MAINTENANCE INNOVATION CHALLENGE

DECEMBER 17–20, 2018
TAMPA, FLORIDA

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OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
3500 DEFENSE PENTAGON
WASHINGTON, DC 20301-3500

SUSTAINMENT

DEC 0 3 2018

MEMORANDUM FOR 2018 DOD MAINTENANCE SYMPOSIUM PARTICIPANTS

The 2018 National Security Strategy (NDS), titled *Sharpening the American Military's Competitive Edge*, requires us to become 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 dominate superiority environment in every operating domain. We are now challenged by near-peer adversaries and a changing character of war. We must regain the advantage that will allow us to fight and win wars of the future and innovation and technology insertion will play a key role. Our Maintenance Innovation Challenge (MIC) is in line with the 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 2018 DoD Maintenance Symposium "Maintaining America's Lethal Competitive Edge," we issued the 2018 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 74 excellent submittals were received from 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 MIC finalists will be presenting their maintenance innovations during the Maintenance Innovation Challenge breakout on December 17, 2018, from 1300-1430 in the Tampa Convention Center, Ballroom A. I encourage your participation in this event to engage with some of the most forward-thinking individuals in our community. The MIC winner will be announced and formally recognized during the Maintenance Symposium's plenary session on the morning of December 18, 2018. Additionally, I encourage you to interact with these innovators throughout the Maintenance Symposium and in Defense Maintenance and Logistics Exhibition.

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

Sincerely,

Kenneth D. Watson
Deputy Assistant Secretary of Defense
Materiel Readiness

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.

With a possible 27 points on the line, 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 and one to two-star general level 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 as well as stay evergreen in the MIC booklet, which all 200+ MIC attendees receive. 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.

THE JTEG PRINCIPALS AND KEY REPRESENTATIVES

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Enabling America's Lethality through Maintenance and Sustainment

The DoD Maintenance Symposium is a tremendous opportunity for the National Center for Manufacturing Sciences (NCMS) to put its industry members and partners in front of the key stakeholders in the DoD community.

NCMS' Commercial Technologies for Maintenance Activities (CTMA) Program supports DoD's emphasis on the importance of warfighter and equipment readiness. CTMA provides collaboration and innovation between government and industry to fill unmet technology needs within the maintenance and sustainment communities.

Visit the NCMS interactive booth #P313 featuring:

Equipois, LLC
Maglogix, LLC—MIC Finalist
One Network
Siemens
Spectro Scientific
Temple Allen
Wet Technologies—MIC Finalist

CTMA PROVIDES A VENUE FOR INDUSTRY PARTNERS TO DEMONSTRATE TECHNOLOGIES FOR DOD EVALUATION PRIOR TO ACQUISITION.

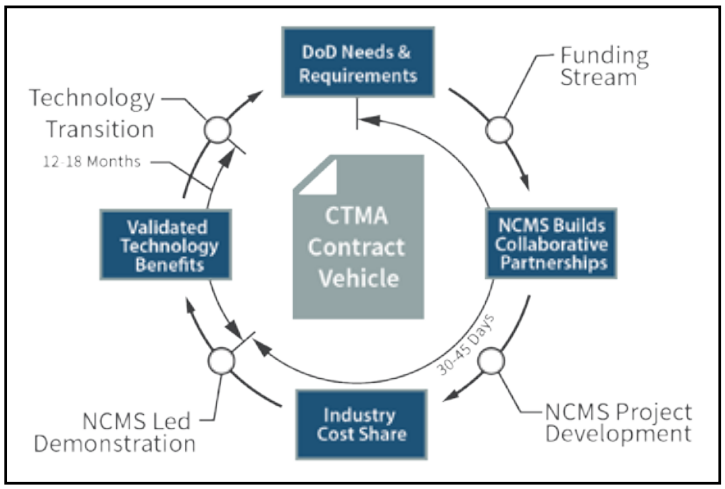
NCMS
NATIONAL CENTER FOR MANUFACTURING SCIENCES

CTMA
COMMERCIAL TECHNOLOGIES FOR MAINTENANCE ACTIVITIES

Technology Transition through Partnerships and Dedication

CTMA brings forward innovative technologies that assist with maintenance tasks and provides the required testing and evaluation processes to prove cost-effectiveness. Because these technologies are commercially available, the process is expedited and efficient; 30-45 days from cradle to execution.

The CTMA Workflow

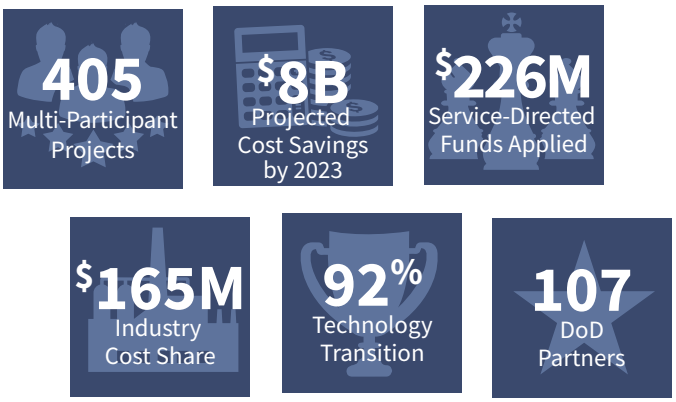


Focus Areas:

CTMA's focus is to drive down maintenance costs and help remove other obstacles. Current projects fall within the following areas:

- Corrosion Prevention
- Business Process
- CBM+
- Reliability Improvement
- Health and Safety
- Enhanced Inspection
- Additive Manufacturing
- Autonomic Logistics

By the Numbers:



About CTMA

The CTMA Program offers a unique contracting vehicle for industry, academia, and the DoD sustainment community to work in collaboration to promote the development, demonstration, and transition of new and innovative technologies which enhance war-fighter readiness at best value and lowest risk.

For more information about CTMA, visit www.ncms.org/ctma or contact Debbie Lilu at debral@ncms.org.

Booth #P313

About NCMS

NCMS is a cross-industry technology development consortium, dedicated to improving the competitiveness and strength of the U.S. industrial base. As a member-based organization, it leverages its network of industry, government, and academia to develop, demonstrate, and transition innovative technologies efficiently, with less risk and lower cost.

For more information about NCMS visit www.ncms.org.

CONGRATULATIONS TO OUR 2017 MAINTENANCE INNOVATION CHALLENGE WINNERS!

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

TECHNOLOGY AWARD:

2017: Drift Composite Heat Damage Evaluation of V-22 Wing – Justin Massey and Andrea Boxell, NAVAIR

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PEOPLE'S CHOICE AWARD:

2017: Small Unmanned Aerial System (sUAS) – Tim Morris and David Freeman, US Air Force, 412th Test Wing, 412th Maintenance Group

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2018 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 2018 DoD Maintenance Symposium.

Moderator:

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

Finalists:

Green Wet Blasting Technology for Maintenance, Repair, and Overhaul of DoD Components
Submitted by Frederick A. Greis, Wet Technologies Inc.

Laser Ablation and Naval Maintenance Applications
Submitted by Janice Bryant, NAVSEA Tactical Innovation Implementation Lab, and Susan L. Sprentall, SurClean, Inc.

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

RAPTOR Means Readiness: How Soldiers Pull on the Digital Thread
Submitted by Timothy Phillis, United States Army Armament Research, Development and Engineering

Robotic Automation for Environment, Safety, and Occupational Health (ESOH) Risk Reduction, Throughput Increase, and Improved Quality
Submitted by Shane Groves, US Air Force

Using Multi-Pole Magnetic Technology to Improve Productivity, Quality and Safety
Submitted by Jim Michael, Maglogix, LLC.

GREEN WET BLASTING TECHNOLOGY FOR MAINTENANCE, REPAIR, OVERHAUL OF VARIOUS DOD COMPONENTS

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Problem

- Traditional technologies for the cleaning, descaling, derusting, striping produce physical exposure to cleaning chemicals and dust found with chemical parts washers and dry "sand" blasting.
- Static build up can lead to ignition, explosions, fire
- Operators must often wear bulky protective clothing and breathing apparatus
- Dust collectors are often inefficient, requiring excess maintenance and floor space
- Examples: descaling, cleaning of aircraft engine/APU components, landing gear, weapons

Technology description

Standard/custom systems are designed/built combining a special, wear resistant pump producing a high flow rate of water, media, and regulated compressed air delivered by a nozzle(s) producing a "scrubbing" effect on metallic, polymer, and/or composite surfaces. This is an application specific, refined variation of a process widely known as "wet blasting".

Current development status of the technology

We have developed the technology to include:

1. A specially designed pump which can deliver media concentrations in excess of 50% to water. This capability allows the process to be more reliant on the slurry, and less so on the addition of compressed air. Thereby providing a safe removal of scale and contaminants without damaging the substrate or removing base material.
2. Complete oil and particle separation
3. Negative pressure filtered exhaust to minimize exposure

Test/simulation data supporting performance claims

Example: APU auxiliary power unit impeller/shaft removed for overhaul. Surfaces are covered in scale and may have light oils.

Current process/average times for single part comparison

1. submersion in chemical parts washer to remove oils and soften scale - 30 min.
2. manually scrubbed with brush - 15 min.
3. open air drying - 15 min.
4. dry blasted with spherical glass bead to remove scale - 10 min.
5. blast media consumed - 1lb.
6. rewashed to remove dust - 5min.
7. total - 75min.
8. new technology: total - 15min. blast media consumed- ¼ lb.

Next steps

Accumulation of documented parts for testing such as:

- Weapons components small to large, typically cleaned on a monthly basis
- Landing gear wheels following tire removal and disassembly
- Jet engine turbine blades, rotating discs and hubs, stators
- APU components
- Composite structures to be etch prepped for bonding

Process testing and verification on a variety of applications can be conducted in an existing lab environment. Documentation to include video of; pre-process condition, complete processing, post process inspection.

Potential benefits based on limited existing installations

1. One major engine manufacturer has written a specification around this process for descaling the root sections of rotating discs and hubs, replacing previous dry blasting, which was found to remove base metal, which lead to lose blades.
2. APU components at one AFB were accumulating due to inefficient traditional cleaning methods. The installation of the process equipment eliminated the problem, while producing better quality parts.
3. A weapons facility practice of physically hand cleaning dangerous fuel residue from missile tubes was replaced by this process, eliminating the previous exposure.
4. Participants from one AFB conducted successful hands on testing in a lab on multiple components including mini gun barrels and deemed it superior to their traditional technology.

PROBLEM STATEMENT

- Human exposure to dust and chemicals from current maintenance operations utilizing chemical parts washers and dry "sand" blasting
- Static build up in dry blast cabinets can lead to dust fires/explosions
- Operators must wear bulky protective clothing and breathing apparatus
- Dust collectors are often inefficient, requiring excess maintenance and floor space
- Examples: descaling, cleaning of aircraft engine/APU components, landing gear, weapons

BENEFITS

- Eliminates exposure to dust and risk of static dust ignition
- Combines existing steps-oils and contaminants are separated and consolidated for disposal.
- The process/equipment is "closed loop."
- Media is interchangeable and reusable with low consumption compared to dry blasting.
- Chemicals are not required; however mild rust inhibitors can be used.
- Systems can be standard or custom designed to meet part size/weight and facilities requirements.
- Dust free systems offer freedom of placement locations to improve efficiency.

TECHNOLOGY SOLUTION

- The Wet Technologies process provides scalable, self-contained systems, combining water, media, and compressed air which can efficiently derust, descale, strip, and etch surfaces.
- Faults such as cracks can be exposed to prepare for LPI-liquid penetrant inspection.
- Paint such as on aircraft wheels can be striped in layers, corrosion is completely removed.
- Surfaces can be post rinsed in the same system with clean, filtered, closed loop water.

Source: Wet Technologies Inc. **wettechnologies.com**

LASER ABLATION AND NAVAL MAINTENANCE APPLICATIONS

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Surface coating inspection, removal, and reinstallation are often the critical path in ship maintenance. To modernize the Navy's approach to surface coating removal, the NAVSEA Laser Ablation Fielding Team embraced the task of gaining approvals, delivering and employing a laser ablation coating-removal system to the upcoming aircraft carrier (USS Carl Vinson - CVN 70) maintenance availability beginning in March 2019. The Carl Vinson team's willingness to implement Laser Ablation is the final stage of gaining approval to apply this technology directly to a major maintenance availability. This initial fielding onboard an aircraft carrier will promulgate this technology across the fleet and exponentially increase the return on investment.

The challenge of surface coating removal currently requires use of mechanical methods and extensive labor to remove the coatings. Initial estimates from the CVN 70 team projected a 70% overtime rate for their paint shop personnel for a large duration of the project given existing methods demanding an alternate solution. This endangered not only the workforce but the already constrained schedule.

To mitigate this problem, the team was tasked to identify and clear all barriers for shipboard application. Laser ablation is the process of removing material from a metal surface by irradiating it with a laser beam. The material is heated by the absorbed laser energy and evaporates, sublimates, or is converted to a plasma. Through a significant effort to challenge norms and change culture while adhering to the scientific process, the team achieved approval of a robust testing plan from all the Technical Warrant Holders after extensive collaboration across other Warfare Centers and the Penn State ARL. The test plan has been designed to provide the basis for additional applicability on other ships in the Navy inventory.

The team worked with multiple vendors to validate system availability and scalability, and leveraged relationships with the USACE Seattle District office to ensure adequacy of permit submittals across the northwest region. Additional collaboration efforts with Ogden ALC and Boeing provided the starting point for Navy standardized process instruction creation.

The team continues to ensure that that follow-on effort beyond the USS Carl Vinson will benefit other aircraft carrier and submarine maintenance as well as new ship construction. Throughout this effort, the team has provided an inclusive and effective communication methodology leveraging partnerships across the Navy to ensure ready fielding by the affected workforce, technical groups, and project.

Benefits include increased throughput of ships thereby returning more operational availability to ongoing national defense efforts, increased resource availability in a group of tradesmen that is stretched thin, improved ergonomics and safety, and a reduction in the amount of hazardous waste removal, storage, transportation and disposition.

PROBLEM STATEMENT

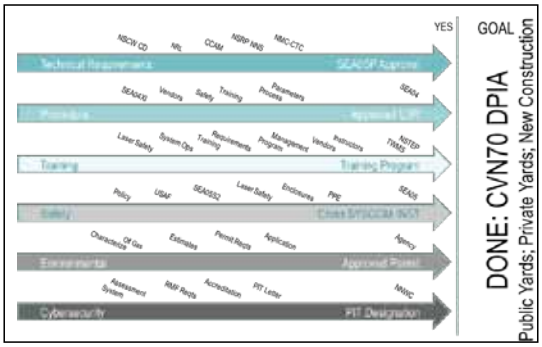
Surface coating inspection, removals, and reinstallations are often the critical path in ship maintenance. In an effort to modernize the Navy's approach to surface coating removal, the NAVSEA Laser Ablation Fielding Team has embraced the daunting task of gaining approvals, delivering and employing a laser ablation coating-removal system to the upcoming aircraft carrier (USS Carl Vinson CVN 70) maintenance availability beginning in March 2019.

BENEFITS

- Increased throughput of ships returning more operational availability to ongoing national defense efforts.
- Increased resource availability in a code that is stretched thin, improved ergonomics and safety.
- Reduction in the amount of hazardous waste removal, storage, transportation and disposition.

TECHNOLOGY SOLUTION

Laser ablation is the process of removing material from a solid, in this case metal, surface by irradiating it with a laser beam. At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates. At high laser flux, the material is typically converted to a plasma. Many systems in use today capture and filter the byproducts within a closed system.



OC-ALC 76TH CMXG REACT METAL AM TOOLING AND TESTING EQUIPMENT

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Sustainment of aging aircraft presents unique challenges due to lack of technical data, aging legacy tooling, and the need to rapidly respond to parts availability issues for a variety of aircraft and exchangeable end items. To meet the needs of the Oklahoma City Air Logistics Complex depot customers, engineering must be responsive and leverage technology to expedite the return of aircraft and their components to service as quickly as possible. The 76th Commodities Maintenance Group (CMXG) has leveraged 3D laser scanning and metal additive manufacturing to create solutions for depot maintenance problems where traditional manufacturing is not possible or too slow. CMXG has had great success augmenting contract and organic manufacturing by enhancing and producing end-use tooling, including crimp dies, gauge blocks, spline keys and testing fixtures created by Direct Metal Laser (DMLS).

When B-1 production was unable to replace their damaged wire harnesses for the critical fuel center of gravity management system CMXG used metrology measurement equipment to reverse engineer the crimp dies and gauge blocks required for wire harness fabrication. Due to the crimp dies needing high strength and the gauge blocks needing to meet tight dimensional tolerances the parts were fabricated using DMLS. This provided Tinker with the capability to fabricate these wire harnesses overnight. DMLS 3-D additive manufacturing greatly reduced cost for machining and greatly reduced turn-around time from 4-6 months to one week.

When B-1 Production was conducting testing on a valve body assembly, they test the internal shafts by shoving a screwdriver in the spline and manually turning it to see if it moved the butterfly valve. This greatly increased risk of damaging a good part simply because they did not have the right tool. CMXG designed and metal AM two configurations of a spline key that either could use a drill or could turn the valve by hand. The parts were added to an existing print and cost less than $3 each in material.

CMXG is also developing load limit tester for B-1 torque tubes. These tubes are being refurbished in production and are supposed to be loaded to 7000 in lbs of torque to ensure they were repaired correctly, however production has no way to hold or torque the tubes. CMXG is designing a fixture to hold both sides of the tube and safely torque the part. The design has been printed using a cheaper AM method to test fit the parts before moving forward with the metal print. The design provides a cheap quick solution and leverages metal AM as the part would be impossible to make with any other fabrication method.

The cost avoidance from metal AM for tooling has expected savings of $125k and 750 flow days annually. CMXG is leveraging modern technology to deliver cost effective engineering solutions to the war fighter.

PROBLEM STATEMENT

- 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 verity parts meet requirements. This leads unnecessarily to scrapping good parts or increasing risks by flying potentially bad parts.

BENEFITS

- Rapidly prototype tooling and test equipment.
  - Reduces material waste by $100K and 720 flow days annually
- Print low production run tooling on demand to offset Local Manufacturing – annually:
  - Free up machine time by 120 hours
  - Reduce lead time by 750 flow days
  - Reduce tooling cost by $125K
  - AM allows for tooling to be designed in a way that would be impossible to machine
- Enabling non-OEM sources of supply

TECHNOLOGY SOLUTION

- Laser scanning and measurement to measure good parts and determine critical dimensions
- Using scan data to design tooling specifically for Metal AM in CAD software
- Metal Additively manufacture tooling and test equipment to rapidly provide capabilities to manufacture and test parts

GRAPHIC

RAPTOR MEANS READINESS: HOW SOLDIERS PULL ON THE DIGITAL THREAD

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Additive Manufacturing (AM) or 3D Printing is a disruptive technology which allows the Warfighter to perform expeditionary repair and mitigate down time caused by battle damage and depleted supply. An overall enterprise-wide view sees using AM in several areas to improve and modernize through advanced technology development.

Focusing on the tactical point of need use case for AM, two direct benefits to the Warfighter are "increased readiness" through manufacturing and/or repairing components in the field and the other is "enhanced Warfighter capabilities" using AM to create new field expedient solutions.

In response to this need for a robust digital thread, RDECOM – ARDEC developed RAPTOR (Repository of Additive Parts for Tactical & Operational Readiness) to provide the required technical data at the point of need. RAPTOR is a repository that provides access to digital data files for expeditionary manufacturing processes to produce battle damage assessment repair (BDAR) or emergency/temporary repair parts while supply system delivers replacement parts. The interface is easy-to-use linking the Warfighter to data via an intuitive graphic user interface. RAPTOR also links the Warfighter to engineering through a reach back process providing rapid engineering oversight for unique field applications. RAPTOR provides the simple, intuitive interface to a 3D repository allowing the Warfighter to use AM at the tactical point of need to increase readiness and enhance their capabilities.

Significance

The digital thread connects equipment, data and users allowing distributed manufacturing. Both commercial industry and the government are facing similar challenges concerning how to implement the digital thread. The Army use case is unique due to the dual missions of temporary field repair (expeditionary, point of need) and traditional component manufacturing performed by industry. The discussion of how the Army is addressing both cases will provide insight to the audience, challenges the Army faces and how these challenges are being addressed. The audience will be able to relate the Army missions to the commercial missions: temporary field repair is similar to creating tooling and fixtures; traditional component manufacturing is the same. The discussion will allow dialogue between the Army and industry on innovative solutions for operationalizing the digital thread. The audience will relate to the Army's enterprise view of the digital thread and learn ways to implement in their use cases.

PROBLEM STATEMENT

- Additive Manufacturing or 3D Printing is a disruptive technology which allows the Warfighter to perform expeditionary repair and mitigate down time caused by battle damage and depleted supply.
- Although the Warfighter has rugged additive manufacturing equipment; data is needed to fully execute the mission.
- What is the data? How is that data delivered to the Warfighter?

BENEFITS

- Data required for expeditionary repair is accessible by the warfighter.
- Expeditionary repair increases system and Warfighter readiness.
- Support by PMs, PEOs and Engineering Support Activities.

TECHNOLOGY SOLUTION

- Repository that provides access to digital data files for expeditionary manufacturing processes to produce battle damage assessment repair (BDAR) or emergency/temporary repair parts while supply system delivers replacement parts.
- Easy-to-use interface which links soldier to data via an intuitive Graphic User Interface (GUI).
- Provides multiple search options such as system type, printer or material, NSN, etc.
- Scalable from point-of-use to enterprise deployment.

ROBOTIC AUTOMATION FOR ESOH RISK REDUCTION, THROUGHPUT INCREASE, AND IMPROVED QUALITY

SHANE GROVES

USAF
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When properly specified and integrated, commercial off the shelf (COTS), articulated arm, robotic systems can provide many benefits to depot operations.

- ESOH risk reduction for operators in hazardous environments including paint, depaint, thermal spray, surface prep, grinding, and milling. Utilizing robotics can limit exposure to chemicals, toxins, extreme heat, dust, and injuries.
- Improved product quality by leveraging the integral repeatability of robots. Once developed and programmed, the process will be carried out the same way every time.
- Increased production output by allowing the robots to operate during breaks and during shift changes. Additionally, some processes can simply be accomplished faster utilizing robotics due to their ability to overcome load and reach constraints that operators face.
- Increased flexibility by utilizing multiple end efforts or end of arm tooling (EOAT), allowing one robot to perform multiple processes. Additionally, as workloads change EOATs can be modified or replaced at a fraction of the cost a new system.
- Increased supportability as opposed to custom "robots" and gantries. The use of COTS equipment ensures maximum support from local contractors and vendors. Standardization ensures maximum organic support.
- Robins CMXG has realized these benefits through a diverse group of robotic processes. We are currently employing robotics in 17 different processes, with contracts awarded for 6 additional uses, and plans to expand that to another 6 for a total of 42 robotic systems performing 29 different processes.

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
Future - Awarded
Sanding
Grit Blasting for Bonding Prep
Laser Depaint
Mobile Wing Defastening
Mobile Core Milling
Mobile Structured Light Scanning
Future - Proposed
Composite (Radome) Repair
Collaborative Microwave Mapping
Welding
Chromic Acid Anodize / Acid Pickling
Stenciling
Ultrasonic Inspection

PROBLEM STATEMENT

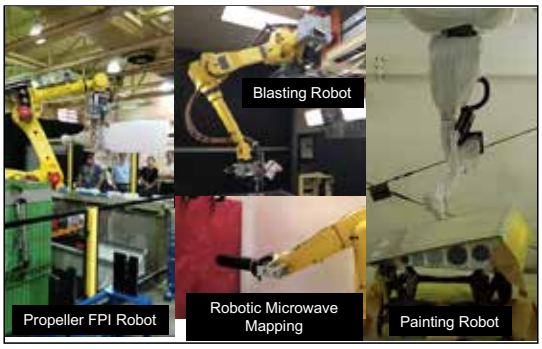
Aircraft maintenance activities contain inherent risks for personnel such as exposure to heat, chemicals, toxins, overload injuries, repetitive injuries, etc. In addition, inconsistent quality arises from human error. Defects cost money to fix, and aircraft can be delayed leaving the depot due to rework. The end result is more cost and fewer assets to warfighters. The 402nd Commodities Maintenance Group has sought to remove personnel from hazardous conditions where possible and has utilized robotics across multiple areas to increase throughput and quality.

BENEFITS

- Operators removed from hazardous environments
  - ESOH compliance (paint and depaint systems)
  - B20128 Blast Robots
- Consistent, repeatable results
  - F-15 radome w/ zero fails due to paint thickness
  - B142 Shot Peen, coupon validation
- Increased throughput
  - Robotic Floursecent Penetrant Inspection (FPI) and Borescope the only ways to keep up with throughput demand.
  - B180 paint robot, decreases paint time by 3.
- Robins CMXG is currently utilizing robotics in 17 different processes, with contracts awarded to increase that to 23.

TECHNOLOGY SOLUTION

- Robotic automation provides 6 or more axes, to allow systems the freedom required to adapt and change as workload demand shift.
- CMXG has standardized to Fanuc robotics to maximize organic support and expertise.
- The robots provide the base for custom end effectors designed for the specific applications:
  - Thermal Spray, Handling, Inspection Camera, Paint Application, Paint Removal, Surface Prep, Drilling, Milling, etc.
- Path programming can be accomplished manually or automatically utilizing 3D models.



USING MULTI-POLE MAGNETIC TECHNOLOGY TO IMPROVE PRODUCTIVITY, QUALITY AND SAFETY

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Department of Defense sustainment facilities are faced with the difficult task of maintaining or upgrading equipment used by our armed forces. Facilities are challenged by an aging work force as well as a new generation of recruits unaccustomed to the physical demands required. Equipment maintenance and sustainment is highly fluid, making it difficult to take advantage of the dramatic advancements made in Robotics. Maintenance facilities have little choice but to continue using traditional methods. Tight work schedules often results in employees using brute force to accomplish a given task. Unfortunately, even with increased safety efforts, we anticipate frequent strains, sprains and crush injuries.

Advancements in human augmentation technology can help minimize injuries and reduce physical effort. However many of these products are viewed as costly, cumbersome and a hindrance to productivity. Partial Exo-skeletal systems aid in transferring loads to other body parts but do not fully mitigate the problems. Full Exo-skeletal systems are somewhat restrictive and in need of further development. Other systems, such as the ZeroG Arm, transfer tool loads and vibration to fixed points, with the primary complaint being lack of mobility and portability. Use of mechanized assistance such as overhead cranes and forklifts still encounter issues of availability and extended wait times even in unconfined areas.

Fortunately, work performed in maintenance facilities involves steel or steel structures. A recent magnetic invention, "Phase Canceling Multi-Pole Permanent Magnets" (MP magnet) is disrupting traditional steel manufacturing methods. MP magnet technology overcomes virtually all viability issues of previous magnet technologies. MP magnets (sold under the trademark Maglogix®), have an unheard of performance to weight ratio exceeding 400 pounds holding force per 1 pound of magnet! MP magnets use multiple shallow magnetic fields to increase saturation density. This dramatically increases magnetic adhesion providing; Unparalleled safety, De-stacking ability, and Elimination of Arc-Blow during welding. MP magnets have a residual magnetic field designed in, to offset the magnets weight, facilitating vertical or inverted positioning. The unique design makes the MP magnet the only switchable magnet made of hardened steel.

Powerful Magnets are no longer limited to "Below the Hook" uses. Products such as Zero G arms can be attached in seconds, rather than carting hundreds of pounds or hard mounting the arm. Hand lifters weighing 3.5 pounds provide 750 pounds grip on ¼" steel eliminating crush, cut and burn injuries. MP Magnetic drills are capable of drilling down to 1/8" thick steel, have no danger of falling during a power loss. Advanced Sensing technology (MagnaSense) determines the breakaway force and can shut the drill motor down prior to detachment. MagnaSense technology is available separately with digital readout on select MP-Magnets. Grip force is provided on any surface irrespective of paint, alloy, shape etc.

MP magnets weighing 16 pounds, (3400 pound grip on >3/8" steel) are used to bend / fair steel, eliminating temporary weld attachments. ROI's of 4 days are common.

MP Magnets are so powerful and lightweight; they are being evaluated by TARDEC to rapidly attach armor onto vehicles ranging from Humvees to Tanks.

PROBLEM STATEMENT

- **Physical demand**
  - Workforce has aged considerably.
  - New recruits are smaller and somewhat less physical.
- **Workload**
  - Facilities have a multi-year backlog and struggle to meet date objectives.
  - Robotics, while helpful are unable to be deployed rapidly in a highly fluidic environment.
- **Safety**
  - Existing manufacturing methods are taking a toll on smaller and / or aging workforce.
  - Injuries have a dramatic impact on schedules and cost.

BENEFITS

Safety
- Requires no power, will not pinch, ergonomic
- Avoids direct contact with sharp or hot steel

Speed
- Eliminates Scars, reduces grinding, reduce support people, rapid on / off

Quality
- Improved position accuracy, rigid hold during welds
- Advanced sensing technology

TECHNOLOGY SOLUTION

- **ZeroG Arm rapid support attachment system**
  - Portability and the ability to work in confined Quarters
- **Fairing and Fixturing Steel**
  - Magnetically bending steel into position eliminate temp welding, reduce manpower
- **Moving and manipulating material more safely**
- **Drilling**
- **Welding**
  - Shallow field does not cause arc blow
- **Customizable and readily configure into many applications**

H-53E MAIN ROTOR BLADE REPAIR USING ADDITIVE MANUFACTURING

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Fleet Readiness Center – East's mission is to provide maintenance, repair and overhaul (MRO) services to the USN & USMC fleet of vertical lift aircraft, among them being the CH-53E and MH-53E heavy lift helicopters. Both aircraft use the same Main Rotor Blades (MRB) which are inspected and repaired by FRC-E. Part of this work includes inspection of a collection of polymer parts, known as Blade Inspection Method (BIM) Vents, for cracks or other damage. The BIM Vents are a crucial part of the In-flight Blade Inspection (IBIS) system that monitors nitrogen gas pressure inside the MRB spar (titanium core of the blade) during flight. If a spar crack develops, gas pressure drops and a warning notification is sent to the flight crew. The BIM Vents provide multiple pathways for the nitrogen gas to escape to the atmosphere. Loss of spar pressure can affect the aircraft mission, making the BIM Vents a Critical Application Item (CAI) component.

BIM Vent damage and cracks are normally found beneath layers of adhesive and foam at the root of the blade. Such damage can be repaired but require replacement parts from the OEM. It was determined that no replacement BIM Vent stock was in the supply system which meant that the only alternative repair was to completely strip and rebuild (re-pocket) the MRB at the OEM. Re-pocketing a single MRB costs $210K with a turn-around time (TAT) of 160 days. The problem was further compounded by the fact that NAVSUP had ~400 F-condition MRB's awaiting inspection and repair. Clearly fleet readiness was negatively impacted by the lack of available BIM Vent repair options.

A cross-functional team was tasked with developing an alternative repair process. The team first determined that the BIM Vent material specified by the OEM was chemically similar to a polymer material used in FRC-East's Additive Manufacturing (AM) printers. The BIM Vent was modeled in CAD and the design optimized for our printers. Numerous sample parts were printed and subjected to extensive laboratory testing. Laboratory testing concluded that AM BIM Vent parts would perform well during the repair. A repair process was developed and tested multiple times on scrap MRB assets. After the repair process was finalized and documented, it was approved by ISSC engineering. The BIM Vent repair process is now in use at FRC-E.

The use of Polymer AM to print the BIM Vent repair parts is unique and beneficial in many ways. An MRB BIM Vent repair at FRC-E costs $15K with a TAT of 14-21 days, which compares very favorably against re-pocketing an MRB at the OEM. We believe this is the first time a polymer AM part is being used as a CAI component. The repair is viable for both USMC & USN aircraft and we believe FRC-East's repair capability is unique within the DOD. FRC-E is now able to begin inducting F-condition MRB assets from NAVSUP for inspection and repair. This has the dual benefit of stabilizing work flow through the blade shop and improving fleet readiness.

PROBLEM STATEMENT

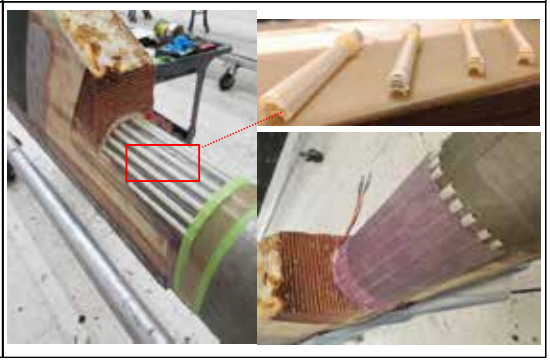
- Inspections of H-53E Main Rotor Blades (MRB) inducted for repair at FRC-East revealed cracking of the Blade Inspection Method (BIM) Vents (a critical application item [CAI] of the component) beneath the layers of adhesive and foam at the root of the blade. Multiple inducted MRB's were found to have cracked BIM Vents. No OEM replacement BIM Vents were in stock. The only alternative to a repair is to completely strip and rebuild the MRB at the OEM.
- Further, NAVSUP reports 400+ Condition F MRB assets in stock. The NAVSUP MRB's require inspection to determine the nature of the defect – BIM Vent cracking or some other deficiency.
- The combined MRB supply posture (FRC-E and NAVSUP) is a readiness degrader.

BENEFITS

- The cost to repair one H-53E MRB using the 3D printed BIM Vents is estimated at $15K per blade.
- Prior to the development of this repair process, the only alternative was to perform a strip and rebuild (re-pocket) of the entire MRB at the OEM, at a cost of $210K per MRB.
- $195K cost avoidance per MRB. Each H-53E has seven MRB's so potential savings per aircraft is $1.37M.
- Turn around time (TAT) for BIM Vent repair process at FRC-E is ~3 days. TAT for OEM re-pocket of one MRB is ~160 days..
- FRC-E is now able to maintain a steady flow of MRB repair work in the Blade Shop.
- Through the development of this repair and the use of AM FRC-E is reducing repair cost and improving readiness.
- This is the first time a Polymer AM process is being used to build CAI repair components for use in-service by the fleet.

TECHNOLOGY SOLUTION

- FRC-E Materials Engineering determined that the OEM specified BIM Vent material (ULTEM 1000) is equivalent to ULTEM 9085, a material used by the Fortus Fused Deposition Modeling (FDM) 3D printers installed and in use at FRC-E.
- The BIM Vent design was modeled in CATIA and modified to accommodate the FDM printing process. The CAD model also provides the flexibility to modify the design, if needed, to better match BIM Vent repair parts with the damaged blade(s).
- Prototype repair parts were tested under pressure & heat to ensure the repair could withstand in-service conditions and future blade repairs.
- A repair procedure was developed, documented, reviewed and approved by FRC-E AIR 4.3 Air Vehicle Engineering.
- The repair was successfully demonstrated on scrap MRB assets.
- The BIM Vent repair has been approved for use on production MRB assets. Refer to photos above.



MELD: A NOVEL SOLID-STATE TECHNOLOGY FOR MAINTENANCE

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Challenges continue to emerge in the dynamic environment we operate while engaging our adversaries. The ability for our Nation's war fighters to maintain and repair vehicles and vessels or print new components on-demand in the field or at sea will not only improve operational efficiency but also reduce the overall cost and logistics overhead associated with holding replacement parts in inventory. Being able to additively manufacture and repair components as close to the battlefield as possible will offer a tremendous strategic advantage with regards to agility, improvements to asset utilization, and a reduction in the risk to life.

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 20 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. However, MELD also works with powder and recent builds with machine shop scrap show the robust power of a fieldable machine to use in theater materials if needed.

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

Weld repair for cracked, corroded, or otherwise damaged components where additional material needs to be added is a common approach for the sustainment of a given part. This type of repair is not possible for certain materials, such as 2XXX and 7XXX series aluminum alloys. These types of materials are susceptible to cracking and porosity when subjected to melt-based operations. Without the ability to repair these components the most common course of action is complete replacement, which in the best case is costly and in the worst case is not possible. Without a compatible repair method, these new materials cannot be leveraged for weight savings or better performance.

BENEFITS

- Quality: Deposit fully-dense material with exceptional mechanical properties (near-wrought or better), greater corrosion resistance, and greater wear resistance.
- Scalable: Repair small to massive components with fast deposition rates (Al > 20 lbs/hour).
- Easy to Use: CNC style machines and g-code allow one-day retrain of machinists.
- Unlimited use: Repairs the unrepairable, welds/joins dissimilar metals.
- Open Atmosphere: Print MELDed material directly onto existing structures/components.
- Safe: No gas, no lasers, no metal powder means safe and portable.

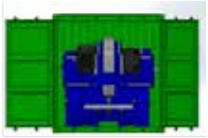
TECHNOLOGY SOLUTION

MELD is a solid-state process for all metal alloys, including those that are incompatible with fusion processes. By remaining well below the melting point of a given material MELD is able to process materials without the problems experienced with melt-based processes such as porosity and hot-cracking.

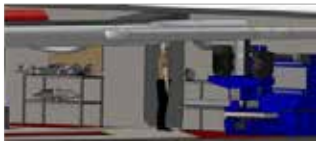
MELD machines are large-scale, open-atmosphere systems that do not require a laboratory environment for reliable operation. These machines are robust and durable and are well suited for deployment in either a depot or forward operating base environment.

MELD machines have high utility, whether on a robotic arm for large repair or stationary platforms for manufacture of replacement parts.

Drive Up, Open Atmosphere Repair



Portable and Safe: Shipboard or Conex



SMART MAINTENANCE OF METAL PARTS WITH EMBEDDED FIBER OPTIC STRAIN SENSORS

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The US government and industry require improved inspection tools for maintenance of critical components. Traditional inspection intervals are based on assumed usage that leads to expensive over-inspection or inspection after it is too late, i.e., the critical component has failed and requires replacing during an inconvenient time. Embedded fiber optic strain sensors in critical parts could allow engineers to record strain time histories on components in critical locations that are not always easy to inspect, thereby enabling accurate assessment of remaining life prior to failure. Ultrasonic Additive Manufacturing (UAM) provides the ability to embed commercially available fiber optic strain sensors into metal parts directly. These fiber optic strain sensors are small (0.006” OD), flexible, operate in extreme temperature environments (glass), and are immune to electro-magnetic interference. UAM is a solid-sate (no melting) 3D metal printing process invented in 1999 with improvements to the tooling in the 2006-8 timeframe. Because no melting occurs in the process, special atmospheres are not needed, and solidification/high temperatures are avoided (allows embedding of sensors without damage and need of adhesives). Recent work with NASA Langley has developed engineering components with embedded sensors for assessment. The team used the embedded fiber optic strain sensors to identify fatigue cracks, measure strain gradients in parts, and assess useful life prior to failure. Fabrisonic LLC, formed in 2011, is the patent holder and commercial supplier of UAM equipment. UAM equipment has a TRL level of 9 and is straight forward to learn while embedded fiber optics is at a TRL of 5. Fabrisonic employs technicians who have CNC backgrounds to operate in-house part manufacturing equipment. Fabrisonic also sells equipment. Customers are national laboratories, universities, and commercial customers.

PROBLEM STATEMENT

- Maintenance currently relies on visual inspection, scheduled intervals, and machine break-down.
- Metallic component inspection and sensing technologies are currently limited to accessible areas, which limit information quality/usefulness.
- Ultrasonic Additive Manufacturing (UAM) enables building sensors directly into metal components, which allows in-situ inspection in difficult to reach areas and provides protection for the sensors against the operating environment.

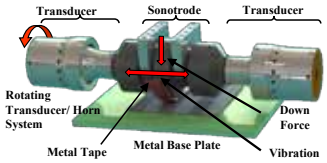
BENEFITS

- Sensor data can be combined with prognostic inspection tools (digital twin) to more accurately identify problems and provide enhanced inspection.
- No melting in UAM avoids damage/melting of embedded sensor and its respective coatings.
- No atmosphere requirements allows large working spaces, flexible geometries, and customized tooling.
- Fiber interface is strong and resistant to fatigue testing. Embedded sensors have found fatigue cracks due to their small size and sensitivity.

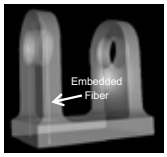
TECHNOLOGY SOLUTION

- UAM is a solid-state (no melting) 3D metal printing process.
- The process has been used to embed small fiber optic strain gauges in aerospace aluminums, stainless steels, and be used on large components with complex internal geometries (6’ x 6’ x 3’). Other embedded sensors are possible.
- The process has been commercialized and patented by Fabrisonic LLC (TRL 9).
- CNC technicians operate the equipment.

Welding Stage: Additive

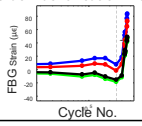


CT Scan of UAM Bracket

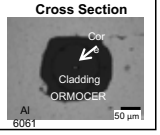


CNC Stage: Subtractive

Crack Identification Via Strain



Embedded Fiber Cross Section



HIGH SPEED ADDITIVE MANUFACTURING OF COPPER AND ALUMINUM COMPONENTS

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Problem

Current Additive Manufacturing methods for metal components rely on slowly fusing layers of powder or robotic control of welding layers in a defined pattern. Copper and Aluminum powdered alloys have been difficult to use in today's laser-based machines, as they tend to reflect much of the light, resulting in uneven heating. In addition, melting results in changes to chemistry and metallurgy that can be difficult to control, especially in less than ideal conditions.

Solution

Supersonic cold spray is a proven technique to apply thin layers of metal materials, currently utilized for specialized properties or repairs, where melting of the metal is not acceptable. Using novel software and simplified hardware, cold spray has been extended to provide additive manufacturing of thick and highly dense, copper and aluminum components. Cold spray additive manufacturing produces metal parts 10-1000 times faster than current additive manufacturing methods, and material properties are predictable and repeatable, since the powdered metal is not melted.

This process can quickly supply casting quality parts for emergency repair and could be evaluated for the design of novel heat exchangers and electrical conductors that can be replaced in the field through a "print on demand" process.

Proprietary software converts a CAD image into a 6-axis robot movement of the part, as metal powder is sprayed from a fixed nozzle at speeds over 600m/s. Using compressed air to accelerate the particles keeps operating cost low and availability of the machine high, as compared to other approaches that are dependent on helium or argon gas. Dense, strong, and ductile properties have been demonstrated in Aluminum, equivalent to typical 356-T6 castings (30ksi UTS; 4% elongation). Copper parts maintain good conductivity (90%IACS), as well as, maintaining strength and ductility after a simple annealing (25ksi UTS; 5% elongation).

Benefits

In addition to designing specialized heat exchangers and electrical conductors, the simplicity of printing has led to copper substituting for cast iron and steel components when replacement castings were not available. If time is of the essence, a small inventory of copper or aluminum powder, has the versatility to quickly transform into a variety of parts. The high speed of printing and the simplified supporting equipment for the cold spray process, could become an essential tool for front line MRO needs.

PROBLEM STATEMENT

- Maintenance of DoD platforms require difficult to source, expensive, and/or long lead time components.
- Repair processes must not degrade critical properties of the components.
- Additive Manufacturing (AM) is being considered for many applications; however, all the current processes rely on melting metal, leaving it *difficult to reliably control* the material properties.
- Current AM technologies are *slow to print* (ranging from .1-2 grams per minute) and constrained by additional supporting structures, as well as, *thickness and density.*
- Powder AM materials are highly specialized with limited *availability and high cost.*

BENEFITS

Improved Readiness
- Variety of components from single metal powder inventory
- Build parts ***Where you need it, When you need it***
- No special gas, just compressed air

Reduce Cycle Time
- No tooling
- ***Faster than subtractive milling*** from metal billets
- Much faster than other AM processes

Reduced Cost
- Wide range of source powders
- ***No expedited supply orders or special tooling***
- Enhanced heat transfer and/or electrical conductivity

TECHNOLOGY SOLUTION

- "Print on Demand" copper and aluminum castings from a simple CAD file and inventory of metal powder
- **Supersonic Cold Spray** to reliably maintain the material properties of the source powder – no melting of metal
- Wide range of powder size and flexibility with quality of powder supply – machine parameters can be quickly tested and adjusted
- Demonstrated ***printing of thick and dense castings*** at ***deposition rates of 20-140 grams per minute***.
- Over 95% of powder adheres to component
- Porosity at less than 2%, typically .5-1%
- Fatigue properties superior to casting
- **Copper – UTS=25ksi, Elongation=5%, conductivity=90%IACS**
- **Aluminum – UTS=30ksi, Elongation=4%**

PCRT RESONANCE ANALYTICS TO QUALIFY ADDITIVELY MANUFACTURED PARTS

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Additive manufacturing (AM) techniques have advanced dramatically in recent years and can solve the Department of Defense (DoD) maintenance and material readiness challenges of diminishing supply sources, part obsolescence, and service life extensions, while reducing operating costs of aging platforms. Before the potential can be realized, however, tools and technologies for qualifying AM components, processes and materials are needed to ensure that AM components are fit for service.

Process Compensated Resonance Testing (PCRT) is a potent tool for process qualification, monitoring and control, and supplier evaluation for AM components. It is a unique, non-destructive evaluation (NDE) technology that is a fast, accurate, full-body means of evaluating structural integrity and micro-structural variations in metallic, ceramic, and some composite parts. PCRT is at the forefront of NDE and process monitoring development for AM applications. A report by America Makes–National Additive Manufacturing Innovation Institute identified PCRT as one of only two methods that can screen geometrically complex parts with 100% coverage.

PCRT was proven in the NDE of engine components, landing gears and wheels, and in process monitoring of cast, forged and machined components for the aerospace and automotive industries. These solutions provide the data needed to prove confidence in AM components. Emerging PCRT studies of AM parts show detection of porosity-related defects, powder supply variation, process variation, retained powder and correlation to performance testing.

PCRT also has unique advantages in low volume applications, supporting the reverse engineering of legacy components for which no supply is available. In these applications, PCRT can confirm that the built component precisely matches the model, and the replacement part matches the legacy component.

PCRT currently stands at Technology Readiness Level (TRL) 6 for AM applications. In its AM IR&D and commercial projects, Vibrant has performed PCRT evaluations with prototype systems in relevant manufacturing environments. Since 2010, when FAA approved PCRT for the testing of a jet engine turbine blade and the ASTM Standard Practice for PCRT was published, Vibrant has proven its ability to advance PCRT technologies from TRL 6 to TRL 9, with fielded and fully operational PCRT inspection systems in just weeks or months.

PCRT systems are production/maintenance-line ready and can be integrated with parts-handling automation. The systems are configurable to a broad variety of part geometries, and provide Pass/Fail results in seconds, without highly trained inspectors or operators.

PCRT assures part quality at every state, from verifying that the part built is the part designed, in order to track the consistency of every part produced. PCRT provides a fast, inexpensive, and effective NDE method that correlates to component material properties and defects, enabling the qualification of end-use AM components.

PROBLEM STATEMENT

Additive Manufacturing (AM) techniques have advanced dramatically in recent years and can solve the DOD maintenance and material readiness challenges of diminishing supply sources, part obsolescence, and service life extensions, while reducing operating costs of aging platforms. Before that potential can be fully realized, **tools and technologies for qualifying AM components, processes and materials are needed to ensure that AM components are fit for service.**

AM processes are being used to produce even critical components, and quality assurance tools have yet to catch up to the challenges posed by AM methods.

BENEFITS

- Resonance correlates DIRECTLY to material properties that affect fitness for use.
- PCRT is proven in commercial, aerospace and automotive.
- Precise, repeatable, whole- or full-body inspection.
- Fast, 100% testing versus sampling.
- Pass/fail results. No operator interpretation needed.
- Records resonance through coatings–no coating removal required.
- Adjustable to various part dimensions and geometries – from bearings and bolts to aircraft wheels.
- Scalable to operation size – from semi-automatic to robotic.
- Green and safe – no hazardous radiation or chemicals.
- Can track accumulation and fatigue over time, providing a digital historical record, enabling CBM+ and Life Management.

TECHNOLOGY SOLUTION

- Process Compensated Resonance Testing (PCRT) is a potent tool for process qualification, monitoring and control, and supplier evaluation for AM components.
- For in-process and post-process AM inspection, PCRT has demonstrated detection of porosity-related defects, powder supply variations, process variation, retained powder and correlation to models and performance testing.
- PCRT has been proven on engine components as well as casting, forged and machine components for the automotive and aerospace industries. DLA and AFRL are currently investing in the development of PCRT systems for Qualification of AM components.

PROGNOSTICS BASED SCALABLE ADDITIVE MANUFACTURING (AM) ASSESSMENT ARCHITECTURE

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Problem

Integrating Additive Manufacturing (AM) capability into existing enterprise wide infrastructure is a major challenge. It requires a method that links all the engineering design expertise, reference geometries, finite element models, knowledge of failure modes, and material science knowledge within operational environments and associated data sets presently in use. Many engineering software tools embed engineering rules into their product. It is impossible to maintain rule based engineering software as AM design and process innovations are rapidly evolving. A software tool without an ability to adapt effectively reduces AM advantages in the areas of reliability, inspect-ability, and maintainability over a component's operational lifetime.

Technology

Analatom's rule adaptive software architecture enables efficient and reliable structural or functional components to be fabricated under enhanced AM processes for improved inspect-ability, performance, and operational safety throughout the AM component's operational life. Using bioinspired associative memory that automatically creates data linkages across millions of attributes, an end to end, prognostics based scalable AM assessment architecture applies modern concepts from simulation, modeling, and control theory along with Prognostics Health Management (PHM) and the Taguchi method to improve understanding of critical AM process control and design spaces. This flexible computational framework incrementally learns optimal parameters and discerns parameter sets that lead to degradation profiles. The architecture has four levels that include molecular dynamics simulation of material degradation and defects, AM advanced statistical process control and monitoring, enhancing end-use items with sensors, and operational environment assessment techniques.

Technology Status

Validation assessment of Analatom's technology using associative memory has involved:

1. Building a multiple element heat exchanger design,
2. Modification of design to optimize sensor placement or NDI inspection probes,
3. Data capture at materials and engineering modeling stages, design stages,
4. Design aids inspections by being manufactured with different geometries to resonate at different frequencies via NDI ultrasonic probes,
5. During build CT scan data collection,
6. After build NDI Quantitative Percussive Diagnostics (QPD) method validating #4,
7. After build planned accelerated corrosion testing and data collection and 8) Link observed data from computational tools.

Test Data Support

Test data was obtained by capturing images during the AM process for every fused build stage. An image-based associative memory linked data for selected "as-built" parts and could distinguish between "normal" and "seeded defects" regions within the fused slice images across the image set provided by the 3D printer team.

PROBLEM STATEMENT

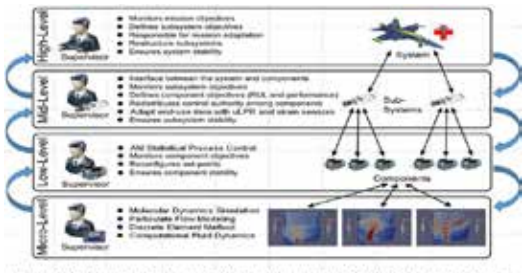
- How to integrate Additive Manufacturing (AM) capability into the existing enterprise-wide infrastructure.
- Difficult to continuously adapt rule-based engineering software systems to keep up with AM design and process innovations.
- ➢ Result — Effectively reduces AM advantages in:
  - ➢ Reliability
  - ➢ Inspect-ability
  - ➢ Maintainability

BENEFITS

- Improved understanding of process control and design space for AM processes.
- Further expand the utilization of AM technologies by incorporating a method to assess in *design*, *manufacture*, and *use*:
  - ➢ Reliability
  - ➢ Inspectability
  - ➢ Maintainablity/Repairability
- Method applies to AM components over operational lifetime.

TECHNOLOGY SOLUTION

- Requires *scalable* approach that can link within operational environments and associated data sets presently in use:
  - ➢ Engineering design expertise
  - ➢ Reference geometries
  - ➢ Finite element models
  - ➢ Knowledge of failure modes
  - ➢ Material science knowledge
- Utilizing bio-inspired software architecture, automatic data linkages can be created across millions of attributes.
- Enables linking all data across all levels, providing systemic control and technical feedback opportunities to organizations and functional specialists associated with each level.



Hierarchical Integration: Micro (materials), Low (components), Mid (subsystems), High (system)

Next Steps/Potential Benefits

This approach further expands the utilization of AM technologies by incorporating a scalable method to assess the reliability, inspect-ability, maintainability, and repair-ability to AM generated parts from initial design through their operational lifetime. A prognostics-based scalable AM assessment architecture will find application in virtually all future design, manufacture, maintenance, and repair activities; and ultimately will become an essential component for all digital designs incorporating AM fabrication processes.

RAPTOR MEANS READINESS: HOW SOLDIERS PULL ON THE DIGITAL THREAD

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Additive Manufacturing (AM) or 3D Printing is a disruptive technology which allows the Warfighter to perform expeditionary repair and mitigate down time caused by battle damage and depleted supply. An overall enterprise-wide view sees using AM in several areas to improve and modernize through advanced technology development.

Focusing on the tactical point of need use case for AM, two direct benefits to the Warfighter are "increased readiness" through manufacturing and/or repairing components in the field and the other is "enhanced Warfighter capabilities" using AM to create new field expedient solutions.

In response to this need for a robust digital thread, RDECOM – ARDEC developed RAPTOR (Repository of Additive Parts for Tactical & Operational Readiness) to provide the required technical data at the point of need. RAPTOR is a repository that provides access to digital data files for expeditionary manufacturing processes to produce battle damage assessment repair (BDAR) or emergency/temporary repair parts while supply system delivers replacement parts. The interface is easy-to-use linking the Warfighter to data via an intuitive graphic user interface. RAPTOR also links the Warfighter to engineering through a reach back process providing rapid engineering oversight for unique field applications. RAPTOR provides the simple, intuitive interface to a 3D repository allowing the Warfighter to use AM at the tactical point of need to increase readiness and enhance their capabilities.

Significance

The digital thread connects equipment, data and users allowing distributed manufacturing. Both commercial industry and the government are facing similar challenges concerning how to implement the digital thread. The Army use case is unique due to the dual missions of temporary field repair (expeditionary, point of need) and traditional component manufacturing performed by industry. The discussion of how the Army is addressing both cases will provide insight to the audience, challenges the Army faces and how these challenges are being addressed. The audience will be able to relate the Army missions to the commercial missions: temporary field repair is similar to creating tooling and fixtures; traditional component manufacturing is the same. The discussion will allow dialogue between the Army and industry on innovative solutions for operationalizing the digital thread. The audience will relate to the Army's enterprise view of the digital thread and learn ways to implement in their use cases.

PROBLEM STATEMENT

- Additive Manufacturing or 3D Printing is a disruptive technology which allows the Warfighter to perform expeditionary repair and mitigate down time caused by battle damage and depleted supply.
- Although the Warfighter has rugged additive manufacturing equipment; data is needed to fully execute the mission.
- What is the data? How is that data delivered to the Warfighter?

BENEFITS

- Data required for expeditionary repair is accessible by the warfighter.
- Expeditionary repair increases system and Warfighter readiness.
- Support by PMs, PEOs and Engineering Support Activities.

TECHNOLOGY SOLUTION

- Repository that provides access to digital data files for expeditionary manufacturing processes to produce battle damage assessment repair (BDAR) or emergency/temporary repair parts while supply system delivers replacement parts.
- Easy-to-use interface which links soldier to data via an intuitive Graphic User Interface (GUI).
- Provides multiple search options such as system type, printer or material, NSN, etc.
- Scalable from point-of-use to enterprise deployment.

POINT OF SERVICE STRUCTURAL AIRCRAFT REPAIR

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Structural repair is a costly activity for DoD. Like the maintenance of most long lived structures, the need for specific repairs is somewhat random due to the large variation in causes: rate of use, hard landings, weather, FOD, corrosion, and most critically combat. Actual costs are generally not captured completely. Total asset force size required, inventory holding costs for rarely needed parts, blue streak expedited manufacturing and acquisition/logistical/transportation overhead costs are a small sampling of costs not directly included in the cost of repair.

Currently, the majority of structural parts require extruded metal cross sections to be press formed and machined to tight specifications before painting and installation. This activity requires large complex machine tools with 440-volt 3phase electrical service, custom tooling for each part being made and specially trained personnel to make tools and operate the equipment.

FT's solution involves two new technologies for point of service manufacturing. The first is SRF (stretch roll forming). SRF is a patented technology that uses conventional forming methods to incrementally create parts without custom tooling, special operators, or unique materials, all with field-able electrical requirements. It only requires standard extrusions and computer code (digital thread) to form a part.

Our second technology, XM (Extrusion Machining) can by using the digital thread data, machine the formed extrusions without tooling. Both these technologies will have the capability of digitally inspecting the finished parts and providing inspection data to airworthiness authorities from the field.

Fairmount Technologies (FT) has received from DLA, two, DMSMS related SBIR, contracts. These phase II awards both address the need for local one off part manufacturing of formed aircraft parts. Both technologies have TRLs in the 5 to 6 range and MRLs above 4 to 5.

Test data shows that SRF forming is equivalent to conventional forming (NIAR/Textron/FT) in fatigue properties. First Article inspection shows dimensional equivalence to conventional forming and machining.

FT is seeking a second phase II award for the SRF. The goal is to begin manufacturing parts for a program of record to show a strong ROI in a manufacturing environment. With a phase III contract as conformation of the processes ROI. For sustainment, we are seeking CRATAs with the service branches to access part data for digital thread file production for demonstration part manufacturing. This is a cost sharing contribution to the effort.

PROBLEM STATEMENT

- Aircraft Structural Parts are costly to DoD in both procurement (purchase cost), logistics (storage & transportation) and readiness (opportunity cost). Component production is a long lead time, multi-step process requiring special tooling, processes and skilled labor to produce parts. Parts are procured through the DLA, from Primes, or organically manufactured at Depots & FRCs
- DMSMS (Diminishing Sources and Material Shortages) are seen regularly with lead-time for parts approaching years, not months. Current technological approaches for airframe components, such as 3-D printing, lack technological maturity and face complex airworthiness approval processes for aging aircraft.

BENEFITS

- Technology Deployable to manufacturing facilities, Depot/RCs, flight lines or in theater.
- No part specific tooling for forming or machining parts, forms many parts from final temper materials – no heat treatment.
- Meets airworthiness standards as an equivalent metal forming manufacturing process.
- Reduces procurement costs as a Digital Thread enabling processes, reoccurring engineering is reduced or eliminated.
- Reduced operator training requirements with computer automation of the process the one off part making process.
- Maturation Path thorough ManTech funding in program of record. i.e; vertical lift, commercially derived, or new program.

TECHNOLOGY SOLUTION

- Advanced Manufacturing Technologies ***SRF*** and ***XM***, were developed with DLA funding, they enable theater-based manufacturing of airframe components that meet airworthiness standards for vertical lift and fixed wing aircraft.
- ***SRF*** is stretch forming reimagined as a novel, portable, tool-less process that uses CNC traction stations to curve straight extrusions into programmed contours. Variable contours of any length along the part can be formed to radii of less than 30 degrees. It produce reverse curvatures and can add twist.
- ExtruMach-***XM*** is a novel CNC mill that machines curved extrusions into required parts accurately without part-specific machining fixtures Like SRF, it uses digital data (digital thread files) to manufacture components to aerospace tolerances.

OC-ALC 76TH CMXG REACT METAL AM TOOLING AND TESTING EQUIPMENT

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Sustainment of aging aircraft presents unique challenges due to lack of technical data, aging legacy tooling, and the need to rapidly respond to parts availability issues for a variety of aircraft and exchangeable end items. To meet the needs of the Oklahoma City Air Logistics Complex depot customers, engineering must be responsive and leverage technology to expedite the return of aircraft and their components to service as quickly as possible. The 76th Commodities Maintenance Group (CMXG) has leveraged 3D laser scanning and metal additive manufacturing to create solutions for depot maintenance problems where traditional manufacturing is not possible or too slow. CMXG has had great success augmenting contract and organic manufacturing by enhancing and producing end-use tooling, including crimp dies, gauge blocks, spline keys and testing fixtures created by Direct Metal Laser (DMLS).

When B-1 production was unable to replace their damaged wire harnesses for the critical fuel center of gravity management system CMXG used metrology measurement equipment to reverse engineer the crimp dies and gauge blocks required for wire harness fabrication. Due to the crimp dies needing high strength and the gauge blocks needing to meet tight dimensional tolerances the parts were fabricated using DMLS. This provided Tinker with the capability to fabricate these wire harnesses overnight. DMLS 3-D additive manufacturing greatly reduced cost for machining and greatly reduced turn-around time from 4-6 months to one week.

When B-1 Production was conducting testing on a valve body assembly, they test the internal shafts by shoving a screwdriver in the spline and manually turning it to see if it moved the butterfly valve. This greatly increased risk of damaging a good part simply because they did not have the right tool. CMXG designed and metal AM two configurations of a spline key that either could use a drill or could turn the valve by hand. The parts were added to an existing print and cost less than $3 each in material.

CMXG is also developing load limit tester for B-1 torque tubes. These tubes are being refurbished in production and are supposed to be loaded to 7000 in lbs of torque to ensure they were repaired correctly, however production has no way to hold or torque the tubes. CMXG is designing a fixture to hold both sides of the tube and safely torque the part. The design has been printed using a cheaper AM method to test fit the parts before moving forward with the metal print. The design provides a cheap quick solution and leverages metal AM as the part would be impossible to make with any other fabrication method.

The cost avoidance from metal AM for tooling has expected savings of $125k and 750 flow days annually. CMXG is leveraging modern technology to deliver cost effective engineering solutions to the war fighter.

PROBLEM STATEMENT

- 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 verity parts meet requirements. This leads unnecessarily to scrapping good parts or increasing risks by flying potentially bad parts.

BENEFITS

- Rapidly prototype tooling and test equipment.
  - Reduces material waste by $100K and 720 flow days annually
- Print low production run tooling on demand to offset Local Manufacturing – annually:
  - Free up machine time by 120 hours
  - Reduce lead time by 750 flow days
  - Reduce tooling cost by $125K
  - AM allows for tooling to be designed in a way that would be impossible to machine
- Enabling non-OEM sources of supply

TECHNOLOGY SOLUTION

- Laser scanning and measurement to measure good parts and determine critical dimensions
- Using scan data to design tooling specifically for Metal AM in CAD software
- Metal Additively manufacture tooling and test equipment to rapidly provide capabilities to manufacture and test parts

GRAPHIC

HULL CRAWLING ROBOTS

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Overhaul and modernization of submarines is an inherently dangerous and difficult task. Portsmouth Naval Shipyard has worked in partnership with a small business (International Climbing Machines) to revolutionize various work processes using robotics technology. The hull climbing machines take the human out of harm's way by providing an autonomous, interchangeable platform to execute functions such as tile removal, blast and paint, cleaning, surveying and more. While still in its early stages these units have been deployed on various hulls and performed experimental tasks.

When discussing a safety example in particular, to remove certain types of tile from the submarine we use very high-pressure water jets to blast it off the underlying metal hull. This is performed with a person holding a lance and maintaining control to blast the tile away. No matter how much personal protective gear one wears, there is risk of losing control and injuring oneself, which has actually happened before.

Using a robot instead to perform this work, we have fully mitigated the risk to personnel by moving them outside of any potential harm from a dangerous blast of water.

When discussing an efficiency example in particular, we cite the job of surveying the dry dock floor. This task generally takes a team of multiple people multiple days to hand mark (crouching to the floor) and survey for contamination. With a hull crawling robot modified for crawling the floor, this may be accomplished with one person in a much shorter timeframe, in a far more ergonomically friendly manner utilizing a remote control.

While much remains to be discovered and trialed in the usage of these robots, we are well on our way to a safer and more productive work environment using this technology.

PROBLEM STATEMENT

- The execution of various blasting, painting and cleaning processes are inherently dangerous when performed directly by humans.
- Radiological surveys of dry dock floors and ship's hull's generally require large numbers of personnel and man days in ergonomically unfriendly conditions.

BENEFITS

- Safer work environment as humans are removed from harms way in regard to dangerous work processes such as sand blasting, water jetting etc.
- Relief from ergonomically unsatisfactory work practices.
- More efficient work process requiring far fewer resources.
- Paves the way for future more autonomous future solutions (think "set it and forget it" for surveying a dry dock floor, similar).

TECHNOLOGY SOLUTION

- Hull climbing robots with a center console that functions as an interchangeable platform for attaching various payloads.
- Operated via remote control to move humans out of harm's way.
- Huge opportunity to partner with private industry and aid in expanding partnerships and collaborations between multiple private companies and NAVSEA.

REDUCING MAINTENANCE CYCLE TIMES BY LOCATION SERVICES FOR YARD AND DEPOT MANAGEMENT

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In military and private environments, hours are lost trying to find the location of an asset that has been moved somewhere in a large unimproved area such as a yard, port, or parking lot. Thousands of man-hours can be reclaimed by locating assets in areas that can be over 4 square miles and comprise of almost 100,000 items. Organizations and companies attempt to mitigate this problem with Radio Frequency Identification (RFID) solutions, most approaches do not address this critical shortfall in item location. The result is increased maintenance and repair cycle times as man-hours are lost tracking either principal end items or critical parts.

In response to this requirement, IR Technologies developed the GlobalTRC+TM and its portable counterpart MobileTRC+TM applications with the Find My Asset (FMA) capability. FMA locates assets on a map, determines the distance to an asset in relation to a user, provides last status of an asset based on the last known location, supports dynamic maintenance operations where repairable items are moved from lot to lot and station to station, and perhaps most importantly supports all types of RFID infrastructures. Other RFID location services provide limited directional context or require handheld readers and the user must be in close proximity to the tag. Handheld RFID readers may have a 'Geiger Counter' type of capability, but the user must be in tag reading range to identify the item.

GlobalTRC+TM and MobileTRC+TM applications that host Find My Asset are easy to use intuitive cloud-based products that requires little training. The system can be cloud or premise based. GlobalTRC+TM provides a comprehensive tag and asset tracking management system, while MobileTRC+TM extends the functionality to personal devices such as a smartphone or tablet and provides the local presence to add, modify, or remove tags and assets from the system.

The benefits of this capability include improved equipment and item management in austere or unimproved environments, quicker turnaround for maintenance of assets in all types of conditions and environments, and increased quality and safety by rapid location of defective lots and items such as cracked axles or contaminated lubricants. For the following scenario, we estimate the following benefits:

An agency has 130-acre unimproved lot holding over 700 vehicles for repair and maintenance. The 700 vehicles are all similar makes, models, and colors. The agency has installed a fixed active RFID infrastructure in the lot and tagged each vehicle with RFID when it enters. Unfortunately, RFID only tells them they have the vehicle, not where the vehicle was located. The agency estimates 90-120 minutes are wasted locating a vehicle on the lot. They average locating 10 vehicles per day. GlobalTRC+TM and MobileTRC+TM with FMA saves 60-90 minutes per vehicle or over 3600 man-hours per year. These hours can be returned to maintaining or repairing vehicles, which increases the maintenance capacity of the agency by one vehicle per day.

PROBLEM STATEMENT

- In military and private environments, maintenance hours are lost trying to find the location of an asset that has been moved somewhere in a large unimproved area such as a yard, port, or parking lot.
- As a result maintenance and repair cycle times are increased.
- Results in reduced profits, customer satisfaction, and military readiness.
- Other RFID location services provide limited directional context or require handheld readers and the user must be in close proximity to the tag.

BENEFITS

- Location of an asset on a map
- Determination of the distance to an asset in relation to a user
- Location of an asset in the storage lot by Serial Number, VIN, model, and make
- Last status of an asset based on the last known location
- Generation of dynamic inventories showing how many assets are on the premises in support of maintenance cycles
- Reduced cycle times for maintenance and repair
- Supports all tracking infrastructure types
- No requirement for expensive Handheld RFID with 'Geiger Counter' functions with limited range

TECHNOLOGY SOLUTION

- IR Technologies developed Global***TRC+***™ and Mobile***TRC+***™ as easy to use intuitive cloud-based software products that requires little training.
- Contains the Find My Asset capability
- The system can be cloud or premise based.
- Global***TRC+***™ provides a comprehensive tag and asset tracking management system.
- Works for all Radio Frequency Identification (RFID) types (Passive, Active, Bluetooth)
- Mobile***TRC+***™ extends the functionality to smartphones or tablets and provides the local presence to add, modify, or remove tags and assets from the system.

Mobile***TRC+***™

Find My Asset

- Blue Arrow points in direction of Item
- Distance and item data is also provided

THEATER INTEGRATED COMBAT MUNITIONS SYSTEM

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The AF Theater Integrated Combat Munitions System is a comprehensive Application as a Service (AaaS) initiative to replace 8 legacy munitions-related IT systems providing critical warfighting mission area capabilities while preserving associated business mission area functionality. Breaking from traditional approaches to IT deployment and management, the munitions community embarked on an aggressive, game-changing strategy to deliver critical capability to AF warfighters.

With a full suite of modular and scalable functionality, including the ability to operate in a planned/unplanned disconnected state, TICMS will revolutionize munitions capability planning, command and control, maintenance, complete-round assembly, expenditure reporting and total asset visibility with full, audit-ready transactional level detail. Partnering with the AF Command, Control, Communications, Intelligence and Networks (C3I&N) program executive office to host, configure and test in a government cloud environment, the munitions community is redefining the model on inserting rapid innovation into today's operations and increasing readiness.

On schedule for User Acceptance Testing in Dec 2018 and full deployment to ~207 locations in Mar 2019, TICMS lays the foundation for continued dominance in air, space and cyberspace and sets the conditions for fully networking the munitions data into warfighting mission area combat systems.

PROBLEM STATEMENT

The US Air Force lacks a single authoritative system to manage safety, security reliability, maintenance, availability and accountability of $25B conventional munitions stockpile

Current system(s) lack ability to:
- Meet Congressional and DoD financial reporting
- Meet Defense Logistics Management Standards (DLMS)
- Implement Item Unique ID and ownership coding
- Leverage decision support tools
- Operate in a disconnected/comm-out environment

Net effect is decreased kinetic readiness, labor intensive manual work-arounds, and increased risk acceptance

BENEFITS

Increased kinetic and audit readiness
- Enables mgrs/planners to view current/proj inventory
- Assess capabilities, direct and monitor movements
- Report/analyze expenditures
- Maintain safe, secure, reliable stocks
- Automates/eliminates manual processes
- Reduces manpower/overhead (81 FTEs to~12-15)
- Projected $8M cost avoidance and $8M savings re-invested in LOG IT modernization across FYDP

TECHNOLOGY SOLUTION

TICMS is the AF's single application for worldwide conventional munitions configuration management, capability analysis and combat support.

Consolidates/integrates functionality of 8 IT systems:

- Combat Ammunition System (CAS)
- Ammo-Web (including SIPR variant)
- Agile Munitions Support Tool (AMST)
- RAM/TMRS (including SIPR variant)
- Integrated Missile Database (IMDB)
- Munitions Command and Control (MC2)

THE 5QUADPOD – A WAREHOUSE IN MOTION

ALEXANDER MCCREDIE
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In 2015, the U.S. freight transportation system moved $52.7 billion in goods per day. Annually, worldwide costs for repositioning empty containers can reach $20 billion, while the Port of Newark proclaims that 1 in 3 containers are left rotting in "container graveyards" across the US, and the World Shipping Council estimates that an average of 568 malfunctioning containers crumble and fall into the sea adding millions to overall freight costs. Add to that a lack of visibility into the packing and storage of the containers, driving manual labor through the roof, and clearly, the current containerization strategy for commercial and military shipping is prime for disruption.

The 5QuadPod™ "System of Systems" supports the needs for unitized portable containers, while providing a platform for selective off-loading and sense and respond technology. This Warehouse in Motion™ can be configured to provide packaging, perform sorting and storage functions, adapt to multiple transportation modalities, including staging for unmanned aerial vehicles (UAV) and provide the vehicle for distribution and final product display. Technology integration, in the form of Global Positioning technology and environmental sensors, will enable logisticians to control cold-chain, chain-of-custody and cargo security in real-time.

The new paradigm consists of a series of articulated of lightweight modular packaging units called Quads™ and collapsible frames called QuadPods™. The Quad™ is the modular packaging system consisting of a configurable pallet base and a box frame with sliding panels. A Quad™ measures 40" X 48" X 45" (W x L x H) and can pack a maximum 7000 lb. payload where axle weight limits permit. Each Quad™ can be interlocked to form a rigid multiple stand-alone QuadCube™ for insertion into a standard ISO container (transitional).

The QuadPod™ is a collapsible frame that has the potential to substantially cut down on the repositioning costs. Each QuadPod™ frame that can handle a payload range of 16,000 to 28,000 lbs. The QuadPod™ frames can be articulated to provide transport via the standard 20', 40' or 53' trailer for truck, rail, and air.

Each QuadPod™ frame is the sole load bearing element of the shipping platform. Each frame can still meet the current 4 point ISO 1496 standard established by the original ISO shipping container configuration, but is designed to re-distribute the stack-weight of the shipping platform over 30 integral pressure points for superior strength and stability to cut down on container malfunction. The structural elements of the exoskeleton utilize leading-edge composite technology to reduce weight, while improving weight-bearing capacity.

The team of Modular Dynamics, Tactical Edge, Inc., and Enterprise Management Systems is asking for $17.2 million over three years. With members strategically placed in Washington, DC, Pittsburgh, PA, Annapolis, MD, and San Diego, CA, the team will use this funding to experiment with the latest materials, refine the integrated tracking technology, and produce the first 9 containers. Six of those containers will be used to gather information to build a business case for the product. The final three containers will be used to obtain ISO 1496 certification.

PROBLEM STATEMENT

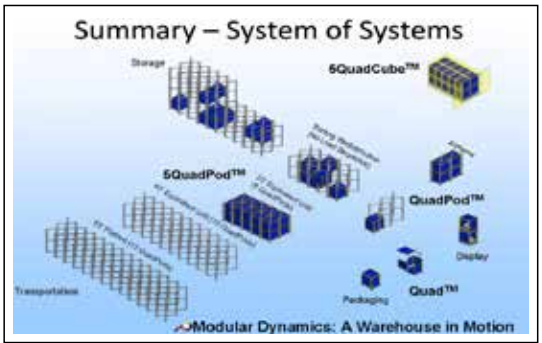
In 2015, the U.S. freight transportation system alone moved $52.7 billion in goods each day. However, worldwide costs for repositioning empty containers can reach $20 billion annually, 1 in 3 containers are abandoned and left to rot in "container graveyards" across the US, and an average of 568 malfunctioning containers crumble and fall into the sea annually adding millions more to overall freight costs. Add a lack of visibility into the packing and storage of the containers that drives manual labor through the roof, and clearly the current commercial and military containerization strategy for the shipping industry is prime for a disruption.
Recent advancements in material and technology now make it possible to build a flexible, light-weight, modular and intermodal system that is needed to address the current demand for a cost efficient solution that provides selective on-and-off-loading capabilities in both commercial and military shipping.

BENEFITS

- Pod Configurations designed to align with the current 1496 ISO standards
- QuadPod Configurations designed to meet the common 20', 40', and 53' shipment container configurations and carry up to 7,000 lbs of cargo
- Empty frames and pallets collapse to 20% of their original footprint, offering a significant reduction in the costs for container repositioning and reducing the footprint for the "container graveyards"
- Technology integration provides the logician with greater situational awareness into the packaging and storage of assets; including where they are in the shipping warehouse as well as what elements they are currently exposed to.
- Eliminate cargo load sequence, allowing the simultaneous loading of multiple pallets and performing sorting and storage functionality
- Materials used to build the containers have ballistic and flame-retardant characteristics

TECHNOLOGY SOLUTION

The 5QuadPod™ "System of Systems" supports the needs for unitized portable containers and provides a platform for the introduction of technology for selective off-loading and the ability to sense and respond. This "Warehouse in Motion" can be configured to provide packaging, perform sorting and storage functions, adapt to multiple transportation modalities, including staging for unmanned aerial vehicles (UAV) and provide the vehicle for distribution and final product display. Technology integration, in the form of Global Positioning technology and environmental sensors, will enable logisticians to control cold-chain, chain-of-custody and cargo security in real-time.



SUPPLY CHAIN TRANSPARENCY FOR DEFENSE MAINTENANCE, SUSTAINMENT AND LOGISTICS

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Defense maintenance, sustainment and logistics suffer from the lack of full supply chain visibility required for real-time mission readiness and inventory carrying reduction. One contributing factor is the disparate resource planning software systems (ERPs) used and lack of connectivity among them. In addition, current paper-based tracking solutions require significant human resources to track an asset.

14bis Supply Tracking has a TRL 4 proprietary middleware system that leverages blockchain technology as a universal connector between physical assets and different software systems. It enables the reading of any existing tagging technology (QR code, barcode, nanoparticles and other stealth marking technologies) and the automatic updating of any existing ERP: from legacy customized ERPs to different versions of SAP, Oracle, DPAS, LMP, GCSS, etc. The system offers many benefits among which maximum security and full traceability, real-time inventory visibility and the opportunity to eliminate needless paperwork.

We are beginning our first pilot in June 2018 with an aerospace manufacturer and are planning another with a Maintenance, Repair and Overhaul facility. Our system is in prototype form.

The benefit of the project will be to provide instantaneous situational awareness of assets in the supply chain project scope. In addition, it will provide a tested and evaluated prototype that can then be developed for larger scale implementation and testing.

An estimated 35% of the time currently spent on supply chain tracking processes will be saved with the full implementation of the innovative commercial small business systems. In addition, the project will provide data proving the time saved compared with current systems. This will be essential for auditing purposes. We will test the ease of use of the system so that it can be improved and require the least friction possible. Less friction for implementation will allow for easier adoption and use. Finally, CTMA will have a TRL 6 prototype and a roadmap proposal for implementation.

PROBLEM STATEMENT

One of the main supply chain challenges is the inability to have full visibility of the supply chain to ensure real-time mission readiness and reduce inventory carrying. One factor of the problem is the disparate resource planning software systems used and the lack of connectivity among them. In addition, current paper-based tracking solutions require significant human resources to track an asset.

BENEFITS

Relevance / How Technology Addresses Requirement
- Bridges functionality gaps between existing ERP systems;
- Bridges physical gap between physical asset and its provenance using existing marking systems;
- Digitizes and renders visible all provenance information;
- User-friendly interface;
- Potential for data collection and analysis.

Transition (Existing Military System, Program or Capability)
- Integration of existing ERPs (GCSS in Navy, for example) in streamlined system showing full asset provenance;
- Commercial applicability;
- Potential for tracking confidential documents.

TECHNOLOGY SOLUTION
- Enable full asset provenance visibility and provide data visualizations from cradle to grave using handheld reader or smartphone with simple user interface to scan existing physical marking capabilities.
- Secure storage of full provenance, automatically updating software systems (ERPs). We can work with any existing ERP and parts marking technology.

Major Activities:
- Develop TRL 6 prototype;
- Provide interoperability integration of existing ERPs, data sources and tagging systems for fully functioning system;
- Ensure easy UI data visualization.

RECONFIGURABLE MANUFACTURING: A NEW PARADIGM FOR IMPROVED PERFORMANCE OF DEPOT PROCESSES

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Current depot-level manufacturing systems are not responsive to changing requirements and flexible specifications. The serial arrangement of individual work cells results in a lengthy timeline to complete the critically needed part; thus, critical assets are out of service for an extended period. The Reconfigurable Manufacturing System (RMS) is a new approach used by mass manufacturers to respond to the short timelines and flexibility demanded by the highly competitive globalized marketplace.

The current aircraft repair process at the Air Force Sustainment Center at Robins AFB (CMXG) is comprised of several steps:

1. Attaching a metal template to the repair region;
2. Back-drilling through the template;
3. Manually transferring the hole locations on the template;
4. Machining of the final repair.

Our RMS replaces this time and resource-consuming workflow with an efficient, effective process that is synergistic with the military's Digital Thread initiative. Our innovative RMS uses CMXG-resident hand-held, digital scanners to create a digital scan of the repair region coupled with custom software that:

1. Enables immediate assessment of scan quality,
2. Accurately locates attachment hole centers,
3. Produces a data file that can directly input into CNC machine tool to produce the repair.

Our novel approach simplifies logistics, reduces cost, improves efficiency, and speeds the return of the asset to service. In addition, our RMS fosters implementation of the Digital Thread by tying the repair history to a particular aircraft or tail number.

PROBLEM STATEMENT

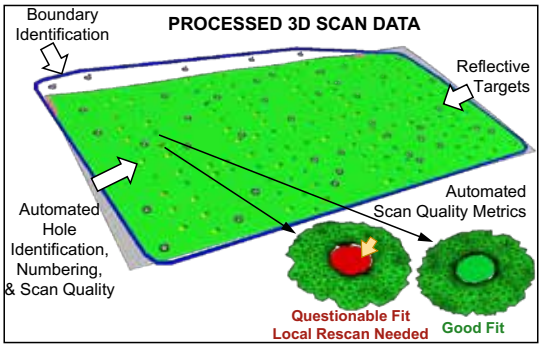
- Current repair process for aircraft damage relies on manually-generated, metal templates to capture locations of fasteners in structures needing repair.
- These physical hole transfer templates are then used to manually produce full machined repairs.
- Key disadvantages of current approach:
  - Time and labor consuming process.
  - No digital record of repair.
  - No ability to anticipate future repairs.

BENEFITS

- Simplify logistics and reduce the number of work days required to return damaged assets to service.
- Enable CMXG, and other repair centers, to decrease backlog and improve efficiency.
- Implement "digital thread" for repairs tied to a particular aircraft or platform.
- Reduce or eliminate the need for manual machining processes, enabling recovery of floor space and personnel.
- Digitize repair history, potentially enabling the stockpiling of repair hardware for known issues on particular platforms or tail numbers.

TECHNOLOGY SOLUTION

- Creare's solution leverages non-contact scanning tools already at CMXG to create a digital scan of repair region.
- Creare-custom software then:
  - Enables immediate assessment of scan quality while scan is being completed.
  - Locates repair attachment hole centers with high accuracy and repeatability.
  - Produces a data file that can be directly input into CNC "conversational" milling machines to produce final repair.



AUTOMATED LOCKOUT-TAGOUT ISOLATION SOFTWARE

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The Lockout-Tagout (LOTO) procedure is the only method authorized for isolating portions of Naval vessels and equipment from hazardous energy sources in order to allow for their maintenance and repair. Before commencing maintenance work, system LOTO isolations are validated by hand-tracing hazardous energy paths on system diagram drawings. With each new LOTO isolation iteration, drawings are re-printed and re-traced. For complex systems, individual party verification of isolations can take days to complete, which is further extended due to the requirement of multiple-party verification checks. The paper-based system is also prone to human errors as a result of the hand-tracing process. With Automated Lockout-Tagout Isolation Software (ALTIS), verification of isolations is performed by a computer within seconds. Because ALTIS maintains a complete database of ship components, it would also provide a more real-time status of ship systems and isolations. Further integration with scheduling software would allow for near-optimal planning of ship maintenance with the ability to analyze the effects of various maintenance-scheduling paths.

ALTIS works by allowing personnel to plan isolations within a computer based, Graphical User Interface (GUI) on top of familiar Piping & Instrumentation and Wiring Diagrams that the hand-traced paper drawings are printed from. Within the GUI environment, isolations from hazardous energy are created by selecting components for Lockout-Tagout until the desired boundary is created. In addition, utilizing algorithms developed for networks, ALTIS validates the isolation boundary by highlighting if potential hazardous energy still exists within the system. Once the LOTO isolations are verified, ALTIS can then generate the Tags list of components for personnel to lockout and tagout, integrating seamlessly into the user's workflow.

Currently, ALTIS is in the proof-of-concept stage and has been incorporated into commercially available CAD software. However, developing ALTIS into a standalone package would aid future development by enabling more avenues of customization for the end-user. Although isolation drawings exist on an individual system level, components and drawings need to be consolidated into a complete ship database.

While testing ALTIS in simulations containing over 250 components, 16 different sources of hazardous energy, and isolations consisting of over 40 isolation Tags, ALTIS verified these isolations in under 30 seconds.

ALTIS proves to not only be a benefit to the Navy, but all industries that utilizes the LOTO process, producing significant time and personnel savings and preventing dangerous mishaps due to improper system isolations. Through digitizing engineering drawings and applying sound mathematical concepts, ALTIS can relieve the cumbersome practices associated with the Lockout-Tagout process.

PROBLEM STATEMENT

- The Lockout-Tagout procedure is the only method authorized for hazardous energy isolations on Naval vessels and equipment.
- The Lockout-Tagout procedure utilizes hand tracing of system components on paper drawings resulting in large time and personnel expenditures. The paper based system can also lead to potentially dangerous and costly errors.
- With the current Lockout-Tagout procedure, "real-time" status of systems and isolations is still paper based.

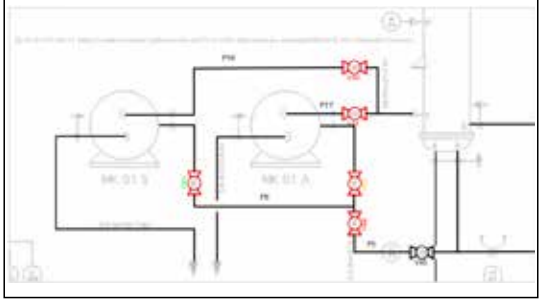
BENEFITS

- Reduction in personnel hours and costly errors with digital validation of isolations.
- Integration with the Shift Operations Management System Database would allow for a closer real-time status of systems and isolations.
- Integration with maintenance scheduling software would enable realizations of near-optimal maintenance schedules.

TECHNOLOGY SOLUTION

- ALTIS is software that enables system isolations to be created within a graphical environment.
- Users select digital components for isolation which are created on top of familiar Piping & Instrumentation and Wiring Diagrams.
- Utilizing algorithms developed for networks, ALTIS validates system isolations and highlights potential sources of hazardous energy.

ALTIS EXAMPLE ISOLATION



QUANTITATIVE ANALYSIS TO ADDRESS FMS INTERMEDIATE LEVEL MAINTENANCE GAP

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Problem statement
Most Foreign Military Sales (FMS) customers lack Intermediate level (I-level) aviation maintenance capabilities. In addition, all FMS component and weapon system repairs above basic, Organizational level (O-level) capabilities are sent to US Depot level (D-level) facilities for full component overhaul, regardless of the component's level of repair-ability. While existing processes track the total quantity of FMS components submitted to D-level facilities, current methods do not exist that enable DoD to differentiate and manage the processing of potentially repairable FMS components or provide alternative solutions to address the FMS Intermediate level maintenance gap. The unnecessary D-level overhaul of potentially repairable FMS components is inefficient and contributes to workflow backlogs within DoD's highest level repair facilities established to provide US Forces, "all repairs beyond the capabilities of the operating units, including rebuild, overhaul, and extensive modification of equipment platforms, systems, and subsystems." These process inefficiencies also result in increased, yet unquantified operational expense and extended repair turnaround time (RTAT) for FMS customers and diminished operational readiness and sustainment rates for US and FMS partner nations.

Solution
Conduct a process analysis of historical quantity, type, associated expense and RTAT of FMS components submitted for DoD D-level overhaul and compare the data to known ratios for US I-level and D-level component maintenance activities tracked via DoD's Web RoR database and Maintenance and Availability Data Warehouse maintained by Logistics Management Institute (LMI). Comparison of data sets will provide a benchmark to determine the statistical total and type of FMS components that are repairable and unnecessarily submitted for overhaul through D-level facilities.

Status
MARSS, Inc. has unique operational experience in this arena and has conducted preliminary analysis and submitted a strategic guidance document for review by the director of Naval Air Systems Command (NAVAIR AIR6.6F) International Program Office which manages the US Navy's $46 billion FMS portfolio supporting 84 partner nations.

Supporting data
Material data and operational experience gathered from the US Army National Guard's 1108th Theater Aviation Maintenance Sustainment Group (TASMG) facility in Gulfport, MS, one of the National Guard's four I-level aviation maintenance facilities, demonstrates that I-level component repair is 33% of the cost and 15% of the RTAT, when compared to D-level overhaul.

Next steps/benefits
Conduct data collection, analysis and interviews with DoD and FMS stakeholders to produce analysis report and recommendations for solutions to reduce maintenance backlog in DoD Depot facilities; increase system efficiencies across the DoD maintenance enterprise; reduce cost and RTAT for FMS customers; and enhance operational readiness and sustainment rates for US and FMS partners.

PROBLEM STATEMENT

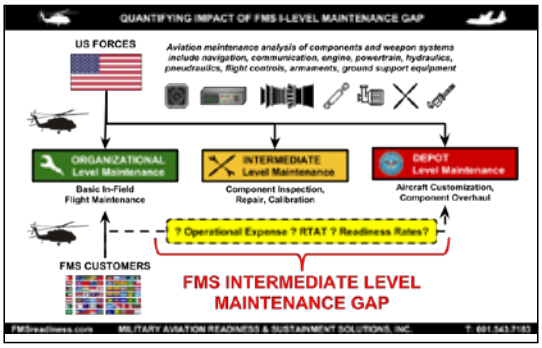
Quantifying the FMS I-Level Maintenance Gap
Most Foreign Military Sales (FMS) customers lack Intermediate (I-level) maintenance capabilities. All FMS aviation component repair above basic, Organizational (O-level) is submitted to DoD Depot (D-level) facilities for full overhaul, regardless of component repair-ability. DoD only tracks total quantity of FMS components submitted to D-level facilities with no existing method to differentiate and manage processing of potentially repairable items or provide alternative solution to address FMS I-level maintenance gap. Unnecessary D-level workflow contributes to backlogs in critical US maintenance enterprise, increases operational expense and repair turnaround time (RTAT) for FMS customers and diminishes readiness and sustainment rates for US and FMS customer nations.

BENEFITS

- **NEW DATA / ANALYSIS:** Provide new, definitive data and analysis for DoD maintenance enterprise leadership
- **REDUCE D-Level BACKLOGS:** Provides a low or no cost method to reduce DoD depot maintenance backlogs.
- **INCREASE EFFICIENCY:** Enhanced D-Level operational efficiencies by reducing workflow of unnecessary overhaul of repairable FMS components.
- **INCREASE READINESS RATES:** Increase DoD (Navy / Marine Corps) aircraft Operational Readiness rates
- **NEW OPPORTUNITIES:** Expand opportunities for US defense industrial base.
- **FMS Partner Benefits**:
  - Reduced maintenance costs
  - Reduced repair turnaround times (RTAT)
  - Increased Operational Readiness rates

TECHNOLOGY SOLUTION

- Conduct analysis of historical quantity, type, cost and RTAT associated with FMS components submitted for overhaul at D-level facilities.
- Compare data to known ratios for US I-level and D-level component maintenance activities tracked by DoD's Web RoR and Maintenance and Availability Data Warehouse.
- Data comparison will provide benchmarks to determine statistical total and type of FMS components that are repairable and unnecessarily processed through D-level facilities.
- Process analysis to provide quantifiable data on FMS I-Gap to DoD maintenance enterprise leadership.
- Recommend process solutions and alternative FMS maintenance opportunities.



ARTIFICIAL INTELLIGENCE (AI): IMPROVED DOD MAINTENANCE RESPONSIVENESS FOR GREATER WARFIGHTER READINESS AND LETHALITY

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Problem Statement
Identify and eliminate operating wastes such as scrap, rework, excess tooling set-up time and costs hindering maintenance response times and limiting warfighter capabilities, mission readiness and lethality. These wastes are faced everyday across the DoD… in Fleet Readiness Centers (FRCs), Air Logistics Centers (ALCs), maintenance and repair depots supporting our nation's Air, Land and Sea forces.

Technology Description
Artificial Intelligence (AI) rapidly analyzes massive quantities of data ("Big Data") using the speed of Cloud Computing to discover previously hidden patterns of waste that constrain higher maintenance productivity and throughput. AI Neural Networks are being successfully used to instantaneously compute all possible sequences (potentially hundreds of thousands) for machining numerous part numbers while identifying the optimal sequence with the lowest total setup time waste. Total number of tooling change-outs are significantly reduced while also lowering the probability of defects (i.e. scrap and rework) and improving process capability (Cpk quality metric). AI dynamically computes remaining process lead time (PLT) throughout the router of each part number in production; thus, allowing for suitable countermeasures using real time work-in-process (WIP) data to ensure on time delivery of vital maintenance and logistics parts and components.

Technology Development Status
An AI Proof of Concept has been prototyped and successfully demonstrated at Kessington Aerospace in Elkhart IN, a manufacturer of high precision machined parts for aircraft engines and landing gears. The performance of the AI solution is being further optimized for large-scale depot application and is nearing completion. The application of AI has led to improved on-time delivery from 52% to >95%, despite Kessington's preponderance of low volume, high mix parts … similar, but on a smaller scale as compared to larger DoD depots (e.g. FRC SE and OC-ALC). Before application of AI it was unknown that the low volume parts, which accounted for only 19% of total parts volume, were in fact responsible for 75% of all factory setup time … consuming as much time in setup (waste) as in value-add machining and responsible for almost all late customer deliveries.

Supporting Data for Performance Claims
Again, overall on-time delivery has improved from 52% to >95%. Overall costs have been reduced by 23%, scrap reduced from 8% to 3%, and operating profits improved from -3% to >20% in less than 18 months. We believe these results to be highly transferable to DoD maintenance environments.

Next Steps / Potential Benefits
AI will arm DoD depot maintenance environments with a most formidable weapon for achieving greater cost-wise mission readiness and lethality by achieving 1) production capacity increase of >20% with no manpower increase, 2) cycle time reduction of >30%, and 3) on-time delivery-to-promise date >90% with no increase in inventory.

PROBLEM STATEMENT

Identify and eliminate wastes such as scrap, rework, excess tooling set-up time and costs that hinder maintenance response times and limit warfighter capabilities, mission readiness and lethality. These waste challenges are faced everyday across the DoD … in Fleet Readiness Centers (FRCs), Air Logistics Centers (ALCs), maintenance and repair depots supporting our nation's Air, Land and Sea forces.

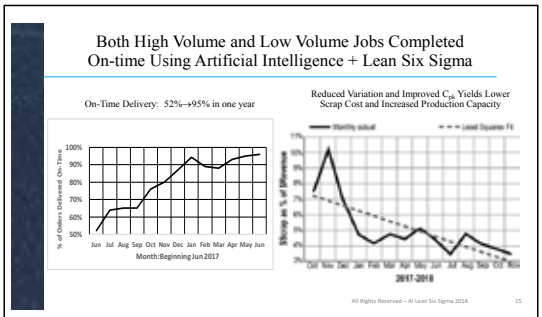
BENEFITS

AI will arm DoD maintenance with a most formidable weapon for achieving greater production capacity, throughput, cost-wise mission readiness and lethality.

AI can be effectively deployed to achieve:
- Production capacity increase of >20% with no manpower increase
- Cycle time reduction of >30%, and
- On-time delivery-to-promise date >90% with no increase in inventory

TECHNOLOGY SOLUTION

AI rapidly analyzes massive volumes of data (i.e. Big Data) to aid in the discovery of hidden wastes which constrain higher maintenance productivity and throughput. AI Neural Networks compute all possible sequences (potentially hundreds of thousands) for machining numerous part numbers while identifying the optimal sequence with the lowest total setup time waste that meets required customer delivery or need dates.



LOGCELL END-TO-END (E2E)

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Navy & Marine Corps Aviation must increase the flight line Mission Capable numbers. To achieve and sustain there must be an improvement to all aspects of our logistics and maintenance system. Challenges include reducing lead-times on contract awards and repair turnaround time at the Fleet Maintenance Intermediate Level/ Maintenance Depot sites. To achieve, we must incorporate early alerts to any sustainment interruption and, receive engineering support to speed supply chain solutions and find demand mitigation opportunities. Supply chain shortages, cannibalization, and the delay of repair is costly to our Mission Capable goals and creating additional manpower requirements. Acceleration of new spares delivery - Identification and stand-up of new repair sources - Removal of I-Level repair barriers.

NAVSUP WSS created a Logistics Cell (LOGCELL) to provide a physical collaborative space based around IT Dashboards with common operating pictures to quickly identify and attack inefficiencies. This innovation has enhanced inter-organizational learning at every level on the End-to-End supply chain. Our new cross-functional teams are held accountable, and aligned to metrics focused on Readiness and decision-making speed. We are getting the right people in the room. Dashboards are fully transparent with friendly interface:

- Create a culture of problem solvers
- Shines a light on hidden barriers.

This initiative brings together supply chain performance areas, segment owners, and other associated metrics to improve the effectiveness and efficiency of the DoD/ Navy supply chain response to customer requirements and material readiness. The meetings are innovative and rapidly evolving into the command's supply chain-focused management system.

LOGCELL has successfully piloted and demonstrated its value for multiple Type Model Series Aircraft and Support Equipment. Joining NAVAIR's Program Executive Office (PEO), we have created a concept of operations for this End to End (E2E) project. We have completed a collaborative review of all top critical repair items with the V-22 Osprey and 8 other T/M/S teams. Utilizing the technology, we have examples of success in each category: Backorder reduction - Reduced overdue assets - Increase in Allowance Effectiveness - Reduction in Customer Wait Time - Cost avoidance.

Change management with employees and education of our naval aviation End-to-End complexities was a challenge, along with the cross collaboration of bringing in other services and DLA Aviation. However, we worked together and solved some of the toughest logistical challenges in our LOGCELL environment and, now, our web-based tool solution is available outside our command to these other services.

We use Cognos Analytics within the defense environment and Oblong's Mezzanine technology to integrate multiple graphical unit interfaces for our Combat Information Center. Teams are getting the big picture & making more accurate confident decisions.

PROBLEM STATEMENT

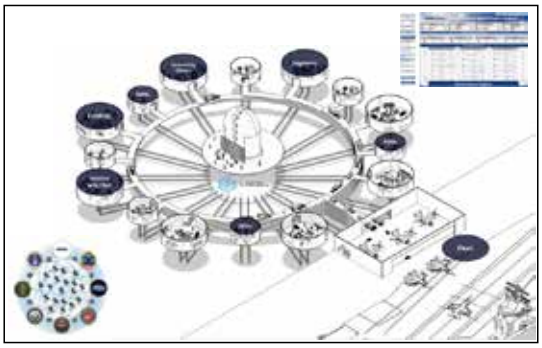
- Navy & Marine Corps Aviation must increase Mission Capable numbers. To achieve this goal and maintain readiness there must be an improvement to all aspects of the sustainment & Maintenance system.
  - Lead-time reduction (admin / production / repair)
  - Consistent, dependable component Depot repair RTAT
  - Allowance products built with accurate maintenance data
  - Metrics leading to early alerts of supply chain interruption
  - Intermediate Level repair turn-around within parameters
  - Engineering support to speed supply chain solutions

BENEFITS

- Aligned industry partners to collectively provide material to the Fleet through visualization and speed of learning.
- Drive increased output and reduced response time into supply system "core".
- Fill the retail shelves and reduce number of aircraft NMCS.
- Optimize Capability and Capacity using the Navy Working Capital Fund (NWCF) and aligned financial resources.
- Accelerate process improvement across the NAE.
- Remove delay-causing barriers that impact lead times.
- Challenge all stakeholders to perform faster.
- LOGCELL is creating a culture of problem solvers .
- P-8's early LOGCELL initiative has exceeded goals with a 75% reduction in Customer Wait Time.

TECHNOLOGY SOLUTION

- Navy Digital Integration with designed and tested use of IT tools to identify and implement process improvement.
- Combined tools into an integrated group that warns supply chain segment owners when performance does not support achievement of MC/FMC goals.
- 45 total metrics on one screen with Level I, II & III drill downs aligned to Fleet readiness: Better support to all Navy & Marine Corps platforms.
- Access to website outside the command and cross service.
- Digital canvas displays to create info-presence and connecting hub and spoke efforts across the enterprise.



UTC AND MAINTENANCE RECOVERY TEAM PROCESS

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At first glance, organizing and posturing teams to be ready to deploy at a moment's notice does not sound like the most innovative breakthrough of the 21st century. However, if you are managing limited resources at the world's busiest maintenance en route squadron, a personnel management process change can produce amazing results. As the gateway for multiple AORs, the 721st Aircraft Maintenance Squadron is given extraordinary responsibility. We provide full maintenance capabilities executed by dual-airframe qualified personnel while simultaneously maintaining four unit type codes (UTC) packages and providing maintenance recovery teams (MRTs) throughout EUCOM, AFRICOM, and CENTCOM.

As Air Mobility Command's only en route Aircraft Maintenance Squadron, we generate approximately 2,000 missions annually with just 255 personnel and since 2015, have supported more than 200 MRTs and deployed over 900 man-days. Maintaining morale and minimizing fatigue to maximize maintenance capabilities is a challenge. In order to mitigate risk to personnel and the mission, subject matter experts (SMEs) in the unit mapped out our MRT selection process, which identified an inefficient way to select personnel. This legacy process was "plug and play" in that whomever was qualified or available when the unit was tasked, was selected. This led to the same "go-to" members traveling multiple times a month, which produced fatigue and unpredictable shift schedules.

Unit leadership and SMEs conducted an in-depth process review and reengineered the MRT process to meet the demands levied upon the unit. The new process couples our four UTCs with a 30-member qualified MRT mitigation team that is trained and medically prepared to deploy. The team fills this critical role for 6 months, after which new members are selected. By coupling our UTC packages with the MRT mitigation team, squadron leaders are better prepared to meet requirements by maintaining the proper amount of deployment ready personnel, which produces a proactive maintenance readiness posture. Additionally, our team developed an MRT Risk Analysis Matrix to assess scheduling, mission, and human factors associated with MRT requirements across the globe in varying force protection conditions. The matrix advises unit and senior leadership by raising concerns to the appropriate decision authority based on unique circumstances of the tasking and location.

Taking care of Airmen and their families while safely executing the mission are top priorities; this initiative--restructuring the MRT process--improved quality of life for our squadron while enhancing mission effectiveness. The benefits of this process adjustment include reduced training requirements by having a steady-state pool of postured members, improved decision-making capabilities, more effective/predictable personnel management, enhanced unit readiness, and improved resiliency. Whether in garrison or deployed, our Airmen are better postured and focused to execute 24-7 ops.

PROBLEM STATEMENT

- In order to mitigate risk to personnel and the mission, subject matter experts in the unit mapped our maintenance recovery team selection process which identified an inefficient member selection process. This process led to fatigue and unpredictable shift schedules.

BENEFITS

- Reduced training requirements across the entire squadron by having a steady-state pool of postured members
- Improved decision-making capability at all leadership levels
- More effective and predictable personnel management
- Enhanced unit readiness as a result of properly prepared technicians and equipment
- Improved unit culture and resiliency of the force.

TECHNOLOGY SOLUTION

- None, simple management tools created a solution by using subject matter experts to reengineer the maintenance recovery team selection process.

NEXT GENERATION SUPPLY CHAIN MODELING

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Investing in the right material at the right time to support fleet requirements, both planned and unplanned, is the primary responsibility of the Navy's Program Support Inventory Control Point (PSICP), Naval Supply Systems Command Weapon Systems Support (NAVSUP WSS). WSS maintains over $34B in inventory managing 500K annual requisitions across Naval aviation, maritime, and expeditionary units. This material supports more than 3,700 operational aircraft and 286 ships and submarines.

WSS managed material has a diverse demand profile with many customers; shipboard maintainers, supply departments, and depots. While some material has predictable steady customer demand in the hundreds or thousands of units every year, a large proportion of items have irregular, episodic, or very limited demand, with intervals between demands often measured in years. Legacy modeling approaches relying on planning factors, forecasts, and closed form equations have not performed well on a large proportion of Navy's low or highly variable demand items.

Leveraging the computational power and the volume of transactional data from the Navy Enterprise Resource Planning (NERP), WSS is building with Naval Postgraduate School (NPS) the next generation of Navy owned and developed inventory models. The new Wholesale Inventory Optimization Model v5.0 (WIOM) combines an advanced discrete event simulation assessment tool with a sophisticated optimization model to prescribe recommended inventory investment strategies for Navy wholesale material.

The simulation component of WIOM, Distributed Requirements Planning Simulation (DRPSim), provides a predictive capability by analyzing thousands of "what-if" future scenarios by combining current asset postures with the NERP's transactional data to include demand, procurement, and repair times. The simulation architecture is not reliant on planning factors, forecasts, or closed form equations, making it revolutionary in analyzing the performance of items with unpredictable demand patterns. The simulation output provides multiple measures, to include but not limited to, material availability, total inventory, and contracting workload.

The WIOM optimization engine uses a sophisticated linear program, which takes into account trade-offs between metrics of interest and prescribes an inventory plan best able to meet the required objectives. The multi metric approach in WIOM 5.0 allows for more efficient and effective inventory policy tradeoffs to be made between often competing organizational objectives.

PROBLEM STATEMENT

- Availability of spare parts in advance of both planned and unplanned maintenance requirements is a critical component of achieving high readiness rates.
- As the Navy's Program Support Inventory Control Point (PSCIP), Naval Supply Systems Command (NAVSUP) Weapon Systems Support (WSS) manages over $34B in wholesale inventory.
- Developing effective and efficient inventory policy to manage a diverse inventory with erratic demand patterns, long contracting lead times, and a limited supplier base in support of achieving national strategic objectives poses enormous challenges.
  - Legacy inventory models are not well equipped for these challenges.

BENEFITS

- The synthesis of simulation and optimization models provides WSS with both a predictive and prescriptive capability.
  - Predictive: "what will happen?"
  - Prescriptive: "what should we do about it?"
- Simulation offers the ability to more accurately assess inventory policy decision consequences with regard to material availability, total inventory, contracting workload, and inventory churn.
- Reduces reliance on simplifying modeling assumptions such as parameter estimated forecasts and lead-times.
- Optimization allows for assessment of a solution under multi dimensional criteria. Allows leadership a fuller picture when making inventory policy decisions.

TECHNOLOGY SOLUTION

- Next Generation Prescriptive Inventory Modeling and Management Software Toolset.
  - Replaces more rudimentary legacy models
  - Organically developed by Navy.
- Distributed Requirements Planning Simulation (DRPSim): Advanced simulation tool that evaluates thousands of "what-if" scenarios.
  - Leverages millions of captured transactional records without reliance on legacy modeling assumptions.
  - Provides predicted outcomes for each scenario.
- Wholesale Inventory Optimization Model (WIOM): Sophisticated optimization tool that takes results from the simulation and prescribes a recommended inventory plan

AUTOMATED UNFUNDED REQUIREMENT (UR) SYSTEM (AURS)

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Automated Unfunded Requirement (UR) System (AURS) The 412 MXG unfunded requirement (UR) development and execution process had a stakeholder satisfaction rating of 2.9 out of the 5.0 goal. The mediocre rating was influence by the lack of efficiency of the manual process, which was creating equipment/service acquisition, disposal, and cost control issues.

As a result, it delayed meeting customers' expectations in replacing or upgrading equipment that are beyond their useful life cycle. This led to the end-users failing to acquiring and installing new equipment and disposing of old equipment in a timely manner. Additionally, end-users acquired equipment/services that had not been prioritized or approved by management in some cases. Moreover, acquisitions were made that did not meet end-users' requirements because specifications were not validated, sustainment requirements were not addressed, and in one case, the equipment did not fit the location it was intended to be installed.

We addressed these issues using a process improvement event, which resulted in the development of a database system that provides transparency and visibility of UR to the staff within the maintenance organization. The UR database system provides:

- Approval for unfunded requirement requests that affect MXG facilities and equipment
- Manages changes of acquisition documentation and incorporate lessons learned and feedback into the system
- Manages compliance with the mandatory Federal Acquisition Regulation (FAR), USAF AFI acquisition, and purchasing mandatory guidelines
- Ensures that all applicable coordination requirements are documented and submitted to leadership, managers, facilities, information technology integrator, and contracting for all unfunded request
- Ensures that communication and information technology acquisitions and purchases are coordinated and approved using the Information Technology Investment Board (ITIB) as applicable
- Manages equipment removals, installations, and disposition actions.

The AURS was built using Microsoft ACCESS because the local IT organization solution would take 12-18 months to develop. We built, tested, and successfully deployed the desktop system in approximately 200 hours. It can be accessed by all 1578 maintenance group staff members and includes an approval and document filing capability that is visible by all user. It provides managers the capability to disapprove, approve, or request additional justification/clarification on unfunded submissions from their staff. The system gives managers the ability to coordinate with their staff, resources, facilities, internal IT integrator, and units that have an interest in a particular (UR). It provides resources with the ability to consolidate similar requirements to take advantage of quantity discounts.

PROBLEM STATEMENT

The 412 MXG unfunded requirement (UR) development and execution process had a stakeholder satisfaction rating of 2.9 out of the 5.0 goal. The mediocre rating was influenced by the lack of efficiency of the manual process, which was creating equipment/service acquisition, disposal, and cost control issues. As a result, it delayed meeting customers' expectations in replacing or upgrading equipment that were beyond their useful life cycle. This led to the end-users failing to acquiring and installing new equipment and disposing of old equipment in a timely manner.

BENEFITS

- Provides enterprise-wide visibility and transparency for all unfunded requirement submissions.
- Improve management oversite and control over mission and infrastructure resources.
- Increased opportunity to consolidate similar requirements within the enterprise and take advantage of quantity discount acquisitions.
- Provides a "one-stop" repository for all requirement purchases and acquisition documents such as statements of work, performance work statement, and marketing research.
- Reduces end-user time in creating required documents and obtaining approvals necessary to move UR forward.
- Provides managers and senior leadership an automated tool for analyzing, reviewing, and monitoring acquisition trends on resources requirements.

TECHNOLOGY SOLUTION

- The AURS was developed, tested, and successfully deployed that provides managers and end-users the visibility and transparency for UR transactions across the enterprise.
- Database is a Microsoft ACCESS based and it is scalable and portable.
- Improved reporting capability for financial resources and funds disbursement.
- Facilitate managers and senior leaders with real-time UR review and "rack-and-stack" procedures.

NAVITAS SYSTEMS STARLIFTER LITHIUM FORKLIFT BATTERY FOR MATERIAL HANDLING PRODUCTIVITY IMPROVEMENTS

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Problem statement
The Department of Defense owns and operates large fleets forklift trucks for material handling purposes. Many of these forklift trucks are electric, powered by very large lead acid batteries. While sufficient for low intensity warehouse applications, the 100+ year old lead acid chemistry has inherent deficiencies for high intensity multi-shift warehouses, hot temperature warehouses, and/or cold temperature warehouse applications:

- Low cycle life requiring replacement every 3 to 5 years
- Regular maintenance required including watering and battery equalizations
- Sulfation problems when left in a partial state of charge for long periods, causing reductions in daily battery runtime and permanent damage to the battery
- Faster Life degradation in hot temperature warehouses due to accelerated corrosion of the lead metal and liquid electrolyte dry-out within the battery
- Slow charge capability, requiring 6 to 8 hours for full 100% charging and another 8 hours for battery cool-down
- Three shifts per day operation may require up to 3 batteries per forklift
- Voltage droop at second half of discharge, causing slowdown in forklifts when they lift as well as drive, resulting in loss of driver productivity
- Low charge/discharge efficiency, causing heating with high intensity use and inefficient/more costly use of electricity
- Dangerous liquid sulfuric acid electrolyte and heavy metal pollution issues associated with lead
- Dramatic loss of useable capacity in cold-temperature warehouses
- High pollution levels when using propane-powered forklifts inside of warehouses

Description of technology
Navitas Systems has developed an industry leading line of Forklift Class 1, 2 and 3 lithium iron phosphate forklift batteries called StarLifterTM, designed to overcome the maintenance and productivity loss challenges experienced in high-intensity and cold temperature warehouse applications.

Current status of the technology
StarLifter is now in use by numerous major corporations spanning food distribution, third party logistics (3PL), automotive, and three of the top five forklift OEMs. Navitas recently deployed Starlifter at the Defense Logistics Agency's single largest worldwide site, the Eastern Distribution Center at Susquehanna PA. Details of the testing at DLA can be found by watching this DLA video entitled "The Heavy Duty Forklift Challenge" at dla.mil/Distribution/Lithium-Ion-Battery-Project/.

Test data or simulation support for performance claims
StarLifter has completed a two year independent test funded by NYSERDA in partnership with forklift manufacturer Raymond Corporation. The testing indicated a 17% improvement in amount of pallets moved per shift as compared against lead acid batteries. A side-by-side video which timed a lift of equal weight between a lead acid powered forklift and a Starlifter lithium-powered forklift showed a 25% increase in speed, and can be viewed **atlithiumforkliftpower.com**.

Next steps / potential benefits
Strong applicability across the government: This past December 2017, DLA San Joaquin has joined DLA Susquehanna as the next to implement Starlifter to replace use of propane forklifts within their cold distribution warehouse; Navy has shown strong recent interest aboard ships to replace lead acid forklifts under main decks.

PROBLEM STATEMENT

- DLA currently has two thousand electric forklift trucks in various warehouse facilities that incur large associated operating expenses by the long-standing/necessary use of lead acid batteries.
- •Current lead acid technology suffers from short life, a requirement for up to 3 batteries per forklift truck to maintain constant duty during two-three shift operations, high maintenance costs, and poor cold temperature performance.
- •Two-three year wear-out/replacement costs of Lead acid batteries exceed the cost of the actual forklift trucks over 10 years.
- •Driver downtime from waiting for battery change-outs and slower lifting as lead acid voltage sags during discharge all adversely affect driver productivity.

BENEFITS

Proposed lithium battery technology will improve operational capability and reduce associated battery costs by up to 30% in the categories articulated by the DLA below:

TECHNOLOGY SOLUTION

Instrumented comparison of 6 Starlifter-powered vs 6 Lead Acid-powered 36 volt Class 2 forklifts at DLA Susquehanna warehouse facility commenced March 2017; second comparison of 5 Starlifter-powered 48 volt Class 1 forklifts vs 5 Propane-powered at DLA San Joaquin commenced December 2017—Both trials are assessing economic and operational benefits of lithium forklift battery technology; see http://www.dla.mil/Distribution/Lithium-Ion-Battery-Project/

ONE FOR ONE REPLACEMENT OF MAIN AND SUB COMPONENTS

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Department of Defense (DoD) maintenance facilities typically have three main constraints: Schedule, Budget and Parts Availability, which by nature, have a negative domino effect to production. The first constraint is Parts Availability. In the maintenance environment an aircraft, for example, arrives at the facility and is then cleaned, stripped down to its bare bones and its components are sent through the various shops for further teardown and inspection. Some items based on historical depot overhaul factors (DOF) are automatically replaced, while others may have a lower replacement trend due to repairability or expected lifespan. For those that are automatically replaced, there is typically stock on hand at all times based on the number of scheduled aircraft to be completed within the fiscal year. For those that are not replaced automatically, there is typically a low number of new parts kept on site or there is a generic forecast established with suppliers which generally lowers the lead times to order and have them shipped to the facility(ies).

The parts that fall into one of the above categories are unlikely to cause any delays to the master schedule or to the overall budget, however, there is a subset of main and sub-components that require extensive teardown, multiple testing, and multiple inspections at which times they can fail and/or be deemed irreparable. These are the ones that cause the most disruptions and have the biggest impact on Schedule, Budget and Part Availability. These main and sub-components (once removed from the aircraft) are sent to cleaning, then they are disassembled, and the sub-components are sent to the various specialty shops for further cleaning, inspection and repair. By this point, the component has accumulated a large number of man-hours spent on the various operations and until each sub-component has been inspected and returned to serviceable condition, the parts are still subject to potential fallout/failure.

If failure occurs then the item is then placed on order and subject to lead-time plus costs associated with ordering the replacement, including expedite fees. We must also account for the cost of man-hours and other resources that have already been spent on the component prior to its failure and the overtime hours that will be spent on the aircraft to bring it back on schedule once the material arrives.

To address this significant problem, we can order a set number of new components and store them as "Safety Stock" until the first aircraft is ready for its installation. The removed component would be sent through the various shops as normal but instead of the aircraft having to wait for the removed component to be made serviceable, it will instead receive the new component. This is repeated until the components in the repair cycle are made serviceable and the inventory has reached the optimal "Safety Stock" level. With this approach the facility maintains schedule reliability, expedite fees are virtually eliminated, overtime hours are drastically reduced, and the military maintains their fleet readiness.

PROBLEM STATEMENT

- The DoD's maintenance facilities face critical scheduling and material challenges, in terms of the number of aircraft in the repair cycle and having serviceable parts ready to be reinstalled on schedule. These scheduling challenges are compounded by the uncertainties that are inherent to the maintenance environment, that require adaptation, especially when faced with unanticipated events such as faults/failures discovered upon inspection at any of the many points of the repair phases.
- There are often times when unrepairable defects are discovered late in the repair process and replacements are often subject to availability and long lead times which further delays aircraft completion.

BENEFITS

- Reduce impacts to the master schedule.
- Increase the number of aircraft released back to the fleet.
- Reduce costs by lowering or eliminating the need for overtime man-hours.
- Reduce or eliminate costs associated with unplanned purchases and schedule changes.
- Improve schedule reliability.
- Decrease negative impacts for long lead items.

SOLUTION

- The solution is a two part approach which consists of purchasing a set number of new main and sub-components and streamlining the repair process of the used serviceable components.
- If a facility can repair (X) number of main and sub-components and we have a set number of aircraft scheduled in the Fiscal Year (FY), we can then calculate how many new assets to purchase that will provide a reasonable safety stock to eliminate or mitigate impacts to the master schedule.
- Instead of waiting for repairs, when the main and sub-components are removed from the aircraft, they are immediately replaced with the purchased ones. The removed ones would then go through the various repair phases while the aircraft continues moving forward instead of being constrained by the progress of the repairs of the removed parts.
- Once the removed parts are repaired they then get placed on the shelf for the next aircraft in line.

AURORA INTELLIGENT SCHEDULING FOR INCREASED MAINTENANCE THROUGHOUT

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Problem statement: The DoD's maintenance facilities face a daunting scheduling challenge, in terms of the size and complexity of the maintenance that is performed on ships, aircraft, ground equipment, etc. This scheduling challenge is exacerbated by the uncertainties that are inherent to maintenance, that requires adaptation per unanticipated events such as faults/failures discovered upon inspection of the asset.

Description of technology: Stottler Henke has studied human expert schedulers making scheduling decisions in critical applications, including maintenance, for 25+ years and has implemented these decision-making processes in the world's most intelligent scheduling software, Aurora. Aurora has been applied to a wide variety of domains, demonstrating its superiority, that is, in every domain where a comparison has been performed; Aurora has always proven more optimal. Most of these comparisons were made by the clients themselves in order to pick the tool that performed best. For example, Aurora beat all competitors in Boeing's scheduling competition, including Boeing's own internally developed scheduler optimized for aircraft manufacturing. The use of Aurora has typically meant that 10% to 25%+ more tasks can be accomplished with the same resources in the same amount of time (or the same tasks accomplished in 10% to 25%+ less time) compared to other scheduling methods.

Current status of the technology: Aurora is a complete software solution that is designed to be easily customized and integrated into new domains. Aurora is used throughout the world to solve many of the world's most challenging project management and scheduling challenges. For example, Aurora is used by Boeing, NASA, Electric Boat, Mitsubishi, Pfizer, the US Air Force, Bombardier, and many others.

Test data or simulation support for performance claims: Boeing selected Aurora initially for the final assembly scheduling of the Dreamliner 787 aircraft due to its superior resource-constrained scheduling. Boeing was kind enough to provide a subset of real data that Stottler Henke is permitted to share. Even though this subset is much simpler than the actual project, it still reveals the significant difference between the scheduling results. The results are as follows:

Microsoft Project	145 days
Primavera P6	115 days
Aurora	102 days

Results with similar improvements have been realized in many different domains. For example, for NASA Aurora scheduled the maintenance, repair & overhaul (MRO) of the Space Shuttle, and NASA currently utilizes Aurora for some of its most complex scheduling challenges.

Next steps / potential benefits: Deploying Aurora for all maintenance related scheduling may be the single most beneficial/impactfull change to overall efficiency and effectiveness possible. Aurora can be used throughout the DoD, improving cycle time, reducing cost & necessary manpower, while improving readiness. Aurora is already the most state-of-the-art scheduling solution available, but thanks to its architecture it can be adapted to the unique aspects of DoD maintenance, providing additional benefits. Aurora has cross-service applicability since all service branches require scheduling of their maintenance. Aurora has already been successfully utilized by the DoD (e.g., Air Force satellite downlink scheduling) demonstrating its feasibility and practicality.

PROBLEM STATEMENT

- The DoD's maintenance facilities face a daunting scheduling challenge, in terms of the size and complexity of the maintenance that is performed on ships, aircraft, ground equipment, etc. This scheduling challenge is exacerbated by the uncertainties that are inherent to maintenance, that requires adaptation per unanticipated events such as faults/failures discovered upon inspection of the asset.
- The problem can be summarized as how best to allocated limited resources to maximized throughput taking into account priorities and other deadlines.

BENEFITS

- Reduce schedule durations 10% - 25%+.
- Deploying Aurora for all maintenance related scheduling may be the single most beneficial/impactful change to overall efficiency and effectiveness possible.
- Aurora can be used throughout the DoD, improving cycle time, reducing cost & necessary manpower, while improving readiness.
- Aurora is already the most state-of-the-art scheduling solution available,.
- Aurora has already been successfully utilized by the DoD (e.g., Air Force satellite downlink scheduling) demonstrating its feasibility and practicality.

TECHNOLOGY SOLUTION

Stottler Henke has studied human expert schedulers making scheduling decisions in critical applications, including maintenance, for 25+ years and has implemented these decision-making processes in the world's most intelligent scheduling software, Aurora. Aurora has been applied to a wide variety of domains, demonstrating its superiority, that is, in every domain where a comparison has been performed; Aurora has always proven more optimal. Most of these comparisons were made by the clients themselves in order to pick the tool that performed best. The use of Aurora has typically meant that 10% to 25%+ more tasks can be accomplished with the same resources in the same amount of time (or the same tasks accomplished in 10% to 25%+ less time) compared to other scheduling methods.

INNOVATION TESTING TEAM

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The use of industrial processes in and around sensitive systems and equipment aboard naval assets pose risk. To mitigate this risk, restrictions on the use of these processes are in place, based on the best testing methods available at the time. Since then, new testing capabilities have been developed and should be used to more accurately evaluate the risks of industrial processes. This may provide a loosening of the restrictions on work around sensitive equipment. For example, the application of this at IMF Bangor recently enabled a near doubling of the number of welders allowed in and around a sensitive area on Ohio Class Submarines, adding capacity to this constrained resource.

Several advances enable this new capability:

- The DOD has many employees trained in principles of project management, process improvement, and industrial engineering. This knowledge should be leveraged to identify those constraints, which could yield the most significant gains for the mission, such as cycle time, schedule risk, and capacity.
- The ability to research state of the art methods and instrumentation, that would otherwise be isolated to academia or laboratory settings, can now be discovered through internet searches.
- The capability, price, and availability allow acquisition of the needed instruments and other equipment feasible even for a small command.
- Advances in computing and analytic software allow the networking and data logging of reading from these instruments at high sample rates, enabling the creation of accurate modeling of the effects of various industrial processes.

Even relatively small organizations can then utilize industrial engineering and process improvement practitioners within their command to assemble a team. At IMF ours is called the Technology Insertion Deployment Evaluation (TIDE) line team. This TIDE line engages with process, equipment, and system technical warrant holders to develop a test plan to capture data, and develop models to provide recommendations. The team then identifies testing opportunities in upcoming maintenance periods, and coordinates with production trades and shops, safety, engineering, planning and ship's force to execute the actual test. Subject matter experts, managers, and qualified trades people are surged into the team for preparation, test execution, and post analysis as needed.

The TIDE line enables the evaluation of both old and new technologies, in both existing and new applications. This fast local response team is able to identify testing opportunities, share results with internal and external warrant holders, who in turn can improve overall maintenance results. These improvements benefit the maintenance activity, the warfighter and the Navy.

The IMF Bangor TIDE line has completed testing of welding, heat induction coating removal, and preliminary tests of plasma blast coating removal. Additional testing of weld, plasma blast and cold spray applications are planned.

PROBLEM STATEMENT

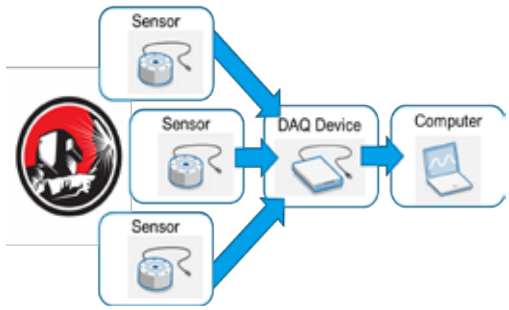
Some procedural, technical, and regulatory restraints on the use of new and existing industrial technologies, for repair processes on systems and equipment, constrain key resources for the execution of maintenance work. Maximizing the use of these processes, with adequate precautions, requires good understanding of the effects of using these processes. Until recently, the capacity to test, collect data and model these interactions has been beyond the capability of most maintenance activities.

BENEFITS

- Obtained permission and guidance for the use of Heat Induction on Ohio Class Submarines, which will eliminate "needle gunning" and other labor intensive coating removal methods, reducing employee exposure, emissions and hazardous waste generation.
- Working with the technical warrant holder, updated instructions to allow seven vice four weld machines for use in and around a sensitive area on the Ohio Class.
- Potential benefits include further loosening of restrictions for welding, and approval of plasma blast coating removal methods, cold spray, and other emerging technologies for the Trident mission, setting a precedent for adoption across the DoD.

TECHNOLOGY SOLUTION

- Leverage industrial engineering and process improvement practitioners in your command to select targets.
- Research state of the art methods and instrumentation, using modern tools such as internet searches.
- Utilize new, inexpensive hardware such as, sensors and data acquisition (DAQ) devices, and identify expertise in your existing workforce to build testing systems.
- Use advances in computing and analytic software to collect and analyze data, working with technical warrant holders to evaluate.



PRC2 AND DEVSECOPS

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The PRC2 team's most recent success has been taking an organic team that was entrenched in following an out-of-date process known as waterfall software development and embracing an effective method known as Agile, which is similar to many leading industry practices. These rapid releases and ability to adapt to change suits the team well in expanding into the agile methodology known as DevSecOps. DevSecOps incorporates the software development, security and operations all in one synchronized two week release cycle, known as a sprint. These sprints have provided the team the ability to adjust to rapid changes, so as new threats or needs arise from the warfighters, our team is ready and able to adapt to changes and provide them with the needed capabilities as soon as possible.

This new way of developing didn't happen overnight and it took the entire PRC2 team working together. It required extremely close collaboration with our stakeholders. Daily stand-up meetings to discuss status, weekly requirements planning and bi-weekly demonstrations of new features are a few of the changes. The team has had to come together to navigate through the maze of established policies, regulations and processes to show that rapid agile development is not only possible but exceeds the current level of quality standards that is expected from our warfighters. The team took a process that would include taking several months of negotiations over requirements and estimation, months software development, up to 8 weeks of internal and external testing, up to 2 months addressing defects found and waiting an additional 6 weeks for a fielding decision. So when an urgent new feature was required by the warfighter they could expect to see it in a year or more. The team realized that the warfighter deserved better and that there were ways to improve.

The team re-designed the development process by automating many of the tasks that were manual and prone to error. Amongst these tasks included; code quality and security scans, penetration testing scans, user testing, and full configured documentation. This process which once took several weeks can now be accomplished in approximately 1.5 hours. The previous testing methods required manual input which was not only time consuming but also prone to user errors. The internal and external testing would last approximately six weeks with several of those weeks at an offsite location resulting in high travel costs to the project. The team also reached out to our external stakeholders and started getting their buy-in to this methodology. After 9 months to develop this process, automation tools, and getting our external stakeholders to buy-in, we have released 8 new releases on two product lines in less than 3 months. These releases contained critical security updates, new user requested features, and corrected existing errors. Our customer and end users see these updates in weeks now instead of years.

PROBLEM STATEMENT

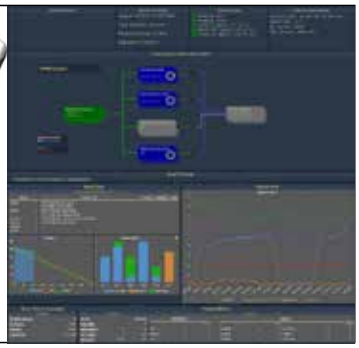
- Waterfall Software development does not meet warfighter's changing requirement needs
- Inability to change requirements once development begins
- Long test cycles needed for each release, delays fielding for up to a year
- Outdated acquisition process delays requirement development and fielding to the warfighter
  - Requirements acceptance
  - Development Test
  - Operational Test
  - AO fielding recommendation

BENEFITS

- **DevSecOps**
  - Shorten timeline of requirement acceptance to fielded usable code
  - All external test agencies integrated with CDP
  - SCAR aware and invested in pipeline stories
  - Stories that pass the CDP are ready to field
- **Significant cost savings to the program office resulting in an estimated 50%+ increase in workload capability**
  - Faster Development time using Test Driven Development (TDD)
  - Pair Programming ensures quality throughout development
  - CDP to cut months of test time to less than 1 hour

TECHNOLOGY SOLUTION

- **Agile software development**
  - Rapid response to changing requirements
  - All stakeholders involved/aware of requirements
  - Smaller efforts with quick turnarounds (2 weeks)
  - Minimum Viable Product will allow just enough code to be created to pass the TDD
- **Continuous Delivery Pipeline**
  - Fully automated, 100% code, testing for each story completed
  - Full Cybersecurity scans for each story completed
  - Full configuration artifacts required for release and produced for stakeholder review
  - DT/OT integrated into pipeline



SYNCHRONIZING MATERIAL PLANNING AND MAINTENANCE, REPAIR, AND OVERHAUL

SEAN WADE

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Maintenance of complex assets has an array of inherent challenges. One of the most complex is synchronizing the parts required to support the work on the Depot floor. Without the exact set of parts required a number of undesirable consequences ensue, including work stoppage delaying asset availability, elongated turn-around times and degraded technician productivity. While considerable effort is put into developing maintenance schedules and associated Bills of Materials to provide as input to material plans there is still a great deal of uncertainty. The schedules themselves can be quite dynamic, especially closer to the event date, which is now likely inside the sourcing lead-time, and the material plan has been set. In addition, the parts required requires a mix of art and science. The roster of parts that are absolutely required is somewhat deterministic based upon engineering and maintenance expertise, but the need for conditional or as-required parts can only be determined once the maintenance even has begun and the status of the asset is known. When there are multiple facilities that are candidates to perform the work, an additional layer of complexity in terms of positioning parts is introduced.

In order to address the challenge, Servigistics Service parts Management (SPM) provides a holistic approach to forecasting demand, creating optimized inventory levels and Management by exception supply planning. Demand planning is derived from maintenance schedules and associated maintenance bills of materials, and is enhanced with probabilistic activity arising from conditional or as-required demand. A complex Multi Echelon Optimization (MEO) module creates inventory targets that can represent an array of targets based upon SLA / PBL contracts fill rate of asset availability targets. By definition, the optimization meets the service targets at the lowest level of inventory investment. Supply planning ensures that the actual stock balances are within tolerances also at the lowest cost by maximizing the utilization of parts already owned whether by rebalancing between locations, repair and overhaul and even de-manufacturing of out of service assets. Role based KPI dashboards monitor the overall performance of the system relative to critical goals.

The Servigistics solution is the combination of the three best of breed SPM solutions, the oldest of which came to market in 1990. Servigistics has incorporated, through organic development, the intellectual capital of the Xelus and MCA products into one code set and database. The resulting product represents almost 70 years of combined development. Servigistics SPM's evolution has been stewarded by the leading minds in parts management across a full range of vertical applications.

SPM is by far the most widely adopted parts planning module worldwide, including managing every weapons system for the USAF – globally. Customers include the US Navy, AF, Coast Guard, Canadian DND, etc.

PROBLEM STATEMENT

Maintenance schedules are dynamic and the materials required to perform the work must be synchronized to avoid disruptions on the depot floor. Missing parts can create work stoppages, deteriorate turn-around times and technician productivity.

To overcome these issues, you must transform the way you manage parts. Demand must account for both scheduled events and random failures whole the establishment of target inventory requires unique and complex math and analytics.

- Forecasting and Event Planning
- Inventory Optimization
- Order Planning
- Asset Sustainability Optimization
- Network Optimization
- Initial Provisioning through Sustainment

BENEFITS

- Management by exception process increases productivity
- Superior forecasting with IOT extensions, combined with
- State of the art optimization minimizes inventory
- Complex location-specific part relationships support strategies
- Creates fluid network with flexible global inventory balancing
- Enable advanced order planning of repair and new parts
- Provide a single platform for service parts lifecycle management

Success Stories:

- 18% increase in inventory turns (Metso
- 95% Service parts availability (Qantas)
- 10-20% inventory reduction (Pratt and Whitney)
- 6% increase in Aircraft availability (US Coast Guard)
- 12 month ROI in less that 12 months (JLG)

Right Part. Right Place. Right Time. Lowest Cost

TECHNOLOGY SOLUTION

Servigistics: PTC's Service Parts Management application, Servigistics is a fully-integrated, seamless, single-instance solution offering the broadest and most functionally rich service parts management solution in the market today. With over 200 customers, Servigistics has the largest install base of customers of any service parts management software vendor in the world.

Servigistics enables an organization to optimize inventory globally, minimize excess or shortage conditions and analyze service supply chain performance while simultaneously meeting service targets and addressing network-wide considerations and constraints.

Servigistics is commercially available software in use across industry, the US AF and the US Coast Guard. www.ptc.com

ACHIEVE DOD 80% MISSION CAPABILITY GOALS WITH VIFD™

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The Department of Defense (DoD) sustainment & logistics budgets cannot afford to waste a single dollar. The Services are seeking ways to reduce No Fault Found (NFF) and increase Mission Capability by 80% for the F-35, F/A-18, F-16 and F-22. OSD has established the Joint Intermittence Testing IPT and has calculated the negative cost impact of NFF at $2 billion to $10 billion annually, with intermittent faults cited as the primary cause. For many DoD weapon system components that cause operational failures, less than half have the actual root cause problem identified and repaired—the other half test NFF. The negative implications for critical combat equipment that form the backbone of our tactical air power are stark according to the Sep 2018 GAO Report "Weapon System Sustainment: Selected Air Force and Navy Aircraft Generally Have Not Met Availability Goals".

Conventional ATE is not designed or optimized to detect momentary intermittent failures that cause NFF. The discovery that conventional ATEs inability to detect and isolate intermittent faults led to the development and deployment of the Intermittent Fault Detection & Isolation System™ (IFDIS™) which was designed to detect and isolate intermittent faults in avionics component interconnections and wiring. IFDIS testing of F-16 Line Replaceable Units (LRUs) and F/A-18 Weapon Replaceable Assemblies (WRAs) has more than tripled operational reliability and realized over $70M in maintenance cost savings. Consequently, the DoD is procuring additional IFDIS systems to exploit the benefits of increased materiel readiness while reducing maintenance costs through intermittent fault detection.

Universal Synaptics has taken the advanced diagnostic capability contained in the IFDIS and made it portable so that it can be applied rapidly, easily, and cost-effectively at O and I levels of maintenance for Electrical Wiring Interconnect Systems (EWIS). Voyager Intermittent Fault Detector™ (VIFD™) meets the DoD requirement for single-man portable, is MIL-PRF 32516 compliant, and can be powered with AC or DC power supplies. Collaboration over the last twelve months with the Army, Navy, Air Force, OSD and CTMA has produced unprecedented results. VIFD has been applied to the F/A-18, V-22, A-10, H-53, AH-64, UH-60 and Patriot Missile Systems, with intermittent faults detected and isolated in 97% of the 30 wiring systems tested. All wiring systems tested had been tested by currently deployed wire test sets and passed. Benefits of VIFD testing are providing a clear and comprehensive outcome to the maintainer, reducing NFF and increasing materiel readiness.

The VIFD can be applied to the complete maintenance spectrum of electrical, electronic and avionics components/wiring across the DoD maintenance enterprise. Increasing Mission Capability to 80% is possible with the VIFD.

PROBLEM STATEMENT

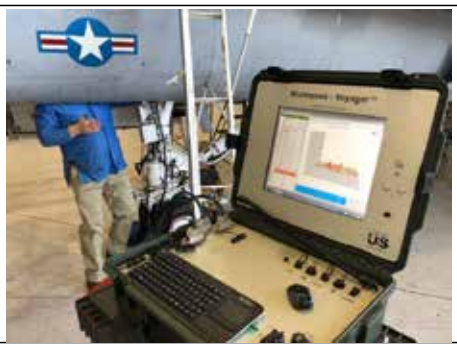
No Fault Found (NFF) test results are primarily driven by intermittent faults. Intermittent faults have become a significant concern, maintenance and life-cycle cost driver, and a materiel readiness degrader within the DoD. Conventional ATE was not designed to detect intermittent faults and is incapable of detecting and isolating momentary intermittent faults that cause NFF, leaving them unrepaired. These NFF sub-systems continuously cycle between the field and depot contributing to the roughly $15B per year in inspection and test, negatively impacting maintenance budgets, warfighter readiness, and materiel availability. NFF is a $2B to $10B annual non-value added expense to the DoD.

BENEFITS

- Improve Materiel Readiness.
- Achieve SecDef directive of 80% availability in 2019.
- Significant reduction in No Fault Found (NFF) occurrences.
- Substantial reduction of MICAPs.
- Reduction in maintenance cost.
- Increased operational availability.
- Cost-effective readiness.
- Reduction in repair cycle-times.
- Superior war fighter support.
- Improved maintenance processes and procedures.

TECHNOLOGY SOLUTION

The Voyager Intermittent Fault Detector™ (VIFD™) was specifically designed and purpose built to detect and isolate intermittent faults, enabling them to be repaired. The VIFD accomplishes this task by monitoring ALL lines ALL the time – no scanning or sampling. By identifying and correcting the root causes of random, intermittent failures, reliability increases on the diagnosed systems and sub-systems. The VIFD requires no TPS development and over the last twelve months the VIFD through an AWTS "patch cable" has detected and isolated intermittent faults in F/A-18, V-22, A-10, H-53, AH-64, UH-60 and Patriot Missile Systems. Deployed conventional scanning continuity test sets missed all the intermittent faults detected by the VIFD. This advancement in test technology directly benefits the warfighter by increasing materiel readiness.



CBM+ DEMONSTRATION FOR F-35 POWER THERMAL MANAGEMENT SYSTEM

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Problem Statement

The Power Thermal Management System (PTMS) is a subsystem of the F-35 JSF aircraft. It is the first successful integration of the Auxiliary Power Unit (APU) functions, the Auxiliary Power Generation (PMG) functions, and the Environmental Control System (ECS) functions on a single shaft for an aircraft application. It provides unique capabilities to the JSF platform and is the only other turbomachine (engine) on the single engine JSF aircraft. SAMMS LLC, therefore, emphasizes the need for continuous monitoring of the operational health of the PTMS, with evidence of need provided by RCM analysis throughout its operational life cycle. SAMMS will team with Honeywell Aerospace, who is the OEM for the PTMS.

CBM+ is a DoD proactive equipment capability that uses system health indications to identify and predict functional failure in advance of the event and provide the ability to take appropriate action. SAMMS is applying to use the CTMA opportunity to demonstrate some of the CBM+ capability on the F-35 JSF platform. The demonstration will focus on "trend analysis" using the PTMS turbomachine data.

Description of Technology

This demonstration will apply current OEM algorithms used for commercial aircraft APUs to show their use on the JSF PTMS. The technology, which involves the use of 'as manufactured' physics-based models, as well as data driven and statistical techniques, has been deployed by the OEM and currently hosts over 5,000 Honeywell APUs and 8,000 Honeywell propulsion engines. The technology involves the adaptation of the physics-based manufacturer's model, the creation of fault models, the use of signal identification and classification techniques, fusion and heuristics for extending accuracies realized from the engineering practice. SAMMS will demonstrate the benefits which include the avoidance of secondary damages and the extension of time on wing for the PTMS. The CTMA demonstration will show that the software capability can be adapted on any enterprise system for any of the services. It will also demonstrate its use for operational sustainment.

Current status of the Technology

For commercial airline applications, the technology has been fielded for more than 12 years on 3 different enterprise systems. The military is investigating several systems engineering approaches for use of such technologies. SAMMS wishes to demonstrate and approach that can be enterprise platform agnostic. We will also show how the analysis and trending can be extended to all other mechanical subsystems on the aircraft.

Test Data and Simulation of Performance Claims

Data for the demonstration will be obtained from JPO. The program office will provide annotations for the fault events. The performance claims will be shown by the triggered alarms prior to the actual event.

Next Steps/Potential Benefits

The next steps will develop an engineering program that will instantiate the PTMS CBM+ software design and development on any of the services enterprise platforms, such as NAVAIR Propulsion and Power System Engineering Sustainment Platform, the US Air Force Enterprise System and the Marines Logistics Enterprise.

PROBLEM STATEMENT

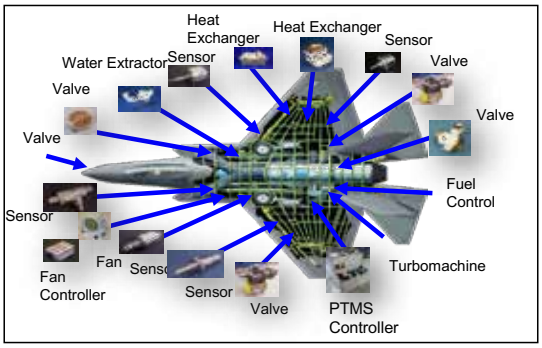
- Demonstrate current commercial web-based APU monitoring SW tool for the F-35 PTMS fleet.
- Provide CBM+ Capability for F-35 PTMS.
- Apply OEM Commercial aircraft SW for Failure Prediction and Corrective Action for the military aircraft Power Thermal Management System.
- Provide Continuous Monitoring of PTMS Operation throughout Subsystem Lifecycle.
- Host a commercial CBM+ capability on a military enterprise.

BENEFITS

- Provide CBM+ Capability for DoD F35 PTMS Fleet.
- Improve PTMS Operational Availability
- Improve PTMS maintenance decisions and integrate PTMS into F-35 lifecycle management process.
- Enable Implementation of proven technology and procedures to improve maintenance support for F-35 Fleet.
- Improve fault detection, diagnostics and prognostics capability for the F-35 PTMS.
- Can expand current COTS SW to include IETMS and support directed troubleshooting on-wing.
- Extend Time on wing.
- Reduce secondary damage and beyond engine repair (BER) experiences with PTMS.

TECHNOLOGY SOLUTION

- Existing Algorithms based on OEM physics-based models, Data-driven models and OEM heuristics.
- Fusion Algorithm applied to results, Trended and Displayed for each installation and for F-35 PTMS Fleet.
- Adapt User Interface for Alarms and Displays from ALIS.
- Data Parsed from ALIS, interpreted and analyzed.
- COTS APU analytic software is host web system agnostic and can be hosted on existing DoD web base or in ALIS.



DATA-DRIVEN & GOAL-DRIVEN CONDITION-BASED PREDICTIVE MAINTENANCE (DCPM/GCPM)

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Condition-Based Maintenance Plus (CBM+) achieves the least total life-cycle cost between Preventative and Corrective Maintenance. The Maintenance Community needs addressed include:

- Increase aircraft availability by developing automated CBM+ turnkey capabilities to discover unknown fault prediction signatures.
- Detect unknown abnormal precursors in C-130 Digital Flight Data Recorder (DFDR) and Automated Inspection Repair Corrosion and Aircraft Tracking (AIRCAT) engine data.
- Discover abnormal behavior detection correlations with C-130 debrief and AIRCAT on-board fault detection reports.
- Discover abnormality correlations with Reliability and Maintainability Information System (REMIS) and other repair data to recommend maintenance orders
- Automated retraining to create turn-key CBM+ system.
- Reduce Versatile Depot Automatic Test Station (VDATS) recalibration costs and improve repair reliability.

To affordably find activity patterns of interest in 'big maintenance data' we need turn-key intelligent data-driven and goal-driven systems. DF&NN is proposing to develop such a CBM+ system based upon a TRL7 system it has delivered to 3 sites. In 2017 this DF&NN E-SAS/ANOM system was installed at 3rd SES at Schriever AFB. It trained on new satellite normal SOH data off-line. Then detected the abnormal SOH effects adversary red-team satellite stimulations in real-time.

This GCPM system automatically learns normal activities in 'big' State of Health (SOH) data sets over many months and then provides abnormality detection scores in real-time for moving time windows of data of over 10K measurands. These abnormality detections are clustered, classified, and tracked over time with capability for the user to add his desired response for each abnormality type. The system detects the unexpected 'unknown-unknowns'. Temporal pattern recognition tools are added to predict effects of detected abnormality precursor signatures based upon historical data.

In the GCPM effort for the 581st DF&NN is detecting abnormalities in DFDR and AIRCAT Take-Off/Stable Flight engine and trend data. We then fuse with faults flagged in debrief and AIRCAT STD data. Then the Smoking Gun tool finds high confidence correlations with REMIS that discover fault causes and recommended repairs. The REMIS data is also used to define GCPM retraining criteria.

The GCPM tells DCPM when to retrain, what to retrain and test on, and when to promote to real-time operations. The Bayesian Fusion Node (BFN) web services support all levels of data fusion defined by the DF&RM Dual Node Network (DNN) technical architecture. It is affordably applicable to any instrumented system since it is data/goal-driven. GCPM is at TRL6 on historical C-130 engine data. We propose to do the testing to move to TRL7 for CBM+.

DF&NN has already converted the historical C-130 engine and VDATS data to be ingested by our DCPM/GCPM software. The promised capabilities include:

- DCPM affordable solution to unexpected precursor abnormality detection & characterization to extend CBM+.
- GCPM turn-key capability that automatically retrains DCPM to learn dynamic normal health behaviors.
- Identify when VDATS needs the more expensive recalibration process based on self-test data.
- Provide extensible, scalable, cross-platform, and multiple user CBM+ for C-130 Functional System Integrity Program and test stations in VDATS.
- Improve confidence in automated maintenance recommendations with the user on-the-loop.

PROBLEM STATEMENT

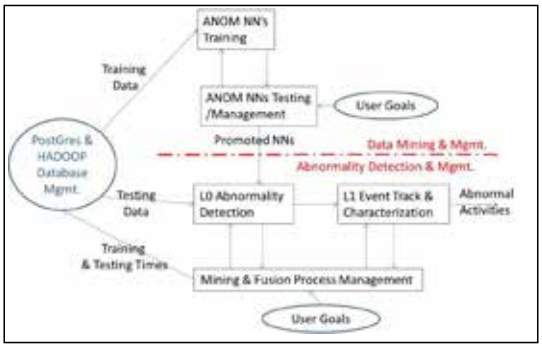
- Increase aircraft availability by developing automated Condition-Based Maintenance Plus (CBM+) turnkey capabilities.
- Detect abnormal precursors in C-130 Digital Flight Data Recorder (DFDR) and Automated Inspection Repair Corrosion and Aircraft Tracking (AIRCAT) engine data.
- Fuse abnormal behavior detections with C-130 debrief and AIRCAT STD on-board fault detection reports.
- Apply Reliability and Maintainability Information System (REMIS) and other repair data to determine maintenance orders and to maintain the CBM+ system.
- Reduce Versatile Depot Automatic Test Station (VDATS) costs and improve repair reliability,

BENEFITS

- DCPM is an affordable solution to unexpected precursor abnormality detection & characterization to extend CBM+.
- GCPM provides a turn-key capability that automatically retrains DCPM to learn dynamic normal health behaviors.
- DCPM/GCPM identifies when VDATS needs the more expensive recalibration process based on self-test data.
- DCPM/GCPM is extensible, scalable, cross-platform, and supports multiple users and roles in Linux and Windows as part of the 581st Functional System Integrity Program (FSIP) for the C-130.
- Improves confidence in automated maintenance recommendations with the user on-the-loop.

TECHNOLOGY SOLUTION

To achieve CBM+ benefits the unknown-unknown abnormal behavior in the aircraft engine and other data need to be detected and correlated with repair data so as to recommend abnormal condition-based repairs. The key to high probability of detection and the correct detection sensitivity is the type of abnormality detection system used. GCPM tells DCPM when to retrain, what to retrain and test on, and when to promote to real-time operations. DF&NN has recently developed the Deep Multi-Start Residual Training (D-MSRT) NNs which are out performing the prior ICA NNs, SVDs, & Random Forests when tested on AIRCAT and DFDR data. Smoking Gun discovers correlations with REMIS data from 2014-2017. GCPM tells DCPM when to retrain, what to retrain and test on, and when to promote.



INTEGRATED AIRCRAFT SENSOR NETWORK FOR REAL TIME CONTAMINANT DETECTION

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Environmental and chemical contaminant accumulation within airframes can result in corrosion, coating degradation, equipment damage, and reduced aircraft readiness. Aircraft structures are composed of a wide range of contaminant and corrosion susceptible materials including aluminum, steel, and titanium alloys, as well as composites and specialty coatings. Ingress of contaminants into the structure, occluded areas, and crevices can breakdown protective coatings, initiate localized corrosion, and eventually compromise the functionality or structural integrity of the system, component, or airframe. To better identify the presence of destructive contaminants, an Integrated Aircraft Sensor Network for Real Time Contaminant Detection has been developed to identify the species and concentration of a range of corrosive airframe contaminants. Coupled with a point-of-maintenance corrosion management tool (ICARR-3D) created by development partner Mercer Engineering Research Center, the system provides an end-to-end solution for locating, identifying, and tracking airframe contamination and corrosion. Use of the system allows for improved monitoring of individual aircraft contamination and corrosion as well as fleet-wide trend analyses and condition management. By tracking environmental conditions and contaminants within targeted areas of airframes and identifying both temporal and geographical patterns of exposure, maintainers may reduce operational costs, increase maintenance efficiency, and improve aircraft readiness.

This material is based upon work supported by the AFSC/PCIOA under Contract No FA8501-15-C-0016. Technical points of contact with the Air Force on this effort are Alan Fletcher and Frank Zahiri.

PROBLEM STATEMENT

- Environmental contamination, coating degradation, and fuel exposure adversely impacts aircraft lifecycle cost, availability, and reliability
- Throughout their service lives, aircraft are exposed to environmental and leakage contaminants that can damage structural components, electrical wiring, interconnection systems, and avionics
- Reduced availability and high maintenance costs due to contamination and corrosion can impact aircraft operations
- Currently, contaminant and corrosion damage are manually tracked by maintainers, resulting in subjective, poorly correlated records with high man hour expenditure

BENEFITS

- Provides enhanced visibility into aircraft contamination stemming from fuel leaks, environmental contaminants, protective coating degradation, and atmospheric pollutants in difficult to access areas
- Potential for reduced maintenance man hours and labor costs
- Leverages the existing Air Force owned and operated ICARR-3D point of maintenance tool for damage and contamination visualization and tracking
- Safety of flight qualified for use in aerospace applications
- Offers capability for long-term, fleet-wide tracking of airframe corrosion and contamination through integration with the existing Air Force AIRCAT maintenance database

TECHNOLOGY SOLUTION

- **Wireless Corrosion, Contamination, and Coating Degradation Detection System** for fuel, chemical, and environmental contamination monitoring
- Couples low-power, light weight sensor hardware with advanced visualization tools to provide enhanced visibility into airframe contaminants and component degradation
- Includes a sensor suite to detect hydrocarbons (JP-8 fuel vapor), NO_2, SO_2, temperature, relative humidity, surface conductance, corrosion, and coating degradation
- Seamless integration with the Mercer Engineering ICARR-3D maintenance tool and the Air Force AIRCAT maintenance database

SMART DATA CLEANSER FOR JUST-IN-TIME MAINTENANCE RISK DISCOVERY

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- Roughly half of Air Force maintenance data is poorly coded, which degrades individual aircraft and fleet analysis. It is no small feat to correct that coding — after identifying rare subject matter experts, the corrections could take four years per platform, resulting in years to complete.
- Research shows that data collection for aircraft maintenance is pretty bad. Why?
- Unrestricted text input – Without pre-defined choices, this creates irregular, inconsistent and insufficient descriptions.
- Poorly coded – Work unit codes (WUC) should identify the needed maintenance. But inaccurate coding, for example a report using a WUC ending with a 0 or a 99 because of poor training or execution, foils maintenance plans.
- Working with the Air Force and Robins AFB in a Phase 2 SBIR and now STTP, Cybernet used artificial intelligence to develop a learning algorithm to correct the coding errors and accomplish in one day what previously took four years.
- SDC technology now touches every plane arriving at Robins AFB and is expected to save $3M annually in unscheduled maintenance and free hundreds of expert hours.
- Original case studies began with 3200 filters for C-130 developed by an Air Force SME over 4 years on and off – 7420 filters were developed by the SDC in 1 day.
- SDC is platform agnostic. With no knowledge of WUC definitions, it also scrubbed F-15 and E-8C data in 1 day.
- By using automation via auto-generated filters, there is an increase in useful and accurate maintenance information, as well as quicker follow through and completion, and even predictability for condition-based maintenance. In other words, garbage in – useful information out.

Smart Data Cleanser offers:

- Algorithms for any platform and coding.
- Advanced decision tree translation with keyword search ability in either discrepancy/corrective narrative.
- Supported keyword parentheses and variant generation.
- Promoted filters to execute at higher levels.
- Predictable filter quality.
- Developed pipelined, two-tiered filter execution.

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ROBOTIC AUTOMATION FOR ESOH RISK REDUCTION, THROUGHPUT INCREASE, AND IMPROVED QUALITY

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When properly specified and integrated, commercial off the shelf (COTS), articulated arm, robotic systems can provide many benefits to depot operations.

- ESOH risk reduction for operators in hazardous environments including paint, depaint, thermal spray, surface prep, grinding, and milling. Utilizing robotics can limit exposure to chemicals, toxins, extreme heat, dust, and injuries.
- Improved product quality by leveraging the integral repeatability of robots. Once developed and programmed, the process will be carried out the same way every time.
- Increased production output by allowing the robots to operate during breaks and during shift changes. Additionally, some processes can simply be accomplished faster utilizing robotics due to their ability to overcome load and reach constraints that operators face.
- Increased flexibility by utilizing multiple end efforts or end of arm tooling (EOAT), allowing one robot to perform multiple processes. Additionally, as workloads change EOATs can be modified or replaced at a fraction of the cost a new system.
- Increased supportability as opposed to custom "robots" and gantries. The use of COTS equipment ensures maximum support from local contractors and vendors. Standardization ensures maximum organic support.
- Robins CMXG has realized these benefits through a diverse group of robotic processes. We are currently employing robotics in 17 different processes, with contracts awarded for 6 additional uses, and plans to expand that to another 6 for a total of 42 robotic systems performing 29 different processes.

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
Future - Awarded
Sanding
Grit Blasting for Bonding Prep
Laser Depaint
Mobile Wing Defastening
Mobile Core Milling
Mobile Structured Light Scanning
Future - Proposed
Composite (Radome) Repair
Collaborative Microwave Mapping
Welding
Chromic Acid Anodize / Acid Pickling
Stenciling
Ultrasonic Inspection

PROBLEM STATEMENT

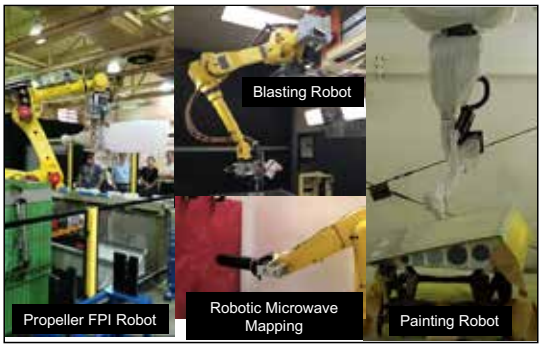
Aircraft maintenance activities contain inherent risks for personnel such as exposure to heat, chemicals, toxins, overload injuries, repetitive injuries, etc. In addition, inconsistent quality arises from human error. Defects cost money to fix, and aircraft can be delayed leaving the depot due to rework. The end result is more cost and fewer assets to warfighters. The 402nd Commodities Maintenance Group has sought to remove personnel from hazardous conditions where possible and has utilized robotics across multiple areas to increase throughput and quality.

BENEFITS

- Operators removed from hazardous environments
  - ESOH compliance (paint and depaint systems)
  - B20128 Blast Robots
- Consistent, repeatable results
  - F-15 radome w/ zero fails due to paint thickness
  - B142 Shot Peen, coupon validation
- Increased throughput
  - Robotic Floursecent Penetrant Inspection (FPI) and Borescope the only ways to keep up with throughput demand.
  - B180 paint robot, decreases paint time by 3.
- Robins CMXG is currently utilizing robotics in 17 different processes, with contracts awarded to increase that to 23.

TECHNOLOGY SOLUTION

- Robotic automation provides 6 or more axes, to allow systems the freedom required to adapt and change as workload demand shift.
- CMXG has standardized to Fanuc robotics to maximize organic support and expertise.
- The robots provide the base for custom end effectors designed for the specific applications:
  - Thermal Spray, Handling, Inspection Camera, Paint Application, Paint Removal, Surface Prep, Drilling, Milling, etc.
- Path programming can be accomplished manually or automatically utilizing 3D models.



ASSET LIFE-CYCLE INFORMATION MANAGEMENT (ALCIM)

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The Asset LifeCycle Information Management (ALCIM) program addresses the Air Force Sustainment Center's (AFSC) high priority technology need to provide operational efficiency metrics of key manufacturing machinery, assess the need for proactive maintenance using advanced machine learning algorithms, and provide situational awareness of these key assets. The ALCIM program effectively addresses these needs through the integration of successful SBIR programs, both, hardware and software engineering support technologies. ALCIM specifically addresses aspects of the Efficient Depot and Intelligent Sustainment Network attributes of the Air Force's Complex of the Future strategy by providing WR-ALC MXSS (Maintenance Support Squadron) with the capability to schedule maintenance based on the actual condition of machine assets to reduce unanticipated downtime in key support areas.

Scheduling for baseline work packages involves careful planning and consideration of multiple factors, including tasks, machine scheduling, work crews, and precedence of some types of work over others in order to maintain smooth overall operations flow. Providing continuous operations support for Efficient Depot requires constant adjustments to resources and schedules as asset availability becomes limited due to scheduled and unscheduled PM events. ALCIM supplies objective evidence to MXSS maintainers of actual machine usage and run time to drive preventative maintenance and reactive maintenance.

Specifically, ALCIM integrates:

1. The LifeMeter hardware based program for Condition Based Maintenance (CBM) where objective evidence of asset utilization at the machine component level is captured and evaluated.
2. The ARViSS (Analysis of Resources with Visualization and Integrated Simulation Support) information visualization and simulation program that provides a robust, macro level view of WR-ALC for aircraft repair and redeployment through data integration and powerful visualization capabilities.
3. A machine learning that uses multiple condition indicators application to notify operators of out of tolerance machine conditions.

ALCIM provides WR-ALC engineering with an integrated "data wall display" solution. CBM information is utilized indicating status of LifeMeter instrumented machines and alerts to out of tolerance operations to reduce costly downtime periods. Specifically, ALCIM features "at a glance" graphical, near real time mechanical, electrical and machine component performance monitoring as well as objective evidence of actual machine usage and run time to drive preventative maintenance and reactive maintenance.

PROBLEM STATEMENT

- The Air Force has a ***need to reduce the impact of machine asset downtime on AF Support Squadrons*** (e.g., WR-ALC MXSS and others) activities to achieve the *Air Force Complex of the Future: Efficient Depot (Attribute #4) and Intelligent Sustainment Network (Attribute #7)* goals.
- Providing continuous operations support for *Efficient Depot* ***requires constant adjustments to resources and schedules as asset availability becomes limited due to scheduled and unscheduled PM events***.
- Scheduling for baseline work packages involves careful planning and consideration of multiple factors, including tasks, machine scheduling, work crews, and precedence of some types of work over others in order to maintain smooth overall operations flow.

BENEFITS

- The *Asset Life-Cycle Information Management* (ALCIM) project addresses the high priority technology needed to provide the Air Force Sustainment Center (AFSC) ***the ability to maintain awareness of the operational availability of key support machinery, assess the need for proactive maintenance and understand the impact of machine downtime to depot throughput.***
- Supplies ***objective evidence of actual machine usage and run time to drive preventative maintenance and reactive maintenance.***
- Provides key ***information about user interaction behavior for more efficient shop operations for future application refinement.***

TECHNOLOGY SOLUTION

- ALCIM integrates two successful SBIR programs for engineering analysis and decision support: 1) The **LifeMeter** condition-based machine asset maintenance program, and 2) The **ARViSS** (Analysis of Resources with Visualization and Integrated Simulation Support) information visualization and simulation program.
- ALCIM provides WR-ALC engineering with integrated "data wall-display" solution. Provides Condition-Based Maintenance (CBM) information indicating status of LifeMeter instrumented machines and alerts to out-of-tolerance operations to reduce costly downtime periods.
- Features "at-a-glance" graphical, near real-time mechanical, electrical and machine component performance monitoring.

IN SITU MONITORING OF CORROSION & PROTECTIVE COATING DEGRADATION TO SUPPORT CBM+ EFFORTS

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Problem

Warfighter platforms are protected with multi-layered coatings to provide corrosion control; critical for mission readiness, reliability, and safety. Corrosion formation under cyclic loads accelerates fatigue crack growth. Corrosion inspection is labor-intensive and time-consuming. Therefore, rapid, automated coating integrity and corrosion detection technology is needed to reduce cost, inspections, and enable early/economical application of preventive measures.

Technology

Analatom's lightweight, internally powered Micro Linear Polarization Resistance (µLPR) Corrosion Rate Sensor System, enhanced with environmental sensing (Time-of-Wetness, Salinity, Relative Humidity, and Temperature) can determine coating integrity and structural loss due to corrosion. Linear Polarization Resistance is an established electrochemical technique—a fast, reliable method for calculating corrosion rates in numerous metal/electrolyte systems, which directly relate both to coating degradation and corrosion loss levels.

Technology Status

The µLPR system is at Technology Readiness Level (TRL) 7 and installed in fielded applications such as aerospace, civil engineering, bridges, and petro-chemical industries. The system is certified to fly on USAF C-130 platforms. Civil engineering applications include monitoring corrosion inside suspension bridge cables in Manhattan, New York. Federal Highway Administration report FHWA-HRT-14-023 states the µLPR makes it possible to measure corrosion activity inside main cables. Petrochemical applications that validated the technology include corrosion monitoring of buried pipelines for NYSEARCH, a natural gas pipeline consortium.

Test Data Support

The postage stamp dimensioned µLPR sensor can—in situ—continuously detect corrosion rates resulting under sealants, insulation, and from crack formation in protective coatings. During accelerated testing, primer coated steel experiencing tensile residual stress from changing temperature exhibited opening of preexisting coating defects resulting in the evolvement of corrosion at the interface. This corrosion progression was monitored by µLPR sensors and validated against experimental results, showing good quantitative agreement with corrosion rate trends.

Next Steps/Potential Benefits

The µLPR system is ideal to monitor corrosion rates in inaccessible areas. The next step is to implement an enhancement of the µLPR for environmental condition sensing, which when coupled with corrosion modeling enables structure-wide corro-sion-related prognostics.

Annual DoD corrosion costs are $20 Billion. In 2010, total C-130 corrosion costs were $634 Million; $127 Million (or 20%) was spent on preventative maintenance, which can benefit from Analatom's system by reducing unnecessary preventive maintenance and scheduling corrective maintenance actions based on the state of the aircraft. Within the first five years of deployment, an Air Force Return on Investment (ROI) study anticipates this system alone can reduce preventive maintenance by $12 Million (or 10%).

PROBLEM STATEMENT

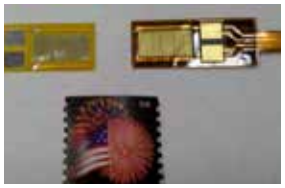
- Warfighter platforms are protected with multi-layered coatings to provide corrosion control; critical for mission readiness, reliability, and safety.
- Corrosion formation under cyclic loads accelerates fatigue crack growth.
- Corrosion inspection is labor-intensive and time-consuming.
- A rapid, automated coating integrity and corrosion protection capacity detection technology is needed to:
  - Reduce cost
  - Reduce frequency of inspections
  - Enable early/economical preventive actions.

BENEFITS

- The µLPR system is ideal to directly monitor critical component corrosion rates in inaccessible areas.
- The thin, postage stamp dimensioned LPR sensors when installed under the structure's coating allow continuous monitoring of protective coating degradation.
- Annual DoD corrosion costs are over $20 Billion. In 2010, total C-130 corrosion costs were $634 Million with $127 Million (or 20%) being spent on preventative maintenance.
- By reducing unnecessary preventive maintenance and scheduling corrective maintenance actions based on condition, AF ROI study anticipates this system can reduce C-130 preventive maintenance alone by $12 Million (or 10%).

TECHNOLOGY SOLUTION

- Analatom's micro Linear Polarization Resistance (µLPR) Corrosion Rate Sensor System, enhanced with environmental sensing, continuously monitors—in situ—both corrosion rate and protective coating integrity/degradation; and coupled with corrosion modeling enables structure-wide prognostics.
- Linear Polarization Resistance is an established electrochemical technique for fast, direct measurement of corrosion rates in metal/electrolyte systems.
- The TRL 7 system is lightweight, internally powered, with postage stamp sized corrosion rate sensors enabling placement in difficult to access areas including behind panels, under coating systems, sealants, and insulation.



NUVU AND NUVU-IR… 21ST CENTURY TOOLS FOR NON-DESTRUCTIVE DIGITAL INSPECTION

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Problem: Given DoD's aging hardware inventory, Readiness & Sustainment remain ever dominant themes across all DoD services. In his May 2011 testimony before Senate Armed Services Committee, now retd. AF Gen Reno sounded the alarm "…this high operations tempo (OPTEMPO) has also had some detrimental effects on our overall readiness. Readiness for full spectrum military operations is a challenge for our combat air forces" - well before the current escalating tensions in the Indo-Pacific Sector. Yet, 7½ yrs later, "Readiness" remains #1 concern & highest priority. How to do more with less?

Three persistent problems force progressively more down time with age:

a. Electrical issues: Damage to wiring & connector
b. Corrosion: Susceptibility to functional loss of component
c. Subsurface / not-in-line-of-sight cracks/ defects.

Need: Improved inspection is key to aging assets - planes, ships, subs, tanks being deployed rapidly and in larger numbers. Advanced automation-driven diagnostic techniques for digital data acquisition/ management and on-demand real-time point-of-use data delivery for prognostics will enhance CBM+ to get the aircraft off to skies and tanks rolling. Augmented Reality and Virtual Reality are today's realities ready to be imported into the DoD world to lower MRO costs and reduce downtime.

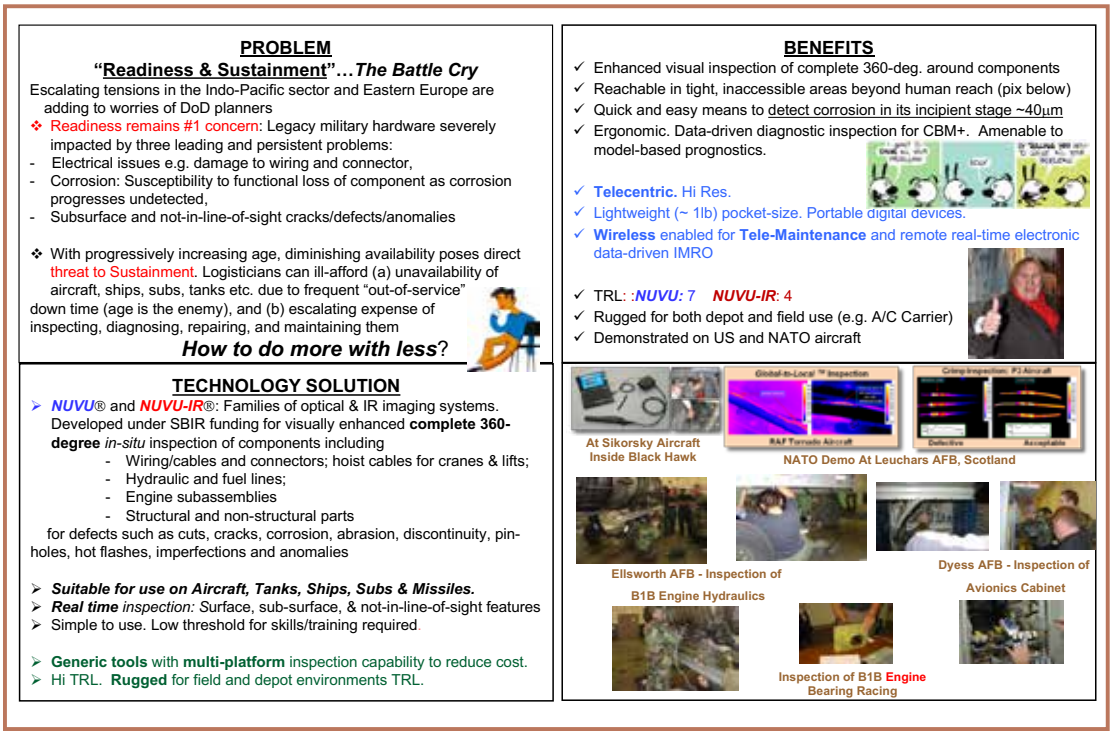
NUVU® and NUVU-IR® Technologies: Under SBIR program, MTC has developed NUVU optical & NUVU-IR infra-red families of instruments for detecting surface & subsurface defects - cracks, cuts, chafes, disconnects, pin-holes, corrosion etc. in electrical wires & connectors, hydraulic & fuel lines, and structural & non-structural components, present anywhere on the 360-degree surface in visual line of sight or out of visual range, inside braided jackets & shields, and to some depth below the surface. The family enables NDI based on telecentric enhanced optical imaging and includes:

- NUVU: Base system in 3 modes: DirectViz, OrthoViz, & CircumViz TRL: 7+
- OVMTM: Collapsible pocketsize. Replaces traditional manual "dental mirror-flashlight" 1960's inspection. TRL: 5/6
- mini-NUVUTM: Miniaturized for tight space inspections. TRL: 4
- NUVU-ZTM: Device for Ultra-Enhanced visual inspection for defects & anomalies. TRL: 4

NUVU-IR: Infrared imaging using cooled or uncooled detection. Current TRL: 4

Demonstrated on:
- 737, 747, MD11, A320
- F-15, F-16, B1B, B52, KC-135, P3, F-111, UH60

Unique features:
- CircumViz: Simultaneous 360-Deg vision
- Versatile – Across multiple platforms
- No interruptive disconnect or decoupling. No destructive preparation for inspection
- Assembled from COTS components
- In-situ: Suitable for incoming or as-is installed component inspection
- Portable, compact, hand-held, pocket-size: 14oz, 7"
- Real-time data-driven detection
- Wireless enabled; Tele-maintenance capable
- Ergonomic
- Affordable
- Data-enabled digital Diagnostics
- Open architecture permits continual technology enhancements for CBM+ for prognostics
- Versatile – Across multiple platforms



INTEGRATED DATA ENVIRONMENT FOR AUTOMATED LABELING (IDEAL)

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Integrated Data Environment for Automated Labeling (IDEAL) Maintenance Innovation Challenge DoD Maintenance Symposium Army rotorcraft routinely capture a large amount of sensor data covering a range of information from engine performance and gearbox vibration to aircraft orientation and outside environment. This data acquisition strategy has been deployed for more than ten years, leading to a very large archive of historical fleet data. Natural language data, such as maintenance logbook and depot repair records, are also generated and stored in disparate databases.

The Army derives great value from the large amount of data it collects and cleanses, but often at great cost. Cleansing programs provide significant benefits, but depend upon SMEs who must manually evaluate the data recorded for each event. These projects are notably resource-limited: cleansing only 10% of logbook entries and documenting failures of only a small set of selected components.

The sensor and natural language data are only useful when processed together, creating ground truth labels essential for SME-guided, data-driven machine learning and analytics. The authors are investigating a potential solution to this problem.

Data Programming is a cutting-edge paradigm to automatically generate large labeled datasets.

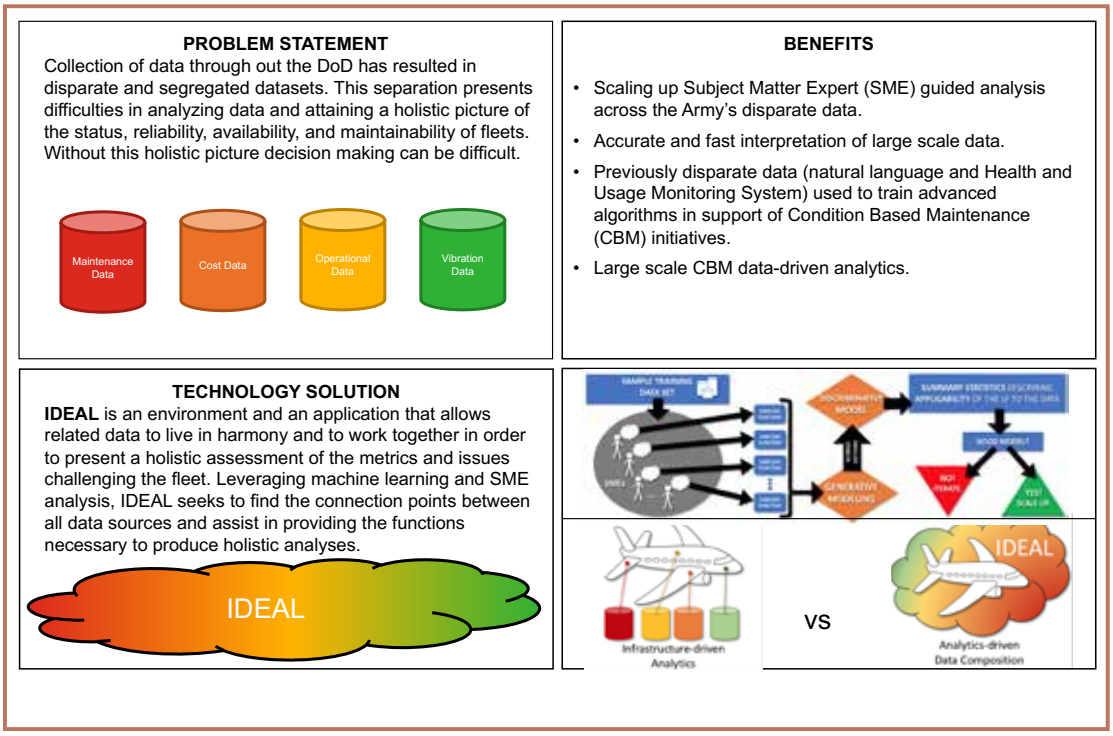
The collaborative team thus introduces the Integrated Data Environment for Automated Labeling (IDEAL), a technology based on the principles of data programming. IDEAL learns the heuristics SMEs use to interpret and label datasets. It then uses its model of the SME labeling process to label massive data collections that might otherwise require years and/or millions of dollars to accomplish.

IDEAL is an environment that uses labeling functions from multiple SMEs who govern the human interpretation of data. Consider a trivial example: how an SME might determine that a rotor blade damper requires service. IDEAL would request labeling functions from the SMEs, whom might provide the following: rotor system balance is out of limits, blue blade is lagging all other blades, installed damper is near the end of service life, and visual inspection indicates damper fluid is low.

On their own, labeling functions have different accuracies, but IDEAL learns the correlations across the SME-provided functions. As more labeling functions are given to IDEAL, the better it becomes at learning the heuristics used by the SMEs to interpret data. It looks across datasets; it balances labeling functions governing natural language and HUMS data.

IDEAL iterates with the SME to determine if the learned model scales up by providing feedback as the algorithm learns. In this way, the SME can monitor the algorithm to determine if additional labeling functions are required prior to its use in generating large labeled training datasets. The goal of IDEAL is to enable a holistic CBM analysis by generalizing its capabilities to all data describing a rotorcraft platform.

The team is developing IDEAL for Army aviation problems. Success will result in a force multiplier for SMEs and successful data-driven analytics for CBM.



CBM+ FOR FIELD ASSET READINESS

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In May 2018, Defense Secretary James N. Mattis discussed our National Defense Strategy. He outlined that a critical part of the nation's competitive, military advantage is a reform of the DoD's business practices and budgets for technological innovation to increase lethality. He stated that cyber, advanced computing, big data analytics, artificial intelligence, and additive manufacturing, "are the very technologies that we need to fight and win wars of the future,". In August 2018, in a message to our forces, he cited "enhanced lethality demands more than obtaining newer, more advanced equipment". Software solutions are needed to address this gap and hyperFIELD has the answer.

Foremost, the focus needs to be maintaining America's weapons-systems, wherever they are deployed globally. Maintaining these assets in the field of operations increases mission-critical availability and improves our combat readiness.

However, challenges have plagued the agencies. Today our nation's weapons-systems are maintained at Defense contractor Depots or DoD organic Depots. These are often located, far from deployed locations leading to long repair turn-around times, counter to an agency's goals to perform asset maintenance at 'Fielded' sites. Secondly, the agency spends the defense budget developing weapons-system/platform-centric proprietary and non-standard software maintenance solutions, instead of common software solutions that work across all platforms. Thirdly, due to the collaborative nature of maintenance work performed and data exchanged from non-standardized systems, highly sensitive data is at great risk. Finally, because numerous maintenance software systems are used, it is difficult for soldiers and field-maintainers to gain knowledge transferable across individual weapons systems. Without addressing these challenges, we are in a reactive-maintenance mode at best.

Today, with the maturation and trust gained in various technologies through industry adoption, we can take giant leaps forward. We can do more with less and transform field services into a condition based and predictive maintenance model.

Imagine being able to maintain any weapons-system on a common software platform from any global location. If our mission-critical systems and infrastructure are retrofitted with IoT (Internet-of-Things) devices, we can drastically reduce our maintenance costs and improve uptime by monitoring and predicting maintenance tasks utilizing AI (Artificial Intelligence) and ML (Machine Learning) algorithms. Utilizing technologies like Blockchain, Additive Manufacturing, and AR (Augmented Reality), we are able to locally or globally source service parts from trusted sources, 3D print service parts, and turn any soldier into a skilled field maintainer with the aid of remote guided goggles enabling them to maintain an asset close to the field. We can accomplish all this, while ensuring the data generated, stored, and shared are cyber-secure in a trusted immutable technology. This would be a game changer that can give America the lethal competitive edge on the field.

PROBLEM STATEMENT

- Persistently low readiness levels across all military agencies
- Unable to increase Field Level maintenance due to lack of skilled labor, readily available/trusted supply/parts, and cybersecure means to share data across agencies/partners & OEM manufacturers
- Aging Weapons Systems and Equipment
- High costs and low innovation relating to Sustainment solutions
- Supply Logistics, Workforce development, Data Integration challenges across globally deployed & fielded weapons systems / equipment

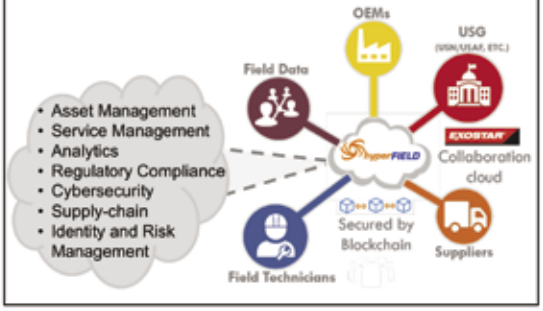
BENEFITS

- Improve readiness levels by 10-30% by increasing Field-Level (O&I vs Depot) Maintenance
- Reduce Maintenance costs
- Improve maintenance/sustainment support
- Increase Fielded Support (Organizational, Intermediate) to decrease system down-time vs expensive Depot repairs
- People, Parts, Data
  - Get parts to accomplish mission
  - IoT/Big Data on critical systems
  - Analytics to address systemic degraders
  - Predictive analytics to posture supply & maintenance
- Maintain America's Lethal Competitive Edge!

TECHNOLOGY SOLUTION

- Weapons-systems-agnostic, Mobile/Cloud-based Field-Service-Management (FSM) solutions
  - Capabilities already developed – Over 46K Development Hours Invested
- BLOCKCHAIN powered Multi-Tier Supply-visibility & Provenance
- Augmented-Reality (AR) solutions to empower Soldier to service near 'Field' of Operations & Remote Maintenance
- Artificial Intelligence (AI) based Analytics to "Predict" vs "React" to, Weapons-Systems Failures
- BLOCKCHAIN trust/immutability, to cyber-securely Capture, Store, Share & Transmit sensitive Data across partners

SOLUTION ARCHITECTURE



SMART - CONNECTED MAINTENANCE EQUIPMENT AND OPERATIONS

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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 insolated environments without remotely monitored alerts, performance data or quality indicators.

The inherent inability to relate test data with part order data and real-time notifications of delays and anomalies creates gap in decision making and quality control. These challenges directly impact the larger maintenance scheduling process resulting in long term impact on delivery. Continuing to rely on manual technique to obtain this information is time consuming, cumbersome and does not provide adequate oversight of operations.

PTC'S Industrial Internet of Things (IIoT) platform – ThingWorx – is commercially available software and is market leading with 21% of market share. PTC will provide immediate value by unlocking information and enhancing performance of the myriad of disconnected operational systems, machines, and databases within maintenance environments. PTC can assist in developing IoT adoption strategies, integrate manufacturing equipment and processes, connect systems and retrieve data to achieve real-time monitoring, data fusion and analytics using our market leading IoT platform.

ThingWorx can rapidly connect existing data, energy and mechanical systems, providing powerful dashboard views of operations while monitoring information flow, energy consumption and performance. This software will allow users to solve common problems in the factory and empower your staff to remotely monitor servers and reduce costly downtime. Empower your users and service technicians to remotely monitor, manage and service connected field assets with real-time alerts. ThingWorx can deliver rapid industrial innovation across your organization, and is already at work in hundreds of smart connected factories around the world.

Here are just a few of the benefits from adopting IoT strategies, and wrapping and extending existing systems and available data.

- Connect Industrial Machines: Gain Oversight of Disparate Systems Landscape, Connect a multitude of proprietary, non-integrated technologies with stovepipes of critical data.
- Real-time Remote Access and Monitoring - Gain visibility into machines operating in Isolated environments, remotely access performance data, remotely monitored alerts and quality indicators.
- Reduce Engineering Analysis Gaps – Process and relate test data with part order data, access to test data, notifications of delays and anomalies.
- Enhanced System/Equipment Performance analysis – Manage and analyze utilization data, equipment status, predictive alarms and anomaly identification.
- Improved decision making and quality control - Relate test data with part order data and real-time notifications of delays and anomalies.

PTC is standing by to provide demonstrations, proof of concepts to unlock the potential within the DoD.

PROBLEM STATEMENT

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BENEFITS

Connecting isolated machines and systems using powerful networking tools, maintenance operations can reestablish visibility, access data maintain control through alarms and enhance decision making tools.
Additional benefits include:

- Reduce manual data entry and human decisions
- Provide visibility to part and order status
- Optimize machine performance
- Access and analyses stranded test stand data
- Improve test scheduling and throughput
- Increase response time and issue resolution
- Improve access to data for engineering analysis

TECHNOLOGY SOLUTION

ThingWorx: PTC's ThingWorx, Internet of Things (IoT), software platform and Kepware, industrial connectivity application. The solution will provide maintenance operations with real-time integration, visibility and analysis of key systems and test equipment. This solution provides analysis, and alerts through connecting the myriad of non-integrated technologies and bringing that data into a proven user interface capable of in-depth analytics, remote monitoring and data fusion..

PTC's ThingWorx technology is commercially available software in use across industry. It is rapidly deployable and cost effective . www.ptc.com

DOD EQUIPMENT RELIABILITY IMPROVEMENT THROUGH THE USE OF NANOCOMPOSITE COATINGS

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Readiness and reliability of mechanical systems are significantly reduced by frictional losses leading to excess wear and corrosion. Performance is diminished leading to excess energy consumption and unplanned maintenance resulting in increased operational costs. Approximately 10% of energy in an internal combustion engine is lost through friction and further, in diesel engines, up to 35% of this friction loss is due to the crankshaft journal bearings alone. Similarly, the driveshaft needle bearings on unmanned aerial systems (UAS), which are widely employed throughout the Department of Defense (DoD), are a consistent source of performance failures leading to unscheduled engine overhauls.

The bulk and surface properties of nano-composite coatings (NCCs) have been engineered through individual layers, dopants and dopant profiles for a wide range of applications including engines, transmissions, and other aircraft and ground vehicle mechanical systems. The NCCs are applied in hybrid physical vapor deposition and plasma-enhanced chemical vapor deposition reactors designed and built by United Protective Technologies (UPT). The reactors have large processing volumes, which facilitate high throughput to minimize cost. A technology readiness level of 9 and a manufacturing readiness level of 10 for coatings of components such as transmission gears, needle bearings, and crankshafts have been achieved. NCCs have created a decrease in friction coefficient by more than 50% and six orders of magnitude in wear reduction for UAS engine and transmission component simulation tests.

Dramatic improvement in the performance of ring and pinion gears through both wear reduction and increased horsepower transfer to the wheels of automotive race engines has resulted from NCCs. These gears are subject to aggressive loads on the order of 1800 MPa (261 ksi). They were coated with a tungsten and carbon-based NCC specifically optimized to withstand the aggressive combination of sliding contact force and elastic deformation of the gear teeth. The gears were tested on a dynamometer at 680 flywheel HP at 8500 rpm for nine individual lap simulations after a ten-lap break-in. The significant results of the testing were an average increase of 3.5 HP over and beyond superfinishing, with a best result of 4.5 HP, and no measurable wear on three pinion teeth analyzed by profilometry. This lab data has fully translated into the highest level of America motorsports with over 90% of winning cars, on superspeedways, utilizing the proposed NCC on ring and pinion gears. These data strongly suggest that NCCs will significantly reduce wear and improve performance to mechanical systems resulting in reduced maintenance throughout the DoD. An autonomous system or piece of equipment with well-documented mechanical failures should be selected as a first demonstration of this innovative, performance enhancing technology.

PROBLEM STATEMENT

Readiness and reliability of mechanical systems are significantly reduced by frictional losses leading to excess wear and corrosion. Performance is diminished leading to excess energy consumption and unplanned maintenance resulting in increased operational costs. For example, in diesel engines, up to 35% of friction loss is due to the crankshaft journal bearings alone. Similarly, the driveshaft needle bearings on unmanned aerial systems, which are widely employed throughout the Department of Defense, are a consistent source of performance failures leading to unscheduled engine overhauls.

BENEFITS

Relevance / How Technology Addresses Requirement
- NCCs dramatically reduce wear at dynamic metal interfaces
- Readiness and reliability improvement of mechanical systems
- Reduced maintenance and extended service life
- No system re-engineering required for application / adoption

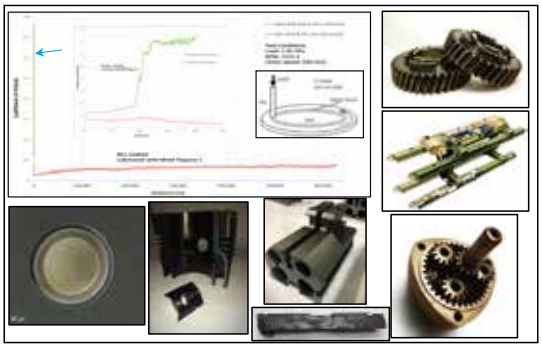
Transition (Existing DoD System, Program or Capability)
- Immediate availability to address mechanical system readiness and reliability for:

•Weapon Systems •Control Valves
•Vehicle Drivetrain Components •Actuator Components
•Internal Combustion Engines •Missile Launch Rails

TRL: Current – 9 Anticipated – 9

TECHNOLOGY SOLUTION

The bulk and surface properties of nano-composite coatings (NCCs) have been engineered through individual layers, dopants and dopant profiles for a wide range of applications including engines, transmissions, and other aircraft and ground vehicle mechanical systems. The NCCs are applied in hybrid physical vapor deposition and plasma-enhanced chemical vapor deposition reactors designed and built by United Protective Technologies. The reactors have large processing volumes which facilitate high throughput to minimize cost.



ROBOTIC LASER COATING REMOVAL SYSTEM (RLCRS)

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Ogden Air Logistics Complex (OO-ALC) has made great strides in the last few years with robotic LASER coating removal technology. Incredible efforts from Engineers, Technicians, 309 AMXG, Department of Defense (DoD) contractors, Air Force Life Cycle Management Center / Enterprise Zone Program, and OO-ALC leadership have led to a viable and fully capable technology that is in use today. Robotic LASER Coating Removal System (RLCRS) for the F-16 aircraft became focus at OO-ALC during the 3rd quarter of 2017. To date, 12 production F-16 aircraft have been processed using OO-ALC's RLCRS to remove their coatings. All 12 aircraft have returned to service to continue their mission.

A RLCRS was installed at Hill Air Force Base (AFB) in 2014 for implementation and optimization. The technology was introduced for the purpose of increasing employee safety, increasing production machine throughput, reducing environmental impact, and eliminate substrate degradation damage caused by the PMB process.

OO-ALC has used plastic media blasting (PMB) as the primary method of aircraft coating removal for decades. While it has been an effective method of removing aircraft coatings, it has several negative second and third order effects. The PMB process is very resource intensive, requiring 5-7 technicians to mask/seal, remove coatings, and de-prep the aircraft; requires full personal protective equipment (PPE) garb to prevent exposure to the Hexavalent Chromium and Cadmium hazardous waste the process generates; additionally, technicians must endure the physical demands of holding and maneuvering heavy blast hoses. Approximately 2000 lbs. of waste material is generated each time an F-16 aircraft uses PMB to remove coatings. This waste is captured via the PMB booth dust collection system and deposited into large containment bags, which are disposed of as hazardous waste.

For F-16, the RLCRS has proven through testing, evaluation, and optimization to: remove the worker from the hazardous environment; reduce the hazardous waste from 2000 lbs. to 10-12 lbs. per aircraft; reduce the process man-hours by 30-50%; eliminate 2-3 flow days; and shows no negative impact to the airworthiness of the aircraft.

Leveraging the success of the RLCRS within OO-ALC at Hill AFB, there are several follow on programs in work to propagate the technology. Building 269 at Hill AFB is being repurposed for a RLCRS that is capable of supporting: F-16, A-10, F-22 and F-35 AC. OO-ALC's Aerospace Maintenance and Regeneration Group (AMARG) at Davis Monthan AFB, is currently planning to implement a RLCRS capable of supporting a variety of DoD weapon system platforms. Warner Robins ALC is looking at the feasibility and planning for possible RLCRS(s) for F-15, Global Hawk and C-130 aircraft.

PROBLEM STATEMENT

- Current process requires multiple workers to be in full PPE garb to protect them from hazardous waste exposure.
- Current method damages aircraft skin.
- Current process generates significant amounts of hazardous waste.
- Current process is resource and flow day intensive.

BENEFITS

- Removes worker from environment.
- Reduces hazardous waste by 99%.
- Reduces process man hours 30-50%.
- Improves aircraft airworthiness and mission supportability.

TECHNOLOGY SOLUTION

- Removes worker from environment.
- Reduces hazardous waste by 99%.
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- Improves aircraft airworthiness and mission supportability.

LOW HYDROGEN EMBRITTLING ZINC NICKEL (LHE ZN-NI)

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Cadmium is a soft metal used as a thin corrosion inhibiting coating on steel parts such as landing gear and missile ground systems shock isolators overhauled at Ogden Air Logistics Complex (OO-ALC). Cadmium was originally specified for these systems due to its excellent corrosion inhibition qualities, lubricity, ease of application, and ease of removal.

Cadmium has been defined as a human carcinogen by the International Agency for Research on Cancer and the US National Toxicology Program and the process for electroplating cadmium requires the use of large amounts of cyanide. Since the 80's the Air Force has sought replacements for cadmium plating and was successful at eliminating cadmium from lower strength steels processed at Robins Air Force Base (AFB) (in the 80's) and Tinker AFB (in the 90's). However, these formulations degraded high strength steels and were not suitable for applications such as landing gear.

In 2007, the OO-ALC cadmium replacement team lead efforts, in coordination with commercial partners, to develop and test LHE Zn-Ni; a new non-proprietary, environmentally friendly corrosion preventative for high strength steel. Testing was extensive and included corrosion, fatigue, hydrogen embrittlement, coating adhesion, paint adhesion, and torque tension, among others. These tests were conducted alongside cadmium control samples. The LHE Zn-Ni samples performed "as good as or better" than cadmium in nearly all cases. In addition, this process can be implemented with no form, fit or function changes, no operational changes to component and has the benefit of a net cost savings.

By 2011, the LHE Zn-Ni had passed the initial tests and a full-scale prototype LHE Zn-Ni line was installed at OO-ALC (Bldg. 505) in 2012.

From 2012 to 2013, the full scale prototype line went through additional verification and testing. LHE Zn-Ni plating of production landing gear components began in June 2014. OO-ALC is working to eliminate cadmium plating as quickly as they can and plan to more than double their LHE Zn-Ni plating capacity during the next few years.

Currently, OO-ALC has the only successful LHE Zn-Ni plating line for high strength steels in the Department of Defense, leading the effort to replace/eliminate cadmium plating on high strength steels.

PROBLEM STATEMENT

- Cadmium is required for corrosion protection of high strength steels.
- Cadmium is toxic and a known carcinogen.
- Other solutions that proved successful on low strength steels degraded high strength steels.

BENEFITS

- Environmental and Health friendly alternative to cadmium for high strength steels.
- Exceeds the performance of cadmium in many tests.
- Can be implemented with no form, fit or function changes to components.

TECHNOLOGY SOLUTION

- LHE Zinc-Nickel developed and tested by OO-ALC and its commercial partners.
- LHE Zinc-Nickel specially formulated to exceed the performance of cadmium and not degrade high strength steels.
- Developed advanced fixtures and tooling to allow a consistent even coating of LHE Zn-Ni in lieu of cadmium on Air Force components

Right Photo: Field corrosion testing between cadmium (left) and LHE Zn-Ni (right) after 3.9 years.

Left Photo: Prototype LHE Zn-Ni electroplating installed at Hill AFB.

SAM DECK SCALER

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Problem Statement
The popular Aurand MP6 surface scaler can remove failing non-skid surface on carrier decks prior to reapplication. Injury rates amongst maintainers wielding the tool, however, are high, and no other tool has been found that can successfully address the particularly durable high-friction coating.

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 to enable maintainers to confidently wield the MP6 while standing comfortably, and adds an integrated dust collection system and carry handle.

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 a commercial product to government and private sector clients. The Deck Scaling configuration featuring the Aurand MP6 is in final testing and should be ready for commercial sale in Q4 2018.

Test Data Supporting Performance Claims
SAM systems have been in regular use at commercial and military locations since the tool was first introduced in 2014. Each customer found that the equipment met or exceeded internal targets for vibration exposure reduction and productivity.

Next Steps
Call Temple Allen to get questions answered, ask for a demo, or configure a system you want quoted.

Potential Benefits
SAM systems improve surface consistency and quality, eliminate injuries associated with manual operations, reduce exposure to toxic dust, and improve schedule reliability.

Big Picture
Maintenance done right, whether by the military or the private sector, takes advantage of all the things humans do well and implements alternatives for those tasks humans do poorly. Many critical-path maintenance processes still suffer from challenging environments, difficult ergonomics, and expensive asset downtime. Better solutions are urgently required - solutions that will protect workers, save money, and maximize productivity – and Temple Allen exists to make them.

PROBLEM STATEMENT

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.

Injured artisans often require surgery, therapy, and retraining. Injured artisans lower net productivity, require training of replacements, and lower morale.

The difficulty of recruiting new artisans for difficult and dirty jobs makes keeping existing artisans healthy especially important.

BENEFITS

- In addition to eliminating injuries associated with manual use of scaling tools, Temple Allen's SAM systems:
- Reduce fatigue levels, reduce errors, and improve morale
- Generate more consistent results from each artisan
- Increase "trigger-on" time in most applications
- Make recruiting and retaining artisans easier
- Improve dust and debris collection

TECHNOLOGY SOLUTION

- 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

DATA-DRIVEN & GOAL-DRIVEN CONDITION-BASED PREDICTIVE CORROSION MAINTENANCE

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Annual corrosion related costs for Department of Defense (DoD) facilities, infrastructure, and equipment are $20 billion. Approximately 25% ($5 billion) occurs at depot-level maintenance for Air Force aircraft and missiles. Analatom has aerospace validated monitoring technologies and experience integrated into innovative, platform-wide solutions. This approach—applying localized and area corrosion sensing, environmental corrosion modeling, and assessment techniques—proposes to deliver cost-effective, integrated solutions and implementation strategies for DoD applications.

The TRL 8 system incorporates in situ corrosion rate micro-sensors, providing data for advanced modeling assessment and prediction of protective coating/CPC system condition. Assessing/predicting coating degradation and corrosion onset through sensor data management, analytics, and hybrid coating condition/corrosion modeling establishes the framework for real-time corrosion assessment of in-service platforms to substantially enhance Condition-Based Maintenance (CBM+) programs.

Benefits

- Heightened Military Capability by ensuring maintenance is performed based on condition, resulting in shortened procedures and reduced depot times.
- Accelerated Military Development when domain experts/engineers can identify areas frequently maintained to improve structural and material designs.
- Reduced Costs and Increased ROI by identifying failure modalities in critical components and reducing life cycle costs associated with unnecessary maintenance, particularly for inaccessible critical components.

Measurements from corrosion sensors and coupons demonstrate pit-depth computed from sensors agrees with coupons to a statistical confidence of 95%; indicating sensors can provide accurate measurements for prognostic application. Proposed application is corrosion monitoring of C-130 aircraft in high corrosion regions like Patrick AFB, Florida. Patrick AFB's fabrication flight team uses sensor technology to measure corrosion changes in aircraft in real time, enabling more effective maintenance decision making.

Augmenting hardware with analytical/data mining software presently at TRL 6, it is proposed to implement practical CBM+ techniques focusing on: (a) required corrosion data determination/collection, (b) corrosion data analysis/modeling, and (c) decision making. Proposal will develop/validate large-scale data/goal driven CBM+ framework specific to aviation platforms via further development of: (1) embedded sensor data requirements, (2) coating/CPC degradation models, (3) wireless DAQ of corrosion and critical environmental data, and (4) hybrid models integration with data mining tools incorporated into Analatom's Intelligent Maintenance Assessment System (IMAS). IMAS supports CBM+ by correlating platform integrated health management sensor data with maintenance actions, flight data, and faults. Proposed system will integrate into maintenance or health monitoring network systems that support CBM+.

PROBLEM STATEMENT

- Annual corrosion related costs for DoD facilities, infrastructure, and equipment are $20 billion. Approximately 25% ($5 billion) occurs at depot-level maintenance for Air Force aircraft and missiles.
- Navy and Marine Corps aviation annual corrosion cost is $2.6 billion; 26.1% of total maintenance costs (FY 2008-2009).
- Existing/emerging corrosion sensing, logging, and monitoring technologies are not applied as a comprehensive, strategic, integrated solution for corrosion management, maintenance, and mitigation.

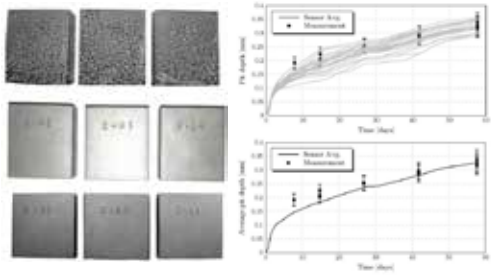
BENEFITS

- **Heightened military capability** by ensuring maintenance is condition-based, resulting in shortened procedures & reduced depot times.
- **Accelerated military development** when domain experts/engineers can identify areas frequently maintained to improve structural & material designs.
- **Reduced costs and increased ROI** by identifying failure modalities in critical components. Proposed CBM+ compatible system reduces life cycle costs associated with unnecessary maintenance, particularly for inaccessible critical components.

TECHNOLOGY SOLUTION

- Proposed monitoring/assessment system incorporates in situ corrosion micro-sensors providing continuous data for advanced modeling assessment and prediction of protective coating & CPC condition.
- Assessing/predicting coating degradation and corrosion onset through advanced sensor data management, analytics software, and hybrid coating condition/corrosion modeling establishes the framework for sustainment groups' real-time corrosion assessment of in-service platforms to substantially enhance CBM+ programs.

GRAPHIC



Comparison of Coupon Measured &Sensor Data Computed Pit Depths.

LONG LIFE CYCLE PEEL AND STICK NONSKID

CHARLES LIGON

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The Navy has long used epoxy based nonskid paint on areas that require nonskid. This nonskid paint adds a huge amount of weight to the ship. The lesser the weight the better the speed and maneuverability. This nonskid paint is very difficult to remove when required. The maximum life expectancy of the present non-skid coating is just 18 months.

Since 2008, the Navy has begun replacing their traditional nonskid paint in noncritical areas with a peel and stick nonskid. This has greatly reduced the weight on ships but has created other problems. The life cycle is no better than traditional nonskid and requires quite an effort to remove and replace so often. This nonskid peel and stick is polymer based. The heat and UV rays of the sun deteriorate these types of nonskid.

Introduction
The Navy has recently caught on to the thermal spray processes. A new thermal sprayed nonskid was selected to spray the deck of the USS Wasp. This thermal spray aluminum ceramic nonskid stood up to the heat when the F35B landed vertically. They have recently sprayed the USS America with a similar thermally sprayed aluminum titanium and are testing the F35B to land vertically. These thermally sprayed nonskids have an expected life cycle of 50 years and add very little weight to the ship compared to traditional nonskid. In addition, can be sprayed on the critical area of a flight deck. However, it is very difficult to thermal spray on decks and walkways of lower levels. Thermal spray requires large dust collectors while spraying.

Thermal Sprayed Peel and Stick Nonskid
The solution for a long lasting life cycle peel and stick has just been invented and patented. It uses the very same nonskid as sprayed on the USS Wasp but in a peel and stick application and can be easily applied in all noncritical areas with a 10 plus year life cycle. Testing has backed up life cycle. Navy has tested and assigned QPL and NSN numbers.

This thermally sprayed nonskid peel and stick has been installed on a Navy destroyer for over 3 years with the same CoF as when applied. The USCG is applying it also. The Navy is writing a new mil spec because of this product. That milspec is to include the ability to handle hot decks and more durability than polymer based peel and stick. This new thermally sprayed nonskid is metal based. The Navy is testing this product in Bahrain and GTMO where the decks are hot.

Conclusion
A metallic based peel and stick nonskid is a far superior, lightweight with Long Life Cycle nonskid for noncritical areas where nonskid is required.

Author's Biographics
Charles Ligon. BS in Business, Ferris State College, Big Rapids, MI. Product Development for Thermal Spray Product Line at American Torch Tip 16 years.

PROBLEM STATEMENT

All known peel and stick nonskid are polymer resin based and wear out easily, requiring removal and replacing often. Sun and UV rays deteriorate resin based nonskid. Life cycle of resin based nonskid is no more than 18 months and as little as 9 months on Navy and USCG ships.

BENEFITS

Long life cycle – reducing cost, corrosion proof, oil and chemical resistant, water proof, UV proof – unaffected by weather or sun, adhesive handles deck temperature up to 270F, weighs almost half of polymer peel and stick, can be painted and offered in many colors of high temp ceramic paint, has CoF of over 1.0, no VOC's – safe and not environmentally sensitive.

TECHNOLOGY SOLUTION

Metallic based nonskid peel and stick offers a long life cycle of up to ten years. A Metallic based nonskid is created by using a thermally sprayed molten ceramic and aluminum to a flexible substrate. This saves money, labor, weight and material.. A Power Point presentation of Navy evaluation and testing is available. Navy recently tested CoF surface after over four years in use and it was the same as when fist applied.

IMPROVING IN-PROCESS CONTROL FOR THERMAL SPRAY

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In an effort to modernize the monitoring and control of thermal spray, three innovative sensors were developed and are being put into use in the 76 PMXG thermal spray area: the plume-optimization camera, the in-situ coating properties sensor, and the in-situ thickness monitor. The thermal spray process is used frequently in the overhaul and repair of engine parts to apply various coatings such as hard face coatings, thermal barrier coatings, abradable coatings, and coatings for material build up. Currently quality control for the thermal spray process is performed in post process through destructive inspection of witness coupons coated alongside the part. This post process inspection is labor intensive and high in volume, as 76 PMXG processes over 9,000 coupons per year. If the coating does not meet quality requirements, the coating must be stripped from the part and re-applied adding cost and flow days to the repair of the asset.

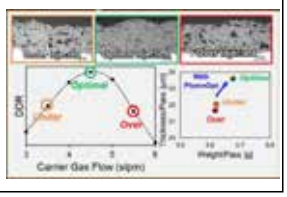
76 PMXG has been working with Reliacoat Technologies to develop and implement in-situ coating property sensors to characterize coating microstructure quality and thickness before the coating is applied to the asset. The plume-optimization camera (Plume Opt), also developed by Reliacoat Technologies, is used to determine optimal injection of thermal spray powder into the gun flame. This reduces powder waste and coating variability which leads to cost savings. Savings generated are substantial as thermal spray powders range from $10 to $60 per pound, PMXG powder usage totaling a cost of $1.7M per year. By implementing this in-process control, the number of recycles due to failed coating quality has been reduced. The average cost of a thermal spray recycle is $4,000 in material and labor. By demonstration of a repeatable, controlled process, intervals between destructive testing can be lengthened, reducing testing cost and reducing time components spend waiting for quality validation.

PROBLEM STATEMENT

- Thermal spray process quality control is based on destructive inspection of witness coupons post process
- Little information is available about coating quality *during* the process
- Due to evaluation being after the part has been processed, rework sometimes occurs when coating is determined unacceptable
- Often several parts have been coated before receiving lab results indicating there is a problem, resulting in many parts being recycled

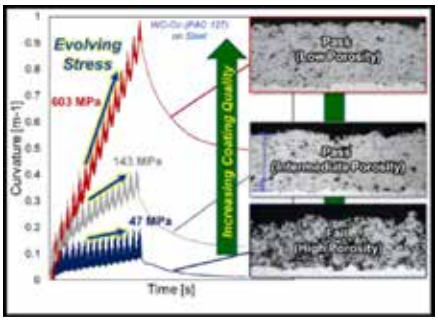
BENEFITS

- Real time parameters available in process
- Troubleshoot difficult coatings and accelerate coating development
- Potentially reduces post-process testing
- Improves coating quality and performance
- Reduces powder waste
- Reduces coating variability



TECHNOLOGY SOLUTION

- Under SBIR projects, Reliacoat Technologies developed in-process sensors including the plume-optimization camera, in-situ coating properties sensor, and in-situ thickness monitor
- Sensors measures stresses in the coating during deposition and take IR images of spray plume
- Stresses are being mapped to evaluate coating properties such as microstructure and mechanical properties
- PMXG installed the sensor set in 3 thermal spray booths to establish baseline properties and to flag process variations before an engine part is coated



MANUFACTURING & MAINTENANCE USING LASER

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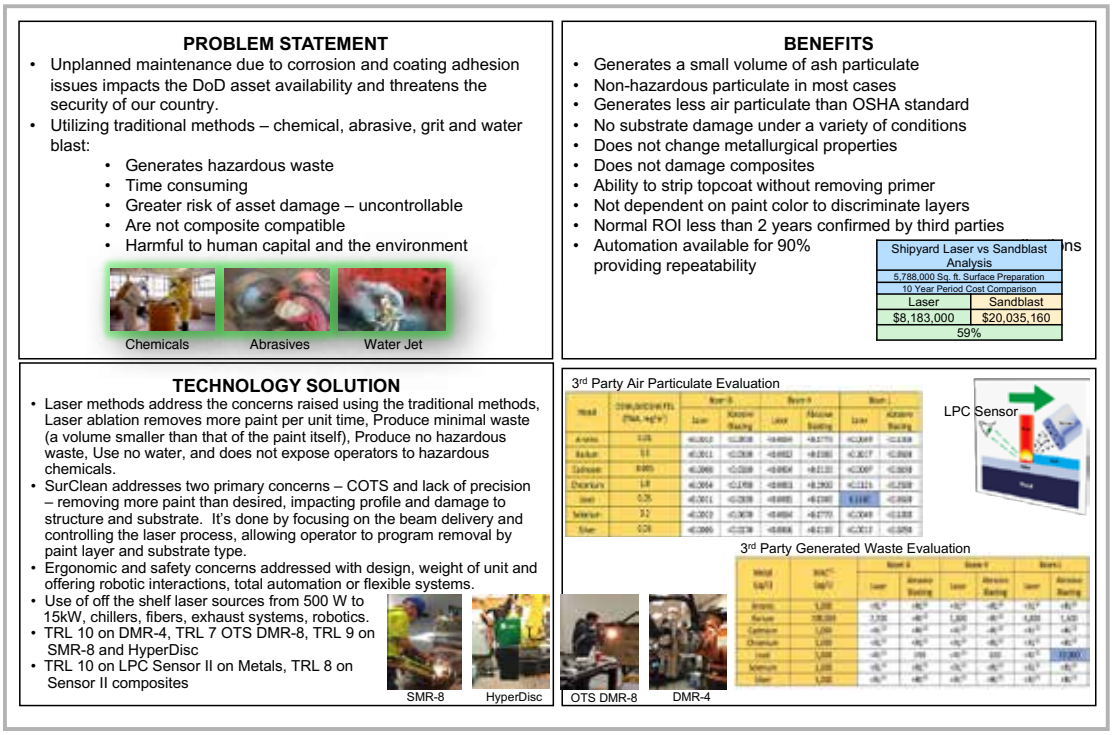
Laser ablation is a proven technology impacting lifecycle costs in two distinct areas – Asset Manufacturing and Maintenance. Laser Ablation or pre-weld cleaning improves weld bonding. It reduces corrosion development and improves coating adhesion. The Automotive industry proved these attributes and now other industries are prime to adapt the lessons learned. As more and more assets incorporate composite and other metals, traditional chemical, high-pressure water and abrasive blasts methods cannot be used across all areas of the asset. Selective processing increases process time requires additional training and man-hours. Additionally, EPA regulations on air and/or water particulate capture and disposal including the tracking of the hazardous waste combined with OSHA regulations protecting human exposure dramatically affect the cost of using these methods.

All assets require maintenance. Unplanned maintenance is expensive, impacts asset availability and caused by corrosion per numerous reports published by various DoD agencies. It impacts our Nation's security.

Laser ablation commonly referred to as Laser De-Paint, dramatically impacts the cost of maintaining assets. The Air Force validated this statement and is leading the exploration of this technology. SurClean started to address issues stated in the Air Force Reports. SurClean is working with the Navy Research Lab and has support from an independent Shipyard. Laboratory tests have proven the technology and how it works on various surface, structure, material, and coating types. The shipyard calculations using their actual data, estimates a cost reduction of 78% with a payback under 2 years. The shipyard asked Sherwin Williams to conduct coating evaluations. Their testing showed surfaces cleaned with SurClean's laser system improved damaged surface texture and the coating adhesion. In fact, the adhesion test is considered passing at 385psi. SurClean samples sustained 1450psi plus. ROI estimate

Laser ablation requires a laser light source, beam delivery system, vacuum system, chiller and electrical source. SurClean's system is unique to our competitors because it utilizes off-the-shelf lasers, vacuum systems, chiller, generators, control systems, robots and generator (for total portability). SurClean focuses on the beam delivery system, the workhorse of any laser system. Our competitors utilize off the-shelf galvo optics providing a 50% power efficiency or a patented polygon scanner (70% power efficiency) focusing efforts on the laser source. SurClean's beam delivery system consists of two main areas – process head or optic and our patented laser process control sensor. SurClean has two optics - proprietary configurations using the Risley Prism theory available for robotic or handheld applications (70%-80% power efficiency) and a patent pending optic that utilizes up to 98% of the laser output power. The patented laser process control sensor allows for real-time processing known as selective layer removal. Additional safety features are incorporated addressing ergonomics, air quality and system on/off.

SurClean is ready for market with our first optic and TRL 8 with the second optic. Next steps are on-site validation tests replicating laboratory testing for the Navy Research Lab, Michigan Department of Transportation (scheduled for June 2018) and a collaboration partner for the Air Force or Commercial aviation market.



ELIMINATION OF CONTACT CLEANING FLUIDS BY USING NONDESTRUCTIVE ELECTRICAL TEST CURRENT

CHRISTOPHER TEAL

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Recent efforts with the US Army Special Operations community allowed for the discovery of electrical contacts being "cleaned" during testing events. Evidence post test provided data that displayed the positive effects of using current tests in both moisture evaporation and in carbon buildup cleaning. Some of the results from the cleaning have resulted in continued operations of those subsystems without NFF or CND issues for up to three years and counting. Our goal is to provide a portable testing/cleaning capability to the war fighter, which will allow for continued operations until the next schedule major maintenance event.

PROBLEM STATEMENT

Many CPC's are used today for cleaning electrical contacts for weapon system interconnecting subsystems. They have shelf lives, can attract further contamination into the interconnecting devices.

BENEFITS

- No fluids introduced to electrical subsystems.
- Quick and easy to operate.
- Ensures mission until next available maintenance.
- No shelf life as existing methods.

TECHNOLOGY SOLUTION

A one person portable device that allows for connection to the end of electrical interconnecting subsystems and allow for automated cleaning of the electrical contacts on those weapon systems experiencing NFF/CND events.

One simple tool versus shelf life hazardous liquids

OR

LASER ABLATION AND NAVAL MAINTENANCE APPLICATIONS

NAVSEA TACTICAL INNOVATION IMPLEMENTATION LAB & NAVAL UNDERWATER WARFARE CENTER KEYPORT

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Surface coating inspection, removal, and reinstallation are often the critical path in ship maintenance. To modernize the Navy's approach to surface coating removal, the NAVSEA Laser Ablation Fielding Team embraced the task of gaining approvals, delivering and employing a laser ablation coating-removal system to the upcoming aircraft carrier (USS Carl Vinson - CVN 70) maintenance availability beginning in March 2019. The Carl Vinson team's willingness to implement Laser Ablation is the final stage of gaining approval to apply this technology directly to a major maintenance availability. This initial fielding onboard an aircraft carrier will promulgate this technology across the fleet and exponentially increase the return on investment.

The challenge of surface coating removal currently requires use of mechanical methods and extensive labor to remove the coatings. Initial estimates from the CVN 70 team projected a 70% overtime rate for their paint shop personnel for a large duration of the project given existing methods demanding an alternate solution. This endangered not only the workforce but the already constrained schedule.

To mitigate this problem, the team was tasked to identify and clear all barriers for shipboard application. Laser ablation is the process of removing material from a metal surface by irradiating it with a laser beam. The material is heated by the absorbed laser energy and evaporates, sublimates, or is converted to a plasma. Through a significant effort to challenge norms and change culture while adhering to the scientific process, the team achieved approval of a robust testing plan from all the Technical Warrant Holders after extensive collaboration across other Warfare Centers and the Penn State ARL. The test plan has been designed to provide the basis for additional applicability on other ships in the Navy inventory.

The team worked with multiple vendors to validate system availability and scalability, and leveraged relationships with the USACE Seattle District office to ensure adequacy of permit submittals across the northwest region. Additional collaboration efforts with Ogden ALC and Boeing provided the starting point for Navy standardized process instruction creation.

The team continues to ensure that that follow-on effort beyond the USS Carl Vinson will benefit other aircraft carrier and submarine maintenance as well as new ship construction. Throughout this effort, the team has provided an inclusive and effective communication methodology leveraging partnerships across the Navy to ensure ready fielding by the affected workforce, technical groups, and project.

Benefits include increased throughput of ships thereby returning more operational availability to ongoing national defense efforts, increased resource availability in a group of tradesmen that is stretched thin, improved ergonomics and safety, and a reduction in the amount of hazardous waste removal, storage, transportation and disposition.

PROBLEM STATEMENT

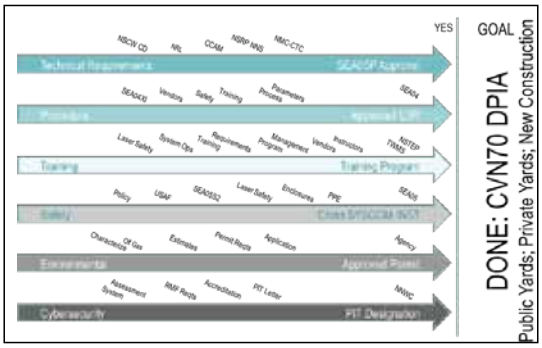
Surface coating inspection, removals, and reinstallations are often the critical path in ship maintenance. In an effort to modernize the Navy's approach to surface coating removal, the NAVSEA Laser Ablation Fielding Team has embraced the daunting task of gaining approvals, delivering and employing a laser ablation coating-removal system to the upcoming aircraft carrier (USS Carl Vinson CVN 70) maintenance availability beginning in March 2019.

BENEFITS

- Increased throughput of ships returning more operational availability to ongoing national defense efforts.
- Increased resource availability in a code that is stretched thin, improved ergonomics and safety.
- Reduction in the amount of hazardous waste removal, storage, transportation and disposition.

TECHNOLOGY SOLUTION

Laser ablation is the process of removing material from a solid, in this case metal, surface by irradiating it with a laser beam. At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates. At high laser flux, the material is typically converted to a plasma. Many systems in use today capture and filter the byproducts within a closed system.



GREEN WET BLASTING TECHNOLOGY FOR MAINTENANCE, REPAIR, OVERHAUL OF VARIOUS DOD COMPONENTS

FREDERICK A. GREIS

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Problem

- Traditional technologies for the cleaning, descaling, derusting, striping produce physical exposure to cleaning chemicals and dust found with chemical parts washers and dry "sand" blasting.
- Static build up can lead to ignition, explosions, fire
- Operators must often wear bulky protective clothing and breathing apparatus
- Dust collectors are often inefficient, requiring excess maintenance and floor space
- Examples: descaling, cleaning of aircraft engine/APU components, landing gear, weapons

Technology description

Standard/custom systems are designed/built combining a special, wear resistant pump producing a high flow rate of water, media, and regulated compressed air delivered by a nozzle(s) producing a "scrubbing" effect on metallic, polymer, and/or composite surfaces. This is an application specific, refined variation of a process widely known as "wet blasting".

Current development status of the technology

We have developed the technology to include:

1. A specially designed pump which can deliver media concentrations in excess of 50% to water. This capability allows the process to be more reliant on the slurry, and less so on the addition of compressed air. Thereby providing a safe removal of scale and contaminants without damaging the substrate or removing base material.
2. Complete oil and particle separation
3. Negative pressure filtered exhaust to minimize exposure

Test/simulation data supporting performance claims

Example: APU auxiliary power unit impeller/shaft removed for overhaul. Surfaces are covered in scale and may have light oils.

Current process/average times for single part comparison

1. submersion in chemical parts washer to remove oils and soften scale - 30 min.
2. manually scrubbed with brush - 15 min.
3. open air drying - 15 min.
4. dry blasted with spherical glass bead to remove scale - 10 min.
5. blast media consumed - 1lb.
6. rewashed to remove dust - 5min.
7. total - 75min.
8. new technology: total - 15min. blast media consumed- ¼ lb.

Next steps

Accumulation of documented parts for testing such as:

- Weapons components small to large, typically cleaned on a monthly basis
- Landing gear wheels following tire removal and disassembly
- Jet engine turbine blades, rotating discs and hubs, stators
- APU components
- Composite structures to be etch prepped for bonding

Process testing and verification on a variety of applications can be conducted in an existing lab environment. Documentation to include video of; pre-process condition, complete processing, post process inspection.

Potential benefits based on limited existing installations

1. One major engine manufacturer has written a specification around this process for descaling the root sections of rotating discs and hubs, replacing previous dry blasting, which was found to remove base metal, which lead to lose blades.
2. APU components at one AFB were accumulating due to inefficient traditional cleaning methods. The installation of the process equipment eliminated the problem, while producing better quality parts.
3. A weapons facility practice of physically hand cleaning dangerous fuel residue from missile tubes was replaced by this process, eliminating the previous exposure.
4. Participants from one AFB conducted successful hands on testing in a lab on multiple components including mini gun barrels and deemed it superior to their traditional technology.

Source: Wet Technologies Inc.
wettechnologies.com

PROBLEM STATEMENT

- Human exposure to dust and chemicals from current maintenance operations utilizing chemical parts washers and dry "sand" blasting
- Static build up in dry blast cabinets can lead to dust fires/explosions
- Operators must wear bulky protective clothing and breathing apparatus
- Dust collectors are often inefficient, requiring excess maintenance and floor space
- Examples: descaling, cleaning of aircraft engine/APU components, landing gear, weapons

BENEFITS

- Eliminates exposure to dust and risk of static dust ignition
- Combines existing steps-oils and contaminants are separated and consolidated for disposal.
- The process/equipment is "closed loop."
- Media is interchangeable and reusable with low consumption compared to dry blasting.
- Chemicals are not required; however mild rust inhibitors can be used.
- Systems can be standard or custom designed to meet part size/weight and facilities requirements.
- Dust free systems offer freedom of placement locations to improve efficiency.

TECHNOLOGY SOLUTION

- The Wet Technologies process provides scalable, self-contained systems, combining water, media, and compressed air which can efficiently derust, descale, strip, and etch surfaces.
- Faults such as cracks can be exposed to prepare for LPI-liquid penetrant inspection.
- Paint such as on aircraft wheels can be striped in layers, corrosion is completely removed.
- Surfaces can be post rinsed in the same system with clean, filtered, closed loop water.

IMPROVED ENERGY SOURCE FOR NDI EQUIPMENT

PAUL MATTER

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Non-Destructive Inspection (NDI) equipment provides important tools for the Air Force to characterize flaws, cracks, and/or defects in aircraft, thus monitoring potential safety issues. This equipment is typically hand-held, and used by maintenance crew in flight lines and hangars to inspect aircraft. Most NDI equipment is powered by a battery (alkaline, NiCad, NiMH, or Li-ion) that typically comprises a large percentage of the size and weight of the equipment.

The Air Force is interested in finding alternative forms of energy for NDI equipment, due to issues with existing battery technologies that include logistical challenges, battery reliability/degradation, limited portability/grid dependence, and safety. pH Matter and its partner, Lockheed Martin, have designed and built a prototype 25-Watt ethanol-powered fuel cell power system for NDI equipment, and demonstrated integration of the prototype with commercial NDI equipment and in explosive atmosphere testing (TRL 6).

The technology has a number of benefits compared to batteries, including:

- High energy density. The ethanol fuel energy density is about 500 W hr/L, about 2 times higher than a lithium ion battery. This translates to smaller size and weight for an equivalent amount of energy to run a device.
- Instant "recharging". Instead of connecting the battery to a power source and recharging for several hours, the cells are instantly refueled. This is a benefit to productivity for the end user.
- Grid independence. Without the need for electrical outlets, NDI equipment can be used for extended periods in remote locations by bringing sufficient fuel with the equipment; and not much fuel would be required considering the high energy density.
- Logistics / fuel availability. The ethanol fuel can be sourced worldwide.
- Safety The cell design (with the non-precious metal air cathode) does not create an ignition source – a major concern for the flight line environment. The prototype has been demonstrated in explosive atmosphere testing.

In this presentation, we will review the technology and prototype test data, as well as projected size, weight, and features of a production design. Future development of the fuel cell technology will further reduce the system size, increase the cell longevity, and optimize the design for production. Future products for the fuel cell technology could include power for other portable electronics, remote sensors, and small-unmanned vehicles.

PROBLEM STATEMENT

Alternative energy sources to batteries for NDI equipment tools are needed:

- Batteries must be frequently recharged.
- Battery logistical sourcing challenges.
- Grid dependence for recharging in remote areas or flight lines.
- Safety concerns in many environments.

BENEFITS

- Instant recharging of the equipment power source / reduced down-time.
- Eliminate dependence on electrical outlets in remote locations.
- Easily sourced non-toxic fuel.
- Improved energy density / longer run-time.
- Safety in Class 1, Division 2, Group B environments.
- Reduced logistical burden with sourcing Li-ion batteries.
- Lower power costs for heavily used NDI equipment.

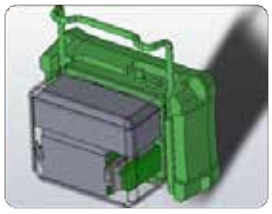
TECHNOLOGY SOLUTION

pH Matter and its partners built a prototype fuel cell power system, and demonstrated the prototype for powering NDI equipment.

Ethanol-fueled low-temperature fuel cell design attributes include:

- 25-W output, 8 hour operation between refueling.
- Unique patent-pending system design.
- Novel fuel cell catalysts and membranes.
- Compact production design for mounting on back of the equipment.

25-Watt Prototype



Production Design

Acknowledgements: Air Force Contract No. FA810016C0002

USING MULTI-POLE MAGNETIC TECHNOLOGY TO IMPROVE PRODUCTIVITY, QUALITY AND SAFETY

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Department of Defense sustainment facilities are faced with the difficult task of maintaining or upgrading equipment used by our armed forces. Facilities are challenged by an aging work force as well as a new generation of recruits unaccustomed to the physical demands required. Equipment maintenance and sustainment is highly fluid, making it difficult to take advantage of the dramatic advancements made in Robotics. Maintenance facilities have little choice but to continue using traditional methods. Tight work schedules often results in employees using brute force to accomplish a given task. Unfortunately, even with increased safety efforts, we anticipate frequent strains, sprains and crush injuries.

Advancements in human augmentation technology can help minimize injuries and reduce physical effort. However many of these products are viewed as costly, cumbersome and a hindrance to productivity. Partial Exo-skeletal systems aid in transferring loads to other body parts but do not fully mitigate the problems. Full Exo-skeletal systems are somewhat restrictive and in need of further development. Other systems, such as the ZeroG Arm, transfer tool loads and vibration to fixed points, with the primary complaint being lack of mobility and portability. Use of mechanized assistance such as overhead cranes and forklifts still encounter issues of availability and extended wait times even in unconfined areas.

Fortunately, work performed in maintenance facilities involves steel or steel structures. A recent magnetic invention, "Phase Canceling Multi-Pole Permanent Magnets" (MP magnet) is disrupting traditional steel manufacturing methods. MP magnet technology overcomes virtually all viability issues of previous magnet technologies. MP magnets (sold under the trademark Maglogix®), have an unheard of performance to weight ratio exceeding 400 pounds holding force per 1 pound of magnet! MP magnets use multiple shallow magnetic fields to increase saturation density. This dramatically increases magnetic adhesion providing; Unparalleled safety, De-stacking ability, and Elimination of Arc-Blow during welding. MP magnets have a residual magnetic field designed in, to offset the magnets weight, facilitating vertical or inverted positioning. The unique design makes the MP magnet the only switchable magnet made of hardened steel.

Powerful Magnets are no longer limited to "Below the Hook" uses. Products such as Zero G arms can be attached in seconds, rather than carting hundreds of pounds or hard mounting the arm. Hand lifters weighing 3.5 pounds provide 750 pounds grip on ¼" steel eliminating crush, cut and burn injuries. MP Magnetic drills are capable of drilling down to 1/8" thick steel, have no danger of falling during a power loss. Advanced Sensing technology (MagnaSense) determines the breakaway force and can shut the drill motor down prior to detachment. MagnaSense technology is available separately with digital readout on select MP-Magnets. Grip force is provided on any surface irrespective of paint, alloy, shape etc.

MP magnets weighing 16 pounds, (3400 pound grip on >3/8" steel) are used to bend / fair steel, eliminating temporary weld attachments. ROI's of 4 days are common.

MP Magnets are so powerful and lightweight; they are being evaluated by TARDEC to rapidly attach armor onto vehicles ranging from Humvees to Tanks.

PROBLEM STATEMENT

- **Physical demand**
  - Workforce has aged considerably.
  - New recruits are smaller and somewhat less physical.
- **Workload**
  - Facilities have a multi-year backlog and struggle to meet date objectives.
  - Robotics, while helpful are unable to be deployed rapidly in a highly fluidic environment.
- **Safety**
  - Existing manufacturing methods are taking a toll on smaller and / or aging workforce.
  - Injuries have a dramatic impact on schedules and cost.

BENEFITS

Safety
- Requires no power, will not pinch, ergonomic
- Avoids direct contact with sharp or hot steel

Speed
- Eliminates Scars, reduces grinding, reduce support people, rapid on / off

Quality
- Improved position accuracy, rigid hold during welds
- Advanced sensing technology

TECHNOLOGY SOLUTION

- **ZeroG Arm rapid support attachment system**
  - Portability and the ability to work in confined Quarters
- **Fairing and Fixturing Steel**
  - Magnetically bending steel into position eliminate temp welding, reduce manpower
- **Moving and manipulating material more safely**
- **Drilling**
- **Welding**
  - Shallow field does not cause arc blow
- **Customizable and readily configure into many applications**

TIME ADAPTIVE BLAST BOOTH VENTILATION SYSTEM

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Hexavalent chromium dust is eight (8) times more likely to cause cancer than asbestos. Hazardous chromium, cadmium, and other dusts are generated by common industrial processes and all sustainment centers ("depots") of all Department of Defense (DoD) components subject personnel to these exposures. The Air Force has received numerous OSHA citations in recent years and have struggled desperately and failed to reduce exposures using the best available equipment, which is technologically outdated and consumes remarkable amounts of energy.

This SIBR project is giving the AFSC capability by developing three technologies contributing to the achievement of the DoD goal to eliminate hazardous dust exposure to personnel:

1. An Advanced Continuous-Time Adaptive Ventilation (ACTAV™) blast cleaning enclosure (BCE).
2. A Continuous Hazardous Environment Monitor (CHEM™).
3. A Dust Migration Mapping™ system.

In addition to enhancing DoD system capability, the three dust mitigating technologies, when inserted into blast equipment, will reduce operating costs by supplying "ventilation on demand," i.e. the right amount of air movement for the task at hand, thereby significantly reducing the energy wasted by conventional systems that can operate at a single "worst case scenario" speed. Maintenance costs and lost production costs will be reduced through machine health monitoring capabilities supported by the ACTAV™ control software, providing maintenance personnel with forecasting and immediate need data, thereby increasing equipment uptime and decreasing unscheduled shutdowns. Measurement of exposures being encountered directly by the operator will provide for more information than simply measuring the general atmosphere. By developing remote monitoring technology, ACTAV response can be tuned to optimally reduce operator exposures.

The ACTAV and CHEM systems are enhancing Air Force capabilities by providing AFSC maintenance depots with the capability to address operator exposures of hexavalent chromium and cadmium to below the OSHA permissible exposure limit (PEL), while minimizing the migration of hazardous contaminants from the BCE to surrounding work areas.

PROBLEM STATEMENT

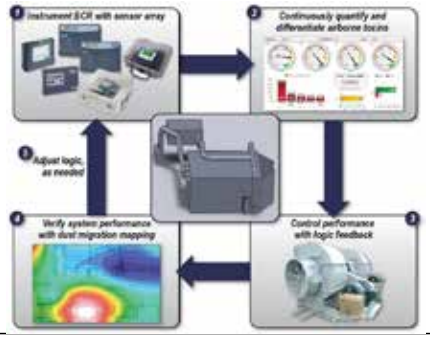
Current Hill AFB blast booths do not meet the minimum exposure limits for cadmium and chrome, therefore they expose both operators and associates to excessive hazardous material (HM) and waste energy.

BENEFITS

- Maintain Operator HM exposures below the OSHA PELs
- Minimize HM migration outside of the blast booths
- Operate with minimum Energy Consumption
- OSHA Compliant
- Environmentally friendly
- Reduced environmental regulatory expenses
- Significantly improved work environment
- Healthier workforce
- More satisfied workforce
- Increased tenure of blasters

TECHNOLOGY SOLUTION

Continuous Hazardous Environment Monitor (CHEM) technology will continuously monitor hazardous cadmium and chromium levels during operations using sensors that will activate the Advanced Continuous –Time Adaptive Ventilation (ACTAV) system when minimum levels of exposure are reached. The ACTAV system will increase airflow within the booth up to 30% more than standard airflow allowing levels of HM to remain below minimal levels and reduce operator exposure.



SEMI-AUTONOMOUS HEALTH AND SAFETY MONITORING WITH REMOTE DISTRIBUTED SENSORS

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Aircraft sustainment work within the Department of Defense is a costly and occasionally hazardous work domain, including flammability risks, volatile organic compounds, and low oxygen conditions within confined spaces. Government investment into maintainer safety has resulted in impressive track record for safety, however this typically comes with a high financial cost and reduced work efficiency. Immense pressure exists to meet critical sustainment deadlines requires all capable personnel to be made available for production work. A solution is needed to increase manpower availability for supporting maintenance work without compromising the ability to detect hazards and prevent safety incidents.

The 402nd Maintenance Group (402 AMXG) at Warner Robins Air Logistics Complex (WR-ALC) and its development team has developed a sensors-based remote monitoring solution that increases safety and reduces manpower needed to assure maintainer safety. An unobtrusive sensor suite is utilized that collects and wirelessly transmits atmospheric hazards and maintainer health signals, as well as indoor location tracking to respond if/when incidents occur. Intelligent algorithms are run on these data for semi-autonomous alerting and intervention based on worker health/safety status, greatly minimizing the time and attention needed by safety attendants. Data are networked into a remotely located decision support station and wearable alerting displays (e.g. smartwatch interfaces) for a reduced number of safety attendants to monitor many maintainers concurrently and respond promptly when needed.

This technology supports the prevention, detection, and intervention of health and safety hazards in aircraft maintenance depots. It reduces the time, costs, and manpower required by current health and safety monitoring practices (e.g., confined spaces). Compared to manual safety monitoring practices, there is greater reliability for ensuring worker safety with less time to recognize and respond to health/safety problem. This technology boosts depot efficiency (e.g., reduced downtime) and offers a reduction in sustainment costs due to manpower reallocation to other supporting functions. A Gen1 prototype has undergone testing and evaluation, and is being planned for full-scale delivery at WR-ALC.

PROBLEM STATEMENT

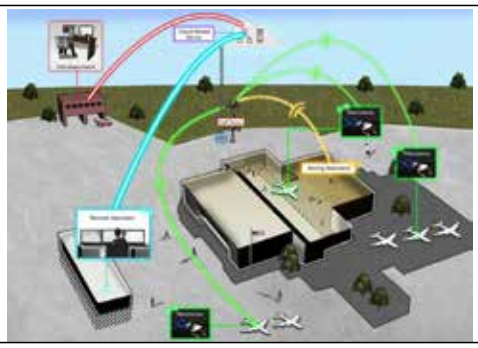
- DoD aircraft sustainment work is a costly and occasionally hazardous work domain, including flammability risks, volatile organic compounds, and low oxygen conditions within confined spaces.
- Gov't investment into maintainer safety has resulted in impressive track record for safety, however this typically comes at a high financial cost and reduced work efficiency.
- Immense pressure to meet sustainment deadlines requires all capable personnel to be made available for production work.
- A solution is needed to increase manpower availability for supporting maintenance work without compromising the ability to detect hazards and prevent safety incidents.

BENEFITS

- Supports prevention, detection, and intervention of health and safety hazards.
- Reduces the time, costs, and manpower required by current health and safety monitoring practices (e.g., confined spaces).
- Greater reliability for ensuring worker safety -- less time to recognize and respond to health/safety problem.
- Improved depot efficiency (e.g., reduced downtime).
- Reduction in sustainment costs due to manpower reallocation to other supporting functions.
- Gen1 prototype has been tested and evaluated, and being planned for delivery at Warner Robins Air Logistics Complex.

TECHNOLOGY SOLUTION

- Sensors-based monitoring solution that increases safety and reduces manpower needed to assure maintainer safety.
- Unobtrusive sensor suite collects and transmits atmospheric hazards and maintainer health signals, as well as indoor location tracking to respond if/when incidents occur.
- Intelligent algorithms for semi-autonomous alerting and intervention based on worker health/safety status.
- Data sources are networked into remotely located decision support station and wearable alerting displays (e.g. smartwatch interfaces) for a reduced number of safety attendants to monitor many maintainers concurrently and respond promptly when needed.



SLAM STICKS ACCELERATING MAINTENANCE

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Slam Stick was developed for the Navy under the DoD Rapid Innovation Fund (RIF) ONR BAA RIF 11-023 and provides engineers a cost-effective wireless vibration, temperature, and atmospheric pressure data logger that can be used anywhere in the world to quickly identify system problems.

Instrumentation at this quality level was previously only available in expensive large data acquisition systems costing tens of thousands of dollars and found in test squadrons and laboratories. This capability is now available for use at a fraction of the cost and can be used by Fleet Maintainers and engineers around the globe to help solve fleet issues.

The Slam Stick family of sensing systems are at TRL-9 and are being sold to industry around the world. Currently over 6,000 sensing systems have been sold including 2,000 to the F/A-18 Program Office.

In July of 2016, Slam Sticks were installed on several F/A-18 aircraft Environmental Control System (ECS) components to test and troubleshoot issues relating to cockpit pressure. Because of that testing, Slam Sticks have been chosen as the sensor of choice and has been integrated into F/A-18 Automated Maintenance Environment (FAME) reporting system. This integration into FAME allows squadrons maintainers to instantly download Slam Stick data and view the recorded cockpit pressure of any flight. To date, over 2,000 Slam Stick devices are in use across F/A-18 Fleet. Slam Stick has also been used to troubleshoot a C-2 aircraft at FRCSW on two separate occasions. NASA Armstrong and other maintenance/test activities are also using it across the DoD to cost-effectively enhance testing capability. Slam Stick can be used by O-D maintainers to troubleshoot aircraft in a way that was previously unavailable. Its only limitation is that that engineers and maintainers are unaware that it exits, so it is only being utilized to a fraction of its potential.

Savings realized is over $10 million (10,000 flights) for F/A-18 alone to date. It is estimated that hundreds of millions more in maintenance savings can been realized across the NAE/DoD enterprise when compared to the cost of using conventional test instrumentation (based off $5,000 saving compared to installing conventional test equipment). Slam Stick can be used anywhere in the world by DoD and industry sustainment engineers to quickly understand, analyze, and solve specific Fleet vibration, temperature, or pressure issues on equipment such as: aircraft, tanks, submarines, avionics, and depot/industry machinery.

If funds can be obtained, future Slam Stick efforts will support the creation of a DoD Job Performance Aid (JPA) that will document Slam Stick use and highlight success stories, and also send Slam Sticks to other DoD maintainers and engineering activities for evaluation of the new capability; a "try before you buy" approach." Slam Stick used broadly across the DoD would improve Time On Wing (TOW) and achieve substantial cost avoidance.

PROBLEM STATEMENT

- **DoD maintainers are in need of wireless data loggers capable of measuring vibration, temperature, and pressure**
- *Example* – Avionics WRA chassis cracking
  - Flight test instrumentation of test aircraft is currently the only option engineers/maintainers have to acquire data when resolving vibration/temperature/pressure issues
  - Can take months or longer to complete due to funding or schedule conflicts
  - Is costly - typically $5K - $100K per test flight
  - May not highlight squadron's specific unique issue
  - For non safety of flight – typically instrumentation at flight test squadron is not considered due to high cost; as a consequence the problem continues for years costing the DoD tens of millions of dollars in maintenance costs

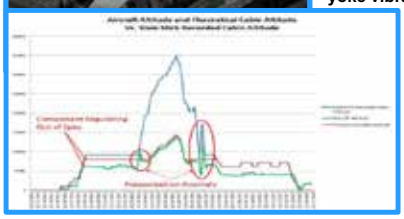
BENEFITS

- Places highly accurate data loggers in the hands of thousands of DoD sustainment engineers and maintainers to assist with system/equipment maintenance and troubleshooting
- Provides for sustainment maintenance testing capability while enhancing current DoD Flight test sensor capabilities
- **Time Critica**l – Reduces troubleshooting time from months to days – installs in minutes
- **Cost Effective** – $800 (one time buy) verses $5K - $100K saving $5K and up per use over conventional testing methods
- **Sustainment Engineering Success Stories:**
  - Used to support F/A-18 cockpit pressure testing for F/A-18 (over 10,000 flights recorded) $10 million in savings
  - Resolved (2) separate C-2 vibration issue at FRCSW flight line
  - Used at F/A-18 VX-23, NASA Armstrong, Boeing, NG, Lockheed Martin, and other Industry partners

TECHNOLOGY SOLUTION

- **Navy SBIR/2012 PMA-265 RIF funded wireless 8 channel data logger- Mide SlamStick-X**
  - National Institute of Standards and Technology (NIST) calibrated
  - Records up to 4 hours of data sampled up to 20KHz, 10 hours at 5KHz (2 GB data card)
  - Fully Programmable using free analysis software
  - Deployed across the globe at TRL-9, 6,000 units sold to date
- Allows for timely cost effective instrumentation of Fleet equipment to support maintenance and repair efforts
- Thousands in use across the DoD
- **Time Critical** - Test results in hours compared to weeks/ months
- **Cost Effective** - $800 per device (bulk price), reduces maintenance man-hours by quickly pinpointing the problem
- Total Cost to implement:$125,000 for NAVAIR to Create Job Performance Aids and Purchase additional Slam Stick devices

One of nine SlamStick-X units installed on C-2 during Depot ground turn to isolate flight yoke vibration issue



F/A-18 cockpit pressure analysis with SlamStick-X

AIRPLANE DAMAGE ASSESSMENT USING 3D HEMISPHERICAL SCANNING TECHNOLOGY

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Today's airlines need a robust system or service to assess damage to the airplane fuselage, wings and control surfaces. Damage typically occurs from bird strikes or other foreign interference. Significant damage can ground an airplane or significantly reduce performance.

To help solve this problem, Three-dimensional Laser Scanning should be used for identifying and assessing damage. Currently, there are a few scanning systems that have proven to be acceptable methods for evaluating damage. Unfortunately, they are low volume or can only measure small areas of the airplane at a time to an accuracy of approximately 0.002". Planes with multiple damaged areas must have the scanning system transferred to each area to perform the inspection. This is a time-consuming process and frequently requires services to get the personnel and scanning equipment to the damaged area. Moreover, it is difficult to identify the damaged area in reference to the aircraft coordinate system or origin. An accurate location relative to planes origin will help engineers evaluate damage and make the process more efficient.

To increase the overall damage assessment efficiency and throughput a new laser scanning system is suggested. The new system would employ multiple (4 - 6) high-accuracy Hemispherical Laser Scanners. These scanners feature long-range capabilities and excellent accuracy of approximately 0.010". These scanners can be strategically located to quickly scan the entire airplane in less than one hour. Specialized software can quickly identify damaged areas or dents and relate them to the aircraft coordinate system. If the damage is within a certain threshold, Engineers can then decide if a more detailed and accurate laser scan should then be made by the higher accuracy portable scanners.

To offer this system, the three-dimensional scanners are currently available in the market. Additional work to create software to quickly interrogate the airplane must be developed. In addition, airlines must decide if the hemispherical scanners should be permanently mounted in a hanger, or would a mobile system that can elevate each scanner to measure harder to reach areas may be more practicable.

PROBLEM STATEMENT

Today's airlines need a robust system or service to assess damage to the airplane fuselage, wings and control surfaces. Damage typically occurs from bird strikes or other foreign interference. Significant damage can ground an airplane or significantly reduce performance.

BENEFITS

- System to easily detect aircraft damage.
- Offered as a product or service.
- More efficient and less downtime over existing technology.
- Resulting reports from scanning system will identify damage magnitude and location on the airplane to the origin.
- Scalable system.

TECHNOLOGY SOLUTION

- Work cell of 4 – 6 high accuracy Hemispherical Laser Scanners that can scan a typical airliner in approximately one hour.
- Automated software that can identify damage and access severity. Linked to aircraft origin.
- Option to inspect damage with a handheld scanner if more detail is required.

C-5M CARGO FLOOR MAPPER

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Aircraft maintenance personnel have no method to search or retrieve historic maintenance data by precise coordinates on a given aircraft. This capability limitation of the current Maintenance Data Collection (MDC) systems has resulted in countless instances in which maintainers are unable to determine whether a specific job has been previously evaluated, deemed within limits, or if it is new and requires further evaluation. This has led to significant rework of structural defects like dents, gouges, and punctures of aircraft structures.

The inclusion of a method to input, track, and query a defect's precise location in current MDC systems will provide maintainers with vital information and prepare them to make better informed decisions. When a maintainer enters a discrepancy against an aircraft, the MDC system should ask the user for technical data derived coordinates of the discrepancy. Once stored, this data can be searched for historic reference. Further, this data could be utilized to generate graphical maps and visual discrepancy diagrams.

To demonstrate this concept, the 436 MXG Continuous Process Improvement office conducted root-cause analysis and built an in-house database called the "C-5M Cargo Floor Mapper." The system stores and retrieves discrepancy data associated to tech data derived Cartesian Coordinates. Additionally, the database then renders a simple visual map of the cargo floor and assigns an appropriate symbol to each defect at their precise location. Arming maintenance personnel with a map, maintainers are empowered to make informed decisions about whether a discrepancy was previously evaluated, or is new. This demonstration project has been limited to the cargo floor on C-5Ms at Dover AFB, but in principal could be applied to the entire structure of any weapon system.

Analysis of FY'17 data for C-5Ms at Dover AFB suggests an estimated 5,000 man-hours was expended by the 436 MXS Aircraft Structural Maintenance section in potential rework, which accounted for nearly 23% of all dispatched jobs that year. These figures can be multiplied across DoD flying units.

Due to the scalability of this project to affect units across the DoD, we expect a rapid return on investment upon completion.

Additional benefits may include increased collaboration between maintenance personnel and engineers, and could even enable data intensive analysis methods such as "heat" mapping to show damage trends over time. To accomplish this, MDC system owners will need to allocate funding and requirements information to database engineers already employed to maintain MDC systems. These engineers can be tasked to implement the principals of operation demonstrated in Dover's Floor Mapper Database. The proposal does not require the purchase or development of equipment. The implementation structure for software development is already in place and robust.

PROBLEM STATEMENT

- Aircraft Structural Maintenance technicians from Dover AFB spend an estimated 5000 man-hours inspecting damage that has been previously deemed within limits on the C-5Ms.
- Up to 23% of the work performed by the shop has been closed out as potential examples of rework.
- Root cause analysis has determined that Maintenance Data Collection (MDC) Systems lacks the capability to track discrepancies by precise location.
- MDC is tracking What, Who, and When, but *not Where*.

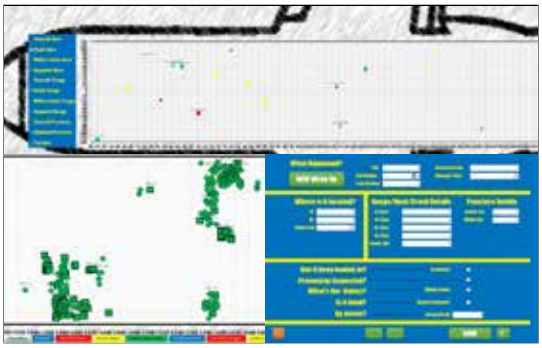
BENEFITS

- Mitigation or outright elimination of thousands of hours of rework.
- Less time spent documenting discrepancies that were already within limits.
- Data intensive analysis opportunities:
  - Enables in depth aircraft damage analysis via "heat" mapping and other visual tools
  - Enables historic analysis of damage
  - Creates opportunities for performing predictive maintenance by identifying potentially stressed structures that have undergone multiple repairs

TECHNOLOGY SOLUTION

Locally developed database (capability demonstration):

- Captures discrepancy information based on associated T.O. required measurements and associates them to physical location on aircraft.
- Capable of rendering physical map of different types and maintenance status of all current and historic discrepancies.
- Allows for easy reference by all maintainers.
- *Concepts portable for implementation to existing MDC platforms.*



718 AMXS THERMAL IMAGERY

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The United States Air Force needs trouble-shooting tools that are effective across specialties.

Some aircraft are very new, and some may have been worked on by our grandfathers. Maintenance of these airframes spans a broad variety of system types with different troubleshooting practices. Manning constraints are pushing cross utilization to of specialties more than ever before. Support of such an initiative is difficult without common tools across the specialties. The majority of the specialties deal with electronics, hydraulics, RF, liquids, and gasses. One thing all of these areas have in common is heat.

Thermal cameras are simple to use devices that can be applied to many maintenance trades. They display hot and cold spots with a simple point and shoot. A major advantage of a camera is that images can be stored for later use or sent to other subject matter experts.

The applications of thermal cameras are almost beyond counting. All of the below can be checked from a safe distance with a thermal camera without disconnection, removal, or item replacement.

Electricians
Shorted wiring will be noticeably warmer at the short.

Damaged or partial contacts will be warmer Properly operating components will be warmer then ambient.

Overloaded components will be hot.

Environmental Control
Coolant leaks will often be cooler then ambient Gas leaks will often be cooler then ambient (LOX, GOX, R-134A) Bleed air leaks may often be spotted when the leak sprays hot air A chilled gas source will lead a technician directly to an issue Reveal pressurization issues at a glance Plumbing leaks create cold spots in walls

Communications and RADAR
Higher power lines will be warmer then ambient after operation.

Broken or crushed lines will have a temperature change at the problem area Antenna water ingress – temperature difference at water line Amplifiers may be extremely hot from reflected power or cold from inoperability.

Hydraulics
The hottest part of any hydraulics system will be the pump and any rotary actuators. Properly functioning actuators should remain cooler than the pump.

Bypassing/internally leaking parts will be warmer then the components around them.

Non-functional regulators may be hotter, cooler than expected, or not change in temperature when commanded to change.

Constraints within the United States Air Force are pushing us to do more with less, but also to evolve and improve. Thermal imaging is a cheap and easy to use resource with a huge range of applications. It can be safely used anywhere electrical equipment is authorized and could cut hours from troubleshooting times. Skills for use of thermal cameras are easy to learn and transfer easily across airframes and trades. Thermal imaging technology could be a huge step forward in the evolution of aviation maintenance that has the potential to decrease cost, training time, and repair times.

PROBLEM STATEMENT

- Aging and new platforms have a large variety of failures due to faulty wiring, connectors and contacts.
- Many failures do not fall within troubleshooting trees or fault analysis guides. This results in long troubleshooting periods and unneeded wear on equipment due to good parts being replaced as part of the troubleshooting effort.
- Copper work hardens. It gets harder and more brittle as it is moved and bent. Wires and connections can be broken inside of an undamaged jacketing or connector.

BENEFITS

- Large areas can be scanned in a very short period of time.
- Data can be gathered without moving equipment or connections.
- Circuits and components can be evaluated without direct contact. Items do not need to be locked out and personnel do not have to work on energized circuitry
- Imagery can be sent to SME's back at the office, or across the world for further analysis.
- Very little training is required. The technology can also be used for analysis of other systems (pressurized gas, liquid, etc.)

TECHNOLOGY SOLUTION

- Thermal imagery can be an excellent way to gather status information on a large variety of systems.
- This technology can quickly pin-point a variety of causes of electrical and non-electrical problems. Open connections may be colder then others. Shallow contacts will be hotter then others. Shorted connections will often be hottest at the point of contact.
- Thermal imagery is not a new technology, but it has significantly decreased in cost over recent years.

INCIPIENT HEAT DAMAGE NDE IN AIRCRAFT INTERIORS

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Polymer Matrix Composites (PMCs), which today constitute the majority of the structural components of high-performance military aircraft, are prone to substantial loss of strength and flexibility from exposure to high heat fluxes from such contingencies as fire, engine exhaust gases, equipment overheats, solar radiation, and even routine operations. Such degradation can occur without exhibiting any evidence of discoloration, delamination, or other indications either visually or through traditional non-destructive evaluation (NDE) methods—a condition that is termed incipient heat damage. A commercial instrument, the 4100 ExoScan FTIR Spectrometer by Agilent Technologies, Inc., has been shown to be effective for NDE of incipient heat damage in a number of Epoxy-based PMCs. Operational employment of this instrument involves applying its sensor head against the surface to be evaluated, which must be flat or curved gently. It is not well-suited for use on sharply-curved surfaces or interior spaces having little clearance. (Massey & Boxell, 2017)

Under ONR MANTECH funding, we recently developed a laboratory surface-fluorescence apparatus and demonstrated its capability to assess incipient heat damage in Epoxy- and BMI-based PMCs (Merdes, 2017; Merdes, et. al. 2017). We propose to package that apparatus into a field-portable instrument for assessing incipient heat damage to composite components in interior spaces that would be inaccessible to the aforementioned FTIR instrument. Due to the nature of surface fluorometry, various sensor probes could be devised to interrogate spots of different sizes; we would develop two probes—one for dime-size spots, which would be suitable for large-scale damage assessment on major structural components; another for spots the size of eight-point type, suitable for use where clearance is tight. The diode laser currently used would be replaced by an inexpensive light-emitting diode (LED); the analysis algorithm would be refined, invested with a self-calibration capability, and packaged into an application that would run on a modern tablet or smartphone; the optical components would be packaged into a rugged, portable instrument that would be battery-powered and could be clipped to the maintainer's belt. The deliverable would be a field-portable prototype instrument configured for heat-damage assessment virtually anywhere in an aircraft's interior, applicable to aviation composite maintenance for all services.

Massey & Boxell 2017. "FTIR Heat Damage Assessment on V-22 Wing Skin", 2017 DoD Advanced Composite Maintainers TIM, Hill AFB, Utah, Aug 22, 2017.

Merdes 2017. 2017 DoD Advanced Composite Maintainers TIM, Hill AFB, Utah, Aug 22, 2017.

Merdes, et. al. 2017. "Laser Induced Fluorescence (LIF) Nondestructive Evaluation of Incipient Heat Damage in Polymer Matrix Composites, A2476", ARL Penn State Technical Report TR16-003, Feb 15, 2017, available at **doi.org/10.18113/S19883**.

PROBLEM STATEMENT

- Non-Destructive Evaluation (NDE) capability needed to assess incipient heat damage to polymer matrix composite (PMC)-based components of military aircraft.
- Current FTIR-based commercial instrument:
  - Works well on Epoxy-based PMCs.
  - Sensor head size limits employment to flat or gently-curved structures (wings, rudders, etc.).
  - Size inhibits employment in small-clearance interior spaces.

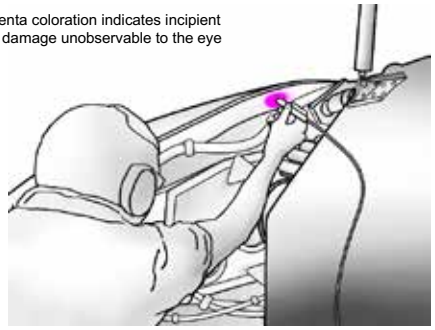
BENEFITS

- NDE of incipient heat damage practically anywhere within the aircraft.
- Probably adaptable to other uses, such as:
  - Assessment of curing of Epoxy, BMI, and other resins (e.g. for repair patches).
  - Assessment of adhesives and sealants.
  - Detection of chemical and biological contaminants.

TECHNOLOGY SOLUTION

- Fluorescence-based NDE shown to be effective on Epoxy- and BMI-based PMCs: https://doi.org/10.18113/S19883.
- A fluorescence-based field-portable instrument could be developed that:
  - Would be small, light, and inexpensive to manufacture.
  - Sensor probe would be on a cable attached to the instrument.
  - Different sensor probes could be designed for different structure geometries.

Magenta coloration indicates incipient heat damage unobservable to the eye



REDUCING FOOTPRINT FOR DEPLOYING THE DOD STANDARD AUTOMATIC WIRE TEST SET (AWTS)

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Recently acquired Automatic Wire Test Set (AWTS) are being deployed around the world in support of our military maintenance personnel. Weapon systems range in size and complexity of each respective Electrical Wiring Interconnect Systems (EWIS) and each need to maintained properly both domestic and abroad.

The AWTS equipment requires test adapter cables and test program software in order to connect up to individual weapon systems. Since the test program sets can be organically supported, each depot and activity designs and build their own adapters. This method of interface design is not standardized. The goal of this effort is to streamline the footprint of deploying this valuable equipment to field activities and to set standards that meet the requirements of true field use.

PROBLEM STATEMENT

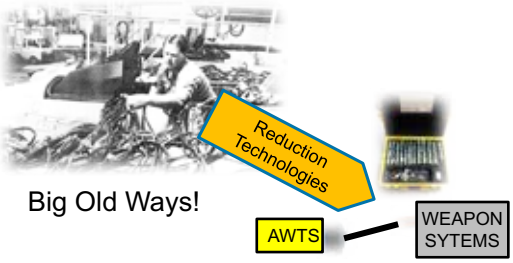
Over 450 electrical test sets were deployed across the globe to assist DoD maintenance in troubleshooting weapon system issues. Under an initial deployment approach, organic support has caused many variants and configurations of Test Adaptation to exist. Little configuration control exists and interoperability amongst the military is less likely. In addition, remedial methods historically applied has resulted in long and large interface cables that increase footprint. This in turn has limited AWTS capability to forward deployed locations.

BENEFITS

- Ability to “inspect” wiring and electrical power components statically and actively while fielded without the need for weapon system power.
- Troubleshoot electrical “gremlin” faults that include NFF/CND.
- Locate the root cause of faults; not just symptomatic faults instigated by the root cause failure.
- Improve mission readiness.
- Greatly reduce avionics requirements while deployed.
- Reduce swaptronics.
- Reduce troubleshooting time by 80%.

TECHNOLOGY SOLUTION

New technology interface devices and components exist to aid in reduction of the AWTS footprint and allow the capability to be deployed to forward operating bases. The Original Equipment Manufacturer (OEM) will participate to assist in overall size and weight.



CBATS REHOST FOR THE F-16 SAU

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EMXG's support team recently completed a rehost of F-16 Signal Acquisition Unit (SAU) to the CBATS/DXR Test station. The CBATS (Common Benchtop Automated Test System) is a member of the Department of Defense "Family of Testers" that was developed as a common platform to replace unique, single end item testers with newer, supportable technology. The CBATS has replaced many such testers, including the two legacy testers for the SAU which had become obsolete and unsupportable.

Many Air Force legacy testers contain very old technology. This tends to make it difficult for such testers to attain the accuracy and definition that newer technology can afford. Often, rehost from old technology legacy testers result in marked improvement in measurable metrics for end items repaired and calibrated. While the obvious results of improved supportability for AF asset test equipment are achieved, often a significant improvement in these metrics occurs as well. This was markedly so with the rehost of the SAU.

Shop through-put for repair/calibration of the SAU increased due to additional test capabilities. As the result of the improved accuracy of the test equipment, the Mean Time Between Failures for the SAU increased from 978 hours in 2016 to 2278 hours today (133% increase) effectively giving the Air Force more than double the amount of flight time from the previous test setup. Backlog for repair of the SAU asset dropped from 9 high priority back orders in 2016 to only 4 today. Mission Incapable Hours (hours where not having the end item available resulted in negative impact to a mission) dropped from 243 hours in 2016 to 39 hours today. Additionally, the number of days an SAU spends in the repair shops dropped from 54 days in 2016 to 37 days and the organic repair shop now out produces the contractor 20:1.

PROBLEM STATEMENT

- F-16 Signal Acquisition Unit (SAU) was tested on two legacy "Slumberger J" test stands that were 30+ years old.
- Test stands were unreliable and becoming unsupportable due to age and obsolescence issues.
- Age of technology in legacy testers reduced accuracy of calibrations of assets.

BENEFITS

Improved metrics for the SAU:
- Shop through-put increased due to additional test capabilities
- Mean Time Between Failures increased from 978 hours in 2016 to 2278 hours today (133% increase)
- Backorders went from 9 priority in 2016 to 4 today.
- Mission Incapable Hours went from 243 hours in 2016 to 39 hours today.
- Shop flow days went from 54 in 2016 to 37 today
- Organic repair shop now out produces contractor 20:1

Reduction of test equipment footprint by elimination of old legacy tester

TECHNOLOGY SOLUTION

Rehost of end items to a common tester
- Common Benchtop Automated Test Stand (CBATS)
  - DoD Standard Family of Testers
  - Newer technology
  - Standard suite of instrumentation
  - Adaptable to multiple applications
  - More accurate
  - More efficient testing solution
  - Automated to reduce test times

KC-135 VHF DATA LINK (VDL) RAMP TESTER

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KC-135 aircraft are re-flown to test data link communications due to the absence of a local system capable of broadcasting a very high frequency (VHF) communication signal. In FY18, 12 aircraft required re-flight due to data link repairs, with each requiring an average of two (2) re-flights. Due to the inability to test the communication system while grounded at Tinker AFB, avionics mechanics would sometimes unnecessarily replace all the communication components within the system. In effort to try and reduce the number of flights for solely a data link communication test, market research was performed. Research led to a data communications company, Airtel being the only provider with a portable data link tester that was small enough for avionics mechanics to use while aboard the aircraft. The small portable system eliminates the need for a large infrastructure Air Traffic Control (ATC) center.

The engineering branch of the 76 Aircraft Maintenance Group (AMXG) procured the system in an effort to save cost of re-flying aircraft. Procurement of the Airtel Data Link Ramp Tester (MTP-100), allows avionics to use the system to simulate a ground station to test the aircraft VHF Data Link (VDL) communication. In-turn, the avionics mechanics are able to troubleshoot and pinpoint components or issues within the aircraft communication system to avoid a full system replacement. Each flight equates to $63,865, which includes preflight and recovery, fuel, and pilot / administration pay. Based on the flight cost, for FY18, 12 aircraft could have potentially saved the Air Force an estimated $1,532,760 if the MTP-100 was available for use. Since receiving the MTP-100, mechanics have used the unit on five aircraft preventing 10 flights and totaling $638,650 over a two-month period. The MTP-100 has already paid for itself and is continuously saving the Air Force money. Based on the initial first two months and each KC-135 aircraft averaging two communication simulations, the projected FY19 savings will be in the area of $3,831,900.

PROBLEM STATEMENT

KC-135s are re-flown to test data link communications due to the absence of a local system capable of broadcasting a very high frequency communication signal. In FY18, 12 aircraft required re-flight due to datalink repairs, with each requiring an average of two (2) re-flights. Due to the inability to test the communication, avionics occasionally replaces the entire communication system.

BENEFITS

- Reduction of FCFs leading to major cost-savings
  - Preflight and recovery
  - Fuel
  - Pilot and Administration Pay
- With each flight costing $63,865
  - Potential cost savings of $1,532,760 for FY18.
- Since receiving the unit, five (5) flights have been saved totaling $638,650 in a matter of 2 months.
  - Continued cost savings of $3,831,900 for FY19.

TECHNOLOGY SOLUTION

- The Airtel Portable Data Link Ramp Tester (MTP-100) simulates a ground station to test the aircraft VDL communication.
- Troubleshooting/pin-pointing issues within the communication system to avoid full system replacement.

INTEGRATED INSPECTION AND REPAIR PREPARATION (IIRP)

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Integrated Inspection and Repair Preparation (IIRP) Components Removed from Aircraft Abstract This is a proposed path to reduce sustainment cost by increasing the availability and reliability of critical structures through replacement of artisan dependent inspection and repair operations with computer-based technology for a wide range of components. Those components can include Control Tabs, Outboard and Inboard Aileron Tabs, Rudder Control Tabs, plus Leading and Trailing Edges, Rudders, and Nose, Tail and Blister Domes, Engine Nacelles and Nacelle Thrust Link Fairings, and possibly others.

The current manual practices often include less-than-optimum inspection methods, manual scarfing to remove the defect, and manual patch preparation, all contributing elements of inaccuracy, waste and lengthy, disjointed processes. Due to the nature of these operations, accurate and reliable digital records of repairs on components are not available. With the proposed automated\ integrated techniques, a digital record for inspection and repairs will be available.

The GFM organization plus the Northrop Grumman Innovation Systems - Aerospace Structures Division are teaming to identify and demonstrate a suite of integrated technologies to achieve this goal. Similar requirements of certain aircraft components that are removed from an aircraft, including engine nacelles and radomes, have previously been successfully addressed by GFM in organized projects employing the similar strategy as stated above.

Those applications include very accurate CNC scanning techniques to establish an accurate digital model database tied to the reference coordinate system for the structure being evaluated.

Various NDI technologies, in some combination, have been employed to identify suspect areas, plus accurate size and depth of defect. This has included multiple layer composites sandwich structures, which present serious challenges to obtain accurate NDI data beyond the depth of the first sandwich layer. However, after a focused search, our group identified and implemented a technology, which provided very accurate data through both first and second sandwich layers.

This data is then overlaid onto the surface of the component via laser projection techniques for visual identification of the defect areas. The resulting fully integrated cell will employ CNC technology to automatically scarf the defect areas, plus ultrasonically cut the appropriately shaped repair patch materials, and guide the repair technician in the most efficient repair process.

GFM has also conducted demonstrations in which measurements were attained to determine incipient heat damage utilizing FTIR Spectroscopy NDI technology, not possible with other NDI technologies, but very important for heat damage assessment.. This was implemented in the same CNC machine tool that subsequently performed the scarfing.

The Northrop Grumman organization brings to the table the background of having developed and produced NDI systems.

PROBLEM STATEMENT

- Automate repair processes for aircraft components.
- Current creation of repair part programs, with partial CAD data not inclusive of all data in same coordinate system.
- Current manual production of repair plies.

BENEFITS

WAY FORWARD:
Investigate processes for handling and lay-up of repair plies with proper fiber orientation

Benefits:
- Controlled automated repair process
- Fast semi-automated process for high volume of similar or dissimilar parts, and controlled processes for low volume parts.
- High precision repair with minimal waste of material, based upon similar criteria for current manufacturing production
- Digital record of inspection and repair data, thus providing history of component availability going forward.

TECHNOLOGY SOLUTION

- Scanning components to acquire accurate digital shape data and digital NDI defect data.
- Macro driven automatic machining part program generation, based on acquired digital shape data and digital NDI data.
- Automatic creation of cutting programs for repair plies, based upon acquired digital data.
- Technologies available and in use in aircraft manufacturing and inspection of produced components.
- Software tools and macros available.
- Successfully performed trials.

Inspection, repair preparation and scarfing integrated on the same machine with automated process.

PERMANENTLY LOCKING FASTENERS THAT ARE REVERSIBLE AND REUSABLE

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Permanently locking fasteners that deform the threads are often used in critical applications where loosening of the fasteners is unacceptable. The problem, however, is that for maintenance these fasteners must be drilled out or cut off for removal, and they require specialized tools for installation or removal. Fasteners relying on nylon inserts do not have a consistent preload (clamping force) for a given degree of torque, and they cannot be used in high temperature applications. Fasteners employing mating washers rely on friction or deformation of the substrate by the washer, so if there is any loss of preload, the fasteners will loosen. Mechanically locking fasteners employing safety wire or castellated nuts with Cotter pins are labor intensive for installation and removal.

A new currently available technology is a fastener that permanently locks; yet it is reversible and reusable. When a standard 6-point socket is applied to the nut, the nut is free spinning, so an accurate preload can be applied. When the socket is removed, it permanently locks. The locking mechanism incorporates engagement of teeth, so it does not rely on friction. The threads are not deformed, so it can also be used repeatedly.

The requirement for a self-locking nut in aerospace (NASM 1312-7) is to withstand 30,000 cycles of vibration. These fasteners survived 300,000 cycles. Following vibration testing the fatigued parts underwent tensile testing, where they proved to be Type I bolts and Class II nuts. They have been tested for reuse up to 250 times. Preload accuracy for a given degree of torque is approximately 5.7%, which is comparable to fasteners that deform the thread.

A primary benefit of the technology is that it saves time and money in installation and maintenance. No specialized tools are required, as only a standard 6-point socket is utilized. As the fastener permanently locks (through teeth engagement), less maintenance checks are required to ensure that the fastener remains tightly engaged. The fastener does not rely on friction or thread deformation for its locking feature, so it can be removed and reapplied numerous times. The teeth of the fastener are not engaged during installation or removal, so there is minimal wear of the teeth over time. As the nut is free-spinning with socket engagement, an accurate preload can be applied. This is essential when clamping composites. All components of the fastener are manufactured out of metal, so they are also ideal in high temperature applications.

The fastener technology is currently available in both a locking nut - washer - bolt combination and in a locking threaded bolt. It can be provided in numerous materials such as Stainless A-286, Inconel 718, and Titanium in sizes from ¼" and greater.

PROBLEM STATEMENT

- Permanently locking fasteners that deform the threads are often used in critical applications, where loosening of the fasteners is unacceptable.
- for maintenance, these fasteners must be drilled out or cut off for removal, and they require specialized tools for installation or removal.
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- Fasteners employing mating washers rely on friction or deformation of the substrate by the washer, so if there is any loss of preload, the fasteners will loosen.
- Mechanically locking fasteners employing safety wire and castellated nuts with Cotter pins are labor intensive for installation and removal.

BENEFITS

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TECHNOLOGY SOLUTION

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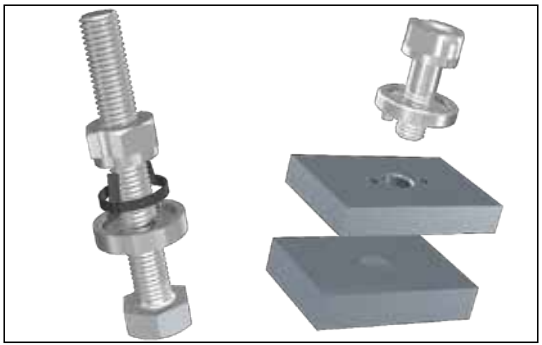

TANK AND BILGE PUMP IMPROVEMENT

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The United States Navy Ship Repair Facility-Japan Regional Maintenance Center at the Fleet Activities Yokosuka and a Detachment at Fleet Activity Sasebo, Japan supports and maintains 21 forward deployed Navy ships. In concert with our host nation, SRF-JRMC employs approximately 2500 Japanese Nationals that form compose the touch depot maintenance labor. Their work efforts are in partnership with the civil service and US Navy military personnel working in a fast-paced maintenance environment. This pace leaves little time to do rework or use tooling that increases down time and decreases productivity.

It is with that mindset, and the Japanese workforce can do spirit called "Nan Demo Dakimasu" or "We can do anything", that lifted them to find solutions to cut the number of tank and bilge pump repairs and reduce the time to pump out tanks and bilges. Over several years, the number of pump repairs continually rose causing the X99 shop to do numerous repairs of pump vacuums. In researching the root cause, the team found that debris or foreign object damage was the main culprit. Further, review showed that while the pumps were in use the vacuum pressure would steadily decrease causing a decrease in water vacating from the tank or bilge. Workers would remove the hose and check the in line strainer to remove the debris, however, this would be repeatedly stopped to remove debris during the pumping of the tank and/or bilge causing an increase in the time to complete the job.

X99 artisans decided to find a solution that would improve the pumping systems operations, decrease work stops, and decrease pump failures. The artisans developed a larger strainer, similar to those on shop vacuums, to catch both, large and small, debris that would still allow the water to flow freely with no reduction in suction capability.

This simple but effective solution provides a 1033 man-hour savings of over the span of less than two years – or an 18.3% savings in labor hours in tank and bilge pumping. Additionally, this ensures tank and bilge pump availability when and where needed to meet ship repair/maintenance schedules with no delays.

Lastly, the reduced hours a worker spends fixing pump problems during a pump out of tanks and bilges equates to a decrease in risk with adverse environmental conditions such as cold, heat, and gasses; making the on the job experience better for the workers.

PROBLEM STATEMENT

Vacuum pumps used for cleaning bilges and tanks can get damaged by the intake of very small pieces of trash like bolts or tie-wraps or foreign object damage. A strainer is fastened at the end of the intake hose, but as trash is picked up during work the intake hose becomes clogged and useless. Workers then need to remove the strainer, clean the area of debris prior to resuming work.

This is time consuming and decreases work efficiency. Additionally, Ship force and other shops encounter the same problem when using loaner pumps, and the pumps are often returned damaged by the debris ingested after the removal of the strainer.

BENEFITS

Man Hour (MH) Reductions:
Reduced MH by 18% of total working hours by improving bilge and tank cleaning process in a stressful working environment.
1,033.2 MH savings / in less than 2 years
- Tank Cleaning: 791.7 (MH)
- Bilge Cleaning: 241.5 (MH)

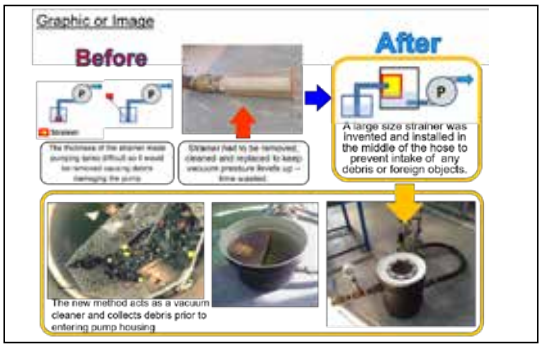
Heat Stress Exposure Reductions:
Reduced time exposure to heat stress environment by 18% and increase safety and efficiency of work.

Reductions in the number of Pump Repair:
Reduced number of pump repair caused by foreign object damage by 100%.

TECHNOLOGY SOLUTION

Final Root Causes	Possible Solutions	Final Solution
Poor filter design	Re-design of filter	X99 team developed a new strainer. By sucking in like a vacuum cleaner, and by setting up a device to sort wastewater and garbage in front of the vacuum pump.
Poor position of filter attachment	Reconsider attachment portion of filter	

Because *Why* *Because* *Why*



SHAPE FABRICATED HUBLESS ONE PIECE ROTOR FOR O&M

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Problem: Marine and Hydrokinetic (MHK) energy is not currently cost-competitive in most resources. A leading design for tidal, river, or ocean-derived water current energy capture is the horizontal axis-flow turbine. For this branch of MHK, the turbine rotor (blades plus hub) is the energy capture element, and its hydrodynamic and structural design is critical to conversion performance. Improving the economic viability of the MHK technology requires driving down both capital and operational costs. The rotor is one of the major cost drivers for the turbine capital expense (CAPEX), and is also a significant contributor to the operating expense (OPEX) of practical arrays of turbines.

Technology: The proposed maintenance-focused project will pursue major advancements in rotor design and fabrication for MHK turbines, and could benefit similar structures (e.g. propeller blades). The research team proposes to build upon the successful development of a net shape fabricated three blade composite One Piece Rotor (OPR) with TRL and MRL of six. The legacy OPR structural robustness was demonstrated by conducting a ¼-scale prototype OPR ten-million cycle fatigue test using operational loads derived from state-of-the-art computational fluid dynamic steady-state and transient analyses. The prototype OPR showed no signs of visible damage or measured degradation after fatigue testing. Although the first-of-its-kind legacy composite OPR was successful both in technical and economic terms, additional innovative modifications can further reduce OPEX and CAPEX.

Next Step: The next step in the evolution of the OPR for the 5 meter diameter MHK rotor, and scale-up to 10 meters and greater, is to advance the OPR to a truly "Hubless" rotor, with no separate rotor parts that require expensive castings of corrosion-resistant metals or fasteners. Operational benefits resulting from the associated and significant weight and parts count reductions include elimination of fasteners, including their inspections and replacements, handling costs, and wear on the main shaft bearings. Unlike the legacy composite OPR design, which required a substantial hub made up of two cast metal clamping parts that connected the composite rotor to the main shaft, the design to be advanced under the proposed project eliminates the hub. Instead, the only metal part will be a cast-in-place tapered sleeve by which the composite interfaces with the tapered shaft. All fasteners and changeable interfaces within the hub will be eliminated.

Transition: The technology development from this project has the potential to accelerate MHK device and system implementation in two ways. First, cost of energy reductions can be realized through capital and maintenance operations cost reductions. Secondly, improved durability and life expectancy of the OPR engenders an improved risk profile and thus affords developers the ability to be insured and financed. The successful implementation of this Hubless MHK turbine rotor technology can enable CAPEX and OPEX reductions of 30% and 75% respectively. Finally, it is envisioned that the transition of this emergent net shape fabrication technology to minimize number of fasteners and provide significant weight and part count reductions may be viable for multiple DoD applications.

PROBLEM STATEMENT

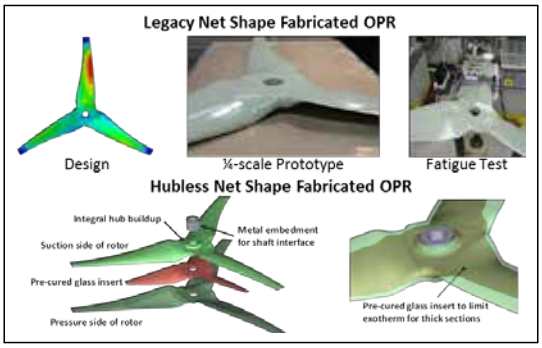
- Marine and Hydrokinetic (MHK) energy is not currently cost competitive in most resources.
- Axial-flow horizontal turbines are a leading type of MHK device.
- The turbine rotor is the critical energy capture element but is a major cost driver for turbine capital expense (CAPEX) and is a significant contributor to operating expense (OPEX).
- Key to improving economic viability of MHK technology is driving down capital and operational expenses.
- The Verdant Power turbine uses a fixed-pitch rotor, which lends itself to the proposed advance.

BENEFITS

- Net shape fabricated low-cost single piece Hubless OPR requires no secondary machining
- Implements state-of-the-art threshold fatigue protocol to preclude composite degradation over operational life
- Significant weight and parts count reductions, complete elimination of two-piece metallic hub and all fasteners
- Hubless MHK turbine rotor technology can enable CAPEX and OPEX reductions up to 30% and 75% respectively
- Transition of this emergent net shape fabrication technology to minimize fasteners and to reduce weight and part count may be a viable solution for multiple DoD applications.

TECHNOLOGY SOLUTION

- Maintenance-focused project will advance MHK composite rotor design and fabrication technology for MHK energy turbines and similar structures including propellers.
- Proposed project builds on the successful development of a net shape fabricated three blade composite One Piece Rotor (OPR).
- Implements a Hubless rotor with operational benefits from significant weight and parts count reductions, elimination of fasteners and elimination of a two-piece metal hub.
- Only metal part is a cast-in-place tapered sleeve that interfaces with the turbine's tapered shaft.



SUSTAINABLE AND JUST-IN-TIME MACHINING WITH OMAX VERSATILE JETMACHINING CENTERS

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Today's maintenance facilities encounter many challenges such as material diversity and a wide range of part size and thickness that often require multiple machine tools operating by different technicians with special training and expertise. Ideally, modern maintenance facilities should have a single machine tool capable of machining 2D/3D parts made from most materials, with a wide range of part size and thickness from macro to micro scales. Such a tool should preserve the structural and chemical integrity of parent materials without inducing heat damage and surface hardening. It should also be environmentally friendly, minimizing hazardous byproducts, and should work seamlessly with current design software and existing machine tools to maximize productivity.

The OMAX JetMachining® Centers® (JMCs) address all of these concerns. The core abrasive waterjet (AWJ) technology allows for a single machine to cut virtually any material, from metals to nonmetals (composites, laminates glass, and ceramic) and from thin sheets to thick blanks. Advances in cutting head technology allows for 6-axis cutting, and the cold cutting process facilitates weld-ready bevels to be cut without the need for time consuming and costly grinding to remove the heat-affected zone (HAZ). The four product lines of OMAX, MAXIEM, GlobalMAX, and ProtoMAX are available for machining from macro to meso scales for various position accuracies. A mobile skid-mounted JMC that features all the necessary equipment was proven for in-theater emergency repair **(sme.org/MEMagazine/Article.aspx?id=78461**). It just needs water and abrasives (recyclable) and power to machine armor and prosthetic components made of various materials anywhere in the world.

The MicroMAX, a Finalist of the 2016 R&D 100 Awards **(sbir.gov/node/1308555**), has a position accuracy within +/-0.0006" for precision meso-micro machining. The fully-enclosed MicroMAX, is compatible for certain classes of cleanroom operations. With the MicroMAX added to the product lineup, OMAX has established an unparalleled capability of precision multi-mode machining of most materials from macro to micro scales ("7M" advantage) for a wide range of part dimensions. The worldwide market demand for the MicroMAX has greatly exceeded our expectation.

Common across all OMAX systems is the latest waterjet controller software. Extensive research coupled with real-world testing has resulted in a system capable of cutting faster while using less resource than any other system. The 4th Generation cutting model in OMAX software advances waterjet 2D and 3D machining to new levels, opening up greater potential for cost reduction and fast turnaround.

DoD maintenance facilities equipped with OMAX JMCs would meet most needs to achieve sustainable manufacturing and just-in-time practice, minimizing the need for laser and plasma cutters and complement CNC precision milling. For heat-sensitive materials, AWJ cuts over ten times faster than solid-state lasers and EDM as these tools must pulse at high frequencies and cut with multiple passes, respectively, to minimize the HAZ. Also hardened steel with high RC values that wears out CNC tools rapidly presents no difficulty to AWJ. For extremely precision parts, AWJ has served as a near-net shaping tool to further shorten turnaround while extending the lives of expensive precision tools.

PROBLEM STATEMENT

- Today's maintenance facility encounters many challenges such as material diversity and wide range of part dimensions:
  - Multiple machine tools supported by different operators with high levels of training and expertise are required.
  - Finishing a complex part requires multiple part transfers.
- Ideally, a DoD modern maintenance facility should establish a high degree of diversity with:
  - Specialized single tools qualified for multimode machining.
  - Automated machining processes maximizing productivity and preserving structural integrity of parent materials.
  - Versatile machine tools that are cost effectiveness with fast turn-around and environmentally safe.
  - Mobile and deployable in battlefields and remote areas.
- Versatile waterjet with unmatched technological and manufacturing merits meets the above challenges.

BENEFITS

- AWJ possesses merits unmatched by most machine tools.
  - Material independent - preserving material properties.
- Cut reflective and thick materials (not for lasers) and nonconductive materials (not for EDM).
- No heat-induced damage (warping, slag, and burnt thin webs) as induced by CO2 laser and plasma cutting.
- Cut 10+ times faster than solid-state lasers (pulsed) and EDM (multi-passes) for heat-sensitive materials:
  - Flexures for microsplines of asteroid gripper (JPL/NASA), and nonlinear load cells with 5 orders of magnitude of force range (MIT patented).
- A single tool qualified for 2D/3D macro-to-micro machining.
- No hazardous byproducts (unlike chemical etching).
- An invaluable tool for integration into DoD maintenance facilities for just-in-time and lean manufacturing practice.

TECHNOLOGY SOLUTION

- OMAX JetMachining® Centers® (JMCs) offer optimum solutions
  - One machine to cut virtually any material from metal, nonmetal, composites, and anything in between
  - Multi-axis accessories allow for 6-axis cutting
  - Cold cutting of weld-ready bevels with no heat-affected zone (HAZ), mitigating time consuming grinding process
  - JMCs for 3D machining from macro to micro scales
  - Award-winning MicroMAX for meso-micro machining
  - Mobile system successfully deployed by US Marine Corps
  - Gen 4 cutting model advancing performance to new levels
  - One operator to control Multiple OMAX machines
- "7M" advantage – Multi-Mode Machining of Most Materials from Macro to Micro scales for various sizes and thicknesses
- Minimize need for laser, plasma, and EDM and complement CNC mills by producing near-net shaped parts

DIRECT MEASUREMENT OF TEMPERATURE IN BONDLINE AND LAMINATE DURING REPAIR

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Problem statement
The present method for repair and maintenance requires a thermal survey using thermocouples within and external to the bondline or structure followed by a cure with only external thermocouples.

The proposed technology uses sensors that are smaller than acceptable critical flaw size for most applications and do not require lead wires to the sensing location.

Description of technology
The technology relies on the Barkhausen effect. (This effect is a well-known electro-magnetic phenomenon. Details are readily accessible on the internet.) The intensity of this effect varies with temperature and material formulation. Three small wires of selected Curie temperature (the point which the wires no longer exhibit the Barkhausen effect) are inside a tube ten thousandth (.010) inch in diameter and approximately one inch in length. This tube and inserted wires constitute the sensor. Each wire in the sensor has a different function. The reference wire (R) has a high Curie temperature that does not significantly change over a normal cure cycle. The measure wire (M) has a Curie temperature slightly above the maximum cure cycle temperature and signal intensity is compared to the reference wire to determine temperature change. The calibration wire (C) has a Curie temperature below the critical cure temperature and is used to auto calibrate the sensor during cure.

Current development status of the technology
The sensors are being used in R&D. A phase II SBIR project with the Air Force is underway to develop a commercial product.

Test data or simulation support for performance claims
AvPro has completed multiple tests on composite hardware. The data clearly demonstrates the technology is ready where specifications allow. Two hundred each of 250F and 350F sensors have been produced by hand and prototype production of machine-built sensors is complete.

Next steps/potential benefits
A collaborative effort is needed to address the multiple issues for deployment. These issues such as methods, procedures, are not related to the basic technology but are essential for deployment and cannot be answered by a small company working in isolation.

Multiple benefits accrue with every cure cycle done on behalf of the DoD in both production and repair. Direct measurement within the bondline or part eliminates the need and cost of the thermal survey and shortens the time a weapon system is out of service. Reducing or eliminating thermo-couple leads reduces potential bag leaks and time sealing around the lead. Present processes are sub optimal because they must compensate for differences between to the heat transfer measurement cycle and the actual cure. A cost benefit analysis will need to be conducted once procedures and methods are established. However, it is intuitively clear that less time to complete the repair with higher confidence in the actual temperature at critical locations will equate to cost savings and improved availability to the war fighter.

PROBLEM STATEMENT

- Thermocouples require wire leads that compromise part integrity and therefore are not allowed in part or bondline.
- Temperatures must be assigned using estimates from heat transfer evaluation prior to final cure.
- Present processes are sub optimal because they must compensate for uncertainty that the thermal survey is precise.
- The heat transfer evaluation doubles the time needed for repair.
- Placement of multiple thermocouples around the repair increases probability of bag failure and further extends the time the weapons system is out of service.

BENEFITS

- Direct measurement within the bondline or part eliminates the need and cost of the thermal survey and associated costs.
- Eliminating or reducing heat transfer measurements shortens the time a weapon system is out of service.
- Reducing or eliminating thermocouple leads reduces potential bag leaks and the time spent sealing around the lead.
- Sensor placement directly in the critical load zones improves confidence the part is properly cured.

TECHNOLOGY SOLUTION

- Temperature sensors have been developed that do not require leads and are below critical flaw size for most parts and repairs.
- Temperatures are read using a magnetic field from an antenna outside the vacuum bag.
- The sensors are auto calibrating using Curie temperature, a material property of the sensors traceable to NIST.
- The task occurs at the level of the repair technician so is, therefore, less demanding than current methods.

Sensor

FLIGHTLINE ARMAMENT TEST: THE NEW NEW

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A warfighting armament test gap exists today across many legacy 4th and 5th generation aircraft due to the inability of current O-level armament test equipment to functionally test MIL-STD-1760 based smart weapon systems. The current USAF handheld O-Level test sets (known as "beercans" because of their cylindrical shape) can test continuity of the 1760 bus, but much larger test sets are required to test the full functionality of the bus interface. The beercans were developed for previous generations of aircraft and armament, and are now outdated and inadequate for ensuring full mission readiness.

This armament test gap creates two major issues for armed aircraft sustainment:

1. Readiness uncertainty – while the testing of the aircraft with a beercan usually results in an FMC aircraft, the reality is far from that due to the inability of the beercans to detect armament system digital faults.
2. Costly maintenance – the inability of the beercans to fully test the aircraft necessitates the use of additional O-Level testers. Additionally, there is no commonality as each aircraft has its own beercan and larger O-Level testers, significantly increasing the footprint and cost of sustainment.

Many DOD programs address obsolescence by replacing the legacy item with a new similar item, creating a "new old" solution that addresses the obsolescence, but otherwise provides few or no improvements. Realizing that current handheld O-Level armament test sets lack comprehensive test capabilities, MTS developed a "NEW" new - a handheld, battery-powered test solution that supports all armament systems on all aircraft: the SmartCan™.

The MTS-3060 SmartCan provides maintainers with an affordable, innovative, easy-to-use test solution for today's aircraft regardless of the armament systems they employ, delivering true FMC aircraft to the warfighter. Initially deployed in 2011, the SmartCan is capable of supporting all legacy and "smart" armament systems on all current and future fighters, bombers, attack helicopters, and UAS across the DOD. The handheld SmartCan weighs under 4 lbs., yet it packs over 30 measurement channels, electronic loads, multiple communications interfaces (MIL-STD-1553, MMSI, Ethernet, CAN Bus, RS-485), video and audio signal generators, and innovative test language that further reduces development and integration costs.

Today, the SmartCan is deployed worldwide with FMS customers on F-15, F-16, TA-50, FA-50, Hawk, F-5, UAS, and F-18 (in 2019) with support for A-10, F-22, and F-35 already available. One customer replaced six flightline test sets used on F-16 and F-15 with the SmartCan, significantly reducing their logistics footprint and benefiting from consistent and common training for all aircraft armament specialists.

The SmartCan's ability to provide commonality and interoperability across the DOD improves the MXConOps by simplifying logistics and significantly reducing the cost of acquisition, test, maintenance and sustainment.

PROBLEM STATEMENT

- Currently deployed handheld O-Level armament test sets are not capable of conducting digital functional testing and troubleshooting of today's 4th and 5th generation aircraft equipped with "smart" weapon technology (MIL-STD-1760).
- Every aircraft utilizes multiple O-Level test sets, creating a large flightline footprint, high operating costs, and high sustainment costs. The test sets are unique to the aircraft – no commonality exists even though the weapons used on these aircraft are often the same.
  - e.g., F-16/F-15/F-22/A-10 USAF maintainers currently sustain 10 different armament test sets

BENEFITS

- Full parametric functional test of all armament systems on any aircraft; also includes troubleshooting capabilities
- Common test solution that is applicable to all manned and unmanned fixed and rotary aircraft and weapons systems
- Eliminates the need for two O-Level test sets used in the current MXConOps – one test solution does it all
- Simplified operation and small flightline footprint makes test easy, thorough, and quick for the warfighter
- Simplified logistics – 4-year calibration cycle using Portable Automatic Test Equipment Calibrator (PATEC) equipment
- Data logging of all test runs for trend analysis, improved troubleshooting, and training

TECHNOLOGY SOLUTION

- The MTS-3060 SmartCan™ delivers tomorrow's test solution today, combining the capabilities of larger test sets in an innovative, handheld, AA battery powered test set that combines performance and ease-of-use with a very small flightline footprint at a cost-effective price.
- The SmartCan provides capabilities including:
  - Enhanced cybersecurity & removable SD storage
  - MIL-STD-1553, MMSI, Ethernet, CAN, RS-485
  - More than 30 measurement channels
  - Audio, Video, e-loads, cable ID, and more

MOBILE MAINTENANCE DOCUMENTATION APPLICATION

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Mobile Maintenance Documentation Application resolves a growing challenge for logisticians to interface rapidly evolving modern technology with legacy Information Technology (IT) systems. Aircraft maintainers from across Air Force's "Log Nation" aligned with Apple at their Headquarters in Cupertino, CA to brainstorm, design, and develop a mobile application to securely interface with their aircraft maintenance mission information system (MIS), and navigate the cyberspace complexities of its integration with its legacy systems.

The result: a secure mobile application that enables aircraft maintainers to capture flight line documentation at the point-of-maintenance, rather than hand-scribing forms, which were previously transcribed onto aircraft maintenance systems of record. The Airmen's knowledge and insight of the maintenance requirements and processes in conjunction with the Apple "Think Differently" method produced a user new experience that is fundamentally transforming and modernizing how Air Force maintenance is done. This effort is also blazing the path to mobile application development for the Air Force.

PROBLEM STATEMENT

Rudimentary flight line inputs for aircraft maintenance are often documented by archaic paper and pen, thus breeding the following problems:

- Human entry errors
- Degraded time management – Airmen must transcribe pen and paper notes then transfer captured data to a mission information system (MIS) terminal which effectively causes a duplicative process
- AF maintenance efficiency and costs are markedly abridged

BENEFITS

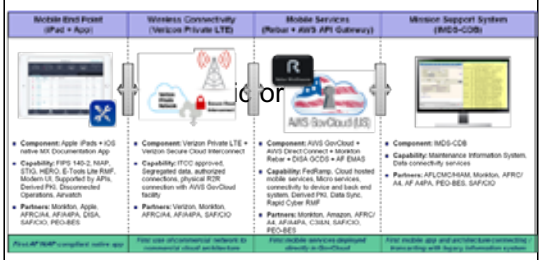
The mobile solution will:

- Deliver Log Nation's first mobile solution to directly transact with a legacy mission information system (specifically - Integrated Maintenance Data System)
- Increase touch-time with the aircraft, as maintainers electronically document and view work orders on the flight line
- Increase data accuracy; reduce data-entry errors
- Enable Big Data to Inform Analytics
- Increase Mission Readiness

TECHNOLOGY SOLUTION

- MMD App is a secure, mobile solution for aircraft maintainers that navigates DoD's complex cyber defense parameters, through the common computing environment, enabling transaction with its legacy system
- MMD is loaded onto a lightweight, portable tablet, and enabled by Air Force enterprise mobile management services

MMD Graphic



FLIGHT LINE MAINTENANCE SMARTPHONE APP

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Army maintainers may not have the best available troubleshooting information at their fingertips. Evidence shows that Army maintainers have been improvising to get valuable troubleshooting information needed to meet the demands of high flight hours and frequent maintenance activity.

In the two-level maintenance environment, the Apache Interactive Electronic Technical Manual (IETM) and the flight line tool kits are used to troubleshoot to the line replaceable unit (LRU). What does the maintainer do if they have followed the steps in the IETM and the problem still exists? Typically, they reach out to their local Field Service Representative (FSR) or peers hoping they have experienced a similar troubleshooting issue with resolution steps. Private Facebook groups have been established to capture lessons learned, however no moderator exists. Over the years on the Apache Modernized Target Acquisition Designation Sight/Pilot Night Vision Sensor (M-TADS/PNVS) program, the sustainment team created maintainability guides with public release approval. Historically, these were printed and shipped out to the unit as posters, making it difficult to transport them to the maintenance sites around the world. In addition, Lockheed Martin FSRs are regionally based so there is often a time delay before information from the FSR gets back to the maintainer.

Lockheed Martin started to develop an Apache flight line maintenance app (iOS followed by Android) with valuable troubleshooting information and FSR contact information to help Army maintainers make the best maintenance decision. This tool would be a supplement to the official IETM used for maintenance. In the Performance Based Logistics (PBL) fixed price contract environment, each LRU returned from the flight line costs the Army and Lockheed Martin to evaluate and repair in addition to the impact on aircraft availability. Some Apache units see a 20% maintenance induced and no evidence of failure (NEOF) return rate. These are the types of returns that can be avoided with improved trouble-shooting information.

Security would be ensured through end-to-end encryption between the smartphone and the server with mail.mil account verification. The public released maintainability guides would be digitized for the maintainer to access while on the flight line. Help videos, lessons learned forum (with approved Army/contractor moderators), and real time field maintenance alerts could be integrated into the app. The app could reduce inventory mistakes by using the camera to capture the UID, found on most LRUs, and convert it to a part and serial number. Different versions of the app could be created to support different countries in their native language.

Opportunities to apply this technology to other military products could be beneficial for the sustainment business of the military.

PROBLEM STATEMENT

- 18+ month lead time for Army to update Interactive Electronic Technical Manual (IETM).
- Limited technical resources for Army Apache flight line maintainers (IETM, Field Service Representatives (FSRs), Facebook private groups).
- No quick notification to flight line maintainers when critical issue is identified or an approved lessons learned database.
- Printed maintenance quick ref guides difficult to transport.
- LM FSR are regional based and not located with each Apache unit, delayed communication between Army maintainer and FSR.
- Performance Based Logistics contracts incentivizes contractor to reduce returns while keeping supply availability high.

BENEFITS

- Capture flight line lessons learned.
- Secured technical maintenance forum with moderator validating accuracy of content.
- Real time notifications to maintainers through app once information is approved/help ticket status.
- Digital posters/videos of maintenance information.
- LM FSR contact information (phone/email).
- Virtually all maintainers have personal smartphones and utilize them already to capture pictures/videos and troubleshoot with peers.
- Supplemental tool to the IETM with expansion capability.

TECHNOLOGY SOLUTION

- iOS and Android app available to Army Apache maintainers on their smartphone (wi-fi/cell data updates).
- End to end encryption, access to data controlled through mail.mil account verification, offline mode.
- Moderated forum to capture 'failure mode' lessons learned.
- Quick reference maintenance guides, 'YouTube' help videos.
- Smartphone camera captures UID code to mistake proof part number/serial number capture for configuration management.
- Unique forum/app for each international customer prevents export violations.
- One click FSR help line access for Army maintainers.

COMFRC ENTERPRISE WIDE DEPLOYMENT OF VR PAINT SIM

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The Virtual Reality Paint Simulator (VR Paint SIM) system provides a realistic training experience prioritizing hands-on practice and technique development. The system motivates practice through friendly competition as well as increases practice time as a result of reducing part prep, cleaning, and drying times. The student's technique improves though objective scoring and detailed performance analysis results that identify areas for improvement. By deploying this system and training curriculum at all sites, all painters will be trained the same way across the enterprise and provide solid, predictable results.

Also, there are additional benefits. Using the simulator allows for the training of more students in less time and the sustainability of the classroom training is also improved as a result of the automation.

An ease of administrative burden happens due to the ability to track student progress and cost savings through detailed student reports, integrated curriculums results which include project scoring. This is done through real-time cues for painter's distance from the part, speed, and travel angle coach students toward proper technique. Students can enter correct equipment settings to prepare the project and are scored on paint transfer efficiency, mil build and correct technique. These scores indicate areas that need improvement and allow students to focus on mastering them.

It is estimated that traditional "on the job" training can cost $16,500 per student. When quality issues are considered as part of the equation, the cost of material waste alone increases to over $300K avg. per year. The simulator accomplishes the task at lower a cost than traditional training.

Commander, Fleet Readiness Centers (COMFRC) recognized the need to quickly train students to become skilled painters. FRC-Southwest (SW) established the first paint training facility which includes two VR SIM units. The new training facility has been adopted by COMFRC to be the standard training system amongst all naval aviation depots and has generated readiness in less than a year of deployment. At the time of this briefing, FRC-East and FRC-Southeast (SE) will have deployed their systems as well.

In closing, a cooperative research and development agreement (CRADA) is in progress to expand the system's capability to specifically train our personnel on aircraft simulated models, as well as adding additional features specific to painting at the FRC's.

PROBLEM STATEMENT

- How can we prepare our painters for success and improve aircraft readiness at the Navy's Fleet Readiness Centers?
- One of the most laborious tasks executed at any of the Naval Aviation Depots is the painting of an aircraft. Excessive learning curve and cost/waste of materials impacts production of aircraft at the Fleet Readiness Centers. Concerns and procedures about excessive personnel exposure to waste and hazardous materials can also contribute to delays.
- Additionally, trade skills such as painting, blasting and surface preparation are becoming more rare.
- Improper painting of aircraft negatively impacts readiness!

BENEFITS

- Realistic training
- The system motivates practice through friendly competition as well as increases practice time as a result of reducing part prep, cleaning, and drying times.
- Materials savings – Virtual supplies are free!
- The student's technique improves though objective scoring and detailed performance analysis results that identify areas for improvement.
- By deploying this system and training curriculum at all sites, the alignment ensures that all the painters will be trained the same way across the enterprise and provide solid, predictable results.

TECHNOLOGY SOLUTION

- **VR Paint SIM** is an interactive virtual reality training system specifically designed to train painters within a modern learning and training environment.
- **Coupled with a traditional class room environment, the simulator augments a facilities existing processes and procedures ensuring the student will transition directly to the production floor.,**
- FRC-SW established the first paint training facility which includes two VR SIM units. The new training facility has been adopted by COMFRC to be the standard training system amongst all naval aviation depots and has generated readiness in less than a year of it's deployment.

ENHANCED MAINTENANCE TRAINING AND OPERATIONS THROUGH AUGMENTED REALITY

SEAN WADE

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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.

PTC 's industry leading AR platform Vuforia has been the leading platform for the past decade. To date there are over 55,000 AR apps created across thousands of customers and use cases. PTC holds over 81% of AR market share with the Vuforia AR platform. Vuforia is commercially available software and ready for deployment today!

PTC has assembled world class solutions that are commercially available, cost effective, and rapidly fielded without the need for costly or timely investment or replacement of systems or equipment. Our AR platform Vuforia and our Internet of Things (IoT) technology ThingWorx will exponentially improve maintenance training for maintainers and operators alike. Additionally, Vuforia Chalk is a ground-breaking new enterprise solution that allows one employee to effectively instruct another from a remote location.

PTC's AR technologies include a suite of solutions to build detailed and compelling virtual 3D content on top of real-world scenes and enterprise applications. This technology allows for the creation of scalable AR experiences that leverage 3D content, IoT, 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. Here are just a few of the benefits our customers are realizing and AR use cases.

AR is well suited for training due to the scalability of the training experiences, collaborative environment, interconnected experiences, and instructor guided learning. Our software is in use today by companies such as Huntington Ingalls Shipyards, Boeing, GE, BAE, Lockheed and many others who are realizing results that were previously not thought possible.

- Boeing & Iowa State: 30% Faster simulated wiring assembly
- SRI: 47% Faster training instruction comprehension
- GE Energy: 35% Faster wiring a turbine control box
- Boeing: 25% installing wiring harnesses
- GE Healthcare: 46% Faster completing a warehouse picklist
- BAE: 30% improvement on knowledge retention

PTC is standing by to execute demonstrations, proofs of concepts and pilot programs within the DoD to unlock the art of the possible and apply these capabilities, already in use today.

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.

TECHNOLOGY SOLUTION

Vuforia and ThingWorx: PTC's Augmented Realty and IoT platforms are **commercially available** and in use across industry today. They include a suite of solutions to build detailed and compelling virtual 3D content on top of real-world scenes and enterprise applications. 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.

Experiences can be developed within hrs. Vuforia is COTS software and no software development is required. www.ptc.com

BENEFITS

- Improve retention, understanding of tasks
- Reduce errors and improve quality
- Empower technicians with step-by-step work instructions
- Enhance operator efficiency
- Rapid problem detection/resolution

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)

MAINTAINING AMERICA'S LETHAL COMPETITIVE EDGE

THE 2019 DEPARTMENT OF DEFENSE MAINTENANCE SYMPOSIUM

Dec. 2-4, 2019 | Spokane, WA USA

MAINTENANCE INNOVATION CHALLENGE

CALL FOR INNOVATIONS

The Deputy Assistant Secretary of Defense, Maintenance Policy and Programs is challenging you to submit your maintenance related innovations.

Revolutionary or Evolutionary; showcase your discoveries to the maintenance community at the 2019 Department of Defense Maintenance Symposium and shape the future of the industry.

An evaluation board comprised of maintenance subject matter experts will select six candidates to participate in the challenge.

This is your opportunity to demonstrate how to keep maintenance ahead of the curve in: processes | testing validation | finance products methodology services | work flows.

Abstracts must meet the following criteria in order to be considered for the maintenance innovation challenge:

1. Must be an original contribution to the state of the art
2. Technically accurate—focused on current or potential maintenance operations or management—and strictly avoid commercialism
3. Must be feasible or practical
4. Abstract must be submitted using the template provided (abstract 300–500 words only)
5. Include a powerpoint quad chart (template details and requirements below) Entries from previous years will not be accepted
6. All submissions must be cleared for public release

All abstracts that meet the minimum criteria listed above will be posted on a public website and included in a Maintenance Innovation Challenge summary booklet, that will be distributed to symposium attendees on site. From the eligible abstracts, an evaluation board comprised of maintenance subject matter experts will select six finalists to present at the 2019 DoD Maintenance Symposium. Each presenter will be allocated exactly 15 minutes, including audience Q&A. The winner will be selected by the Maintenance Executive Steering Committee and Joint Group on Depot Maintenance Senior Leaders, and recognized at a Symposium Plenary Session.

Individuals representing the six Maintenance Innovation Challenge finalists are responsible for registering for the symposium and any associated fees, if not attending in another capacity.

If you have any questions or need further information regarding the 2019 Maintenance Innovation Challenge please contact Kristie Saber of SAE International at kristie.saber@sae.org.

Administrative support provided by SAE International under contract with the U.S. Department of Defense

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