determined to be defective. 	<div data-bbox="868 1264 1182 1281"> BENEFITS </div> <p>The benefits of introducing machine learning image processing and analysis techniques include:</p> <ul style="list-style-type: none"> Decrease image evaluation time Increased evaluation consistency Reduction in need for corrective operations Automated improvement of algorithms over time (machine learning) Unsupervised operation
<div data-bbox="259 1612 641 1629"> TECHNOLOGY SOLUTION </div> <p>AURA Technologies, LLC proposes the use of machine learning algorithms to analyze Non-Destructive Testing data. Deep learning algorithms are showing great promise for identifying anomalies in images. For example, the medical field is utilizing deep learning for automated tumor identification where the algorithms inherently identify features in an image that indicate a tumor, such as dark spots in unexpected areas. Using this same premise, AURA intends to diagnose failure modes in a component by identifying key features in radiographic images (e.g. voids in the energetics fill of munitions seen in the image to the right).</p> <p><small>Proprietary and Copyright©2019 AURA Technologies, LLC. All rights reserved.</small></p>	

FLUKE SONIC IMAGING ANALYZER FOR BLEED AIR, PRESS, & O2 LEAKS

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Many of today's mission critical assets – especially aircraft were manufactured 15+ years ago and maintenance and inspection procedures are based on using older technology for fault isolation and repair. Over the last several years Operators and Airframe OEMs are looking at what advanced technologies used in other sectors can apply to the commercial and DOD aircraft, ship, and ground based platforms for critical system troubleshooting. Some of these new technologies can troubleshoot faults we could not in the past. Creating a paradigm shift to Proactive Maintenance Troubleshooting methods on how we perform maintenance and inspection.

Today, for Oxygen, Bleed Air, Pressurization Systems, many Aircraft Maintenance Manual (AMM) or Fault Isolation Manual (FIM) do not test at Ultrasonic levels. The unaided human ear can only detect sound between 20 Hz and 20 KHz— well below what is required to detect pressurization leaks that are normally found in the ultrasonic 35kHz to 45 kHz range. The ability to find and fix leaks of various kinds is critical to the reliability of aircraft. In the past, finding these leaks has been time consuming and tedious. In some


cases, this has required inspection during down times or in a quiet environment. These extended downtimes are very costly. The Fluke ii900 Sonic Industrial imager converts and amplifies inaudible ultrasonic sounds for visual presentation.

The Fluke ii900 Sonic Industrial imager turns sound waves into a real-time image, to accurately pinpoint leaks at a glance. The ii900 can be utilized from a distance, while other background noise is present, and with minimal training. Equipped with an array of miniaturized microphones and the ability to filter out background noise (by frequency or dB level), the ii900 Sonic Industrial Imager can isolate and detect leaks with ease. The 7" LCD touchscreen overlays a SoundMap™ on a visual image for quick leak location identification.

Benefits include simple to use SoundSight™ technology. SoundMap™ overlaid on visual image in real time clearly identifies leak location. Straightforward, intuitive interface via touchscreen. Ability to filter and isolate the sound frequency Fast. Scan a large area more quickly than current methods. SoundMap™ images and videos saved for

easy reference and reporting. Ultrasonic detection up to 52kHz. Frequency ranges/filters selectable by user. Long range: detection up to 150'

Affordable, easy-to-use advance technology. Quick to adopt and deploy, offering significant cost saving and mission critical availability of assets.

<p>PROBLEM STATEMENT</p> <p>The ability to find and fix leaks of various kinds is critical to the reliability of aircraft. In the past, finding these leaks has been time consuming and tedious. In some cases this has required inspection during down times or in a quiet environment.</p> <p>Issues: Pressurization Leaks, Oxygen Leaks, Bleed Air Leaks</p> <p>The ii900 Sonic Industrial Imager provides a fast and easy way to locate air, gas and vacuum leaks. The tool can be utilized from a distance, while other background noise is present, and with minimal training.</p>	<p>BENEFITS</p> <ul style="list-style-type: none"> • SoundSight™ technology is simple to use. • SoundMap™ overlaid on visual image in real time clearly identifies leak location • Straightforward, intuitive interface via touchscreen • Ability to filter and isolate the sound frequency • Fast. Scan a large area more quickly than current methods • SoundMap™ images and videos saved for easy reference and reporting • Ultrasonic detection up to 52kHz • Frequency ranges/filters selectable by user. • Detects a 0.005 CFM leak at 100PSI from 30' • Long range: detection up to 150'
<p>TECHNOLOGY SOLUTION</p> <p>The Fluke ii900 turns sound waves into a real-time image, to accurately pinpoint leaks at a glance</p> <p>Equipped with an array of miniaturized microphones and the ability to filter out background noise (by frequency or dB level), the ii900 Sonic Industrial Imager can isolate and detect leaks with ease.</p> <p>The 7" LCD touchscreen overlays a SoundMap™ on a visual image for quick leak location identification.</p>	<p>Fluke ii900 Sonic Industrial Imager</p>  <p>Bleed Air Leaks</p> <p>Pressurization Leaks</p> <p>Oxygen Leaks</p>

SSBN SUBMARINE TANK WORK TECHNOLOGY INSERTIONS

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The Strategic Deterrent Mission depends on a high level of operational readiness for the SSBN fleet. Trident Refit Facility Bangor provides maintenance, repair, and modernization for the West Coast SSBN's through incremental depot level repairs during refit periods. The notional schedule for these refits is two thirty-five day waterborne refits followed by a fifty day dry-docking. Adding further complexity and schedule risk to this work are hardware degradations, due to the aging Ohio class SSBN fleet. Within these refits, tank work is critical path work that could delay on-time completion. Tank work includes un-restricted operations (URO) inspections, paint and preservation, and mechanical system maintenance.

Two innovations have dramatically improved schedule performance for this work: heat induction paint removal, and 3D scanning. These new methods replace mechanical paint removal (needle gunning,) and manual patterning, two processes that have changed little since the beginning of Naval ship repair.

Heat induction, for discrete coating removal to enable URO inspections, has reduced the time needed to prepare those inspection

sites from two weeks to two days. By completing these inspections earlier in the refit, repairs are completed earlier, freeing those resources, for example welders, for other critical path repairs.

3D scanning of lead bins in tanks has reduced the time needed to pattern the replacement canning from six days to one, and ensures first time quality of the fit-up and installation. Similar gains were realized for rope guard work. Early completion of lead bin work enables earlier completion of preservation work in a given tank, freeing another constrained resource, and reducing schedule risk.

The approval of these technologies was possible through the work of the TRF Bangor Technology Insertion Deployment Evaluation (TIDE) team. This team works with the Strategic Systems Programs (SSP) office and other key stakeholders, to obtain permission, guidance, apply for permitting, establish safety requirements, etc., for use. Lessons learned will further accelerate additional technology evaluations, such as plasma blast to add additional paint removal capability.

PROBLEM STATEMENT

The strategic deterrent mission depends on a high level of operational readiness, accomplished through incremental depot level repairs during 35-50 day refit periods. Trident Refit Facility Bangor executes these for West Coast SSBN's. The age of the Ohio class SSBN's further contribute to the complexity of work required. Within these schedule-constrained refits, tank work is critical path work that could delay on time completion. Tank work includes un-restricted operations (URO) inspections, paint and preservation, and mechanical system maintenance.

BENEFITS

- Five days (out of six) reduction for time to pattern a lead bin, for a 50 day docking refit.
- 12 days (out of 14) reduction to remove paint for URO inspections for a 50 day docking refit.
- Both gains mitigate resource constraints such as welding and painting, allowing more time to evaluate and complete repairs. This results in less deferred work, and reduces schedule risk.
- Relationships built and capabilities gained by the Tech. Insertion team will accelerate testing and approval of additional technology, such as Plasma Blast, for additional improvements.

TECHNOLOGY SOLUTION

- Working with the Strategic Systems Programs (SSP) office and other key stakeholders, obtained permission, guidance and permitting for use. This was accomplished through data collected by the commands Technology Insertion team.
- Adopt magnetic heat induction, and laser 3D scanning into production processes to improve schedule performance and improve effectiveness.
- Heat induction replaces needle gun selective paint removal for URO inspection sites
- Laser Scanning replaces manual patterning



SITEHAWK RF ANTENNA & CABLE ANALYZER - AVIATION SOLUTION

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Many of today's mission critical assets – especially aircraft manufactured 15+ years ago, the maintenance and inspection procedures are based on using older technology for fault isolation and repair. Advanced technologies used in other sectors can apply to the commercial and DOD aircraft, ship, and ground based platforms for critical system troubleshooting. Some of these new technologies allow us to troubleshoot faults using methods not available previously. Creating a paradigm shift to Proactive Maintenance Troubleshooting methods on how we perform maintenance and inspection.

Most Aircraft Maintenance Manual (AMM) or Fault Isolation Manual (FIM) do not test antennas and cables at operating frequencies. Tools such as Time Domain Reflectometers (TDR) do not test antenna. For Cables & Connectors, continuous direct current of an ohmmeter is ineffective at reading resistance of cables due to the effects of capacitance and inductance distributed along the length of the cable. Hard to use TDRs only ping cable with a very low frequency, they do NOT sweep the frequency band of the system at the required

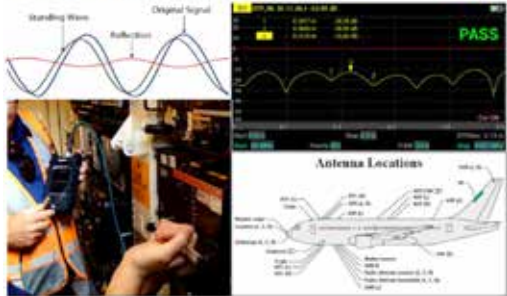
operating frequency. Not having the right procedures and right tools unfortunately causes a process of not identifying root failures quickly and accurately.

1. The SiteHawk AV RF Antenna & Cable Analyzer – Aviation Kit Solution as a Proactive Maintenance Troubleshooting Tool, provides the capability of using a Frequency Domain Reflectometer (FDR) to perform a Voltage Standing Wave Ratio (VSWR) test by transmitting a continuous RF sweep of the cables and antenna at their operating frequencies, and then monitoring the absorption of the wave by the antenna. The FDR identifies standing or reflected waves due to loose connections, corrosion, moisture, or defective cable, or faulty antenna, which changes the system impedance resulting in a reflected or standing wave. Standing waves not only decrease output transmission, resulting in weak, intermittent operation, but may also harm the transmitter if the reflection is quite large. The recommended FDR is an easy to use handheld tester, with a Go/No-Go function by use of a limit line and simple distance to fault

measurement. It can be used to quickly identify improper connections, defective cables and faulty antennas easily from the Equipment rack, eliminating disassembly of the airplane to test the RF system.

2. The SiteHawk AV Optional Automatic Mode — Consists of predefined tests, tailored to specific aircraft systems. These tests in conjunction with troubleshooting procedures in the aircraft's technical manual allow the technician to quickly isolate malfunctions. This Touchscreen with Smartphone like functionality allows GUI interface and easy Go/No-Go workflows for every DOD aircraft, ship, or ground based vehicle platforms with RF Systems.

Affordable, easy-to-use advance technology. Quick to adopt and deploy, offering significant cost saving and mission critical availability of assets.

PROBLEM STATEMENT	BENEFITS
<p>No Aircraft Maintenance Manual (AMM) or Fault Isolation Manual (FIM) to test antennas and cables at operating frequencies:</p> <ul style="list-style-type: none"> • Antennas – No On-Wing Tests in manuals <ul style="list-style-type: none"> ◦ Time Domain Reflectometers (TDR) do not test antenna • Cables & Connectors <ul style="list-style-type: none"> ◦ Continuous direct current of an ohmmeter is ineffective at reading resistance of cables due to the effects of capacitance and inductance distributed along the length of the cable ◦ Hard to use TDRs only ping cable with a very low frequency, they do NOT sweep the frequency band of the system at the required operating frequency 	<p>Effective and Efficient: Used for Proactive Health Checks or upon RF Failures to swiftly ID faults for communications, navigations, and surveillance RF systems. Proactive tests reduces in-service faults. During Line Maintenance, root cause is easily and swiftly identified.</p> <p>Time and Cost Savings: VSWR tester test antenna and cables at same time. Distance to fault leads to easy ID location of faulted cable or antenna.</p> <p>Scalability: Handheld Tester with Touchscreen with Smartphone like functionality allows GUI interface and easy Go/No-Go workflows for all platforms with RF systems.</p>
TECHNOLOGY SOLUTION	On-wing Coax & Antenna Testing Less Than 5 Minutes – From the rack
<p>An easy to use Frequency Domain Reflectometer (FDR) handheld tester, with a Go/No-Go Function to perform Voltage Standing Wave Ratio (VSWR) test by transmitting a continuous RF sweep of the cables and antenna at their operating frequencies and then monitoring the absorption of the wave by the antenna. The FDR identifies standing or reflected waves due to loose connections, corrosion, moisture, or defective cable/faulty antenna which changes system impedance resulting in a reflected or standing wave. It can be used to quickly identify improper connections, defective cables and faulty antennas easily from the Equipment rack, eliminating disassembly of the airplane to test the RF system.</p>	

THERMAL IMAGING TECHNOLOGY FOR MAINTENANCE & INSPECTION

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Many of today's mission critical assets – especially aircraft were manufactured 15+ years ago and maintenance and inspection procedures are based on using older technology for fault isolation and repair. Over the last several years Operators and Airframe OEMs are looking at what advanced technologies used in other sectors can apply to the commercial and DOD aircraft, ship, and ground based platforms for critical system troubleshooting. Some of these new technologies can troubleshoot faults were we could not in the past. Creating a paradigm shift to Proactive Maintenance Troubleshooting methods on how we perform maintenance and inspection.

Today, for Air Conditioning, Bleed Air, Pressurization Leaks, Electrical, Hydraulic, Flight Control, Braking, Pitot-Static and other Critical Systems, many Aircraft Maintenance Manual (AMM) or Fault Isolation Manual (FIM) do not use Thermal Imaging for test applications. Lacking Thermal Imaging tools & procedures will contribute to reduced reliability of Air Conditioning, Bleed Air, Pressurization Leaks, Electrical, Hydraulic, Flight Control, Braking, Pitot-Static and other Systems to identify latent/ intermittent

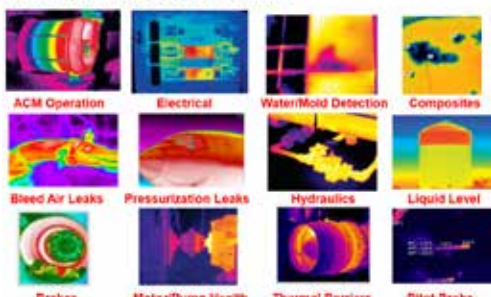
failures as part of a proactive maintenance program. Not having the right procedures and right tools unfortunately causes a process of not identifying root failures quickly and accurately.

The Fluke Pro Series Thermal Imagers are a Proactive Maintenance Troubleshooting Tools, providing the capability of using heat signatures to identify faults within Air Conditioning, Bleed Air, Pressurization Leaks, Electrical, Hydraulic, Flight Control, Braking, Pitot-Static and other Systems. Providing quantitative and qualitative analysis of temperature rise. Detects differences as low as .3°C (.5°F). Used at a safe distance, reducing exposure to high current and high temperature components.

Incorporate in Aircraft Maintenance Manual to swiftly identify ACM, Bleed Air, Pressurization Leaks, Hydraulic Bypassing, Flight Control, Pitot-Static and Electrical faults. Use during "Health Checks" to identify latent/intermittent failures as part of a proactive maintenance program. Asks about tasks related to Aircraft Troubleshooting.

The Fluke Pro Series Thermal Imagers are Handheld Solutions with touchscreen functionality easy-to-use across every DOD mission asset -aircraft, ship, or ground based vehicle platforms.

Affordable, easy-to-use advance technology. Quick to adopt and deploy, offering significant cost saving and mission critical availability of assets.

PROBLEM STATEMENT	BENEFITS
<ul style="list-style-type: none"> Need new tools & procedures to swiftly identify ACM, Bleed Air, Pressurization Leaks, Hydraulic Bypassing, Flight Control, Pitot-Static and Electrical faults Lacking tools & procedures will contribute to improve reliability of Air Conditioning, Bleed Air, Pressurization Leaks, Electrical, Hydraulic, Flight Control, Braking, Pitot-Static and other Systems to identify latent/intermittent failures as part of a proactive maintenance program Issue 	<ul style="list-style-type: none"> Quickly Isolates Intermittent Faults Health Checks Capture Degradation and Validate Systems Integrity Faster Turnaround User Friendly Reduces Man-Power Measures and Records for Traceability Reduces Lifecycle Operating Costs <ul style="list-style-type: none"> Proactive Maintenance vs. Reactive Maintenance Identifies Root Cause to Drive Product Improvement Decreases speculative LRU Replacements
TECHNOLOGY SOLUTION	Thermal Imaging Applications
<ul style="list-style-type: none"> Thermal Imager IR Camera provides a visualization of heat Provides quantitative and qualitative analysis of temperature rise. Detects differences as low as .3°C (.5°F) Used at a safe distance, reducing exposure to high current and high temperature components Incorporate in Aircraft Maintenance Manual to swiftly identify ACM, Bleed Air, Pressurization Leaks, Hydraulic Bypassing, Flight Control, Pitot-Static and Electrical faults Use during "Health Checks" to identify latent/intermittent failures as part of a proactive maintenance program 	

HANDHELD WIRING TESTERS

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The DOD faces ongoing challenges with aircraft readiness rates across multiple platforms due largely to aging wiring and increasingly complex electronic systems. Recent activities at JSWAG highlighted the special attention being given to electronic wiring interconnect systems on aircraft and focus on training efforts to help maintainers meet operational goals. Factors such as aircraft readiness, flight schedules, maintainer knowledge, and current testing methods indicate the need for more efficient and cost effective solutions for trouble-shooting aircraft wiring systems.

The HT-128 Handheld Wiring Analyzer is an easy-to-use, cost-effective solution to assist avionics technicians from all branches of service and all aircraft platforms in daily aircraft troubleshooting to quickly locate faults and return aircraft to flight ready status. This 128 point tester expands up to 8 units (1,024 test points). Individual testers connect to each wire harness connector, testing for opens, shorts, mis-wires, high resistance connections, and verification of passive components. Short adapter cables eliminate the need for shorting plugs or long loop-back adapter cables. Test results report

on-screen with measured values logged in printable error reports. HT-128's communicate wirelessly, or in-line through the UUT. Programming is simple. With minimal training using a Microsoft Excel™ template the user is ready to test within minutes.

The HT-128 is currently available with continuity analysis, repetitive testing, probing, and identification. Learn and Auto-Test Program Generation (APG) are currently under development. Learn Cable creates a test program from a presumed good wire harness connected to the tester. APG software allows data from the aircraft IETM to be used to automatically generate test programs.

Attendees at past JSWAG meetings from the MV-22, H-60, H-64, H-53, F-18, C130, and F-35 platforms expressed great interest in implementing the HT-128 to complement current test equipment on the flight line. Simulation data suggests enormous benefits to all branches of service in faster turnaround times, reduced maintenance man-hours and cost savings compared to the digital multi-meters used on the flight line today. A comparison of current test methods using

DMM's to the HT-128 on a 100 wire harness, testing for continuity and isolation, showed a savings of 2.40 man-hours for one test. The reduction in man-hours can be translated into increased aircraft availability as technicians accurately and expeditiously complete assigned maintenance tasks.

DIT-MCO desires to provide a solution needed by today's avionics technician in the fastest turnaround time possible. Monies awarded by CTMA would help fund development of additional requested features requested by the JSWAG audience. With these features available sooner, demonstrations on multiple aircraft platforms could verify the need of this technology by the entire military aviation community.

PROBLEM STATEMENT

Today's maintenance technicians face a constant battle when trying to troubleshoot wiring errors onboard the aircraft. Hand buzzing, or point-to-point testing with a DVM, is time consuming and can easily miss errors. Automated Wire Test Sets are large, cumbersome and often not used, particularly when just one or two branches of a harness need to be quickly tested.

BENEFITS

- Easy to use – limited operator training required
- Compact, lightweight, portable
- Test installed cables without loopback plugs or long adapter cables
- Quickly catch opens, shorts, mis-wires, high resistance errors
- Measure resistors, verify proper polarity of diodes
- Saves test reports for documented test results
- Rugged, handheld, durable
- Battery operated for true portability

TECHNOLOGY SOLUTION

The DIT-MCO HT-128 is a portable, wireless cable test system that allows technicians to connect individual testers to each harness branch connector instead of using a single, centralized tester and multiple return adapter cables. This allows technicians with small, battery powered testers to achieve the desired wire harness test coverage. The HT-128 performs continuity and resistance tests on each wire in a harness. Opens, shorts, crossed wires and high-resistances are reported within seconds. Test results for each harness can be saved for proof-of-testing documentation.

DIT-MCO HT-128 Handheld Wiring Analyzer



MINIATURIZING IMPROVED ELECTRICAL TEST AND INSPECTION

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Problem Statement

The influence and integration of cutting-edge technology on our country's existing weapons system is tremendous. Heavy modifications to existing Electrical Wiring Interconnect Systems (EWIS) are being accomplished globally and include such critical subsystems as countermeasures, flight controls, glass cockpits, etc. Such advancements come with extraordinary challenges with how personnel are to test, troubleshoot, and conduct preventative and unscheduled maintenance. Signal levels of less voltage more common yet require higher fidelity. Each are necessary to ensure a specific weapon system will accomplish their missions as designed if even in a backup or secondary role.

Description of Technology

Success from our initial efforts with CTMA and NCMS as early as FY 2000 involved the insertion of very capable inspection testing of EWIS using the Automated Wiring Analysis (AWA) product line. That first effort to a Joint Service Acquisition of the Automatic Wire Test Set (AWTS) for use by D, I, and O level maintenance activities world-wide. It includes hardware and software which has resulted in reducing historically very long troubleshooting

times and reducing them from days/hours to just a few minutes. Feedback voiced and documented show a clear request to advance the technology and also reduce footprint so that it can be further deployed at more limited O-Level maintenance tasks.

This response has led our organization to produce a new product line known as the Mini-Mux™. The plan of this project is to take a luggage size test equipment and brings it down to in size to that of a hand-held. Our plan integrates and improves the device in order to enable use on the actual weapon system. We plan to concentrate further development for on aircraft Electrical Wire Interconnect System (EWIS) inspection, test and troubleshooting tool.

Current Development Status of the Technology

Technology to be used is currently a DoD ATS Directorate approved support equipment sets. It is readily available to the warfighter for maintaining sophisticated, complex, and high-cost Weapons Replaceable Units, Line Replaceable Units and the interconnecting EWIS itself. Using the Central Processing Unit element of the support equipment

will allow for modification of the Eclipse Language Integrated Test Environment (ELITE™) to include capability for data tie-in to Mini-Mux™ directly without use of the larger circuit analyzer.

Test/Simulation Data Supporting Performance Claims

The Automatic Wire Test Set (AWTS), is a DoD approved support equipment. It is readily available to the warfighter for maintaining sophisticated, complex, and high-cost Weapons Replaceable Units, Line Replaceable Units and the interconnecting EWIS itself. The AWTS System provides test results on failures experienced at each level of maintenance, to include Intermittent operation, Cannot Duplicate and Re-Test Okay.

Next Steps/Potential Benefits

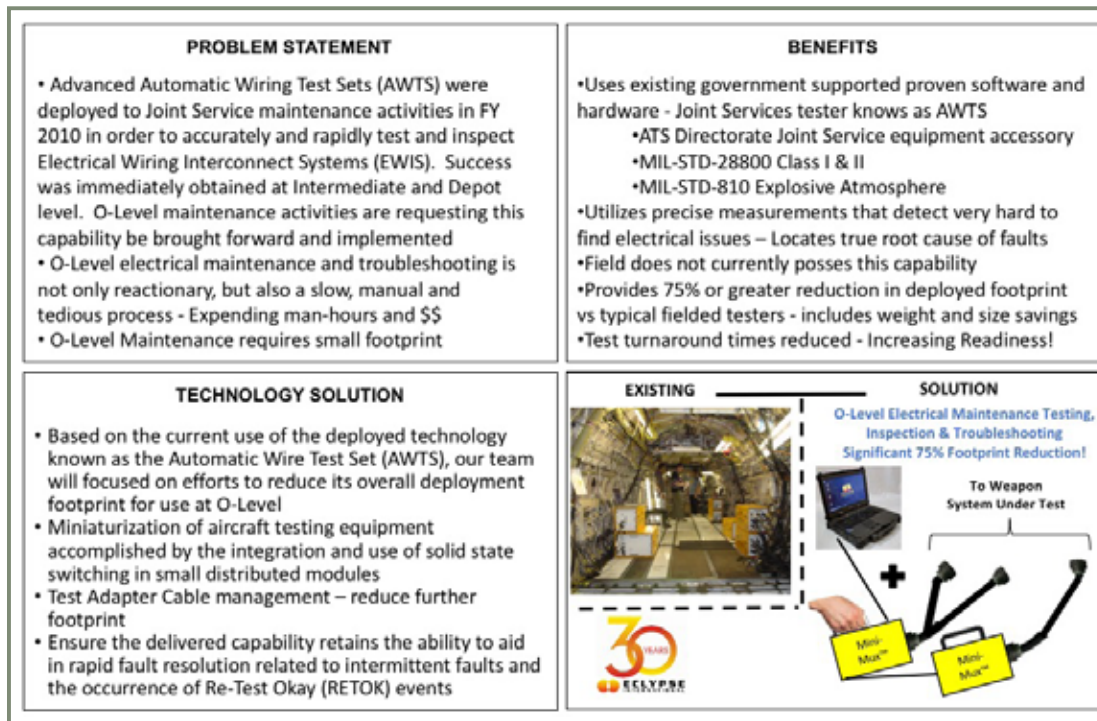
Benefits would bring a never before capability to government field activities which includes an automatic and repeatable test method for:

1. Reactionary Troubleshooting of complex electrical systems – Rapid detection of even the hardest to locate faults (intermittent system failures, corrosion, moisture, and similar) by use of testing

the end item without the need to physically manipulate components.

2. Preventative maintenance by use of a proven "Certification Test Protocol" adopted by the Joint Services due to its diagnostic value to accurately and precisely determine faulty paths that are causing the faults including those types mentioned in A.
3. Predictive analysis on current health and ability of the electrical system to perform as designed.

Use to date by military customers has provided 90% + improvement in those electrical systems using it. Reduction in over 50% of Avionic Spare requirements (due to historical misdiagnosis by Fault Isolation Procedures). End customers include but are not limited to - US Army Aviation, US Navy and Marine Corps, and the US Air Force.



FOAM FILLED TIRES AND RED GEAR WHEELS

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Naval aviation wheels operate in extreme conditions: high loads, high speeds, high temperature, high moisture and salinity, while at the same time having tight geometric and material tolerances. The inherent engineering and operating environment of naval aviation wheels causes these high value assets to have high scrap rates, costing the Navy tens of thousands of dollars per wheel. For example, one F/A-18A-D main landing gear wheel costs upwards of \$20,000 dollars. We cannot afford to limit our mission environments or envelopes, but what we are able to do is extract value out of wheels even after they stop being airworthy.

Foam filled tires are used where operations are low speed and the goal is to minimize maintenance while simultaneously maximizing service life. Foam filling, as the name suggests, turns pneumatic tires into solid tires by filling them with a two part liquid polymer mixture that solidifies after 24 to 48 hours. While the foam filling process increases the mass of the tire, it also makes it impervious to punctures, maintenance-free and increases safety due to there no longer being an explosive

potential. Most importantly for this project, foam filling enables the use of wheels that are no longer suitable to withstand the high inflation pressures of naval aviation tires. An F/A-18A-D main landing gear tire serviced for carrier operations holds 350 psi of pressure, enough to seriously injure personnel or damage the aircraft if it were to fail. Using foam filled tires on temporarily or permanently grounded aircraft would not only eliminate all tire servicing requirements, it would also eliminate any tire safety concerns.

The application of foam filled tires in naval aviation maintenance can improve safety, reduce costs and increase the supply of airworthy wheels available to the fleet by using red gear wheels wherever airworthy ones are not needed. Foam filling can also reduce costs and maintenance in all other places where pneumatic tires are used: Fork lifts, cranes, carts, dollies, tow vehicles and auxiliary equipment.

PROBLEM STATEMENT

- Currently, a majority of aircraft in long-term storage and preservation, planned maintenance (PM), as well as stricken aircraft, have airworthy wheel and tires installed.
- Aircraft wheels with a high scrap rate are at risk of supply shortage.
- Aircraft wheels becoming scrap with no further value to the DoD.
- Aircraft in PMI still need to follow tire and wheel inflation, maintenance and safety procedures because their tires hold high pressures.

BENEFITS

- Increased safety:
- No inflation pressure = No explosive potential
- Unlocks value of scrap wheels by using them as red gear.
- Decreased tire and wheel maintenance.
- Capable and safe beyond normal wear limits.
- Impervious to FOD.

TECHNOLOGY SOLUTION

- A foam filled tire is a pneumatic tire made into a solid tire by filling it with expanding foam or two part liquid rubber that hardens.
- Potential use in any situation where weight is not a concern (storage, PMI towing, AMARG).
- Potential for any low speed application that has pneumatic tires (component dollies, trailers, etc.)



MELD: A NOVEL SOLID-STATE TECHNOLOGY FOR SUSTAINMENT

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Sustainment challenges continue to emerge in the dynamic environments in which we operate while engaging our adversaries. The ability for our Nation's war fighters to maintain and repair strategic assets in the field or at sea not only improves operational efficiency but also reduces overall cost and logistics overhead. There is a need to enable these types of sustainment activities for materials that are not compatible with traditional repair strategies, such as high-strength aluminum alloys used in aircraft landing gears, armor plating for light-weight ground vehicles, and structural components of LCS watercraft.

MELD is uniquely suited to provide both cost and time effective repairs in theater. MELD represents a portable process able to build, repair, and join metals, including non-fusion weldable materials.

The MELD process has unique benefits. It creates fully-dense products with little-to-no distortion at deposition rates orders of magnitude faster than other metal additive processes. MELD is a solid-state no-melt process, which yields near net shape parts with superior mechanical properties,

meaning there is potential for parts to go from the machine to the field. MELD is an open- atmosphere process and is not restricted to vacuum chambers or powder beds, allowing for extreme scalability to make or repair large structures. By the nature of the process, all depositions, repairs, and coatings are fully dense and do not require any additional processing for densification such as sintering or hot isostatic pressing.

Deposition rates are extremely high; for example, MELD currently exceeds 30 lbs per hour in Aluminum. Machines have a low operating cost (comparable to a CNC mill) and can be operated by traditional machinists. Special material is not required. MELD is compatible with a wide array of materials including, but not limited to, stainless steels, titanium alloys, nickel alloys, copper alloys, magnesium alloys, and aluminum alloys, including non-fusion weldable alloys such as 2XXX and 7XXX series. MELD machines work with solid bars of metal, removing the risk of explosion and health hazards inherent in metal powder.

Over the last decade this technology has been matured and repairs have been

demonstrated while working with partners, including ONR, NAVSEA, TARDEC, and AIR FORCE, and is now commercially available. Types of repairs demonstrated include cracks, simulated ballistics damage, and corrosion pitting. MELD offers a multifunction technology to those tasked with MRO activities within one piece of equipment, such as the ability to print near-net parts that are difficult or costly to procure, the ability to repair the unrepairable, and the ability to add corrosion/erosion resistant coatings to existing structures.

PROBLEM STATEMENT

Sustainment challenges continue to emerge in the dynamic environments in which we operate while engaging our adversaries. The ability for our Nation's war fighters to maintain and repair strategic assets in the field or at sea not only improves operational efficiency but also reduces overall cost and logistics overhead. There is a need to enable these types of sustainment activities for materials that are not compatible with traditional repair strategies, such as high-strength aluminum alloys used in aircraft landing gears, armor plating for light-weight ground vehicles, and structural components of LCS watercraft.

TECHNOLOGY SOLUTION

The MELD process is a solid-state additive technology enabling the repair of otherwise unrepairable assets due to the part's/component's inherent material limitations. MELD is a field deployable technology able to expeditiously repair, join, and build metal components, including non-fusion weldable materials such as high-strength aluminum alloys. This technology has been demonstrated on projects with numerous defense partners, including ONR, NAVSEA, TARDEC, DEVCOM, and AIR FORCE. MELD Machines and Services are commercially available and have a high TRL/MRL.

BENEFITS

- **Compatibility:** MELD is compatible with all metals, including non-fusion weldable high-strength aluminum alloys.
- **Throughput:** High deposition rates enabling rapid repairs (30 lbs/hr in Al).
- **Operation:** MELD systems are user friendly and field deployable.
- **Logistics:** No limitations on material source. Use the material you have on hand to perform the repairs
- **Safety:** No flammable or hazardous powders required.
- **Performance:** materials deposited during the repair operation possess wrought or better properties.



HIGH EFFICIENCY ENGINE IMPROVEMENTS FOR OPTIMIZED SUSTAINABILITY

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Because of their breathing deficiencies, many utility and service engines operate well above the necessary RPM that should be required for a given power demand. In recent years, forced induction has been used to counteract this problem. Many of these engines, however, are not or cannot be supercharged or turbocharged. As a result, maintenance cycles are shorter than they could be due to higher wear affecting the engine's reliability. It has been shown that, from a reliability standpoint, higher cylinder pressure is preferable to higher piston speed to meet a power load requirement. This has been borne out in practice in the automotive industry, where mean piston speed in cruise mode has been lowered dramatically in the last decades, resulting in improved mileage and much longer engine life. The key to solving this problem is to make the engine breathe more efficiently, and combust the mixture more quickly and completely. Not only does this consume less fuel, but less heat is transferred into the engine. Increased intake flow energizes the cylinder more fully, which creates a faster, more consistent flame-front.

A unique porting system has been developed to meet these needs. Instead of the standard single port for each intake valve, Twin Vector Induction (TVI) uses two straight, high efficiency ports set up tangentially to the valve annulus. This new system eliminates the flow restriction from valve stem interference and "near side" tuning losses. Its balanced flow around the entire valve annulus makes the system backflow resistant, even under high load at low RPM, and allows maximum breathing. The tangential ports generate swirl, and promote combustion efficiency.

Dynamometer testing on otherwise identical engines has justified these claims. Four iterations of the Cosworth BD series engines have been before-and-after tested with TVI cylinder head replacements. All features other than the porting remained exactly the same. In all cases, the peak power increased by 15% or more; and more importantly, the low and mid-range performance was radically higher. Peak cylinder pressure rose from 14.5 bar to 17 bar. At the same time, the full ignition advance dropped by a minimum of 7 degrees, fully

demonstrating the combustion efficiency improvements. Many service engines operate in a steady-state mode for extended periods; TVI equipped engines make more torque at lower piston speeds.

The technology is ready for market adoption, and can be used with any standard IC piston engine. Anticipated downstream developments include engines specifically designed for TVI that completely eliminate top ring crevice pollution, and allow superior exhaust gas energy recovery (EGER). From ground-based utility engines to UAVs, TVI-equipped engines will be smaller, lighter, easier to handle, and have longer TBO's than other piston engines. Forced-induction TVI engines will require less boost to produce the same output.

PROBLEM STATEMENT

The price of energy/sustainment continues to rise over time. Concerns over climate/cultural changes have been identified as critical issues threatening the environment and the overall security of the US

Because of breathing deficiencies with internal combustion engines, many utility and service engines operate well above the necessary RPM that should be required for a given power demand. In recent years, forced induction has been used to counteract this problem. However, many of these engines cannot be supercharged or turbocharged.

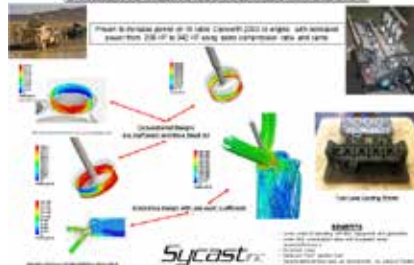
TECHNOLOGY SOLUTION

A new, unique head porting system has been developed to meet these needs. Instead of the standard single port for each intake valve, Twin Vector Induction (TVI) uses two straight, high efficiency ports set up tangentially to the valve annulus. This new system eliminates the flow restriction from valve stem interference and "near side" tuning losses. Its balanced flow around the entire valve annulus makes the system backflow resistant, even under high load at low RPM, and allows maximum breathing.

BENEFITS

- Improved Engine Efficiency
 - Reduced Carbon Footprint
 - Engine Temperature Cooler
 - Improved Reliability
 - Reduced Maintenance
 - Improved Vehicle Range
 - Increased Engine Performance/Horsepower
- Lower Cost of Sustainability
- No Hard Tooling Required Utilizing Additive Manufacturing

INNOVATIVE CYLINDER HEADS UTILIZING AEROSPACE TECHNOLOGY



RELIABILITY IMPROVEMENT (HARDWARE)

ZOLLER »ZIDCODE« FOR RELIABLE, ACCURATE AND EFFICIENT DATA TRANSFER

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Problem :

Finding a reliable, secure, accurate method for transferring tool life data and tool offset information to the machine controller is a constant challenge. The process often involves human intervention - the operator will hand key in the tool offset values or tool life information. But what happens if the operator makes a mistake in transferring this information to the machine controller?

To put it simply, you leave your manufacturing process open to potential errors, which could result in anything ranging from time wasted on inefficient processes, to a scrapped part or even a machine crash.

The real challenge lies in having a secure mechanism to transfer tool offset and tool life information in a fast, reliable and user-independent way for all machine tools in a time-saving manner.

Challenges:

- Achieving Reliable Data Transfer
- Eliminating the Potential for Human Error (typos at Machine Controller)

- Guaranteeing 100% Accurate Tool Life and Tool Offset Information at the Machine Controller
- Eliminating Scrapped Parts

Technology Solution:

The ZOLLER »zidCode« is the reliable, flexible and efficient way to transfer tool data from the presetting and measuring machine directly to the machine tool. »zidCode« offers a quick, correct and paperless process for direct data transmission at the respective machine tool with no possibility for data entry errors.

The ZOLLER »zidCode« is connected to the machine controller, either via RS232 cable, USB cable or via RJ45 cable. By scanning the tools or setup sheet information, tool offsets and tool life information is transmitted via Bluetooth technology. »zidCode« ensures DoD Maintenance Facilities are prepared to respond in a fast, work efficient and accurate manner to produce critical parts.

Benefits:

The ZOLLER »zidCode« provides many benefits in creating a more reliable, efficient

and accurate production process and fits seamlessly into existing processes, including:

- Process Security
- 100 % Correct Tool Offset Information at the machine controller
- Tool life and warning limit information at the machine controller
- Improved productivity, reliability
- Paperless Process

Flexible Integration:

- Any machine tool controller (of any age) can be integrated with low investment

PROBLEM STATEMENT

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GRAPHIC OR IMAGE



MODULAR AND CONFIGURABLE SUBSEA ROBOTIC ARM SYSTEM

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Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility (PHNSY & IMF) has focused on adopting a culture of affordability by teaming with the U.S. Naval Academy (USNA) to design, test, and field a modular and configurable subsea robotic arm system that complements the Remotely Operated Underwater Vehicles (ROUVs) used in the shipyard's maintenance, salvage, and mobile repair efforts. The subsea robotic arm system allows for specific modular capabilities required by the shipyard dive locker at a cost less than commercial procurement of a similarly capable system while strengthening ties to external agencies. In short, the subsea robotic arm system has a simple, user-friendly design that can quickly enhance the capabilities of any ROUV within the Department of Defense at a low cost, and utilizes readily available resources found within PHNSY & IMF.

The main successes of this project include:

1. The robotic arm is fully functional, can be operated using an Xbox controller, and has been through in-water testing
2. The robotic arm can be configured for a range from 1 to 8 degrees of freedom
3. The output torque, each joint, and end-effectors can be changed to fit individual needs
4. It can be reconfigured to a different application in under 15 minutes with only two wrenches
5. The low production cost and its ability to be repaired or reproduced in a basic machine shop
6. It can be adapted to work in littoral or deep sea operations
7. Increased safety for diving missions as ROUVs paired with the robotic arm can be used instead of divers

The robotic arm project will significantly reduce long term costs for the Navy's ROUV efforts. The PHNSY Divers currently use two models of commercial ROUVs without robotic arms. A larger commercial ROUV with robotic arm costs approximately \$450,000. Based on the new design, the cost to manufacture a robotic arm is approximately \$6,000-\$8,000, as opposed

to commercial robotic arms, which cost roughly \$60,000. The robotic arm can be manufactured, reproduced, and repaired using affordable materials and can be made in a basic machine shop.

PHNSY & IMF will further partnership efforts by establishing a relationship with the USNA and the University of Hawaii at Manoa (UHM) School of Engineering to use students to improve the robotic arm design. This teaming relationship further exposes students to PHNSY & IMF resulting in possible future collaborations and an increased pool of future candidate employees from the UHM. Launching multiple partnerships between PHNSY & IMF and academic institutions for developing robotic arm technology. This enables PHNSY & IMF to reproduce robotic arms, which significantly reduces costs over the life cycle of the robotic assets and allows scaling of capabilities at a fraction of the cost of commercial procurement. This savings may be spread throughout the Naval enterprise and other shipyards who are interested in our products.

PROBLEM STATEMENT

Navy Divers currently use remotely operated underwater vehicles (ROUV) designed for largely commercial purposes to augment the human divers' capabilities and capacity. The capability set required by Navy Divers spans a scope greater than any one commercially available robotic solution achieves. Rather than buying several limited-capability platforms, Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility (PHNSY & IMF), with partnership with the US Naval Academy (USNA), is developing payload-based capabilities to augment existing robotic platforms.

BENEFITS

- Allows for procurement of lower-cost host ROUVs
- Reduces cost of payloads by incorporating design, development, and testing into student projects
- Can be manufactured and reproduced by sponsoring organization resulting in at-cost production for future copies
- Payloads tailored and developed to meet future mission needs
- Payloads adaptable to future robotic host platforms; payloads optionally used as standalone or diver-carried.
- Increases STEM outreach by teaming with universities
- Cost to manufacture \$6-8K vs. purchase commercial >\$60K
- Design supports >1000 feet application.

TECHNOLOGY SOLUTION

Modular Robotic Arm Systems provide mission-tailored, low-cost capabilities using an ROUV to host configurable mission-essential payloads. The Modular Robotic Arm was developed with the USNA and includes:

- 5+ degrees of freedom (DOF) motion that exceeds the human arm
- Modular joint allows for interface with various host robots, ship's hull, or static objects (e.g. mount of harbor bottom)
- Universal shoulder allows the arm to rotate 360 degrees at the base
- Modular hand joint allows for development of various graspers, cutter, and other manipulators

GRAPHIC OR IMAGE



MESHBOX FOR MAINTENANCE ACCOUNTABILITY

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Problem:

Many maintenance facilities and bays where mechanical work is conducted to maintain and repair vehicles and other heavy equipment lack network infrastructure. This inhibits maintainers and their managers' ability to take advantage of real time reporting of parts inventory and tool accountability. There exist products that provide connected and RFID enabled equipment to address accountability and inventory counts, but these devices are large and require infrastructure for power and networking. For military services and companies that operate in austere environments, the logistics of managing these products becomes complex. Therefore, they are left behind when operating in field type environments, and maintainers revert to paper-based methods of tracking inventory. In these instances, the standard procedure is to place items in boxes and palletized containers. These storage devices lack technology to provide an inventory count or item accountability in a dynamic environment. Additionally, in military environments, cybersecurity concerns prohibit the ability to connect these devices to a network in a rapid fashion.

Approach:

IRT proposes to provide configurable and scalable Meshboxes to address this problem. Meshboxes consist of bins and boxes that contain embedded shelves that sense the weight of items and RFID reading technology to account for higher value items such as RFID marked tools and critical parts. Additionally, the Meshboxes contain a low-cost Internet of Things based Box Management Device (BMD). The BMD maintains the inventory and accountability through connection to the weight sensors and RFID antennas. The BMD is powered by a rechargeable battery, solar powered lids, or plug in house power. Furthermore, they use standard Wi-Fi direct technology to create local networks that can be used by other devices in maintenance facilities. Depending on an organization's cybersecurity policies the local mesh network can be connected to the enterprise network or the Internet. In the case of strict no connection policies, each Meshbox contains the ability to convert the data to an optical format that can be read by standard accredited bar code readers for uploading each box's information to enterprise systems. An advanced version of this capability allows automated transfer

of data through the "air gap" into the secure network environment.

Benefits:

While a Meshbox will cost more than a simple box or standard PALCON, all requirements for inventory and accountability of maintenance parts and tools as well as real time or near real time reporting is provided. These boxes are more mobile and just as capable as larger infrastructure based connected accountability devices and are operable in multiple environments. A group of Meshboxes can enable the benefits of a network where none currently exists, supporting decreased maintenance and repair cycle times while reducing loss of tools and critical parts.

PROBLEM STATEMENT

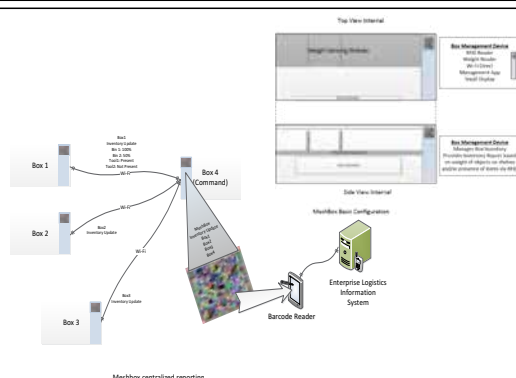
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LOW-MAINTENANCE, HYDROPHOBIC, NON-DELAMINATING RADOME

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The US Air Force owns and maintains radomes all over the world, which are used to enclose and protect ground-based radar systems and personnel from harsh elements. For the radar systems to work effectively, the radomes require rigid panels that must be transparent to the radar frequencies. Many of the older radar systems are no longer in production; thus, it is critical that the radomes protect the radar systems since replacement parts are expensive and require a long lead time. In addition, the current radomes are delaminating before their design life is reached, requiring premature panel replacement and needing continual maintenance to sustain their operational effectiveness.

The Tactical Shelters, Radomes and Towers (TSRT) Office spends ~\$4M/yr for radome maintenance. To improve radar performance and save on maintenance costs, AFLCMC and AFSC in an open SBIR solicitation, awarded Phase I and II to Ebert Composites Corporation. The goal of the R&D award was to research, develop and procure an innovative hydrophobic, non-delaminating and low-maintenance solution for the next generation radome.

The newly developed Teflon (PTFE-infused) technology, processed on the exterior of an innovative sandwich panel, has uniquely combined two technologies that do not delaminate and have a proven track record of remaining hydrophobic for 25 years in all climates, including arctic and arid. The non-delaminating, 3-D sandwich material has passed extensive analysis and coupon testing over the years. Applications for structural panels in various fields of use have successfully been deployed since 2002, verifying the integrity of the panels at 100% design load. The innovative material has had thorough coupon testing performed to verify the radar signal loss is within specifications.

This solution is expected to provide significant maintenance benefits over the life of the radome:

- Greater Reliability: 3D sandwich technology ensures non-delamination, which minimizes/eliminates premature radome panel replacement/maintenance
- Improved Performance: the radar signal never degraded due to poor exterior coating, thus reducing continual

maintenance to sustain radar operational effectiveness

- Proprietary Processing: a radome panel is pultruded in the spherical shape with the hydrophobic coating which is proven to last 25 years, reduces exterior maintenance
- Greater Cost Savings: lower installed cost and maintenance over 25 years

In a 2019 economic analysis, performed by the TSRT Office showed a payback period of 11 years and a saving over \$15M compared to maintenance of the legacy radomes.

The basic technology is fully developed and has been recently commercialized. The material can be customized to each specific radome system to meet the specific frequency, mounting type, and local and specific mission requirement. The FAA has purchased this technology for their radomes and the Air Force is planning on using the technology for future radome replacement.

PROBLEM STATEMENT

The US Air Force owns and maintains radomes all over the world. Many of these radomes are in difficult to reach locations in the arctic and remote islands in the Atlantic and Pacific oceans. These locations are expensive to get to and have harsh environments. Furthermore, the current radomes are delaminating before their design life is reached, requiring premature panel replacement and need continual maintenance to sustain their operational effectiveness.

AFSC, AFLCMC and Ebert Composites Corporation worked together to research, develop and procure an innovative hydrophobic, non-delaminating and low-maintenance material for the next generation radome.

BENEFITS

The material solution is expected to provide significant maintenance benefits over the life of the radome:

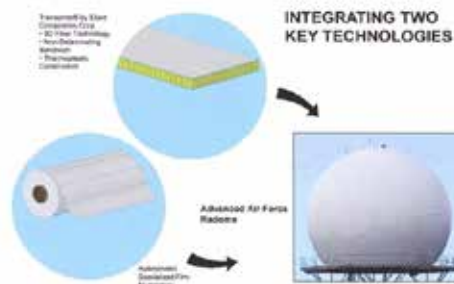
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TECHNOLOGY SOLUTION

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RELIABILITY IMPROVEMENT (HARDWARE)

INFLATABLE SCAFFOLDING (BECHTEL + NAVATEK)

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This submission is a cross-industry collaboration between Bechtel and Navatek.

Problem:

Conventional scaffolding is heavy, bulky, and labor intensive to erect/disassemble. It exposes crews to safety hazards and slows down production in a construction and/or maintenance environment. Inflatable scaffolding would allow teams to rapidly deploy a safe and easily configurable work platform anywhere and without heavy equipment.

Approach:

Inflatable scaffolding is an inflatable/deflatable multi-member, modular cube or other geometric design solution permitting transverse and longitudinal assembly with a configurable working platform, similar to traditional scaffolding, without compromising the structure integrity of the system. The incredibly durable composite textile material is a tested and proven material and is already US DoD approved.

Benefits:

The benefits of such a solution on the jobsite is that it is highly portable, light-weight,

confined space friendly, and can be hand assembled (no heavy machinery needed) therefore saving time and resources.

PROBLEM STATEMENT

Conventional scaffolding is heavy, bulky, and labor intensive to erect/disassemble. It exposes crews to safety hazards and slows down production in a construction and/or maintenance environment. Inflatable scaffolding would allow teams to rapidly deploy a safe and easily configurable work platform anywhere and without heavy equipment.

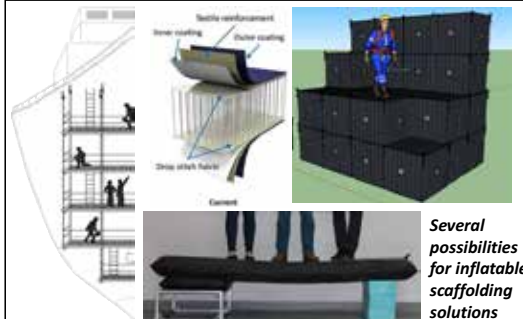
Inflatable Scaffolding: 'Work softer, not harder'

BENEFITS

- **Portable**, fit for purpose work platform on-demand.
- **Light-weight**, inflatable and modular enhancing mobility & accessibility.
- **Common** shipyard system (air system for inflation).
- **Modular** and highly configurable arrangements.
- **Confined space** friendly.
- **Semi-rigid**, safe around sensitive assets.
- **Crane / heavy equipment free** assembly.
- **Schedule & cost savings** for construction & maintenance projects

TECHNOLOGY SOLUTION

- Utilize **DoD approved composite** textile material – highly durable.
- Inflatable multi-member geometric design solution permitting efficient transverse and longitudinal assembly.
- Redundant, **multi-chamber ballasted** structures ensure rigid platform.
- Light-weight, **modular design** allows for manual assembly.
- **Interlocking coupling** mechanism allows for safe stacking configurations.



ATLAS COPCO - MOBILE ASSEMBLY STATION

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So how will Atlas Copco create value in the context of the Future of Assembly? The overall goal is to reduce rework, scrapping and warranty costs caused by defects. By providing in-station error-proofing and zero-fault fastening strategies with electric tools, it is possible to reduce assembly defects considerably. Our goal is provide a flexible production environment with optimized floor space, reduce station clutter and centralized visualization/management of equipment for faster/simpler rebalancing. Atlas Copco Tools are the gold standard in ergonomics, and are constantly evolving to provide safety improvements and to reduce training requirements.

How do we prevent with operator errors in the assembly process? Ex. Wrong torque, wrong fastener, missed fastener, incorrect process, new operator. How do we eliminate tripping hazards due to air lines and power cords? How do we address high torque applications causing ergonomics issues and injury risk? How do we eliminate the need for torque buyoffs (second employee needed to sign off on torque applied)? How do we

ensure that we have traceability back to each individual torqued bolt?

The answer? Atlas Copco's Mobile Assembly Station. Portable bench including: HLTQ PC with intuitive operator guidance software, RFID operator badge sign in/supervisor sign off, cordless/battery powered "smart" tools with capability to torque up to 120 ft lb one handed/reaction free, and smart socket/bit trays integrated into operator guidance software.

Proper assembly process is programmed into the Operator Guidance software, ensuring that the job is done correctly. The mobile station is free from power cords and air lines. Low-reaction battery powered "smart" tools improve ergonomics, eliminate injury risk, and improve quality. Data from each tightening is automatically stored and tied back to the operator who performed it.

Catch quality issues as they happen, not when it's too late.

PROBLEM STATEMENT	BENEFITS
<p>Operator error in assembly process. Ex. Wrong torque, wrong fastener, missed fastener, incorrect process, new operator</p> <p>Tripping hazards due to air lines and power cords</p> <p>High torque applications causing ergonomics issues and injury risk</p> <p>Second employee needed to sign off on torque applied</p> <p>No traceability back to individual tightening</p>	<p>Proper assembly process is programmed into the software, ensuring that the job is done correctly</p> <p>Mobile station is free from power cords and air lines</p> <p>Low reaction battery powered "smart" tools improve ergonomics, eliminate injury risk, and improve quality</p> <p>Data from each tightening is automatically stored and tied back to the operator who performed the work</p> <p>Catch quality issues as they happen, not when it's too late</p>
TECHNOLOGY SOLUTION	
<p>Atlas Copco's Mobile Assembly Station</p> <ul style="list-style-type: none"> • Portable bench • HLTQ PC with operator guidance software • RFID operator badge sign in/supervisor sign off • Battery operated "smart" tools with capability to torque up to 120 ft lb reaction free, integrated into operator guidance software • Smart socket/bit trays integrated into operator guidance software 	

MDMC M777 BREECH COLLAR REPAIR PROCESS

THOMAS PEREZ


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Marine Depot Maintenance Command (MDMC) is the primary provider of depot-level maintenance for the USMC's fleet of M777 Lightweight 155 mm Howitzers. While performing repairs, artisans discovered excess material loss in the base of the aluminum breech collar on around 50% of assets in production. Due to OEM design, the breech assembly was designed as an inseparable item with no drain to allow water to escape from the mating surfaces of breech collar and breech. Corrosion was further accelerated due to the breech collar and breech being dissimilar metals with inadequate coating between mating surfaces. Although breech collars were available for purchase, no process existed to separate the breech collar from the block. There was no choice but to replace entire breech assemblies at a cost of approx. \$64K each. Limited supply of breech assemblies put the fleet readiness in jeopardy as depot Repair Cycle Time (RCT) were increased due to lead-time of assemblies. With this critical component being so severely degraded, there was significant potential for asset failure and safety implications on deployed assets.

A collaborative effort between the Program Manager, Towed Artillery System (PM-TAS), and MDMC resulted in a benchmarking trip to Watervliet Arsenal in New York, the facility where the M777 breech was originally assembled. The purpose of the visit was to view the assembly process in order to design a process to disassemble the breech. A process was developed and documented at MDMC by subject matter experts. Prototype tooling and equipment were designed and fabricated to support the effort. Using the new process, MDMC was able to separate the breech collar from the block. It was evident that due to the OEM design, water was becoming trapped between mating surfaces and causing severe corrosion to form. Additional coatings were applied to both the aluminum breech collar and steel block in order to address the issue of dissimilar metals. A rust-inhibiting gel was applied to the threads between mating surfaces to further provide corrosion prevention.

Through the development and application of this process, there has been significant cost avoidance by being able to repair the breech vice replacing. The cost to repair

one assembly is \$1,200 compared to \$64K to replace. There is a 98% savings with this new process, which is 5,233% cheaper. MDMC has applied this restoration to over 200 assets, saving a projected amount of \$12M since implementation. M777's that have had the restoration applied are now returning back to MDMC for repairs, and upon inspection it has been found that corrosion and material loss is virtually nonexistent. MDMC continues to find innovation solutions to enhance service life expectancy and increase fleet readiness.

PROBLEM STATEMENT	BENEFITS
<ul style="list-style-type: none"> Depot-level repairs of M777 Lightweight 155mm Howitzers revealed that approximately 50% of their Breech Collars had significant material loss of the aluminum threads, (a critical part of the component). The OEM, Watervliet Arsenal, designed the Breech Assembly as an inseparable assembly. With no established repair process or tooling to remove and replace the Breech Collar, the only alternative was to purchase complete Breech Assemblies at a cost of approximately \$64K each. A limited supply posture of Breech Assemblies would result in negative impacts to fleet readiness. 	<ul style="list-style-type: none"> There is a 98% savings with this new process, which is 5,233% cheaper. The cost to repair one assembly (labor & materials) is approximately \$1,200, a significant savings in comparison to replacing the Breech Assembly (\$64K). Of assets returned from the fleet after having the new procedure applied, 100% of assets were deemed serviceable upon inspection with virtually no signs of corrosion. The efficiencies gained from this process have allowed MDMC to produce M777's more quickly, improving M777 fleet readiness by 50% and reducing life cycle costs. The potential for significant failure has been greatly reduced by maintaining material integrity and extending service life. This procedure was transferred to the Anniston Army Depot, creating cross-services savings, and Program Office, TACOM-PSID is in process of implementing in the M777 DMWR update.
TECHNOLOGY SOLUTION	GRAPHIC
<ul style="list-style-type: none"> Subject-Matter Experts determined excessive corrosion on the Aluminum Breech Collar was caused from trapped water between the Breech and Collar. A repair procedure was developed and documented by MDMC and approved by Program Manager, Towed Artillery System (PM-TAS). The new process enabled MDMC to safely disassemble the components and apply CPAC barrier, Tef-Gel®, and re-anodize the Aluminum. The repair was successfully demonstrated at MDMC and has been approved for use on production assets. 	

RELIABILITY IMPROVEMENT (HARDWARE)

T-GLASS

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A lack of experience repairing or modifying equipment ranging from a jet fighter to a rifle can be difficult without an experienced individual to guide one through the process. Technical Manuals are often difficult to navigate in instances less than absolute certainty, and maneuvering through the manual can be a lengthy task. To eliminate the cumbersome manual, the San Jose Innovation Cell plans to create a device known as T-Glass: ballistic protective eye-wear which allows one to search technical manuals using hands-free, voice activated technology. T-Glass will be retrofitted with an ambidextrous, modifiable, and easily adjustable computer eye lens which has the capability to allow the user access to technical manuals with voice activated search functions, while simultaneously repairing gear.

The use of this technology will mitigate the need for constant pacing between a physical paperback technical manual and the broken piece of equipment, or the use of a laptop containing a virtual copy of said technical manual as well as providing a hands free search option. The technology will allow maintainers to increase their level

of efficiency by reducing the amount of time needed to refer to manuals that would otherwise take additional time to search through, either by walking back and forth between the gear and manual or computer screen. Not only does this make the lives of maintenance personnel easier and more efficient, but it will significantly decrease time wasted and increase unit readiness by making it possible for personnel to allocate the time saved towards other tasks for their unit.

In addition to the aforementioned improvements this technology can provide a relatively inexpensive alternative to utilizing a laptop, and far less cumbersome than a lengthy paperback. Technology similar currently exists. One notable example is the Google Glass. AdaFruit has also made a similar project using a Raspberry Pi and a pair of glasses. Both of these devices can be used to browse the internet privately through an eyepiece overlaid on a lens and attached to a pair of glasses. The T-Glass will be specifically used to look up Technical Manuals. Future versions of the T-Glass will include utilizing mixed reality headsets similar to Microsoft's HoloLens,

and 3-dimensional surface recognition which will have the ability to display 3D models in within immediate vision. This product will essentially replicate having a computer overlay everywhere you look.

While the technology is developing and being improved on a regular basis, we will create a similar product moving forward whose focal point is the military maintainer. It is our intent to completely rid the military of paper-training manuals. If all the information ever needed is available everywhere one looks while continuing to work hands-free, we will greatly decrease work time, increase efficiency, uphold safety standards, and reduce wasted time. We intend to provide that necessary change.

PROBLEM STATEMENT

- Maintenance activities require the use of both hands, often while attempting to follow detailed instructions or checklists within equipment Technical Manuals.
- First major innovation in Technical Manual utilization
- Removes necessity of cumbersome paper manuals and laptops
- Available immediately when needed
- Dual purpose as protective eyewear

BENEFITS

- Reduces the time needed to access technical data
- Increases efficiency of maintenance personnel
- Protects the eyes from potential hazards
- All relevant Technical Manuals available instantaneously
- Hands-free feature allows for easy searching

TECHNOLOGY SOLUTION

The T-Glass incorporates well-known voice-activated technology common in everyday life, and links the advancement to maintenance personnel, allowing the maintainer access to Technical Manuals, all while hands-free.



RELIABILITY IMPROVEMENT (HARDWARE)

REVERSE WEAR WITH ANISOTROPIC (STICKY/SLIPPERY) NANOFLOAKES DURING NORMAL OPERATION

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Often miniscule amounts of wear render many devices inoperable or severely reduce their performance. Common devices that are susceptible to wear include; bearings, hydraulic actuators, pumps, engines, gearboxes, and etc. Compression loss, hydraulic fluid leaks, noise, vibration are so ubiquitous that repair and overhaul of such components constitutes substantial part of maintainers workload in all branches of the US military and industry. Condition Based Monitoring identifies onset of the wear early on by vibration, oil temperature increase, acoustic and thermal emission. However, no cost-efficient solutions previously existed to address early wear problems during normal operation without costly downtime.

TriboTEX® developed flat nanoparticles with two functionally different sides to form functional friction reducing and wear reversing films during normal operation of mechanisms. The “sticky” side of nanoflake binds to the surface of the part, under normal load, thus reinforcing the surface. While the other side, the “slippery” side provides a reduced friction surface. When particles build up on the surface, particle by particle, the thickness of the

film compensates for years of accumulated wear restoring the part to better than new conditions. We actually coined a marketing term REVERSE WEAR indicating an increase in part mass and our unique approach to early wear mitigation.

Currently, our self-forming and self-healing nanocoating has been deployed in tens of thousands of internal combustion engines and show dramatic improvement in operational parameters such as fuel consumption, compression and oil pressure. In addition, subjective parameters including noise, performance, and smoother operation also improved. Low duty cycle engines are especially responsive to a TriboTEX treatment including standby generators, ground support equipment and idling vehicles at depots. TriboTEX is also widely applicable in mission-critical applications ranging from improving performance and longevity of gearboxes, engines, and firearm barrels. We designed TriboTEX to repair and upgrade without disassembly or downtime, keeping in mind a variation of applications. It is easy to apply in a single application with long lasting results.

Additionally, it is safe to handle and transport due to its nontoxic, nonflammable nature. TriboTEX is applied in low volume quantities due to the fact that only a small amount is needed to gain the benefits of billions of nanoparticles.

For maintenance operations in the defense sector, TriboTEX has the ability to reduce the amount of routine maintenance required, saving millions in repairs and keeping equipment mission ready.

Value Proposition: Repair and upgrade without disassembly or downtime in a multitude of applications.

TriboTEX technology received the Defense Innovation Award 2017, National Innovation Award 2017 AFWERX Phase I SBIR Award.

Problem

Miniscule amounts of wear often leads to large issues in many systems. Loss of operability or performance due to wear is common in many components such as bearings, engines, hydraulic actuators, pumps, gearboxes, etc. Compression loss, hydraulic fluid leaks, noise, vibration are so ubiquitous that repair and overhaul of such components constitute substantial part of maintainers workload in all branches of military and industry.

Condition Based Monitoring identifies onset of the wear early on by vibration, oil temperature increase, acoustic and thermal emission but no cost-efficient solutions previously existed to address early wear problem during normal operation.

Benefits

Fast and easy

Adding TriboTEX® nanoflakes to existing lubricant or fuel **takes seconds** and requires **no disassembly** or system modification.

Effective

Resulting **surface is harder** than underlying substrate and poses **self-healing** properties with **extreme reduction in friction**.

Condition Based Monitoring Integration

Enabling technology to **boost Condition Based Monitoring** efficiency, deployment, and wide adoption.

TriboTEX offers smart lubricant forming coating on surface of parts from flat nanoparticles with two functionally different sides (sticky/slippy). Coating rebuilds and upgrades friction surfaces of lubricated mechanisms during normal operation

Relevance including Transition to Military Systems or Programs: **Mechanical life extension and efficiency boost of existing machines (bearings, actuators engines, and gearboxes)** Mid-life in-field mitigation of early wear in response to CBM+ Lower barrier of entry point into supplemental equipment Civilian edition (TRL 7) deployed in >35,000 cars, growing demand. Available for consumer vehicles on Amazon, Walmart Further expansion into other Military platforms
TRL: Current – 6 Anticipated – 8



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RELIABILITY IMPROVEMENT (HARDWARE)

UNIVERSAL O-LEVEL ARMAMENT TEST SYSTEM MTS-3060A SMARTCAN

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Today's flightline armament maintainer faces the challenging task of performing O-Level activities with an existing (legacy) generation of armament test sets that greatly limit the ability to quickly and efficiently verify armament system readiness, diagnose failures, and return the aircraft to service.

Warfighters have identified an armament test gap that exists across legacy 4th and 5th generation aircraft equipped with "smart" weapon technology (MIL-STD-1760). The current USAF handheld O-Level test set (SERD-75060 and A/E241-199) is only capable of performing stray voltage and continuity tests of the MIL-STD-1760 Bus. This approach does not detect digital faults and will not fully validate the functionality of the interface requiring the use of additional, larger test sets.

The resulting maintenance ConOps of using multiple test sets increases maintenance costs (longer test times, training, logistics support), impacts readiness uncertainty, results in a larger footprint (size and weight) and lacks commonality across aircraft platforms.

Maintainers understand these short comings and have expressed the need for a common solution that supports smart (MIL-STD-1760) and legacy weapons, functions across multiple aircraft platforms, adheres to cyber security requirements, supports predictive maintenance, provides menu driven operation for ease of use and training, and maintains a small, handheld form.

The MTS-3060A SmartCan Gen2 Universal O-Level Armament Test Set was developed to address these needs; the result is an advanced flightline armament test set capable of testing any aircraft and weapons systems. This tester weighs just 4.2 lbs., and incorporates over 30 measurement channels, electronic loads, multiple communications interfaces (MIL-STD-1553, MMSI, Ethernet, CAN Bus, RS-485), a switch matrix, and video/audio signal generators. Data collection and storage is also included for trend analysis and predictive maintenance.

Field setup and test times are significantly reduced. F-16 test setup, when compared to the current solution, was reduced from

45 minutes to 4 minutes; (91% reduction). Similarly, F-16 test execution times for a pylon utilizing MIL-STD-1760 and the LAU-129 were reduced from 20 minutes to 3 minutes (85% reduction), and 35 minutes to 4 minutes (89% reduction) respectively. F-15 testing realized similar savings.

Logistics footprint, training and support requirements are also significantly reduced. Field input from one FMS customer documented that (6) flightline test sets used on the F-16 and F-15 were replaced by (1) MTS-3060A SmartCan, significantly reducing their logistics footprint. Benefits were also realized from consistent and common training for all aircraft armament specialists. An extended 4-year calibration cycle and (6) AA battery operation further enhance maintainability.

Advanced cybersecurity features and protection are provided including data and test program set (TPS) encryption, and removable.

PROBLEM STATEMENT

- Currently deployed flightline (O-Level) test sets limit the maintainer's ability to quickly and efficiently verify armament system readiness, diagnose failures, and return the aircraft to service after repairs have been completed
- Factors impacting current flightline test set effectiveness include:
 - Very limited test capabilities for all hand-held test sets
 - Requires at least (2) armament flightline test sets per aircraft
 - Extremely long test times
 - Cybersecurity vulnerability
 - Large flightline footprint - size / weight
 - No predictive maintenance capabilities
 - Inconclusive test results - false positive / negative
 - Limited or no support for "smart" weapon systems (MIL-STD-1760)
 - No commonality across aircraft platforms - multiple test sets required

TECHNOLOGY SOLUTION

- The MTS-3060A SmartCan Gen2 Universal O-Level Armament Test Set delivers comprehensive flightline test capabilities in an intuitive, handheld, light-weight, battery powered instrument
- Innovative, state-of-the-art design delivers the most advanced handheld flightline test set available today, eliminating the need for multiple test sets and associated cables
- Broad measurement capability including MIL-STD-1553, CAN, Ethernet, RS-485, MMSI, Audio, Video, e-Loads, Cable ID and more than 30 Analog / Digital measurement channels
- Supports multiple aircraft and their armament and munitions employing emulation - enables active versus conventional passive testing
- Currently deployed around the globe on multiple aircraft platforms with (10) FMS customers including the Israeli, Korean, Finnish, Turkish, Thai, Iraqi, Polish, Chilean, Indonesian, and Philippine Air Forces

BENEFITS

- Compact, hand-held, lightweight, intuitive warfighter machine interface
- Significant reduction in test time and weight:

	Test Time (min)		Setup (min)	Weight (lbs)
	Pylon with MIL-STD-1760	LAU-129		
MTS-3060A SmartCan	3	4	4	4.2
Current F-16 Test Set	20	35	45	83.8
Improvement w/MTS-3060A SmartCan	85%	89%	91%	95%

- Advanced cybersecurity features and protection
 - Data and TPS encryption / removable SD storage
- Simplified life cycle support, training, and maintenance
 - 4-year calibration cycle / AA-battery operation
 - Predictive maintenance capability with printable test logs
- Weapon emulation for comprehensive armament test vs. passive testers
- Single test set capable across multiple aircraft and weapons systems
 - F-35, F-15, F-16, F/A-18, A-10, FA-50, F-5, TA-50, Hawk, RPA
 - JDAM, SDB, AIM-9, AIM-120, AGM-65, Gun, AGM-84/88, AGM-114



SKYPLATES: PARTS MANAGEMENT SYSTEM

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The parts management system is the integration of Continuous Improvement into maintenance execution. A specific emphasis on time-tested Lean methodologies as applied within automotive and aerospace has now been expanded for weapon system maintenance services. It all begins with the application of 5S + Safety.

Sort: Each parts management system is engraved to identify what part of the weapons system it represents and where the hardware from the weapon system component will be installed in the parts management system.

Set: Our parts management systems arrange hardware according to an organized system.

Shine: Our parts management systems are powder coated in brightest colors to visually attract the human eye.

Standardize: Our parts management system hole configuration create a culture of consistent hardware management which increases maintenance effectiveness and boosts productivity.

Sustain: Creates a new standard of maintenance cleanliness and organization. Each time our parts management system is used, a maintainer is trained on hardware location on the weapon system and necessary hardware management discipline and organization. It creates a habitual cycle of sustainment.

Safety: All parts and hardware are accountable in one location at all times. No longer are there loose parts and hardware floating around the maintenance floor. This consolidation eliminates FOD saving valuable life's and preventing injuries.

Boost Productivity: Productivity is the function of an efficient process and effective result. Our parts management systems eliminate wasted materials, man-hours, labor cost, and time. This results in minimizing maintenance turn times. This streamlined system organizes hardware and parts off the weapon system into a single location, while simultaneously training maintainers on the orientation of parts and hardware. This improves efficiency, increases quality, and makes it simpler to spot discrepancies.

In the past, off-weapon system parts and hardware were stored all over the hanger floor or maintenance area in paint cups and plastic bags; they are now organized into a standardized static plate in one location, accessible for tool inspections and tool accountability at all times. By localizing off-weapon system storage, the parts management system reduces span times to repair the weapon system for unscheduled, scheduled, and depot level maintenance.

Reduce FOD: In the aviation industry, FOD directly impacts costs. The costs are represented in delays, unscheduled maintenance, damaged weapon system parts and the deaths and injuries of not only maintenance workers, but passengers and pilots as well.

Increase Profits: Efficient maintenance contributes by adding value through a better utilization of resources. A parts management system that is not standardized will produce ineffective maintenance and at the same time increase production cost, and span times which reduce profitability.

PROBLEM STATEMENT

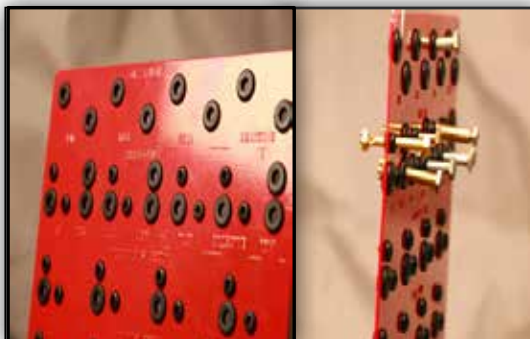
Every day there are **HUNDREDS** of nuts, bolts, washers, and screws laying around the hanger in paint cups and old plastic bags just waiting to be lost or F.O.D. out an aircraft engine.

BENEFITS

1. Organizes fasteners, nuts, and hardware used in the assembly and disassembly of weapon system components
2. Reduces risk to engine damage
3. Mitigates **FOD** risk
4. Minimizes weapon system downtime
5. Control hardware inventory cost
6. Maintenance turn-time redux

TECHNOLOGY SOLUTION

The parts management system is the integration of Continuous Improvement into maintenance execution. A specific emphasis on time-tested Lean methodologies as applied within automotive and aerospace has now been expanded for aircraft maintenance services.



USING 3D CAD MODELS FOR TEACHING, PERFORMANCE SPT AND VR TRAINING

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Generally, the production of 3D models (and 3D animations) is a heavy task that requires 3D modeling of the equipment and the creation of an animation scenario that is consistent with the system's behavior.

Since technical training and maintenance products are commonly built at the end of the project, generally by a separate department or a subcontractor, creating 3D educational models is problematic: on average, producing 3D education materials and training products is estimated in 20-30% of overall project cost, while resulting 3D models and animations comprise less than 5% of theoretic training time.

During the last year, we have started a new approach for education, training and technical information products for the maintenance of Israel Defense Forces' Namer APC and Merkava MBT.

With this approach, derivation of technical and training documentation is done directly from 3D CAD models used for the development and manufacturing of the product itself, instead of building 3D models as a separate and costly activity.

The 3D models are incorporated into performance support system and integrated electronic technical manual (IETM) + Virtual Reality (VR) training system.

In this approach, educational (classroom-oriented) and technical (field service-oriented) documentation is combined, forming a single continuum from training at recruitment to actual technical work and later on, reserve service.

Overall, this enables 3D-based training both in class and in field units, where 30-50% of the materials are based on 3D models.

Benefits of the method:

- Shortening instruction time by using 3D models compared to traditional methods and tools.
- Raising motivation and deepening knowledge during the course and over time.
- Better preparation for practical lessons, faster gaining minimal practical ability and raising the professional level in service

- Reducing costs, as with 3D models that are already available, less additional information is required.

PROBLEM STATEMENT

Generally, the production of 3D models (and 3D animations) is a heavy task that requires 3D modeling of the equipment and the creation of an animation scenario that is consistent with the system's behavior. Since technical training and maintenance products are commonly built at the end of the project, generally by a separate department or a subcontractor, creating 3D educational models is problematic: on average, producing 3D education materials and training products is estimated in 20-30% of overall project cost, while resulting 3D models and animations comprise less than 5% of theoretic training time.

BENEFITS

- Shortening instruction time by using 3D models compared to traditional methods and tools.
- Raising motivation and deepening knowledge during the course and over time.
- Better preparation for practical lessons, faster gaining minimal practical ability and raising the professional level in service
- Reducing costs, as with 3D models that are already available, less additional information is required.

TECHNOLOGY SOLUTION

- Derivation of technical and training documentation directly from 3D CAD models used for the development and manufacturing of the product itself, instead of building 3D models as a separate and costly activity.
- Incorporation of 3D models into performance support system and integrated electronic technical manual (IETM) + Virtual Reality (VR) training system.
- Overall, proceeding to 3D-based training both in class and in field units, where 30-50% of the materials are based on 3D models.

GRAPHIC OR IMAGE



ACCELERATE JOB PERFORMANCE WITH AUGMENTED REALITY

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The only thing harder than keeping up with changing technology and equipment is to maintain them. Lengthy training processes on complex machines, mixed with a rapidly evolving workforce can make it difficult to sustain equipment. Augmented Reality brings a job performance paradigm to the table that has been proven to be successful in multiple industries.

Augmented Reality provides an interactive digital overlay to the real world, showing digital information in real time and in context on the physical asset. This is done using digital twins and 3D/Textual overlays.

This digital information can be work instructions, IoT data, and even 2-way communication for 'over the shoulder' support. Instructions and notes can all be viewed within the operator's field of view with the use of either a headset or tablet, whichever is preferred for the job.

Benefits to implementing Augmented reality include

- Improved retention and understanding of tasks

- Reduced training time
- Reduction of errors
- Empowering technicians with step by step visual work instructions
- Enhancing operator efficiency, allowing them to work faster
- Rapid problem detection with remote assistance

Augmented Reality will exponentially improve maintenance training and job performance for maintainers and operators alike. Additionally, AR can create a collaborative environment where an expert can remotely assist numerous operators throughout the different locations without leaving their office.

Several of PTC's Aerospace and Defense customers have experienced positive results with Augmented Reality, including

- 25% faster wiring harness install (Boeing)
- 47% faster training instruction comprehension (SRI)
- 34% faster wiring a turbine control box (GE)

- 20-30% Increase in training rates (BAE)
- 32% more productive workforce (Industry Report on AR)
- 30% Higher quality output (Industry Report on AR)
- 40% Higher on the Job Training retention (Industry Report on AR)

PTC's Augmented Reality platform, Vuforia, has been a top performer and a leader in the industry for the past decade. With over 55,000 AR apps created across thousands of customers, PTC holds over 65% of the AR market share. PTC has assembled several Vuforia packages to create the perfect solution for any problem that maintainers may face.

PROBLEM STATEMENT

Lengthy training pipelines and increasingly complex machines, coupled with dwindling skilled workforce requires a new approach to learning, maintenance activities and manufacturing operations.

Augmented Reality experiences rapidly train your workforce on complex tasks, improve employee retention and productivity, oversight and operations management, and maintenance accuracy. Augmented Reality allows the maintainer to experience the digital information and digital representation of the aircraft or equipment in the context of a physical product using digital twins, 3D overlays, augmented work instructions with IoT data in a safe environment with full scale or miniature representations in any location or environment

BENEFITS

- Improve retention, understanding of tasks
- Reduce errors and improve quality
- Empower technicians with step-by-step work instructions
- Enhance operator efficiency – work faster
- Rapid problem detection/resolution – with remote assistance

Success Stories

- 25% faster wiring harness install (Boeing)
- 47% faster training instruction comprehension (SRI)
- 34% faster wiring a turbine control box (GE)
- 20-30% Increase in training rates (BAE)
- 32% more productive workforce (Industry Report on AR)
- 30% Higher quality output (Industry Report on AR)
- 40% Higher on the Job Training retention (Industry Report on AR)

TECHNOLOGY SOLUTION

Vuforia Augmented Reality



This technology allows for the creation of scalable AR experiences that leverage 3D content, the Internet of Things and Enterprise Systems data that can be merged to present a holistic representation of not only the physical asset, but layers of data and instruction not before available in a single view point. This software allows one employee to effectively instruct another from a remote location that combines powerful AR technology with real-time video to provide the ultimate solution for remote assistance.



INTERACTIVE ONLINE SIMULATORS

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Problem:

3d interactive simulators, some of which use virtual reality, are gaining attention. These simulators are useful for training maintenance personnel. But these simulators are often being developed as download, install, and run software, like computer games. While the technological underpinnings are shared, simulators have more to gain than games from web deployment.

Solution:

A simulator that can be accessed by browser will work on PC, Mac, iPhone, and Android. Since the simulator is accessed like a web page, analytics can be gathered. Information such as "What are the most frequent mistakes that users are exhibiting", can be identified. Furthermore, simulators can be used to measure the effectiveness of the training, thereby providing metrics to design improved and more effective training. New training could be loaded on the web quickly and different trainings can be available to each user.

PROBLEM STATEMENT

New interactive training is slow to get to the end user, and the information from students isn't gathered to improve the training

BENEFITS

- Analytics
- Testing of different training
- Quick deployment of new training
- Platform portability

TECHNOLOGY SOLUTION

WebVR is an open specification that makes it possible to experience virtual reality (VR) in your browser. The goal is to make it easier for everyone to get into VR experiences, no matter what device you have.

- <https://webvr.info/>
- <https://www.khronos.org/webgl/>



VIRTUAL REALITY TRAINING

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Problem Statement:

Maintainers are unable to practice engine runs and emergency procedures in a low-threat, controlled training environment.

Technology Solution:

We recommend using virtual reality (VR) technology to simulate an engine run and emergency procedures, giving students the perception of being physically present during an engine run and providing the ability to respond to emergency procedures in a low threat, controlled environment.

Benefits:

Virtual reality allows the student to see the aircraft and cockpit in a 360 degree immersive environment. Furthermore, it provides the ability to use real sounds and communication interactions students will experience running engines on the flight line.

Possibly the most valuable aspect of VR is that it permits students to practice emergency procedures, interacting with a simulated cockpit and performing tasks as they would occur in real-time to help build muscle memory on how to react during a stressful, intense, and time-sensitive

situation. Currently, the only option available to practice engine run and emergency procedures are aircraft simulators and few maintenance organizations have access to them. Those organizations that do have aircraft simulators have limited time available for this training. Each simulator costs millions to purchase and operate so the equipment is limited and isn't readily available to perform non-pilot related training. In most maintenance units, instructors have no way to allow students to practice running engines or to train on emergency procedures other than verbally walking the student through the steps before an actual engine run. It is critically important personnel follow proper engine run procedures and react appropriately during an emergency to prevent possible loss of life or damage to aircraft.

Implementation:

Presently, VR equipment can be purchased for around \$1,000 a unit, allowing numerous stations to be utilized simultaneously for a fraction of the cost of operating an aircraft simulator for this training. Current VR technology has the capabilities required to simulate these procedures and is already

utilized in training pilots and technicians across the globe. For example, Armed Forces Reserve Center in Austin, TX is using a prototype VR system designed for the military to simulate flying an F/A-18 Hornet including throttle, stick, heads-up display, and even details such as the handle for the ejector seat between where the pilot's legs would be. Going forward, maintenance organizations could use this technology in other courses to provide other specialized training on tasks that are dangerous, have the potential to damage aircraft, or even use VR to take the student "inside" equipment to better explain system operation. Virtual reality's impact on training is greatest when safety and manual practice are of the utmost importance and could be utilized across the Air Force in other career fields. The options for utilizing this technology are virtually limitless.

PROBLEM STATEMENT

Maintainers are unable to practice Engine Runs and Emergency Procedures in a low-threat, controlled training environment.

BENEFITS

Virtual Reality provides a safe, controlled, and low cost solution allowing students to gain confidence and practice procedures before performing a real engine run for the first time

TECHNOLOGY SOLUTION

Establish virtual reality stations in Maintenance Training Sections to allow instructors to train students with this technology.



AUGMENTED REALITY TRAINING GOGGLES

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We as a team within AFMC are tasked to ensure we sustain the technological advantage for U.S. air superiority. This technology advancement will posture us for mission success by advancing our training techniques without the cost of holding aircraft down which decreases aircraft availability to perform the mission daily. Developing and fielding technology at the speed of relevance will ensure we don't wait for training opportunities based on when an aircraft is Non Mission Capable. This time can be utilized to actually repair the aircraft without the training burden.

Currently, we are forced to prioritize each task and determine if there is a target of opportunity to train which could drag out repair efforts with the understanding training will take more time and remove aircraft from the flying schedule. If we close the gap from task exposure to task proficiency with the augmented reality training goggles, we eliminate additional down time for our aircraft. This will not only develop our Airmen in task upgrade training, but will also increase our capabilities across each skill level.

This advancement will give us the option to isolate and study specific systems (i.e. PC1, ECS, bleed air) at length outside of technical orders (T.O.). This platform can be designed in conjunction with T.O. information adding the benefit of troubleshooting the various deficient systems as well.

The return on investment is exponential providing knowledgeable and proficient maintainers at all skill levels propelling our experience to levels as seen prior to the shred out removal days. AFMC/CC has asked if we are optimized for innovation and anticipating future Air Force needs, this will prep us for that future.

PROBLEM STATEMENT

The 96th AMXS conducts the wing's primary missions of developmental testing and evaluation of conventional munitions, command and control systems, F-15 and F-16 avionics, and navigation and guidance systems.

Challenges / Issues Confronted:

- Scheduling aircraft down time for training
- Providing hands on training without creating collateral damage
- Comprehension of aircraft prints and technical orders vs actual hardware placement
- Maximizing/creates in-depth training opportunities
- Increases aircraft availability

BENEFITS

- Increased efficiency of learned knowledge delivered to Airmen
- In-depth lessons for theory of operation never before captured
- Reduce damage from excess component installation and removal
- Increase fully mission capable to meet DoD/war fighting requirements
- Engine run simulator replacement
- Field Training Detachment curriculum
- Reduced training time and cost

TECHNOLOGY SOLUTION

Augmented/Virtual Reality Training Equipment

- Attain technological advantage by evolving training to meet maintenance requirement
- Posture mission success by growing more task proficient Airmen at the speed of relevance
- Optimize innovation to maintenance needs
- Anticipate Air Force needs - confronts antiquated maintenance training process
- Addresses The Deputy Assistant Secretary of Defense for Materiel Readiness' challenge in the areas of process, methodology, work flow to create more efficient end result

Program Creation Flow

