MAINTENANCE INNOVATION CHALLENGE

DECEMBER 7, 2020

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

SUSTAINMENT

DEC 0 1 2020

MEMORANDUM FOR MAINTENANCE AND SUSTAINMENT COMMUNITIES

The importance of sustainment innovation development and adoption is increasingly relevant in our current unforeseen and unpredictable environment. We must now strive more than ever to accelerate materiel availability by improving the viability of the Defense industrial base and our organic capabilities. The COVID-19 pandemic once again illuminated gaps in our domestic resources, industrial capabilities, and supply chain approaches. Innovations, such as those we received in the Maintenance Innovation Challenge (MIC), may address a variety of these gaps.

We received a record 128 submissions this year and I am excited for the possibilities and potential gains these innovations may bring. With assistance from the DoD Joint Technology Exchange Group and staff from the Office of the Secretary of Defense, the submittals were thoroughly reviewed and six finalists were identified. Principals from the Maintenance Executive Steering Committee and Joint Group on Depot Maintenance selected this year's MIC winner.

The six MIC finalists will present their maintenance innovations virtually on December 7, 2020. Based on the presentations, the virtual audience will select the MIC People's Choice Award winner. I am not only seeking your participation in the virtual challenge, but also encouraging you to examine the submissions contained in this publication.

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

Sincerely,

Steven J. Morani

Principal Deputy Assistant Secretary of Defense Logistics

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THE MAINTENANCE INNOVATION CHALLENGE AIDS IN WARFIGHTER READINESS

Each day, DoD maintainers work hard to keep the U.S. military in peak readiness condition. And yet, there are inventive technologies already available on the market that could help make the maintainers' jobs easier. The Maintenance Innovation Challenge (MIC), which normally takes place at the annual DoD Maintenance Symposium, was conducted virtually in 2020 due to the COVID 19 pandemic. The MIC 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, DoD and other government personnel, and academic and research institutions. The submissions consist of a 500-word abstract and a quad chart. All applicants are on a level playing field.

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

Evaluation Criteria:

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

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

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

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

JOINT TECHNOLOGY EXCHANGE GROUP (JTEG)

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

JTEG Mission:

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

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

The JTEG conducts virtual monthly technology forums that provide opportunities for the DoD maintenance community to exchange information and share ideas. The forums feature a different maintenance topic each month and are open to the public. 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 manufacturing and repair, or advanced wiring inspection

2) maintenance and sustainment processes such as better ways to adopt new capabilities, workforce development, or safety

3) organizational perspectives which describe maintenance capabilities and initiatives at specific DoD maintenance activities such as maintenance depots or research centers.

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

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CTMA: Changing Maintenance Paradigms within the DOD

Transitioning maintenance and sustainment technology to support warfighter readiness and mission success.

Commercial Technologies for Maintenance Activities (CTMA) initiatives have changed the DOD maintenance and sustainment paradigms. The streamlined and agile non-FAR based contracting vehicle provides an appealing and efficient option to demonstrate, evaluate, and validate innovative technology.

From leadership to maintainer, transitioning innovative technology to support warfighter readiness, has become the priority within the DOD maintenance and sustainment operating space. Over the last 20 years, the CTMA Program has become the preferred venue to make that happen.

From hands-on technologies that make routine maintenance tasks safer and more efficient, to combating obsolescence, all the way to digital innovations that can diagnose, prevent, and even predict future maintenance needs, CTMA initiatives have led the way in getting the right technology in the hands of those who need it most.

Some examples of CTMA initiatives and their impact on the warfighter:

- **Inspection and Fractographic Analysis to Develop a Digital Twin for B1 Aircraft:** A pilot program, and first of its kind, to create a digital twin of an entire aircraft. In conjunction with the Air Force and the National Institute for Aviation Research (NIAR), this initiative will address obsolescence and result in increased maintenance avoidance and reliability, repair turnaround time, cost savings, and more aircraft in operational readiness.

- **High Speed Metal 3D Printing for Improved Sustainment:** An additive manufacturing solution that rapidly responds to the urgent need for low-volume production as an alternative source of supply and manufacturing. This initiative shortens supply chain lead times, reduces logistical requirements and costs, and ensures more weapons systems are mission ready when needed by the warfighter.

NATIONAL CENTER FOR MANUFACTURING SCIENCES

CTMA
COMMERCIAL TECHNOLOGIES FOR MAINTENANCE ACTIVITIES

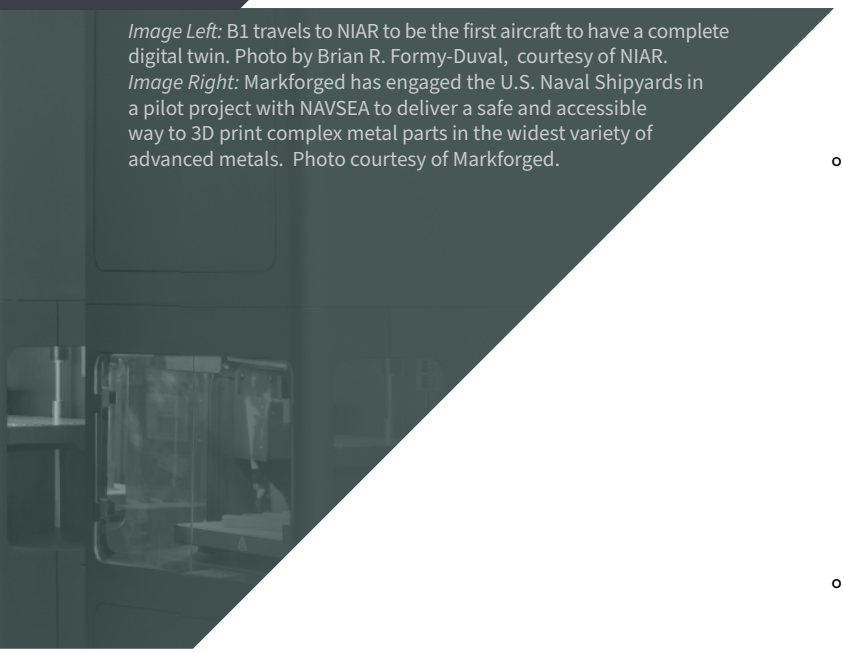


Image Left: B1 travels to NIAR to be the first aircraft to have a complete digital twin. Photo by Brian R. Formy-Duval, courtesy of NIAR.
Image Right: Markforged has engaged the U.S. Naval Shipyards in a pilot project with NAVSEA to deliver a safe and accessible way to 3D print complex metal parts in the widest variety of advanced metals. Photo courtesy of Markforged.

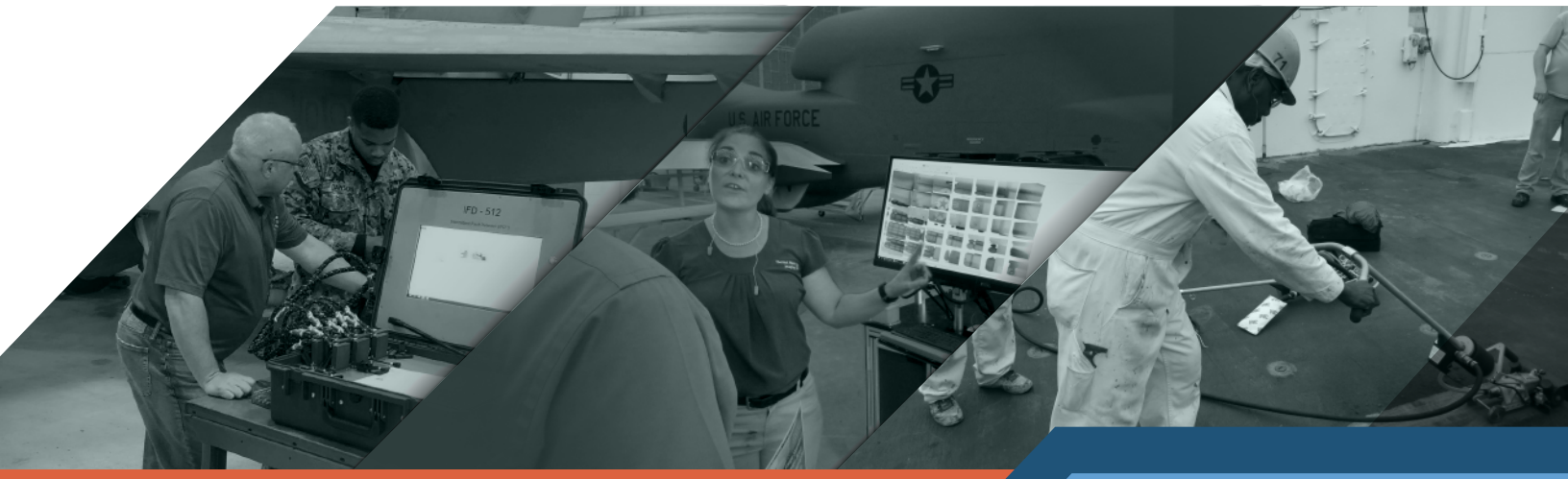
- **Development of Intermittent Fault Detection System:** Electronic maintenance poses an ever-increasing challenge for the maintainer today because of the limitations of current No Found Fault (NFF) equipment and the resulting aircraft grounding concerns. This initiative has introduced the Intermittent Fault Detection & Isolation System to the DOD, which has developed into a game-changing technology to return aircraft to mission ready status.

- **Stand-Up Abrading Machines for Surface Coating Removal:** Eliminating the need for the maintainer to manually remove decking material, a difficult and time-consuming task, this specially-designed technology will safely, and efficiently complete the task 50% faster than traditional methods.

- **Large Standoff, Large Area Thermography Non-Destructive Inspection of Composite Structures:** As composite materials improves lightweighting in aircraft, internal inspection for cracks, warping, and other non-visible subsurface fissures is difficult without removing large parts of the aircraft. Using thermography, this CTMA initiative successfully demonstrated non-destructive inspection technology at the Warner Robbins Air Logistics Complex that will promote increased inspection rates with no contact or gantry required.

For more about the CTMA Program contact Debbie Lilu, NCMS Vice President of Maintenance & Sustainment Business Development at debral@ncms.org or call 734-262-0758.

Lower Left: IFDIS technology demonstrated at the Lemoore Naval Air Station. Photo courtesy of Universal Synaptics.
Lower Center: Thermal Wave Imaging testing the LASLAT system on RQ-4 Global Hawk. Photo courtesy of Warner-Robins Air Logistics Complex.
Lower Right: Maintainers at Norfolk Naval Shipyard try Temple Allen's Stand-Up Abrading Machine. Photo by Cele Bryan, courtesy of Temple Allen Industries.



CONGRATULATIONS TO OUR 2019 MAINTENANCE INNOVATION CHALLENGE WINNERS!

From six highly anticipated finalists, it came down to two.

TECHNOLOGY AWARD:

US Air Force, Oklahoma City ALC

Congratulations to the Oklahoma Air Logistics Complex (OC-ALC), the Air Force Sustainment Center, Air Force Lifecycle Management and Air Force Research Laboratory for taking the Maintenance Innovation Challenge Technology Award at the 2019 DOD Maintenance Symposium. Their submission, **Fully Organic Repair of Air Force Assets Via Cold Spray** impressed the panel of judges as an excellent example of revolutionary and evolutionary maintenance and sustainment technology idea. The OC-ALC has retrofitted an existing thermal spray booth to have a dual capability to include cold spray and has become a qualified source for cold spray repair of cast magnesium housings using entirely organic Air Force personnel. This technology is a potent weapon against obsolescence and elongates the productivity of legacy systems.

PEOPLE'S CHOICE AWARD:

MELD Manufacturing Corporation

Based on strength of presentation and applicability to critical maintenance and sustainment needs, MELD Manufacturing Corporation took the 2019 People's Choice Award. Their submission, **A Novel Solid-State Technology for Sustainment** addressed the need for the warfighter to make critical repairs in the field or at sea. The MELD process is a solid-state additive technology enabling the repair of otherwise unrepairable assets due to the parts/component's inherent material limitations.

2020 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 2020 DoD Maintenance Innovation Challenge Finals.

Moderator:

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

Finalists:

Augmented Reality Remote Maintenance Support Service (ARRMSS)
Submitted by Aristides Staikos, US Navy NAWCAD Lakehurst

How to Pinpoint the Absolute Positioning of Flaws using Portable and Modular NDT
Submitted by Ryan Myers, Hexagon Manufacturing Intelligence

Maintenance Capacity Model
Submitted by LtCol Michael Malone, United States Marine Corps

Qualifying Laser Based Directed Energy Deposition Repair Strategies for Thin Walled Components
Submitted by Cory Jamieson, The Pennsylvania State University ARL

Robotic LASER Coating Removal (F-16 and F-35)
Submitted by Richard Crowther, USAF

vTag – 'Tagless' Item Level Traceability
Submitted by Naresh Menon, Covisus Inc.

AUGMENTED REALITY REMOTE MAINTENANCE SUPPORT SERVICE (ARRMSS)

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Augmented Reality Remote Maintenance Support Service (ARRMSS) is an enabling technology for an overarching augmented reality for maintainers framework. ARRMSS is an active research and development effort in the CREATIVE Lab based in NAWCAD Lakehurst NJ.

Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated content, also known as augmentations, in the users' field of view. Information about the surrounding real world of the user becomes interactive and digitally manipulated. Information about the environment and its objects is overlaid on the real world.

The Navy is very interested in the use and deployment of AR technologies to help the fleet during operation, maintenance and troubleshooting of equipment both ashore and afloat. The CREATIVE Lab is focused on researching and developing AR technologies to support the operation, maintenance and troubleshooting of Support Equipment (SE) and Aircraft Launch and Recovery Equipment (ALRE).

ARRMSS provides the ability for a fleet maintainer to communicate with a Subject Matter Expert (SME) remotely using video/audio/text with the added capabilities of the SME being able to place augmentations/drawings/files onto systems and objects in the maintainer's field of view to help guide them during operation/maintenance/troubleshooting. Allowing the SME to see in real-time what the maintainer sees can exponentially help reduce system downtime and improve fleet performance.

PROBLEM STATEMENT

- Current CONOPS for unresolved maintenance issues involve a Subject Matter Expert (SME)/NATEC representative traveling to a location to help with troubleshooting/repair
  - Increases repair time
  - Increases cost
  - Creates a cascading effect on schedule
  - Negatively impacts equipment and aircraft availability
  - Hinders Fleet readiness

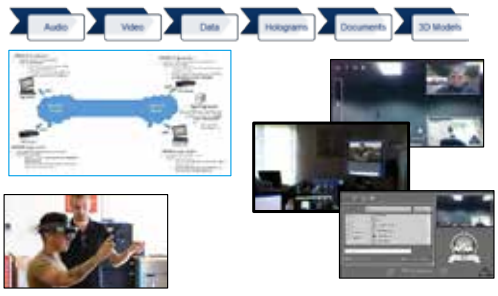
BENEFITS

- Provides the means for a SME to communicate in real-time with a Maintainer deployed in the field
  - SME sees and hears exactly what a Maintainer sees and hears
- Using Augmented Reality capabilities, SME can place Holograms in Maintainers 3D Field Of View to help guide troubleshooting/maintenance steps in real time
- Can share other digital content such as PDF and Text Documents, 3D Models and Images that the Maintainer can use additional reference right in their field of view without having to take their eyes off of the task at hand

TECHNOLOGY SOLUTION

- ARRMSS is an application framework that connects a SME (using a Windows PC/tablet) to a maintainer (wearing a Hololens 1 or 2) and allows for the transfer of applicable data over a DoD network
- ARRMSS supports:
  - Video/Audio/Data Transfer
  - Holographic Augmentations (Holograms) – Arrows, Free Drawing, Text, Beacons
  - PDF and text document sharing
  - 3D Model Sharing

ARRMSS



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

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Imagine rapidly scanning a part, looking at its internal properties, and determining if it is good or bad – all before machining it. Envision the quality assurance potential with that level of data and intelligence. The mashup of two tried and true technologies – non-destructive testing (NDT) and portable scanning arms – has evolved into a completely new approach to inspection and dimensional control.

Portable measuring arms are used extensively in the manufacturing environment for on-demand measurement and inspection. Their ability to instantly adapt to applications as a measure-ready tool without the need for re-calibration is the reason for their industry adoption. The integration of an NDT sensor with this portable device has wide-ranging possibilities for manufacturing, engineering, and scientific applications.

Combining technologies from both Hexagon and Pragma can effectively create a digital twin for maintenance operations with exact scanning for dimensional accuracy and exact location of flaw detection for preventative actions. This pinpointing of the location of flaws and defects in a part before it becomes critical is instrumental in doing targeted maintenance on the areas that absolutely require repairs now and provides a mechanism for closely monitoring other flawed areas when they become critical over time. This enables the maintenance operations to more quickly turn the asset back over to the warfighter, after repairing the most critical areas.

PROBLEM STATEMENT

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

BENEFITS

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

TECHNOLOGY SOLUTION

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

MAINTENANCE CAPACITY MODEL

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Understanding maintenance productivity and how it impacts the capacity of an equipment heavy military unit is extremely difficult and discussion on the topic frequently becomes contentious. Efficient management of productivity has a traceable impact on unit readiness.

The complexity of interactions throughout the supply chain and within organizations have made it appear impossible to identify cause-and-effect behaviors of productivity which can be measured and are meaningful from a management perspective.

A study completed in 2018 proposed a method for measuring key behaviors in Marine Aviation units and using the measurements to understand the productivity and operational capacity of the unit. Measurement uses only authoritative source data available from documentation completed when work is completed on aircraft, when aircraft return from flight, and when daily readiness is reported. The data is used to calculate the productive behaviors of workers in Direct Maintenance Man Hours per Worker per Day (DMMH/W/D), number of workers per day (W/D), and the interaction of DMMH per Flight Hour (DMMH/FH). Next a method of calculating capacity was explored along with the impact on readiness of operating at, above, or below that capacity.

The study demonstrated that a method exists to measure behaviors in a way that empowers understanding of what to look for in forming solutions. The study didn't answer "why" because each aircraft (equipment) type faces unique context such as aircraft age, support equipment availability, and quality of technical data.

The study spawned a toolset and management technique known as Maintenance Capacity Model (MCM). An experimental employment of MCM performed at an F/A-18 squadron showed measurable performance improvements. A second employment MCM with improved calculation tools and aligning far more closely with the authors proposed techniques delivered startling results at a CH-53 squadron. By achieving a 200% increase in W/D employment, 20% increase in DMMH/W/D, and effort to control DMMH/FH to a tolerable level; significant performance improvements were achieved in just one year. From FY 2019 averages to second half of FY 2020 the CH-53 squadron achieved the following performance improvements: 72% increase in mission capable aircraft, 35% increase in flight hours, 35% reduction in aviation depot level repairable cost-per-hour, 5% increase in worker job satisfaction, 72% reduction in declined reenlistments, 77% reduction in backlog maintenance on the aircraft.

Maintenance Capacity Model demonstrated that improved management with existing resources can deliver significant improvements for Marine Corps Aviation by delivering more readiness, more flight hours, lower costs, happier Marines, and healthier machines. Strategic application of resources can amplify this technique and over time can improve performance in cost and readiness.

PROBLEM STATEMENT

A lack of consistent and predictable workforce productivity behaviors has had an outsized impact on:

- Poor Aircraft Readiness
- Poor Aircraft Material Condition
- Low workforce experience levels
- Low flight hour production
- Lack of predictability in flight hour generation

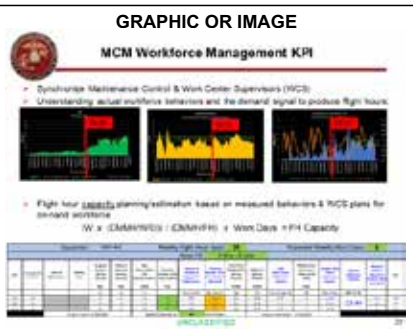
BENEFITS

- Increased productivity of workforce
- Increased aircraft readiness
- Increased flight hours
- Reduced costs
- Increased job satisfaction of workforce
- Reduced declined reenlistments
- Reduced backlog maintenance on aircraft
- Increased understanding & predictability of flight hour generation by unit

TECHNOLOGY SOLUTION

- Information technology is applied to measure and present workforce productivity data to local and mid-level management in order to demonstrate actual performance to combat unproven notions.
- Information technology is applied to calculate flight hour generating capacity based on measured behavior; serving as a fact-based starting point for operational planning.
- Continuous Process Improvement methodologies are used by senior squadron & Marine Aircraft Group maintenance leadership to coach supervisors in identifying and removing constraints.

GRAPHIC OR IMAGE



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QUALIFYING LASER BASED DIRECTED ENERGY DEPOSITION REPAIR STRATEGIES FOR THIN WALLED COMPONENTS

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Gas turbine engines utilize a series of rotary knife edged seals which cut into stationary compliant material to compartmentalize engine components of varying pressure ratios. Naturally, the contact surfaces wear and require periodic repair or replacement. Traditional arc-based repairs are often unattainable because they introduce a large heat affected zone (HAZ) that negatively impacts material properties and results in unmanageable distortion. To resolve these issues, additive manufacturing, specifically, laser based directed energy deposition (DED) has been identified as a viable option for repair and sustainment of such components. When comparing processes, laser-based DED delivers heat energy to a localized area reducing distortion and minimizing the HAZ, along with providing a measure of control and repeatability when tailoring process parameters.

In an effort to transfer advancements in laser-based DED weld repairs from development to practical application, Inconel 718 was selected as the alloy of choice based on it widespread usage. The purpose of this work was to develop two process strategies: (1) providing a low energy process and (2) providing a process capable of high deposition rates. Following either strategy, the objectives were to reduce distortion, reduce the HAZ, eliminate cracking and limit the propagation of detrimental phases formed during solidification. The scientific evidence collected in support of this effort was obtained by building a representative repair geometry using laser-based DED on multiple systems with both powder and wire feedstock to address critical variables required to produce quality repairs. Initially, the representative repair geometry was built and evaluated based on the presence of defects (lack of fusion, porosity, and cracking), microhardness, and distortion. Insights gained during the initial effort enabled down-selection to a subset of process conditions targeted for continued exploration to included additional microstructural evaluation, post-deposition heat treat, and mechanical testing.

The results of this work show by employing laser-based DED and powder feedstock following a low energy process strategy was able to resolve HAZ issues, produce depositions with low distortion, and eliminate cracking. Furthermore, laser-based DED using wire feedstock following a high deposition rate process strategy was shown to reduce material consumption and build times to be more cost-effective. Through this effort Laser-based DED has proven to produce acceptable material properties and is ready for the transition from development to scheduled maintenance. By adopting laser-based DED repair practices maintenance depots can expect to see an increase in efficiency by reducing the touch time required for specific repairs.

PROBLEM STATEMENT

Traditional weld repairs on critical thin featured components are unattainable due mainly to excessive heat build up during the repair process resulting in:

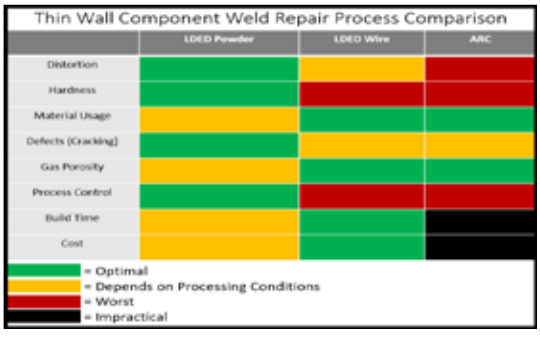
- Deformation due to high energy input (thin wall repairs)
- Large heat affected zones (HAZ) with degraded properties
- Solidification and liquation cracking
- Formation of detrimental phases
- Potential for increased grain size in the HAZ increasing susceptibility of microfissuring

BENEFITS

- Process control and repeatability
- Multiple process strategies (low energy or high deposition rate)
- Material accessibility (both power and wire feedstock)
- Reduced material consumption
- Qualifiable repair solutions (not personnel)
- Applicable process monitoring
- Easily integrated (additive + subtractive manufacturing)
- Adjustable material properties (functionally graded materials)
- Process automation (increase workforce productivity)
- Increased safety
- Reduced cost

TECHNOLOGY SOLUTION

- Laser-based directed energy deposition (DED) using multi-axis process control has been identified as a viable option for repair and sustainment activities based on recent work.
- Comparing weld repair solutions, laser-based DED delivers heat energy to a localized area reducing distortion and minimizing the HAZ, along with providing a measure of control and repeatability when tailoring process parameters.
- Thin feature weld repairs using laser-based DED have been analyzed to returned acceptable material properties enabling repairs that have previously been deemed impracticable.



ROBOTIC LASER COATING REMOVAL (F-16 AND F-35)

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F-16 Problem: USAF F-16s typically have 8-15 mils of coatings that have been applied to them. De-painting an F-16 AC is primarily done using plastic media blast (PMB). Per AC, this process generates 2000 lbs. of PMB dust that contains Hexavalent Chrome and Cadmium, which in turn has to be treated and disposed of as Hazardous waste. PMB requires workers to be in full PPE with breathing air as it is a very dusty and hazardous environment to work in. PMB also degrades the fatigue life of the AC skins as it imparts mechanical stresses on the surfaces. This is why the F-16 Program Office has limited the number of times that an F-16 can be de-painted with PMB to 3 times. PMB is also very labor intensive requiring well over 500 man hrs. and 10 Flow days to complete.

F-35 Problem: F-35 needs to remove 2-3 mils of coating from the entire outer mold line of the AC and then reapply the same amount to keep the coatings on the AC within specifications. The only currently available method to accomplish this is hand sanding. This is estimated to take 500-800 man hours and 12-15 Flow days. The other challenge of this is that it is very difficult to precisely remove the correct amount of coating. The coated surfaces do not have uniform thickness and the process will require the tedious task of taking thousands of measurements over the AC while sanding.

RLCRS uses high power LASERS to put energy into the coating, causing it to release and ablate into dust. Temperatures are controlled well below critical AC skin thresholds via use of multiple control systems to work in real time to discern coating locations and types.

Data driven benefits of RLCRS for F-16 are proven and the system is in place de-painting production F-16s since 2017. The system saves 2000 lbs. of hazardous waste per AC. It removes the worker from the Environment. It has no negative impact to the AC airworthiness so there is no limit on how many times it can be used. It saves an average (depending on coating thickness) of 150-250 man hours per AC and reduces 3-5 flow days from the process.

OO-ALC is in the process of upgrading the RLCRS to read precise coating layer thicknesses on metals and composites. This will afford an even more improved ability to achieve the precise coating removal needs for F-35 in order for them to refresh the coating (Take 2 mils off, put 2 mils on) without having to take all of the AC coatings off. RLCRS technology can, conservatively estimating, remove the 2 mils of coating and afford the AC to be ready to paint in 5 days vs. 15.

OO-ALC is currently evaluating all data regarding feasibility of this application and conservatively estimates $15M/yr. of annual savings as planned workloads hit their stride. Hazardous waste and worker stress/strain related to this process will be significantly reduced or eliminated.

PROBLEM STATEMENT

Plastic Media Blast (PMB) of F-16 AC:
- Generates 2000 lbs. of hazardous waste per AC
- Requires operators to be in full PPE surrounded in hazardous conditions exposed to Hexavalent Chrome and Cadmium.
- Causes significant worker stress strain
- Damages the AC surface substrates
- Requires 500+ man hours, and 10 flow days per AC

F-35 Scuff Sand for Refresh application of Coating:
- Estimated to take 500-800 man hours and 12-15 Flow Days
- Difficult to uniformly remove 2-3 mils of coating from entire AC outer mold line (OML)
- Significant Worker Stress/strain

BENEFITS

F-16 De-paint:
- Generates 10-12 lbs. hazardous waste per AC
- Removes operator from hazardous PMB environment
- Does not impact Airworthiness of the AC substrates
- Saves 150-250 man hours per AC and 3-5 Flow days
- Saves $2.5M per year

F-35 Scuff Sand:
- Estimated eliminate 300-500 man hrs. and 10 Flow days
- Accurately and uniformly remove coatings to yield much better surface to recoat to specified thickness
- Remove worker from hazardous Environment 90%
- Potential to save more than $150K per AC
- One RLCRS can while process up to 100 AC per/yr ($15M/yr. savings)

TECHNOLOGY SOLUTION

Robotic LASER Coating Removal System (RLCRS)
- Use of multiple high fidelity control systems that deliver specified LASER power and precision to various areas, substrates, and coatings on the entire OML of the AC.
- Utilized new control technology to accurately measure and remove desired amount of coating thickness from all areas of a non-uniformly applied coating.
- High power vacuums capture 99% of affluent keeping the process area clean and safe for Personnel and the Environment.

GRAPHIC OR IMAGE

VTAG - 'TAGLESS' ITEM LEVEL TRACEABILITY

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Item level traceability is needed in tracking components and subassemblies during system maintenance. Current methods include bagging and tagging parts with visible labels that can often be separated from the part during busy maintenance cycles. This results in considerable costs in re-working and re-creating chain of custody. Furthermore, when components are replaced, it is critical to know the provenance of the part in order to protect the assembly from substandard/counterfeit components.

Covisus is an emerging industry-leader in tracking and tracing solutions for products in the global supply chain. Current methods for tracking products rely on physical tags, such as bar codes, QR codes, direct part marking and RFID. Through its proprietary, patented vTag® technology, Covisus offers the only "tagless" tracking technology that does not require any physical marking or tag. A vTag uses intrinsic micrometer scale surface features (texture) of an item to identify it from all other items of its kind. Like a fingerprint, a vTag is unique, unforgeable and intrinsic to the part. It can be applied to individual items of any size or shape made from virtually any material – on parts as small as 4 mm in size. They are invisible, covert and cannot be modified. The vTag system enables parts to be traced back to their origin to verify authenticity or detect tampering.

The vTag® technology was built with funds from the DoD to meet IUID and microelectronics traceability requirements (TRL 8). The technology is in advanced pilots at various DOD (NSWC Crane) and commercial organizations (Boeing, J&J, …)

www.covisus.com

PROBLEM STATEMENT

Maintenance and sustainment requires disassembling, tracking and tracing of components and subassemblies, documentation associated with all work performed and often replacement with parts whose provenance is well known. Currently, the entire process is based on cumbersome manual paper-based steps

Often part/subassembly data is 'lost', require re-working and potential risk of introducing substandard/counterfeits into the full assembly

This is fundamentally because each part/subassembly cannot be easily tracked and traced with existing digital methods.

'Bag & Tag' processes are vulnerable to human error, is slow and arduous

Establishing provenance of replacement components is difficult

BENEFITS

"vTag® creates an intrinsic and immutable link between an item and its data"

vTag® enable cost effective item level traceability.

Because it is based on capturing an image, the process does not require any change to the part and/or packaging.

It works with any part type (metal, ceramic, wood, plastic, rubber, …) and has been validated by DLA to work with a broad range of FSGs

It is rapid (less than 5ms to capture an image), provides complete digital thread, scalable such that one can attach meta-data at the item level

The solution is resilient to normal production/manufacturing environments

TECHNOLOGY SOLUTION

We are a Small Business located in the Los Angeles area who, with pilot funding from the DoD (MDA, DLA, DMEA) have developed 'virtual tags' (vTag®)

vTag® is based on taking a photograph of an item and from it, digitally extracting surface texture. This surface texture is like a 'fingerprint' and is proven to be highly unique to the item level

vTag® is intrinsic to the part, covert, unforgeable, and unique

The technology has been validated by DoD entities as well as the private sector (Boeing, Johnson&Johnson) and has broad applicability at various points in the supply chain

We are compatible with IUID (integrated with DLA database) and meet regulatory standards for DOD microelectronics

TRL 8: In advanced pilots at leading organizations

vTag® solution includes hardware and software
Multiple hardware configurations for different applications

AMCLAD® AS A KIRKSITE DIE REPLACEMENT

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Problem Statement: Tooling expenditures represent a significant lead time and cost impact in the production and maintenance of defense platforms. One example is the production of dies utilized for aluminum sheet metal forming at DOD depots. These dies are cast from a zinc alloy called Kirksite. The traditional approach is to generate a model to create a sand casting mold in which Kirksite is cast to near net shape then finish machined to exact dimensions for use in the metal stamping process. To form the actual casting molds, synthetic materials are CNC machined to create forms/patterns. Thus, the finished tool requires two separate machining steps. The first for the mold pattern and the second on the cast Kirksite forming die. Additionally, the fumes and dust from Kirksite melting are toxic. DOD maintenance facilities have integrated binder jetting 3D printing technology to speed casting production (including dies) and produce sacrificial, low green strength molds for pattern-less manufacturing of sand molds for the Kirksite castings to speed mold development but mitigating Kirksite toxicity remains a challenge.

Technology Description: Freshmade 3D, a small additive manufacturing business, developed a patented material called AMClad®, which takes advantage of the fast output and large-scale capabilities of binder jetting technology. AMClad products start as binder jetted low green strength 3D printed sand parts, which are then processed into durable and functional parts used for hard tooling, prototypes, and end use parts across many industries. The AMClad process can directly fabricate the forming die for the aircraft skin sections. The patented AMClad process involves applying durable resins and surface finishes to the printed sand shape to enable net shape manufacturing of the forming dies. This eliminates the use of Kirksite and reduces the machining steps. Thus the technology benefits are the elimination of health hazards and providing savings in time and in cost.

Technology Development Status: AMClad has been utilized in several industry focused production tooling applications for automotive and aerospace manufacturing. However, it has not been applied in a depot setting for assessment.

Data supporting performance claims: AMClad, a patented isotropic engineered particulate composite, differs from other 3D printing materials because of its speed and print size capabilities, and its unique material properties. AMClad is abrasion resistant and durable due to its patented internal design configurations, higher compression, flexural, and tensile strengths. AMClad's compression strength is approximately 18,000 psi. New design enhancements have improved its impact strength.

Next Steps/Potential Benefits: Partner with University of Northern Iowa. Fabricate an AMClad forming die and assess the technology application at Tinker AFB. Assess die performance, cost, turnaround time, hazard reduction, surface finish and the ability to create larger dies

PROBLEM STATEMENT

Tooling expenditures represent a significant lead time and cost impact in the production and maintenance of defense platforms such as aircraft, vehicles and ships, etc.

Current Solution: Rapid prototyping/low volume aluminum sheet metal forming using Kirksite dies at Air Force depots.

Problem:

- Kirksite dies require sand casting mold in which the zinc alloy is cast near net shape and then final machined to exact dimensions for the dies used in the metal stamping process.
- To form the actual casting molds, synthetic materials are machined to create forms for the sand molds. The forms require two separate machining processes; one for the sand mold pattern and one on the finished Kirksite forming die.
- Process challenges includes hazards (toxic dusts and fumes); multiple machining steps, disposal of used sand

BENEFITS

- Reduced lead time for aircraft skin sections
- Reduced overall cost
- Elimination of process variables associated with the casting process.
- Print sand, AMClad® infusion and die is created for metal forming
- Same 3D sand printer can produce sand molds and cores for metal casting as well as AMClad® parts and tooling

Assessment of Benefits:

- Assess the technology application in a relevant setting at Tinker AFB as an alternative to Kirksite die manufacturing.
- Assess the AMClad® enabled approach regarding performance, cost, lead time, hazard reduction, surface finish and the ability to create larger dies for aluminum sheet metal forming
- Our small business is partnering with the University of Northern Iowa Metal Casting Center and Additive Manufacturing Center for objective assessment of the technology approach

TECHNOLOGY SOLUTION

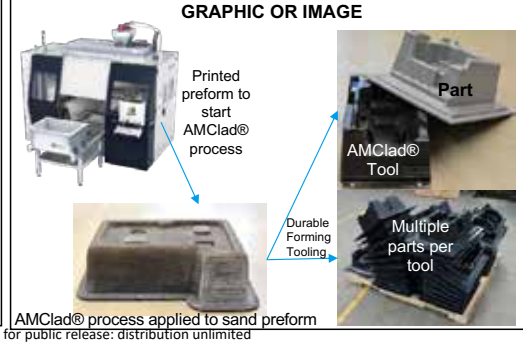
Description: AMClad® products start as low green strength 3D printed sand parts, which are then processed into permanent, strong, durable, and functional parts used for hard tooling, prototypes and end use parts across many industries.

Development: The AMClad® patented process has been utilized in several industry focused production tooling applications for automotive and aerospace manufacturing.

Performance: AMClad®, a patented isotropic engineered particulate composite, differs from other 3D printing materials because of its speed and print size capabilities, and its unique material properties. AMClad® is abrasion resistant and durable due to its patented internal design configurations, higher compression, flexural, and tensile strengths. AMClad's compression strength is approximately 18,000 psi. New versions have improved its impact strength.

US Patent 10,773,456 and US Patent Application: US20180079134A1

GRAPHIC OR IMAGE



AMClad® process applied to sand preform

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ADVANCEMENT OF THE SUSTAINMENT OF HIGH-STRENGTH ALUMINUM AIRCRAFT COMPONENTS

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Sustainment of critical structural aircraft components made from non-fusion friendly aluminum alloys is presently without a qualified repair technology. More specifically a repair process is not currently in place that is qualified to add material to structural (aluminum) components that have suffered material loss because of corrosion, erosion, impact, etc. With no approved method of repair, components that could otherwise be reworked are either shelved/discarded and replaced with new part(s), placing an unnecessary burden on the supply chain.

The MELD process, a novel solid-state additive manufacturing technology, offers a path forward to the qualification of a repair process that is compatible with the aluminum alloys (2XXX, 7XXX, etc.) used to fabricate these aircraft components and is capable of producing materials that satisfy wrought requirements, both mechanical and chemical, of these alloys. Working with engineers at Robins Air Force Base, MELD Manufacturing Corporation has identified a sustainment need related to AMRAAM/Launcher system. This component (launcher rail) is made from a 7XXX aluminum alloy and experiences wear at the point(s) of contact between the rail and missile. In a previous effort, the team at MELD Manufacturing Corporation worked to demonstrate the ability of the MELD process to create an acceptable repair of the launcher repair, which was functionally tested by the team at Robins. Since this demonstration, the cost of this component has increased by over 300%.

With this new opportunity MELD Manufacturing Corporation proposes to generate additional data that can be used by the team at Robins Air Force Base to begin to establish the body of information needed to qualify the process as an approved repair technology. In this effort, MELD Manufacturing Corporation will fabricate material specimens focused on demonstrating that the hardness of the deposited material remains within the acceptable range of the component requirements. Further, MELD Manufacturing Corporation will also demonstrate that the deposited material does not adversely affect the hardness of the original material adjacent to the location of the repair. While the focus of this proposed effort is in support of aircraft components, 7XXX series Al alloys find use across many different platforms among all branches of service, which would all equally benefit.

PROBLEM STATEMENT

Sustainment of critical structural aircraft components made from non-fusion friendly aluminum alloys is presently without a qualified repair technology. More specifically a repair process is not currently in place that is qualified to add material to structural (aluminum) components that have suffered material loss because of corrosion, erosion, impact, etc. In this effort MELD Manufacturing Corporation will continue their support of the AMRAAM/Launcher system team at Robins Air Force Base to generate additional data focused on demonstrating that the hardness of the material after the repair remains in compliance with the specified requirements. The goal of this effort will be to advance the technology towards being a certified repair process.

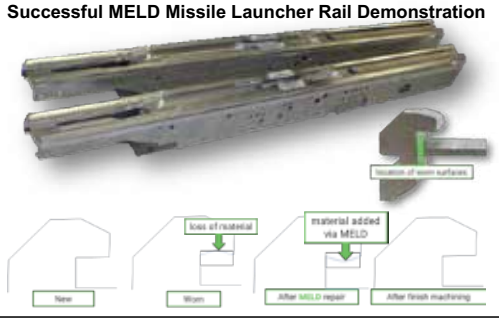
BENEFITS

- Scalable technology supporting large-size AM applications with fast deposition rates (Al > 20 lbs/hour)
- Able to print MELDed material direct onto existing structures/components
- Previous effort on repair of missile launcher rail material demonstrated:
  - *MCVN testing showed MELDed Al7075 absorbed higher impact energies that baseline data; at -40F testing MELD material average impact energy was 18% higher than baseline
  - MELDed Al7075 material exhibited better fatigue life at -40F

TECHNOLOGY SOLUTION

MELD is a solid-state process that is compatible with all metal alloys, including those that are incompatible with fusion process. By remaining well below the melting point of a given material (0.6-0.8 of the melting temperature), MELD is able to process materials without succumbing to the problems experienced by melt-based processes such as porosity and hot-cracking. Further, the MELD process requires significantly less energy than melt-based processes, does not require the utilization of a vacuum chamber, or an inert environment.

Successful MELD Missile Launcher Rail Demonstration



CHEMICAL AUTHENTICATION FOR 3D PRINTING

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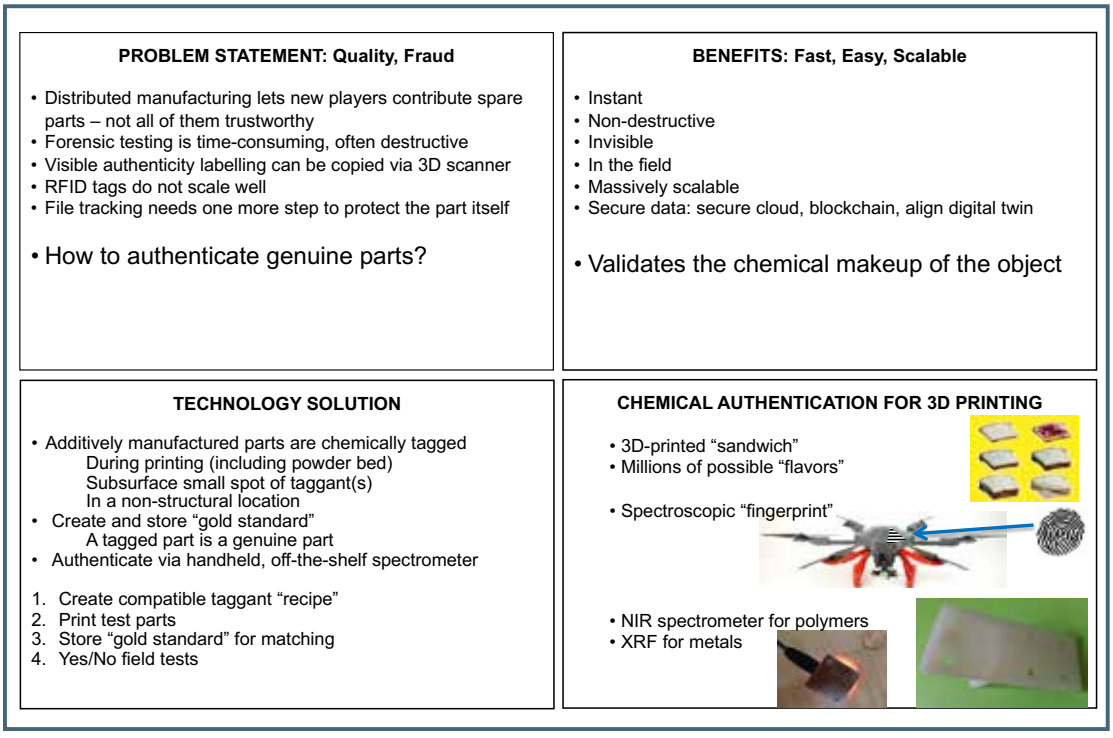
Problem: The future of maintenance will incorporate additive manufacturing, so that parts can be created near the point of need, from digital files. Distributed manufacturing brings opportunities for outsourcing… and for trouble. Not every printer will be fully monitored by a trusted party. How do you ensure that a failed or fraudulent part does not get used?

Technology: We propose a protection strategy that uses in-print chemical tagging and instant field authentication via handheld spectrometers. We create a model of a good part: made of the correct materials, and authorized, with a covert, print-compatible, chemical taggant inserted during printing to allow for non-destructive field validation (multiple patents issued and pending). The chemical taggants are selected from the set of print-compatible materials – not a pre-selected fluorescent tag, nanoparticle, or special sauce that would require its own secure supply chain. Generally polymers tag polymers and metals tag metals, with compatible melting point profiles and chosen for good adhesion, in the way that grilled cheese helps hold a sandwich together, but a slice of tomato does not. The chemical tagging and tracking data are spectral profiles: sets of (x,y) coordinates that are easy to manage but impossible to reverse-engineer to generate fakes with the same profiles. For polymers, we use near-infrared (NIR) spectroscopy, in which the peaks influence one another and are therefore immune to reverse lookup. For metals, we use x-ray fluorescence (XRF), where the covert nature of the tagging is supported by the fact that the tags are invisible (subsurface) and not disseminated throughout the part. Limiting tagging to a tiny (non-structural) spot is important for structural integrity; it has the additional benefit of making it hard for a counterfeiter to find.

Current Development Status: The tagging technology (TRL-4) has been tested on a dozen different printer types, including with support from America Makes, 3D-printed electronics, and most recently, for near-real geometry brackets for Lockheed Martin Aeronautics.

Test/Simulation Data: Our modeling so far shows that 100% of the tagged samples clustered in chemometric analysis separate from untagged samples: we have succeeded in identifying a detectable, printable taggant mix for each matrix material, including nylons, acrylics, ULTEM, ABS, PC, Ti6Al4V. Proof-of-concept testing has shown that good, genuine parts can be distinguished in an instant, in the field, from rogue parts.

Next Steps/Benefits: Chemical tagging is compatible with a digital twin model and blockchain tracking, and in fact adds materials and quality insight to the digital data. Our plan includes testing additional geometries and taggant placement for further military applications, and tackling scale-up. Part reliability in the era of distributed manufacturing will depend on fast, easy-to-use tests, integrating chemical quality monitoring into the digital supply chain.



HIGH VALUE COMPONENT REPAIR CELL COST/BENEFIT ANALYSIS

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Problem Statement: Today, weapon systems repair and refurbishment within the DOD involves many discrete process steps and a heavy dependency on manual labor and outsourcing with ad hoc workflows. More efficient processes exist within industry, such as automated inspection, laser cladding and robotic finishing, but they have not been widely adopted within the DOD. Furthermore, even in industry's usage, these processes are point solutions that do not benefit from integration and automation. The result is an MRO process within the DOD that is riddled with inefficiencies that result in high cost, poor yield and slow turnaround, impeding the overall readiness of the warfighter.

Technology Solution: Optomec proposes performing a detailed cost/benefit analysis showing the advantages of implementing automated repair work-cells within the DOD. The goal will be to show payback of such a strategy in terms of cost and lead time reductions. The analysis will rely on developing Cost of Ownership models for the automation of standalone repair processes (i.e. inspection, prep, cladding, finish, etc.), as well as a work-cell that integrates and automates these functions in a seamless setting. At the core of the work-cell rests industry proven additive repair technology that is already widely used within industry for the production repair of high value metal components, including flight critical hardware such as turbine blades from aircraft engines.

Benefits:

- Reduce Yield and Uptime issues with Manual Operations
- Reduce Cost up to 80% vs. Manual/ Outsource
- Improve Repair Quality and Yield
- Lower Heat Affected Zone (HAZ)
- High Repeatability
- Reduced machining/finishing cost
- Reduced abrasive material usage
- Reduce Lead times to Improve Warfighter Readiness

Current Status/Data Supporting: Optomec has unparalleled experience in delivering automated DED/Cladding repair solutions for high value components. We have fielded more than 200 DED/Cladding machines. These machines are in high volume production within industry. Fifteen countries have certified Optomec cladder repairs for flight critical aircraft engine components. Our position as the market leader is due in part to our unique and proprietary AutoCLAD software that automates the process of imaging a part, compensating for distortion and optimizing weld parameters. Optomec is proud to count many DOD and government users, including US Army, US Navy, NASA and DOE. Optomec has delivered systems with automation for part load/unload and batch processing. We are in active discussions with potential work-cell partners, capable of providing and integrating capabilities.(see quad chart)

Next Steps: We recommend NCMS/CTMA help us to identify a high priority repair opportunity that could reap the benefits (higher yield, lower costs, higher quality, and improved warfighter readiness) and we will complete this cost/benefit analysis. Upon successful analysis, we would provide a follow-on proposal for full implementation.

PROBLEM STATEMENT

Today, weapon systems repair and refurbishment within the DOD involves many discrete process steps and a heavy dependency on manual labor and outsourcing with ad hoc workflows. While more efficient processes exist within industry, such as automated inspection, laser cladding and robotic finishing, they have not been widely adopted within the DOD infrastructure Furthermore, even in industry's usage, these processes are point solutions that do not benefit from seamless integration and automation. The result is an MRO process within the DOD that is riddled with inefficiencies that directly result in high cost, poor yield and slow turnaround, impeding the overall readiness of the warfighter

BENEFITS

- Reduce Yield and Uptime issues with Manual Operations
- Reduce Cost Savings up to 80% vs. Manual / Outsource
- Improve Repair Quality and Yield
  - Lower Heat Affected Zone (HAZ)
  - High Repeatability
  - Reduced machining/finishing cost
  - Reduced abrasive material usage
- Reduce Leadtimes to Improve Warfighter Readiness

TECHNOLOGY SOLUTION

Optomec proposes performing a detailed cost/benefit analysis showing the advantages of implementing automated repair workcells within the DOD MRO infrastructure. The goal will be to evidence the payback of such a strategy in terms of cost and leadtime reductions. The analysis will rely on developing Cost of Ownership models for the automation of standalone repair processes (ie: inspection, prep, cladding, finish, etc.), as well as a workcell that integrates and automates these functions in a seamless setting. At the core of the workcell rests industry proven additive repair technology that is already widely used within industry for the production repair of high value metal components, including flight critical hardware such as turbine blades from aircraft engines.

Industry-Proven Solution Elements

- Automated Inspection
- Automated Tool Path Generation
- Automated Surface Prep
- Automated Surface Finish
- Robotic Material Handling
- Automated Laser Cladding

Automated Workcell, mitigates risk, cost and delays by implementing production-verified processing steps into a single workcell.

QUALIFYING LASER BASED DIRECTED ENERGY DEPOSITION REPAIR STRATEGIES FOR THIN WALLED COMPONENTS

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Gas turbine engines utilize a series of rotary knife edged seals which cut into stationary compliant material to compartmentalize engine components of varying pressure ratios. Naturally, the contact surfaces wear and require periodic repair or replacement. Traditional arc-based repairs are often unattainable because they introduce a large heat affected zone (HAZ) that negatively impacts material properties and results in unmanageable distortion. To resolve these issues, additive manufacturing, specifically, laser based directed energy deposition (DED) has been identified as a viable option for repair and sustainment of such components. When comparing processes, laser-based DED delivers heat energy to a localized area reducing distortion and minimizing the HAZ, along with providing a measure of control and repeatability when tailoring process parameters.

In an effort to transfer advancements in laser-based DED weld repairs from development to practical application, Inconel 718 was selected as the alloy of choice based on it widespread usage. The purpose of this work was to develop two process strategies: (1) providing a low energy process and (2) providing a process capable of high deposition rates. Following either strategy, the objectives were to reduce distortion, reduce the HAZ, eliminate cracking and limit the propagation of detrimental phases formed during solidification. The scientific evidence collected in support of this effort was obtained by building a representative repair geometry using laser-based DED on multiple systems with both powder and wire feedstock to address critical variables required to produce quality repairs. Initially, the representative repair geometry was built and evaluated based on the presence of defects (lack of fusion, porosity, and cracking), microhardness, and distortion. Insights gained during the initial effort enabled down-selection to a subset of process conditions targeted for continued exploration to included additional microstructural evaluation, post-deposition heat treat, and mechanical testing.

The results of this work show by employing laser-based DED and powder feedstock following a low energy process strategy was able to resolve HAZ issues, produce depositions with low distortion, and eliminate cracking. Furthermore, laser-based DED using wire feedstock following a high deposition rate process strategy was shown to reduce material consumption and build times to be more cost-effective. Through this effort Laser-based DED has proven to produce acceptable material properties and is ready for the transition from development to scheduled maintenance. By adopting laser-based DED repair practices maintenance depots can expect to see an increase in efficiency by reducing the touch time required for specific repairs.

PROBLEM STATEMENT

Traditional weld repairs on critical thin featured components are unattainable due mainly to excessive heat build up during the repair process resulting in:

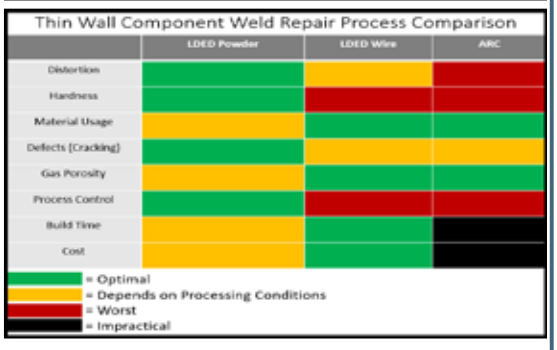
- Deformation due to high energy input (thin wall repairs)
- Large heat affected zones (HAZ) with degraded properties
- Solidification and liquation cracking
- Formation of detrimental phases
- Potential for increased grain size in the HAZ increasing susceptibility of microfissuring

BENEFITS

- Process control and repeatability
- Multiple process strategies (low energy or high deposition rate)
- Material accessibility (both power and wire feedstock)
- Reduced material consumption
- Qualifiable repair solutions (not personnel)
- Applicable process monitoring
- Easily integrated (additive + subtractive manufacturing)
- Adjustable material properties (functionally graded materials)
- Process automation (increase workforce productivity)
- Increased safety
- Reduced cost

TECHNOLOGY SOLUTION

- Laser-based directed energy deposition (DED) using multi-axis process control has been identified as a viable option for repair and sustainment activities based on recent work.
- Comparing weld repair solutions, laser-based DED delivers heat energy to a localized area reducing distortion and minimizing the HAZ, along with providing a measure of control and repeatability when tailoring process parameters.
- Thin feature weld repairs using laser-based DED have been analyzed to returned acceptable material properties enabling repairs that have previously been deemed impracticable.



REAL-TIME MONITORING OF ADDITIVE MANUFACTURING

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Addiguru provides real time monitoring solutions for the additive manufacturing (3D-Printing) processes. Part defects formed during the build process can be difficult or costly to detect after a part is already built. The defect rate can be as high as 40% and these defects are detected only after each part is scanned. In addition, historical data is difficult to access, inconsistent across machine types and often incomplete.

Addiguru's monitoring technology detects defects using novel computer vision and artificial intelligence algorithms during the build process, which then inform the user via notifications. The user can then make changes to easily repair defects or stop failed prints. Intelligent imaging collects layer by layer data without the need to physically connect to a 3D printing machine. The intuitive software interface allows the user to see the layer data in real-time. In addition, proprietary image compression technology reduces the storage by 90%.

Addiguru's monitoring platform is machine brand agnostic and can easily incorporate different kinds of sensors and data. Addiguru's system that can be easily incorporated into existing and newly developed additive manufacturing equipment. This is done using affordable, practical and off-the-shelf hardware with software absorbing the complexity.

Currently, the software collects layer by layer data using high resolution (15 megapixel) optical camera to take images of powder-bed and after fusion layers. The powder-bed pictures are then analyzed by an artificial intelligence (AI) model and notifications are sent if anomalies are detected. We are able to detect anomalies of 150 micrometers or larger. The detection accuracy is 90% and is determined by using a test dataset not used to train the AI model. The software is currently deployed on two pilot customer machines and will be deployed on two other customer machines next week.

The next steps are to improve the computer vision and artificial intelligence model to classify the cause of defects. This will be done by collecting more data and training the model. The roadmap is to incorporate infra-red and near infra-red cameras to detect hot spots and lack of fusion spots. This will help increase the accuracy of detection and the fidelity of defect size. Addiguru will create a CAD digital twin of the printed part in real-time. The goal is to detect in real-time whether the part is going out of tolerance and send notifications accordingly.

PROBLEM STATEMENT

- **In Additive Manufacturing historical Data is**
  - Difficult To Access
  - Inconsistent across machine type
  - Often Incomplete
- **Up to 40% defect rate**
- **Scan every part after production for defects**
  - No affordable and practical real-time monitoring

BENEFITS

Save time and materials by stopping the builds with issues via real-time **notifications**

Valuable insights from historical data

Better understanding of underlying issues

Save time and money to determine issues

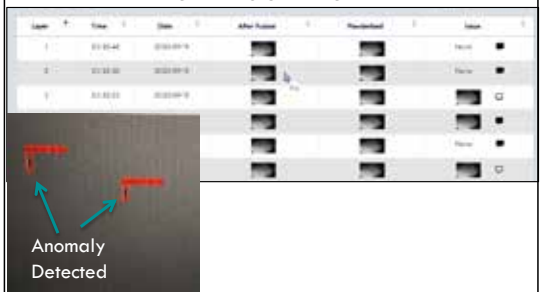
Reduce or eliminate scanning costs

Reduce data storage costs through proprietary compression

TECHNOLOGY SOLUTION

- Real-time (*In situ*) monitoring using cameras, IR cameras, sensor data and
  - Computer vision
  - Artificial intelligence
- Affordable and practical off-the-shelf hardware
- Within 1 sec of layer creation and 150 micron accuracy
- Compression of image data by 90%
- Intelligent imaging using computer vision and AI
  - No connection with printing machine needed

GRAPHIC OR IMAGE



AI Detection Result

ON-DEMAND METAL DEPOSITION

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The Directed Energy Deposition (DED) technology is a versatile metal deposition process that enables its users to handle several different applications such as FORM, ENHANCE, and REPAIR applications. DED can FORM complex geometries using its powder-fed deposition process for spare part fabrication on-demand. With FormAlloy's high deposition efficiency and in-process monitoring, high quality parts can be manufactured 2-100X faster than traditional manufacturing methods.

DED can also ENHANCE existing parts or new designs with additional geometrical features with the same base material or other materials with a full metallurgical bond. Advanced coating systems can extend the life of equipment and add vehicle protection.

The FormAlloy AX deposition head and powder feeders can be utilized for laser cladding and functionally gradient material (FGM) systems to give superior part properties. Lastly, the DED technology can REPAIR high-valued components to reduce down time and scrap. Did you know that corrosion damage cost the US Army $1.2 billion in 2016? With DED, you can repair damaged metallic parts and improve them also.

FormAlloy and the DED technology has the solutions to help solve pain points within the DoD maintenance and sustainment communities.

PROBLEM STATEMENT

Need/Problem: Technology capable of

1. Applying corrosion resistant coatings
   - Corrosion damage to military ground vehicles cost the U.S. Army ~ $1.2 billion (2016)
2. Performing full-quality metallic component repairs
   - Return parts back to service in hours to days instead of weeks to months.
3. Producing replacement parts on-demand
   - High value, complex geometries, large freeform fabricated structures, and functionally graded materials (FGMs) capable

BENEFITS

Potential Uses/Impact:

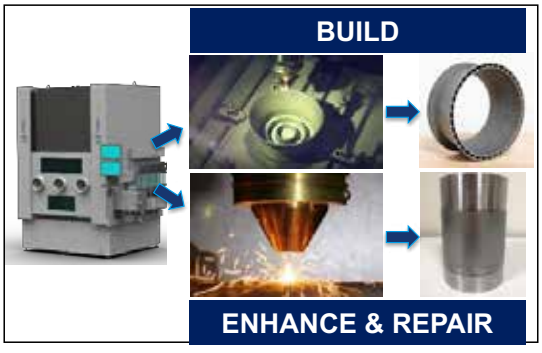
1. Additive Manufacturing > Improved components for enhanced lethality
2. Lightweight and advanced materials development > Increased vehicle protection and transportability
3. Advancing coating for improved corrosion resistance > Extended life
4. Advanced joining development > Advanced repair processes

High TRL: 7+

- Fast build rates (15 lb/hr)
- Scalable
- Multi-Material Capable
- Open Source Materials
- Waste Reduction
- Field Deployable

TECHNOLOGY SOLUTION

- Metal Additive Manufacturing *to BUILD, ENHANCE, & REPAIR* On-demand
- *BUILD* fully-dense components on-demand, up to 15lbs/hr
- *ENHANCE* existing components with multiple materials to improve strength/corrosion/wear
- *REPAIR* damaged components and return to service quickly and cost effectively
- Widest range of alloy processing - steels, nickel super alloys, copper, titanium, cobalt alloys and exotics
- Machine programming in G-code is transferable skill to/from CNC machine tools
- Closed-loop monitoring & control for high quality



MAINTENANCE DIGITAL TWIN FOR ADDITIVE MANUFACTURING

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Supplying legacy parts for aging, yet still mission critical systems presents an ongoing challenge. New advances in additive and agile manufacturing have great potential for addressing the DoD's need to maintain mission readiness with parts that meet or exceed original part specifications. Implementing an additive/agile manufacturing process for the DoD requires integrating the capabilities of multiple domains, both from the real world and the digital world. Creating 3D geometry of legacy parts, creating and maintaining a materials database, developing strategies for printing parts, and controlling the quality of those parts in a cyber-secure database are just some of the hurdles inherent in this endeavor.

This solution enables maintainers to take control of quality at all the key stages of their additive manufacturing process. Through an unparalleled portfolio of digital manufacturing technologies spanning CAE solutions for design and engineering, CAD/CAM and complementary software for production applications, metrology hardware and software solutions, as well as data management and analytics tools, we empower technology users throughout the process with deep and actionable insight into product quality, ensuring that quality drives productivity. Computer Aided Engineering (CAE) is an integral part of any maintenance enterprise. Also, It is one of the most important strategies employed to maintain quality and to reduce time and costs associated with physical prototyping/testing. Recent advances in additive manufacturing require CAE methods and tools to adapt to not only simulating the form, fit, and function of the finished component, but of the manufacturing process itself. This capability results in greater control of the manufacturing process and an increase in the quality of components produced.

CAE departments typically use a wide variety of simulation tools. These tools produce huge amounts of data in a variety of different formats. Most of this data is Work-in-Progress (WIP) data. This data and the processes associated with it are important intellectual property. It needs to be managed and harnessed to arrive at important decisions faster and in an efficient manner. It is not practical to manage this data and associated processes in a PDM (Product Data Management) system because PDM systems lack the workflows and architecture required to manage this tremendous volume of heterogeneous content. Therefore, a separate simulation and process data management (SPDM)system is necessary to manage this data. The focus of an SPDM system is to manage both data and processes associated with simulations. The solution presented herein represents multiple hardware and software assets of the Hexagon team. These assets have been stitched together to form a digital thread that is unique to additive manufacturing for maintenance operations.

PROBLEM STATEMENT

Supplying legacy parts for aging, yet still mission critical, military systems presents an ongoing challenge. Getting accurate information on the repair parts, without original specifications or OEM technical data is part of this challenge. Even when you have a "golden part", how will you know if will work if additively manufactured?

BENEFITS

- Identifies additive manufacturing materials that substitute, meet or exceed original legacy material specifications, which increase physical properties, improve corrosion and temperature performance
- 3D conversion technology which improve upon accuracy, speed, complexity, translation, image quality and cost
- Centralized, coherent data management system that addresses how data is managed, unified, defined, aggregated and organized
- Process monitoring and inspection data that can be folded into process modeling tools

TECHNOLOGY SOLUTION

New advances in additive and agile manufacturing have great potential for addressing the DoD's need to maintain mission readiness with parts that meet or exceed original part specifications. Implementing an additive/agile manufacturing process for the DoD requires integrating the capabilities of multiple domains, both from the real world and the digital world. For example, creating 3D geometry of legacy parts, creating and maintaining a materials database, developing strategies for printing parts, and controlling the quality of those parts in a cyber-secure database are just some of the hurdles that are overcome in this integrated workflow.

ACCELERATE ADVANCED MANUFACTURING THROUGH INNOVATIVE PARTNERSHIPS

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Oklahoma City Air Logistics Complex (OC-ALC) is called upon to restore, maintain, and expand the hardware and software capabilities across five generations of weapons systems. This mission is executed by 10,104 maintenance professionals, leveraging a $3.5 billion budget, 8.1 million feet of production space and $2.1 billion in equipment, aligned at producing airpower for our nation. This sustainment enterprise has tremendous inertia, and represents not only the most lucrative opportunities for technology advancement in the DoD, but also the most challenging.

OC-ALC has created an unprecedented model for deploying advanced manufacturing and sustainment technology to this depot ecosystem by establishing ourselves as a national laboratory. This empowers our team to create potent, mutually beneficial partnerships with thought leaders across academia, industry & government, and creates sustainable models of technology transition. New Educational Partnership Agreements (EPAs) with the University of Oklahoma (OU), Oklahoma State University (OSU) and Oklahoma Christian University (OC) represent a move from transactional relationships to true collaboration.

Cooperative Research and Development Agreements (CRADAs) with industry, the Life Cycle Management Center (AFLCMC), the Air Force Research Laboratory (AFRL), and Oak Ridge National Laboratory (ORNL) formalize joint endeavors to improve throughput, cost effectiveness, safety, and quality. Together, these teams have worked to deliver unique capabilities:

- Advanced tech including additive manufacturing, cold spray, hybrid manufacturing, advanced casting & non-destructive inspection techniques resulted in $25.8M in FY20 cost avoidance
- Rapid proliferation of additive manufacturing--4950 parts in service AND the first metal additive part on an engine powering the B-52. Pacer Edge collaboration between the Rapid Sustainment Office (RSO), Propulsion Directorate, & General Electric will continue to accelerate the design and manufacture of airworthy additive manufactured parts
- An additive enabled casting of a B-1 bearing housing with OC is currently undergoing destructive testing. Success will establish the Air Force's first organic foundry bypassing a 5 year industry cold start
- A collaborative 35-person team located on OU's campus developing machine learning algorithms in support of Command and Control & Condition Based Maintenance application
- An academic/government team creating a Government-owned DevSecOps pipeline focused on embedded software, to include provisions for airworthiness, safety of flight, and nuclear certification
- A partnership with AFRL, AFLCMC and the Manufacturing Demonstration Facility at ORNL to pilot technologies prior to capital investment, reducing technology transition time by 5 years and avoiding investment in unsuccessful technologies
- Over 80 manual masking operations replaced with 3D printed polymer masks, resulting in $162K in cost avoidance and reducing flow days.

PROBLEM STATEMENT

- OC-ALC must support hardware and software weapons systems across five generations of Air Force Platforms.
- Lack of technical data, insufficient data rights, legacy tooling, legacy processes, limited parts availability, and limited network capabilities provide significant challenges to OC-ALC's ability to restore, maintain, and expand the capabilities of the HW and SW weapons systems it supports
- Sustainment represents lucrative technology opportunities but the must challenging transition ecosystem

BENEFITS

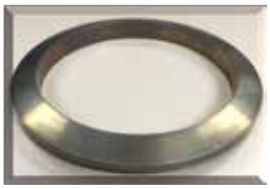
- $25.8M of FY20 cost avoidance leveraging reverse engineering and advanced manufacturing capabilities
- 4950 OC-ALC additive parts in service flying on weapons systems and on the ground in equipment, tooling, & fixtures
- First metal additive manufactured part designed, fabricated, and flying on an Air Force engine powering the B-52!
- First airworthy cold spray repair process, with first repair flying on TF-33 gearbox--enables reconditioning costly parts
- Government/industry/academia software enterprise collaboration developing government owned CBM+, machine learning, command & control, and DevSecOps technology
- First AF foundry capable of casting weapon systems parts

TECHNOLOGY SOLUTION

- Established OC-ALC as a defense laboratory to enter formal Educational Partnership Agreements (EPAs) and Cooperative Research and Design Agreements (CRADAs) with academic, industry & federal laboratory partners
- Leverage EPAs and CRADAs to develop an applied engineering capability that is focused on solving depot-related challenges via technology transition and modernization
- Deploying software technologies, additive manufacturing, hybrid manufacturing, cold spray & advanced casting to improve the mission at unprecedented rates

GRAPHIC OR IMAGE

B-1 bearing housing casting using additively manufactured tooling shatters 5 year cold start paradigm



Additive manufactured metal TF-33 engine seal represents first of its kind flying on an Air Force engine

ROSA-RAPID ORGANIC SUSTAINMENT OF AIRFRAMES

HAL PLUENNEKE

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Problem Statement: Airframe components 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 part-specific tooling and fixtures. Parts are procured through the DLA, or from Primes Contractors. DMSMS (Diminishing Sources and Material Shortages) are seen regularly in aging aircraft fleets with lead-time for parts approaching years, not months. AM approaches for airframe parts, such as 3-D printing, lack of technological maturity, and face complex airworthiness approval processes for aircraft.

Solution: Stretch Roll Forming (SRF) applies current approved processes (cold forming) to metallic materials, in a novel way. SRF has been developed to manufacture one-off discrete parts for aircraft maintenance without the need for part-specific large monument tooling.

SRF is analogous to wire-feed additive manufacturing. Its CNC programs convert straight extruded and rolled sections into a large variety of assembly ready components. By starting with simple common extrusions as feedstock (like wire), SRF can be considered a new class of additive manufacturing methods classed as Metamorphic Manufacturing. However, since SRF conventionally process, cold stretch forming, begins with wrought feedstock, SRF formed part are qualified by current OEM specs. SRF is already used for manufacturing spare parts for military aircraft including the A10 and B52.

ExtruMach (XM) was developed to post-process SRF formed parts. Long flexible, curved components are a challenge to machine. Currently, part-specific fixtures must be fabricated to enable machining to aerospace tolerances. XM is a fixtureless, flow-thru CNC machining process that drills, trims, and thins complex curved components. XM has already used for manufacturing spare parts for the A10, C135, KC135, and B52.

Other technologies for fieldable Airframe Maintenance: Reverse Engineering & Inspection (RE&I) is a laser-based inspection system for reverse engineering, in-process, and first article inspection. Hot Joggling (HJ) is a hot or cold forming process. A configurable die system is in testing and has produced a joggled component for the C-135.

TRL & MRL of the effort: SRF TRL 7, MRL 6 XM TRL 6, MRL 5 RE&I TRL 4, MRL 3 HJ TRL 4, MRL 3

Performance: Within the last 18 months, we have been awarded a total of twenty-three (23) part making contracts from the DLA through DIBBS. We have completed 10 of these contracts, with the other 13 in-progress. A contract for, a half ring, on the A10 aircraft, showcases SRF's stretch forming capabilities. We received First Article Approval on this part and delivered in December 2019, 19 months ahead of the original required delivery schedule (2021).

Next Steps: Fairmount Technologies LLC is currently seeking, seed capital, development partners and the opportunity to complete TRL8 trial at a DoD facility.

PROBLEM STATEMENT

- Airframe components 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, or from Primes Contractors
- DMSMS (Diminishing Sources and Material Shortages) are seen regularly in aging aircraft fleets with lead-time for parts approaching years, not months.
- Other Digital approaches for airframe components, such as 3-D printing, lack technological maturity and face complex airworthiness approval processes for aging aircraft. SRF and XM technologies apply current processes to current materials, in a novel way, making parts identical to current practice.
- Depot Organic Manufacturing capacity requirements are different from commercial entities. Depots lack the tooling required to make most airframe parts ⇒ outsourcing ⇒ Negatively impacts asset availability

BENEFITS

- Enables organic manufacturing to produce stretch-formed airframe and other extruded components that currently require forming tooling & machining fixtures
- No part-specific tooling for forming or machining parts
- Many parts formable in final temper of use – no heat treatment
- Conventional metal forming and machining processes
  - Technologies do not need qualification
  - Parts meet existing process specifications and standards
- Increases asset availability
- Technology deployable to manufacturing facilities, Depot/RCs, flight lines, forward operations, in-theater
- Reduces procurement costs by enabling Digital Thread
- Non-reoccurring engineering is reduced or eliminated
- Reduced operator training requirements due to CNC & automation
- Maturation pathway thorough funding in program of record: vertical lift, commercially derived, or new program. Title III or SBIR funding.
- Parts are currently being supplied thru open competition in DIBBS
- Parts can be purchase without bidding as a Phase III SBIR award

TECHNOLOGY SOLUTION

- **XTRUE** is a **digital thread** driven suite of **tool-free** technologies packaged as an integrated solution to **enable organic manufacturing** of airframe components & extruded structures in an agile manner to **increase asset availability**

1. **Stretch Roll Forming (SRF)** is a *key enabling technology* that forms extrusions to a CNC programmed contour, in the final temper of use, without part-specific stretch block tooling or heat treatment
2. **ExtruMach (XM)** is a *key enabling technology* that utilizes a universal feeding fixture for drilling and trimming formed extrusions without part-specific tooling or large-bed CNC milling machines
   - ***SRF** and **XM** - advanced manufacturing technologies funded by **DLA SBIR***
3. **Joggling** is a commercially available technology that can be packaged by FT as a robotic joggling cell for curved and straight parts. FT currently owns a patent on flexible universal die systems that can be matured to enable a flow-type flexible joggling system
4. **Reverse Engineering & Inspection (RE&I):** FT's solution for inline inspection of the contour of parts will be integrated with commercially available technology for scanning, to create an integrated solution for reverse engineering failed airframe components, and for inspection of manufactured parts

AUTOMATED 3D SCANNING SYSTEM FOR SPARE PART DIGITAL TWINS

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Digital Twins provide 3D digital data for problem solving and avoidance. 3D scanning is about capturing parts and spaces in the real world to create 3D digital data for design, analysis, visualization, and manufacturing. With so much demand for digital design, analysis, and fabrication, and with so little of the physical world in digital form, 3D scanning enables engineers, designers, and fabricators to accurately blend reality into digital.

Direct Dimensions has developed a novel 3D scanning system for small part digitization into 'digital twins' for subsequent analysis for supply chain management, sourcing, design and conversion to additive manufacturing, dimensional inspection, counterfeit analysis, part comparison, remote part identification, and much more. We have tested the system at a DLA depot and commercial stockrooms. We will be deploying to DLA depots in the next year.

PROBLEM STATEMENT

- *Digital Twins* provide 3D digital data for problem solving and avoidance.
- 3D scanning is about capturing parts and spaces in the real world to create 3D digital data for design, analysis, visualization, and manufacturing.
- With so much demand for digital design, analysis, and fabrication, and with so little of the physical world in digital form, 3D scanning enables engineers, designers, and fabricators to accurately blend reality into digital.
- *How do you get your real-world parts and spaces accurately into 3D for subsequent design, analysis, visualization, or manufacturing?*
- *More importantly, what challenges do you have solving dimensional issues with parts, assemblies, structures, vehicles, gear & equipment?*

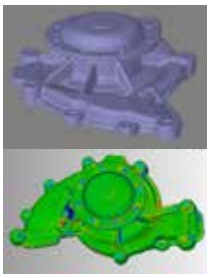
BENEFITS

- Direct Dimensions has unparalleled skill and experience for 'reverse engineering' complex legacy part & assembly hardware into 3D CAD.
- We provide project-based support and have performed 1000's of projects.
- We own, use, support, and represent a wide range of 3D scanning equipment and software for virtually all types of scanning problems.
- We use the best equipment for the project and can therefore recommend the best solutions for your projects, including custom automated solutions.
- We've worked with groups in the Navy and many other DoD organizations around the country for most of our 25-year history.
- We look forward to working with you too!

TECHNOLOGY SOLUTION

- For over 25 years, Direct Dimensions has provided advanced 3D scanning services and products for capturing physical objects and facilities into 3D digital formats for a variety of applications from aerospace, automotive, art and architecture to museum, military, medical and movies.
- We are located near Washington DC in Owings Mills, MD
- We have over 25 highly skilled and experienced technical staff.
- We represent, sell, train, and support a variety of 3D scanning solutions including long range, handheld, high accuracy and other *COTS* 3D scanners.
- We provide both services and products to support Navy 3D digital needs.

Automated 3D Imaging System for Spare Part Digital Twins



NUCLEAR AND BIOLOGICAL RESISTANT COLD SPRAY COATING FOR EXISTING COMBAT VEHICLES AND SHELTERS

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The proposed innovation is to use a high pressure cold spray (CS) additive manufacturing process to deposit a copper-based coating reinforced with boron carbide and cuprous oxide onto existing ground combat vehicles and shelters to mitigate against chemical, biological, radiological, and explosive weapons.

In the cold spray process, micron-sized metal particles are accelerated supersonically toward a substrate, where the collision results in significant plastic deformation, mechanical interlocking, and metallurgical bonding of the particles to the substrate. During the process, the metal particles never reach melting temperatures, but are fused through kinetic energy transfer and adiabatic shearing processes. Substrate heating is minimized, dimensional stability is maintained, and unwanted thermal effects such as heat affected zones, thermal stresses, tensile residual stresses from re-solidification, and dilution layer formation are avoided.

Brittle materials can be deposited when combined with a ductile base material, and this is done routinely in CS. A blend of copper, boron carbide, and cupric oxide will be deposited to form an in-situ coating or structural repair that will be capable of exceptional wear resistance for mitigating the impact of explosives, nuclear radiation, chemical attack, and biological agents. Boron carbide is used for both tank armor and control rods in nuclear reactors because it is extremely hard yet light (3770kg/mm2 Vickers hardness and 2.52g/cm3 density, or 7x the hardness of hardened 4340 steel yet 10% lighter than aluminum) and absorbs neutrons. It is also used for neutron shielding. At the same time is highly resistant to many chemicals. Copper is a widely known antimicrobial material and cuprous oxide has shown antimicrobial and antifungal properties that would protect against biological events, including COVID-19, noroviruses, influenza, MRSA, and others, but would also be able to add abrasion and wear resistance to the coating. The powders will be blended and subsequently cold sprayed in various ratios to optimize biological and mechanical performance (i.e. adhesion, porosity, deposition efficiency, hardness, ballistic resistance, and wear resistance).

At the conclusion of this effort, the team will make recommendations for an economical and timely plan to cold spray this advanced deposit on large-scale structures. This innovation addresses the need to create technologies that will reduce mass, improve performance, be more resilient and extend the life of combat structural systems. Depositing the coating directly onto the structure eliminates the need for mounting hardware, which reduces mass and complexity.

PROBLEM STATEMENT

Warfighters are subject to threats from conventional and nuclear weapons in armed conflicts, with chemical and biological threats added by non-state or rogue state actors.

A solution that mitigates these threats is needed, preferably one that can be retrofitted to existing vehicles and structures.

TECHNOLOGY SOLUTION

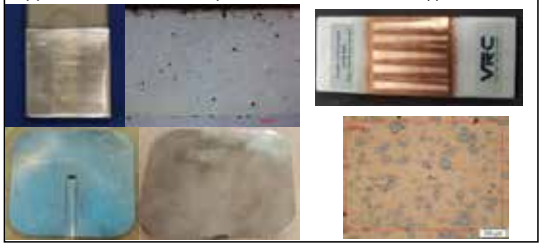
Copper blended with boron carbide and cupric oxide will be deposited by high-pressure cold spray to form a **coating** that is **resistant to corrosion and chemical attack, kills bacteria, viruses, and fungi, shields against neutron radiation, and confers wear and ballistic resistance.** Copper is ductile, highly corrosion resistant, and kills bacteria and viruses on contact. Boron carbide is light, extremely hard and absorbs neutrons. Cupric oxide also kills bacteria, viruses, and fungi and is also hard.

Brittle materials (boron carbide, cupric oxide) can be deposited when blended with ductile material (copper). These material will be blended in powder form and cold sprayed in various wt% ratios to optimize the multifactor threat mitigation.

BENEFITS

The proposed cold spray technology will provide **Enhanced Protection for Military Vehicles and Tactical Shelters for Explosive, Biological and Nuclear Assaults** by the in-situ addition of a multi-functional coating. Since the coating will be applied in-situ, there will be **Reduced Downtime**, as the vehicle and/or shelter can be cold sprayed on location with no special jigs for fixtures. Finally there will be a **Reduction of the Total Cost of Ownership**, as the coating can be applied on existing military assets. This coating will also be a protective coating against standard environmental elements (corrosion, erosion) that can offer **Longer Service Life** to the vehicle and/or shelter.

The project team has already demonstrated Ni – CrC repairs on High Hard Armor (a & b), and 5056 Al on 5083 aluminum armor (c & d), along with unblended copper on aluminum (e) and copper blended with hard phases on stainless steel (f)



MACHINE LEARNING SOFTWARE FOR ADDITIVE MANUFACTURING

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Problem statement: Out-of-production parts are expensive and time consuming to procure due to increased restart costs and low volume requirements. Additive manufacturing (AM) is one solution to this issue. Senvol's machine learning software (Senvol ML), which can be applied to any AM process or material, ties the processes that produce parts to their material properties to ensure the design of the right material for an application. This reduces the cost and time to qualify AM created parts over the current methods.

The DoD's supply chain is a massive, complex undertaking – shipping material across the globe. Mission Capability rates are directly impacted by the accessibility to spares. AM is one method to provide out of stock or out of production parts in a timely manner.

Senvol has developed data-based machine learning software that supports the qualification of AM processes, machines and materials, rapidly optimizes process parameters, predicts material properties of components, supports quality assurance, and minimizes data generation costs.

The software tool models, simulates, and predicts part quality and performance based on input process parameters including local composition, microstructure, residual stresses and/or distortion, and mechanical properties. The software can be applied to any AM process or material and has been prototyped and functionality verified. This technology significantly decreases AM data generation costs so that qualification of AM components can be achieved faster with fewer resources.

The technology was developed through SBIR/STTR funding from the Office of Naval Research (ONR), DLA, and NIST, and is currently at TRL 6. The technology was successfully deployed and utilized by ten different commercial users during an Alpha program (i.e. prior to the technology being commercially launched in November 2019). Since launch, the technology is currently being used to support an Air Force program (which is the technology's first transition contract).

During its Phase II STTR with ONR (completed November 2019), Senvol conducted various validation experiments with the technology. Cost and time savings for AM process parameter development of 67% were achieved for stainless steel 316L data generated for the Navy. In another case (for a Fortune 100 company in the aforementioned Alpha program), Senvol's technology saved the company 75% in cost and time (representing approximately $150,000 and 6 months savings, respectively).

Senvol's data-based machine learning software is applicable to all DoD services (and DLA). When deployed at scale, Senvol estimates that its technology will reduce the cost of AM material and part qualification from approximately $1.5 million to approximately $500,000 on a per part basis.

Next steps are focused on transition of the current technology, with successful use cases within the DoD being particularly valuable. Senvol is continuing to develop new capabilities (e.g. transfer learning).

PROBLEM STATEMENT

- Operational Need and Improvement: Parts no longer in production are expensive and time consuming to procure due to increased restart costs and low volume requirements. Additive manufacturing (AM) is one solution to this issue. Senvol's machine learning software (Senvol ML), which can be applied to any AM process or material, ties the processes that produce parts to their material properties to ensure the design of the right material for an application. This reduces the cost and time to qualify AM created parts over the current methods, further enhancing operational availability and decreasing total ownership cost.

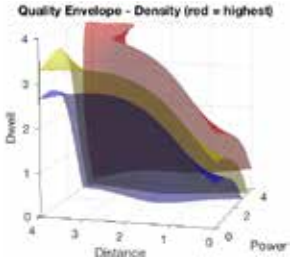
BENEFITS

- Warfighter Value: The DoD's supply chain is a massive, complex undertaking – shipping material across the globe. Mission Capability rates are directly impacted by the accessibility to spares. AM is one method to provide out of stock or out of production parts in a timely manner. This technology further drives down the cost and time in procuring qualified parts – possibly allowing for production at any site with AM production capability. This technology further reduces AM qualification time and cost over current methods, providing further incentive to increase adoption of AM as a logistic enabler of combat readiness.

TECHNOLOGY SOLUTION

- Senvol ML is machine learning software for AM that will be used to support qualification of any AM process, machine and material, rapidly optimize AM process parameters, predict material properties of AM components, support quality assurance, and minimize AM data generation costs. The software has been prototyped and functionality validated. Sustained competitive advantage is provided as this technology allows users to significantly decrease their AM data generation costs such that qualification of AM components can be achieved faster and with fewer resources.
- The technology was developed through SBIR/STTR funding from the Navy, DLA, and NIST; the technology is currently being used to support an Air Force program (first transition).

GRAPHIC



The three surfaces (red, yellow, purple) indicate what AM machine process parameters should be used in order to achieve a target material density. All points on the surface would allow the build to achieve the target material density.

This image is from data analyzed for the U.S. Navy.

AI-GUIDED ICME FOR PREDICTING AS-BUILT AM PERFORMANCE

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A problem statement describing what problem the technology is meant to solve: Metal laser powder bed fusion (LPBF) additive manufacturing (AM) machines are used to manufacture aircraft components. However, these parts cannot meet fatigue performance requirements without expensive post-processing (e.g., hot isostatic pressing, polishing), inspection (e.g., CT scan), and trial and error (experimental) builds to characterize the material, qualify the process, certify the part, and establish manufacturing acceptance criteria. In order to enhance as-built part performance, we must first predict fatigue performance from design and process parameters and then feed this knowledge back into design and manufacturing to influence the AM build process.

A description of the technology: The technology leverages current Integrated Computational Materials Engineering (ICME) tools to generate simulated data sets that are then used to pre-train an AI toolset that will predict part performance from design and process parameters. The goal is to merge simulated (synthetic) data with actual (ground truth) data from in-situ and ex-situ measurements. The fusion of various sensor modalities and data types presents unique challenges for which algorithm development will aid in automatic processing and translation of data into AI-ready datasets.

The current development status of the technology: The combined AURA-ARL Penn State team have the designed approach and implementation architecture in place and now are awaiting funds to proceed.

Test/simulation data supporting performance claims: The AI toolset will use actual part, process and performance data sets that ARL Penn State captured from previous research efforts and DOD projects. This includes data from collaborative work with NAVAIR from the V-22 Nacelle Link and Fitting flight demo, data from an Army sponsored project with an H-60 bell-crank, data from an American Makes sponsored research project, and additional NAVAIR sponsored AM process parameter studies performed at ARL.

Next steps/potential benefits: At a high level, the next steps of our technical approach include the design, build, and test process; the proposed data capture process; and our AI implementation strategy:

- Capturing “as-designed” part features such as geometry, material, loading conditions
- Integrating AM build parameters, such as laser power, scan speed, and layer thickness
- Predicted or as-built performance indicators such as porosity, microstructure, surface finish, and residual stress
- In-situ sensor data collection such as melt pool features (shape, size, and temperature profiles) or powder bed features (homogeneity, temperature profiles) as well as post-process inspections (flaw populations)
- The fusion of the AI toolset with actual data to develop advanced fatigue prediction capabilities
- A flexible data collection framework for metal LPBF processes will be developed and demonstrated

PROBLEM STATEMENT

- Metal LPBF (Laser Powder Bed Fusion) Additive Manufacturing (AM) machines and processes are being used to print aircraft components. However, these parts cannot meet fatigue performance requirements without expensive post-processing (e.g., hot isostatic pressing, polishing), inspection (e.g., CT scan), and trial and error (experimental) builds to characterize the material, qualify the process, certify the part, and establish manufacturing acceptance criteria.

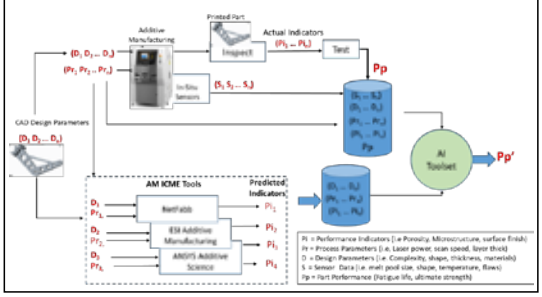
BENEFITS

- The AURA **AMP Optimizer™** advanced artificial intelligence (AI) toolset will predict the fatigue performance of metal Laser Powder-Bed Fusion (LPBF) additively manufactured (AM) components
- The AURA **AMP Optimizer™** AI toolset will optimize design and process parameters to achieve enhanced fatigue performance of as-built parts
- The AURA **AMP Optimizer™** will generate simulated data sets that are then used to pre-train an AI toolset that will automatically predict part performance from design and process parameters in preparation for AM

TECHNOLOGY SOLUTION

- To leverage current ICME tools and AI to generate simulated data sets that are then used to pre-train an AI toolset that will predict as-built performance from design and process parameters, by merging simulation (synthetic) with actual (ground truth) in-situ and ex-situ measurements

GRAPHIC



WIRELESS SENSORS FOR PROCESS DATA ACQUISITION OF 3D PRINTED SAND MOLDS AND CORES

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A recent Defense Acquisition Agency summit was held to determine issues with the availability of casting and forgings needed for DoD weapon platforms. It was determined that a high percentage of RFQs either had very long lead times or had no response from the supply chain. The DLA has identified over 32,597 National Stock Number (NSN)s that have cast or forged parts, of these in 2016 there were 13,014 contracts valued at $9.6M with 5,205 unfilled contracts. Of these unfilled contracts 52% were cast parts. AM enables the reverse-engineering of structures from defense systems that were developed decades ago. Consequently, 3D printed sand molds improve the responsiveness of the supply chain to fabricate urgent replacement parts for the Department of Defense for a diversity of applications. As with other traditional molding methods process variation has been the source of casting defects and ultimately delays in product delivery. It is estimated that quality issues including casting defects resulting from process variation can cost manufacturers millions in rejected parts or increased lead times.

Determining variations in the molding and casting process can predict casting success and provide valuable data to improve the casting process. This data forms the basis of manufacturing 4.0 and can aide metal casters in refining their processes to higher levels than ever before possible. Low cost sensors placed within molds can collect process data which include temperature, pressure, moisture, gas chemistries, and dimensional data. Gas chemistry has been used to determine the rate and degree of cured sand by measuring volatile organic compounds released during curing. Analysis of the curing rate will provide information on the relationship of sand mixing, environmental conditions including humidity and temperatures. This information will be used as input to process modeling software and to identify significant variables to control.

Proposed efforts funded under this topic will encompass the development of a hardware/software platform for facilitating state-of-the-art process monitoring of sand casting in order to reduce unit cost by improving yield. The Defense Manufacturers industry seeks to dramatically reduce both unit costs and lead times for cast parts. Advancements in the production of molds and cores has not kept pace with a shrinking manufacturing base as well as the loss of a highly experienced workforce through attrition and retirement. The metal casting industry has been slow to recognize and utilize technologies including Manufacturing 4.0 and IOT data driven processes. Driven by the cell phone industry and Wi-Fi capabilities, sensor systems are inexpensive, deliver a diversity of manufacturing data, and provide wireless data transmission – all within a small physical footprint. Coupled with additive or conventionally manufactured molds, in-mold sensors can enhance the quality and yield of metal castings.

PROBLEM STATEMENT

- Aging DoD weapon platforms require maintenance & sustainment parts to extend their useful life.
- Cast parts for DoD maintenance & sustainment have high cost, long lead times and a high degree of unfilled orders.
- The commercial metal casting industry is shrinking from overseas competition and loss of retiring skilled labor.
- Manufacturing 4.0 technology has the opportunity to enhance the defense casting supply chain to fill current and future needs of the DLA.

BENEFITS

- Reduced lead times associated with cast parts providing greater support of the warfighter.
- A reduction in failures of first article testing or production quality issues.
- Lower costs to the DLA resulting from a higher overall quality and reduced rejection level.
- Greater utilization of computer process simulation tools leading to higher initial casting quality levels.

TECHNOLOGY SOLUTION

- Advances in the miniaturization of computers and sensor technology has enabled the sensing of critical casting process data.
- Computer process modeling has drastically improved first piece acceptance but is based on a detailed understanding of process variables.
- Improvements in the casting process can be realized with real time sensors that provide feedback and control.

PHOTO-BASED IDENTIFICATION AND FILE RETRIEVAL TO ENABLE ADDITIVE MANUFACTURING OF MAINTENANCE PARTS NEAR THE POINT OF USE

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The Joint Additive Manufacturing Model Exchange (JAMMEX), a program of the DLA and multiple military services, has stated a vision to use laser scans of physical parts for identification and retrieval of the files necessary to enable additive manufacturing (AM) of maintenance parts near the point of use.

PROBLEM: In a request for white papers titled Project DLA-OTA-000-0001: Joint Service Additive Manufacturing the document describes "three high-value problem areas" that impact achieving JAMMEX: limitations of scanning, lack of robust method for geometric search; and printer management.

SOLUTION / BENEFITS: iSEEK Corp. addresses DLA's concerns for both scanning and geometric search with a solution that uses a single photo of a physical part, taken on a standard tablet computer or smartphone, for part identification and geometric search. The advantage of photos rather than scans include:

- Skill: a photo is familiar and intuitive, requiring little training and no advanced skills.
- Environment: requires no specialized equipment, accommodates environmental variables such as lighting and power, and the hardware is ubiquitous, robust, inexpensive, and is easily transportable.
- Efficiency: scanning and post processing time is eliminated.
- All–In-One Solution: The solution integrates capturing the shape, geometric search, and file retrieval for AM into a single application and process.

TECHNOLOGY: The backend of the system is a search index generated from 3D CAD models or 3D scans. The encoding process generates 2D and 3D search signatures and classifies those components into two respective indices. Utilizing 3D data enables highly accurate search. On the frontend, the photo is first searched against the 2D index. The search results are presented in 3D on the smartphone or tablet, allowing users to view results in 3D just like the maintenance part they photographed. If desired, any search result can be selected for a subsequent 3D to 3D search against the 3D search index to potentially retrieve additional items, and to identify or qualify potential suppliers.

STATUS / SUPPORT OF CLAIMS / NEXT STEPS: The proposed solution has been rigorously tested and validated for accuracy by John Deere to identify inventory. Ongoing improvements include broadening inputs such as PDFs.

GEOMETRIC SEARCH FROM 3D INPUTS: Additional utility is also provided by this solution. The backend technology enables geometric search directly from 3D CAD and 3D scans (not photos) using standard PCs. This technology has been commercially available for a decade and is used by leading companies such as John Deere, Kenworth, Peterbilt, Kohler, Embraer, Moen, Bridgestone, and Manitou, working in CAD libraries as large as two million items. The technology is universal across all types of CAD formats, standard formats such as STEP and IGES, and derivatives such as the STL format which is the most commonly used for AM.

PROBLEM STATEMENT

The adoption of additive manufacturing (AM) for production of maintenance parts near the point of need is limited by part **scanning** requirements and inadequate **geometric search** capabilities for identification and retrieval of files for AM. 3D scanning and post-processing requires significant skill and training as well as expensive and delicate equipment with sensitive environmental requirements such as lighting and power. A secondary problem is a lack of search technologies that can utilize the scan to search CAD or scan libraries.

BENEFITS

- **Skill**: The process is familiar and intuitive, requiring very little training and no advanced skills.
- **Environment**: The solution requires no specialized equipment, accommodates a wide range of environmental variables such as lighting and power, and the hardware is ubiquitous, robust, inexpensive and easily stored.
- **Efficiency**: The time and skill required to perform scanning and post processing is eliminated.
- **All–In-One Fully Integrated Solution:** The solution integrates capturing the shape, geometric search, and retrieving the file required for AM production into a single application and process.

TECHNOLOGY SOLUTION

The solution utilizes photos taken on a tablet computer or smartphone rather than 3D laser scans, creating simplicity in both use and hardware requirements.
The system is enabled by a backend search index generated from CAD models or 3D scans which drives accuracy. The encoding of that data generates both 2D and 3D search indices which enable an integrated solution from identification to retrieval of the file needed for AM production. Additional information can also be retrieved such as printer setting, part manufacturer, and potential substitute parts. This system has been rigorously tested by John Deere.

GRAPHIC OR IMAGE

BUILDING A DIGITAL STORAGE SYSTEM FOR ADDITIVE MANUFACTURED PARTS

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Problem: Managing your technical Additive Manufacturing data can be challenging, especially when you're required to follow an ever evolving list of manufacturing standards and specifications. Currently there are over 100 variables that need to be resolved, documented and stored for each production AM Part. Companies are having to build bespoke tools to track and store this information or are allowing teams to stand up siloed solutions, which may or may not map to industry standards. This challenge makes the process of using 3D Printing to build or maintain a manufacturing supply chain.

Solution: We built a software tool called TRACE to help streamline that process. Built based on the core workflow of the 3D Printing process (Design Inputs, Materials, Process, Post Processing, and Inspection), TRACE enables the entire data chain that's developed during the process of producing a 3D Printed part to be digitized in one place.

It all starts with TRACE's production dashboard, which is your go-to place to see exactly what's happening with all of your products. It gives you a quick, clear snapshot of active projects, quality analytics, and an inventory of your critical factory management documentation. It's an easy way to quickly assess utilization and progress – but we know users need more. So, Trace also gives you the ability to customize the tool to capture every detail you might need.

Benefits:

- Saves time and money. It takes an average engineer about one day of time to collate data for each 3D Printing project. With TRACE, guided workflows make this process easy and intuitive.
- Helps ensure compliance. Our tool follows industry standard best practices and is regularly updated to reflect changes in standards from agencies like the FDA and FAA.
- Enables part traceability throughout the lifecycle. If there is a problem with a batch of material or question about who touched a certain part, it's easy to quickly trace the parts, in perpetuity.

This is critical for a robust maintenance and sustainability program as it allows a central repository to drive on-demand usage of 3D Printed parts.

PROBLEM STATEMENT

Many variables, no consistent framework. Currently there are over 100 variables that need to be resolved, documented and stored for each production AM Part.

No centralized data source. Companies are having to build bespoke tools to track and store this information or are allowing teams to stand up siloed solutions, which may or may not map to industry standards.

Knowledge transfer and data retention is fragmented. Teams warehouse their own data and documentation is inconsistent – when people leave, so does the information.

BENEFITS

TRACE addresses these challenges by creating a tool that:

- **Saves time and money**. It takes an average engineer about one day of time to collate data for each 3D Printing project. With TRACE, guided workflows make this process easy and intuitive.
- **Helps ensure compliance.** Our tool follows industry standard best practices and is regularly updated to reflect changes in standards from agencies like the FDA and FAA.
- **Enables part traceability throughout the lifecycle.** If there is a problem with a batch of material or question about who touched a certain part, it's easy to quickly trace the parts, in perpetuity.

TECHNOLOGY SOLUTION

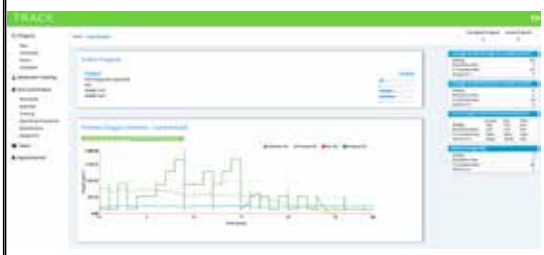
TRACE is a project management for all stages of the 3D Printing workflow to allow for a fully digital repository of 3D files for maintenance and sustainability applications.

We built TRACD to BE SIMPLE and intuitive so the potential of the digital thread can unlocked within your organization -- capturing the data you need for your facility and users to have confidence in your workflows. It all starts with Trace's production dashboard, which is your go-to place to see exactly what's happening with all of your products. It gives you a quick, clear snapshot of active projects, quality analytics, and an inventory of your critical factory management documentation. It's an easy way to quickly assess utilization and progress – but we know users need more. So, Trace also gives you the ability to customize the tool to capture every detail you might need.

So, how does it work? TRACE can help you keep track of your part inventory at all stages of the maintenance and repair processes. This part was marked with a custom and secure tag that ties directly back to the TRACE software. The information embedded in this tag can help staff keep track of things like part numbers, the originating vehicle or assembly, the current location of the part as well as its last service date and current status for instant visibility.

This data is archived and can be quickly referenced both during and after the work has been performed. We've even taken care of reporting for you. With one click the key data is summarized in a professional PDF that can be shared with your team.

GRAPHIC



ADDITIVE MANUFACTURING POWER BY GENERATIVE DESIGN AND SIMULATION

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Problem: Increasing demand for assets reliability, maintainability, parts and materials availability for the field operations and across supply chains, requires end-to-end Additive Manufacturing capability. The multifaceted challenge to ensure high fidelity in parts 3D design, based on different material properties and different 3D printing equipment, combined with request to meet standards and certifications, materials and inventory availability, as well as, production consistency and data management across the Additive Manufacturing workflow, is creating a risk for operational readiness, service and repair logistics and impacts costs and productivity.

Tech Description: PTC Additive and Agile Manufacturing solution is a multidisciplinary Digital Thread Solution offering, based on open framework of connected and interoperable, industrialized software products. The solution connects multiple disciplines: Materials Engineering, Design for Additive Manufacturing, Data and Lifecycle management, Production and 3D Printers management, into one solution. PTC 2D and 3D CAD tools with advanced generative design features help to design and re-engineer complex parts, manage, visualize and connect the data into 3D printers with advanced additive materials. PTC's solution connects and encompasses multiple phases, such as:

- Parts Request & Requirements – Digital Twin models creation, with scanning, reverse engineering, AI-driven generative design and analysis
- Parts Design – advanced material engineering libraries, 2D designs into 3D models conversion, Solids and Lattice Structures analysis, visualization and simulation
- Parts Build Preparation and Processing, with light-weighting and topology optimization, build preparation, plan and processing, simulation and manufacturability analysis
- Parts 3D Print and Production – Optimized Fabrication Management, with MES connectivity, routing transfer, operator and work instructions (also via AR), print authorization and scheduling
- Parts 3D Print Post-Processing – Per-Part post-processing and finishing, with process monitoring, materials and parts tracking, materials supply automation, for an individual or multiple 3D printers.
- Parts Validation and Verification – Digital Twin Quality Analysis, with inspection, build data analysis, materials compliance, quality control against legacy, re-engineered parts and process performance analytics.

PTC solution offering is based on several industrialized software tools, which can be deployed On-Premise or on Secure Cloud infrastructure.

The software is commercially available with out of the box functionality and being utilized by the DoD today.

Next steps/potential benefits: PTC Additive and Agile Manufacturing solution provides the benefits of shortened product development timelines, reduce lead times for manufacturing and many more.

PROBLEM STATEMENT

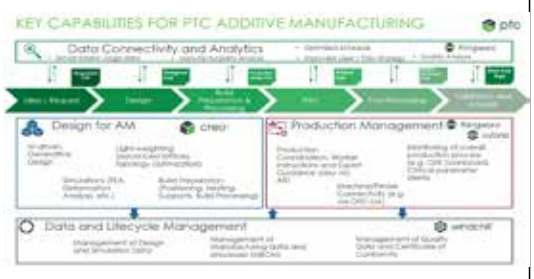
- Lead Time, Cost and Design complexity for Parts prototypes designs.
- Complexity in fabrication of composites structures
- Long cycles for new parts product development, legacy parts retrofits and reverse engineering for unavailable spare parts
- Lack of Simulation and Generative design to improve design accuracy
- Siloed data management approach across AM supply chain
- Production consistency and materials availability

BENEFITS

- Shortened product development cycles – 26%
- Lead time reduction to manufacture spare, alternative, replacement parts - 12%
- Production, Fabrication and Material Cost Reduction – 15%
- Logistics and Service Cost Reduction – 18%
- Parts and Final Assembly Quality Improvement – 10%
- Savings from Parts and Materials Optimization (weight & waste reduction) – 10%-20%

TECHNOLOGY SOLUTION

PTC Additive and Agile Manufacturing solution is a multidisciplinary Digital Thread Solution, based on open framework of connected and interoperable, industrialized software products. The solution includes: Materials Engineering, Design for Additive Manufacturing, Data and Lifecycle management, Production and 3D Printers management. PTC 2D and 3D CAD tools with advanced generative design features help to design and re-engineer complex parts, manage, visualize and connect the data into 3D printers with advanced additive materials.



MAC 50 SHEAVE PULLEY

VAN WEAVER

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In December 2018 the call came to Marine Depot Maintenance Command from CLR15 that the readiness of MAC 50 cranes was dropping severely low. The estimated time to obtain a sheave pulley through the supply system was about six months. The question from CLR15 was could the depot provide a readiness solution?

Conversation over the next several months with MARCORSYSCOM Program Office for MAC50s and LOGCOM created a way forward to make the pulley.

In March MDMC began the re-engineering process. The Creaform Handyscan scanners were employed to replicate the demotions of the pulley. Through hours of scanning and using computer aided drawing software the technical data package for the part was created. The sheave mesh shown below displays the sheave's geometry and groove profile.

In early April the printing of the part began. The print time for the sheave turned out to be 13 printing days plus 4 days of post processing.

In July of 2019 the depot began working with Georgia Tech Research Institute to ensure the powder used in the additive manufacturing process would produce a part that had the same functional characteristics as a cast part from the original equipment manufacturer. Through Functional Operational Specification (FOS) testing GTRI had a high level of confidence that the EOS MS-1 material was a viable replacement candidate for the OEM material when considering part failure due to exceeding the yield strength.

When the part was complete the real tests began when the pulley was shipped to CLR15. CLR15 installed the pulley and began closely watched exercises using the MAC 50 crane. By all accounts, the pulley held up great. This was an excellent example of AM being a readiness multiplier and MDMC being able to provide logistics solutions to the Fleet Marine Force.

PROBLEM STATEMENT

- The United States Marine Corps 50-ton Military All-Terrain Crane (MAC50) has seven sheaves that are integral to the lifting capability of the crane. They are integrated into the crane's boom and hook block.
- The Fleet Marine Force (CLR-15 at Camp Pendleton, CA) was experiencing drastic capability reduction due to lack of sheave pulleys. This reduces the ability to move containers for rapid embarkation.
- A 24-month demand history reveals a shortage of: 108 (USMC) and 101 (DOD).
- There were 28 backordered for the USMC with an estimated delivery date between 212-766 days.

BENEFITS

- Reliability - Tests by Georgia Tech Research Institute (GTRI) provide a high level of confidence that the MS1 Maraging steel used is a viable replacement candidate for the original material.
- Speed to support – 13 day build-time and 4 day post processing time for a total of 17 day order to build time; resulting in a 6 month decrease in wait time.
- Consistency – uniformity is achieved by repeatable process and expert artisanship at the Marine Depot Maintenance Command (MDMC).

TECHNOLOGY SOLUTION

- MAC-50 Sheave pulley was scanned with a Creaform Handyscan 700 laser scanner to aid in reverse engineering and the creation of the tech data package.
- The part was produced using additive manufacturing on an EOS M400-1 metal printer at the Marine Corps depot.
- Post processing and testing were completed by MDMC artisans and GTRI engineers.
- Testing and analysis used on this application can be applied to similar high strength components.

Pulley installed on MAC-50 Crane for CLR-15. (Right)

Marines from CLR-15 install the 3D printed pulley on a MAC-50 Crane for testing. (Left)

Detailed side view of 3D-printed pulley. (Bottom)

MARKFORGED X7 FIELD EDITION

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Supply chain management in forward deployed locations being of the utmost importance, using traditional methods can take from weeks to months for a critical replacement part or component to reach the point of need. Resulting in increased downtime and delays. The DoD faces many challenges supporting its aging aircraft, vehicle fleet and diverse global operations such as part obsolescence, diminishing manufacturing sources, and rising cost of inventory. These can be improved by integrating advanced manufacturing technology.

Through collaboration with the USMC and US Navy, Markforged has optimized our standard X7 COTS printer with rugged packaging and enough material/spare parts to support multiple weeks of forward deployed printing at the point of need. The X7 Field Edition is purpose built to enable end users to deploy 3D printing into theater level maintenance to increase resilience and flexibility. By printing tools and replacement parts for critical equipment the USMC will be able to recover faster when parts break, operate with less local inventory/when existing supply chains are disrupted, and save money from transporting fewer parts around the world.

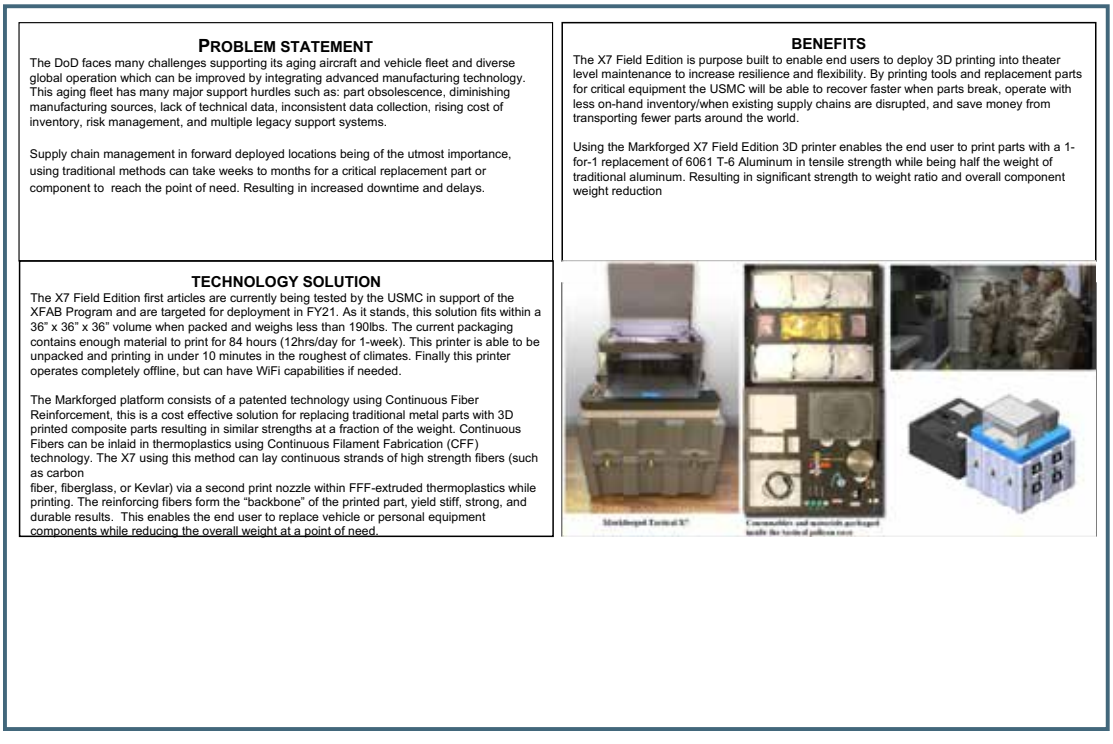
The Markforged platform consists of a patented technology using Continuous Fiber Reinforcement, this is a cost effective solution for replacing traditional metal parts with 3D printed composite parts resulting in similar strengths at a fraction of the weight. Continuous Fibers can be inlaid in thermoplastics using Continuous Filament Fabrication (CFF) technology. The X7 using this method can lay continuous strands of high strength fibers (such as carbon

fiber, fiberglass, or Kevlar) via a second print nozzle within FFF-extruded thermoplastics while printing. The reinforcing fibers form the “backbone” of the printed part, yield stiff, strong, and durable results. This enables the end user to replace vehicle or personal equipment components while reducing the overall weight at a point of need.

The X7 Field Edition first articles are currently being tested by the USMC in support of the XFAB Program and are targeted to deploy in FY21. As it stands, this solution fits within a 36” x 36” x 36” volume when packed and weighs less than 190lbs. The current build contains enough material to print for 84 hours (12hrs/day for 1-week). This printer can be unpacked and printing in under 10 minutes in the roughest of climates. Finally, this printer operates completely offline, but can have WiFi capabilities if needed.

Internal drop tests have been conducted to simulate military testing. The drop test consists of dropping the fully loaded case on each of the bottom four corners from a height of 30”, measured from floor to the corner of impact. The kit has gone through a drop test and survived a 30” drop on each of the four bottom corners while retaining nominal operation and accuracy.

Through this submission we hope to accelerate widespread adoption of forward deployed 3D printing within the DoD.



PROBLEM STATEMENT

The DoD faces many challenges supporting its aging aircraft and vehicle fleet and diverse global operation which can be improved by integrating advanced manufacturing technology. This aging fleet has many major support hurdles such as: part obsolescence, diminishing manufacturing sources, lack of technical data, inconsistent data collection, rising cost of inventory, risk management, and multiple legacy support systems.

Supply chain management in forward deployed locations being of the utmost importance, using traditional methods can take weeks to months for a critical replacement part or component to reach the point of need. Resulting in increased downtime and delays.

BENEFITS

The X7 Field Edition is purpose built to enable end users to deploy 3D printing into theater level maintenance to increase resilience and flexibility. By printing tools and replacement parts for critical equipment the USMC will be able to recover faster when parts break, operate with less on-hand inventory/when existing supply chains are disrupted, and save money from transporting fewer parts around the world.

Using the Markforged X7 Field Edition 3D printer enables the end user to print parts with a 1-for-1 replacement of 6061 T-6 Aluminum in tensile strength while being half the weight of traditional aluminum. Resulting in significant strength to weight ratio and overall component weight reduction

TECHNOLOGY SOLUTION

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AUTONOMOUS YARD TRUCK

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Maintenance support costs within the DoD continue to expand as military operations become increasingly more complex. With critical operations across the globe, manpower and situational readiness are stretched thin. Automation and co-operative autonomous systems will become an invaluable tool in solving these challenges of the future.

One challenge that Ouster is keenly focused on is, "How can we improve yard automation in airports and seaports to drive efficiencies and accomplish more with less manpower? Are there systems that can be designed to act as a force multiplier for our maintenance and support personnel?"

Over the last few years, we have seen immense private sector investment into technologies which enable autonomous systems such as self-driving cars. One of the fundamental enabling technologies to this new wave of robotic autonomy is LIDAR. LIDAR (Light Detection and Ranging) is a type of echo-location technique, similar to Radar, however it uses laser beams instead of radio waves. Millions of laser pulses are emitted from the sensor and return to create a high resolution 3D map of the surrounding geospatial environment. LiDAR was created as the ideal robotic eye and is the fundamental technology that allows computers to visualize and interact with the physical world.

LiDAR sensors have matured quite rapidly and are now seeing commercial deployment in a range of industrial applications. Today, LiDAR sensors are used to help unload container cargo, to help dock marine vessels, and to help monitor shipping yards and flag unauthorized intruders. There is a real opportunity to further automate shipyards, air bases, and maintenance depots with Automated Guided Vehicles (AGVs) to help with common tasks like refueling, cargo loading/unloading, and facility maintenance.

AGVs are flexible and can be designed to accomplish a variety of tasks. One common use of an AGV is as a tugger or puller. Similar to an engine car on a locomotive, the AGV can pull various pieces of equipment on a cart and bring them into position on the yard. By automating the driving and positioning of the equipment, operators save time walking over to the equipment and driving it into position to get ready for its operational task. The AGV can be used to pull into position an aircraft fuel pump, a De-icing system, a payload cart, and many other tools and implements used in naval yards and air force bases.

Ouster is proposing a research and development project to investigate further the use of autonomous systems and equipment within the US DoD. Ouster would be able to offer initial trial unit sensor hardware in support of the project. Ouster could also help with connections to organizations who are working on this technology already in the private sector. Along with the Maintenance Innovation Challenge, Ouster also works with several other branches of the US military & government.

PROBLEM STATEMENT

How can we improve yard automation in airports and seaports to drive efficiencies and accomplish more with less manpower? Are there systems that can be designed to act as a force multiplier for our maintenance and support personnel?

BENEFITS

- LiDAR is the key enabling technology for autonomous vehicles.
- Automated Guided Vehicles (AGVs) can drastically increase the efficiency of yard operations.
- Equipment can be driven into position (or close) to where an operator is waiting.
- Force multiplier allows the operator and maintenance personnel to focus on higher value tasks instead of walking and driving.

TECHNOLOGY SOLUTION

- LiDAR sensor – Light Detection and Ranging.
- Map the area with high definition geo-spatial data points.
- Real-time data enables autonomous systems to navigate safely in unstructured dynamic environments.

GRAPHIC OR IMAGE

ANALYZING MAINTENANCE WORK ORDERS WITH NESTOR

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Maintenance Work Orders (MWOs) provide a semi-structured method of recording information about maintenance activities in an industrial setting. These MWOs often contain information related to the asset, the technician(s) and operator(s), various maintenance times, and information about the problem(s), the cause of the problem(s), and the solution(s) provided. Some of this data is captured in free text fields, which contain misspellings, domain-specific abbreviations, and grammatically incorrect sentences, which makes using out-of-the-box natural language processing solutions difficult. Many researchers have shown the value in parsing this data for various maintenance decisions (Brundage et al. (2019); Sexton et al. (2017, 2018)). This presentation discusses one method called ranked tagging. Ranked tagging cleans the data by:

- Extracting and ranking words from the MWOs
- Clustering words around a common alias
- Classifying words according to a schema
- Automatically annotating the MWOs with the clean data

This ranked tagging method has been implemented in an open-source application called Nestor. Nestor currently uses a schema to classify single words (1-grams) into "Problem", "Solution" and "Item" (Sexton et al. (2019)). Using this classification allows for rules for subsequent multi word (n-gram) combinations (e.g., Hydraulic [Item] + Leak [Problem] = Hydraulic Leak [Item-Problem]).

Brundage, M. P., Sexton, T., Hodkiewicz, M., Morris, K. C., Arinez, J., Ameri, F., ... & Xiao, G. (2019). Where do we start? Guidance for technology implementation in maintenance management for manufacturing. Journal of Manufacturing Science and Engineering, 141(9).

Sexton, T. B., & Brundage, M. P. (2019). Nestor: A Tool for Natural Language Annotation of Short Texts (No. Journal of Research of the National Institute of Standards and Technology).

Sexton, T., Brundage, M. P., Hoffman, M., & Morris, K. C. (2017, December). Hybrid datafication of maintenance logs from ai-assisted human tags. In 2017 IEEE International Conference on Big Data (Big Data) (pp. 1769-1777). IEEE.

Sexton, T., Hodkiewicz, M., Brundage, M. P., & Smoker, T. (2018, September). Benchmarking for keyword extraction methodologies in maintenance work orders. In Proceedings of the Annual Conference of the PHM Society (Vol. 10, No. 1).

PROBLEM STATEMENT

- Maintenance work orders (MWOs) are a historical record of maintenance work performed on different assets.
- Analyzing MWOs can improve maintenance procedure, but, MWOs are difficult to analyze with out-of-the-box solutions because of:
  - Short sentences (e.g., "fan making noise", "bad bearings maybe")
  - Domain specific abbreviations (e.g., hyd = hydraulic = hyds)
  - Misspellings (e.g., replace = repalc = repalcd = replaced = replacing)
  - Missing different data fields (e.g., asset not correctly listed in "asset" column)

BENEFITS

- Analyzing MWOs can lead to improved:
  - Component inventory
  - Capital improvement strategies
  - Dispatching/Scheduling decisions
  - Standard Operating Procedures
- Improving the process to clean and analyze MWOs can lead to high time and cost savings.
- Using text-based data can enhance more traditional data analysis (i.e., MWOs provide context to sensor readings and analysis).
- Analyzing MWOs can help bridge the gap between technicians, management, and analysts by studying how issues are dealt with on the floor.

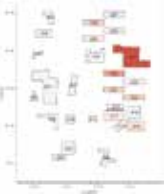
TECHNOLOGY SOLUTION

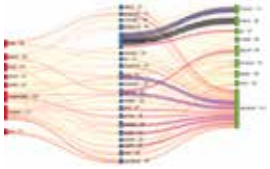
- Nestor is an open-source, free tool developed by the National Institute of Standards and Technology (NIST).
- Nestor uses Natural Language Processing (NLP) Methods to present words in ranked order of importance to address important concepts first.
- This tool intelligently provides a human annotator the ability to determine classifications and similar concepts.
- The tool outputs an annotated MWO dataset in a shorter amount of time than traditional methods for use in analysis.

Nestor website

GRAPHIC OR IMAGE

Discover Problem Hot Spots
Use the output of Nestor to identify problem hotspots using a heatmap. This example shows HVAC problems on the NIST campus.





Investigate Correlations
Investigate linkages for different assets with their components, problems, and solutions.

BEYOND VISUAL LINE OF SIGHT (BVLOS) CAPABILITY ENABLERS FOR UAS'S OPERATING IN DOD RESTRICTED AIRSPACE ENVIRONMENTS

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BVLOS restrictions represent the Achilles heel of Unmanned Aerial Systems and must be addressed to realize the full value of autonomous logistics. Our technology solution combines custom sense and avoid software and precision landing capability onto an existing medium-lift UAS platform. This combination enables safe and reliable operation of UAS's in BVLOS scenarios. The integration of these technology enhancements will serve as a watershed moment that will greatly contribute to fully realizing UAS-based autonomous logistics mission potential. All the hardware and software technologies described here currently exist as COTS products.

Enhanced semi-autonomous flight within and outside BVLOS is made possible through ingestion of Flare Stack mapping data integrated into the flight control software. The Flare Stack applies proprietary algorithms to imagery creating 3-D shape files of static vertical objects. This enables the Kittyhawk to sense and avoid those obstacles along its flight path and remain within established flight zones. A uAvioni PingRX ADS-B receiver will be added to our UAS. The PingRX receives precision position information from surrounding aircraft's ADS-B transponders as directed by the Federal Aviation Administration (FAA). Our team will develop custom software to process this data, identify potential hazardous situations, and give instructions in real time to the flight control software. This will enable our UAS to sense and avoid aircraft in the area and may augment conventional radar solutions. Precision takeoff and landing in BVLOS scenarios is made possible through the addition of an optical/RF sensor package. A QR-code is placed on the landing zone (LZ). The optical sensor on the Kittyhawk will scan for and identify the correct QR-code, and then land within inches of the target. Combining the optical sensor with passive and active RFID tags can further enhance this capability. Combining high accuracy 3D mapping of static obstacles, sense and avoid technologies and precision landing capability, our solution greatly reduces dependence for human-based terminal guidance of a UAV.

Our team will also develop an LZ "Easy Button" feature designed to allow a 'non-pilot customer' on the receiving end to initiate the UAS to return to base after payload is delivered or picked up. Our recommended next steps are to complete Systems Integration work using our UAS to develop a proof of concept and demonstrate the capabilities described herein. Follow-on work should focus on developing these capabilities on other UAS platforms for increased benefit to autonomous logistics via UAS in BVLOS scenarios.

PROBLEM STATEMENT

- BVLOS restrictions represent the Achilles heel of Unmanned Aerial Systems and must be addressed to realize the full value of autonomous logistics. Our technology solution combines custom sense and avoid software and precision landing capability onto an existing medium-lift UAS platform that is capable of payloads above 55 pounds.

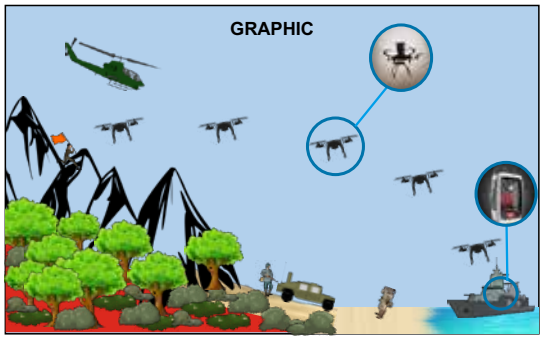
BENEFITS

- **Risk Reduction**: Introduces different means of transport in high risk environments
- **Flexibility**: Creates new options and alternatives for movements and maneuvering
- **Reducing Pack Load**: Relieves weight stress by reducing the size of carried loads
- **Velocity**: Reduces the time in-between resupply and maintenance cycles – more resupplies with less time
- **Optimization**: Streamlines the distribution process by reducing the amount of human interaction
- **Visibility**: Increases in transit awareness and asset tracking

TECHNOLOGY SOLUTION

1. UAS Platform: Kittyhawk, Payload 55lbs, TRL-8
2. Detect and Avoid
   a) Flare Stack Imagery with Machine Learning Output
      - Identifies Obstacles
      - Custom software to integrate with flight computer to create geo-fence (avoidance).
   b) Integrate ADS-B receiver information with flight controller to act autonomously to avoid collision
      - Custom software integration.
3. Precision Landing
   a) Utilizing RFID/QR image to precisely land in an LZ or on ships.
4. Easy Button in Landing Zone or Flight Deck.
   a) Non-pilot can initiate launch sequence at the LZ or on a ship.

GRAPHIC



KYMERA ASSET TRACKING

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Problem: Maintainers and other commercial and government service providers are constantly required to account for the tools or other low density/high value items. Lost or misplaced tools/safety equipment can result in safety issues and excessive costs. Vendor provided tool tracking systems are expensive, proprietary, and require manual interaction. This creates a sub optimized process. Furthermore, these systems have no analog for tracking tools and other assets when in mobile environments such as a utility vehicle.

Approach: IRT in has developed a prototype asset and tool tracking system based on Internet of Things (IoT) Technologies based on open source hardware. The Kymera System architecture can be used for toolboxes, containers, and vehicles. Using IoT, Kymera can provide asset accountability, including last GPS location, over the internet to be viewed either on a computer or smartphone. For vehicles, Kymera accounts for equipment inside the vehicle to include a trunk or bed mounted boxes and containers. Due to its micro-services architecture, Kymera can be scaled to manage entire fleets of containers or vehicles. Kymera contains extremely low-cost IoT brains and unique algorithms to process RFID tagged items in small spaces. Depending on an organization's cybersecurity policies Kymera can connect to the local network, the enterprise network or the Internet. In the case of strict no connection policies, Kymera can be self-contained and battery operated. The Kymera System is currently in the pilot phase.

Benefits: Kymera provides a low-cost solution for automatic inventory and accountability of mission critical tools and equipment. The system also supports automatic asset transfer so that users don't need to interact with the system. Kymera supports improved safety, decreased maintenance and repair cycle times, and reduces the loss of tools and critical equipment

PROBLEM STATEMENT

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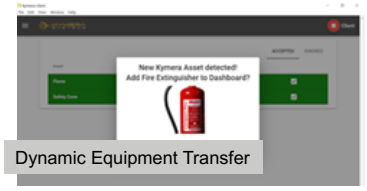
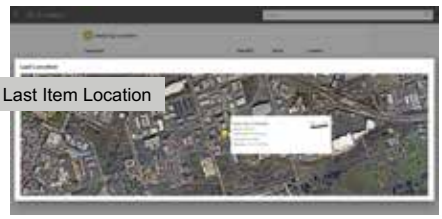
GRAPHIC



Dynamic Equipment Transfer

Kymera Screens



Last Item Location

CTK RFID

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Problem Statement: The majority of consolidated tool kits (CTK) (i.e. where the maintainers go to get tools) are archaic and extremely time consuming. In most places, maintainers have to go to CTK and wait on the 1 or 2 CTK technicians to go get them their tools. This causes long lines and long waits (30 min- 1 hr) at the beginning and end of each shift.

Technology Solution:

- Utilize radio frequency identification (RFID) so maintainers can walk into CTK themselves, grab what they need, and walk out.
- Cameras would be utilized to hold maintainers accountable and show that they actually inspected their tools.
- RFID would be able to autonomously check in and out tools.

Benefits:

- The less time maintainers spend in CTK equals more time on the flight line fixing planes – which equals an increase in aircraft availability.
- Fewer daily frustrations result in greater morale.
- Greater morale results in higher retention and fewer suicides.
- Greater morale also results in maintainers who are more willing to go get the job done, which also increase aircraft availability.
- Fewer maintainers assigned to CTK = more maintainers on the flight line and/or less manning requirements.

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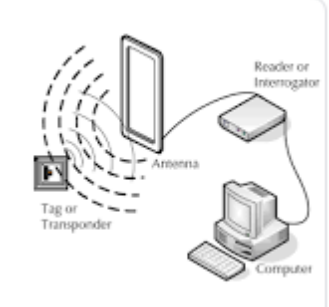
- Fewer daily frustrations result in greater morale.
- Greater morale results in higher retention and fewer suicides.
- Greater morale also results in maintainers who are more willing to go get the job done, which also increase aircraft availability.
- Fewer maintainers assigned to CTK = more maintainers on the flight line and/or less manning requirements.

TECHNOLOGY SOLUTION

- Utilize radio frequency identification (RFID) so maintainers can walk into CTK themselves, grab what they need, and walk out.
- Cameras would be utilized to hold maintainers accountable and show that they actually inspected their tools.
- RFID would be able to autonomously check in and out tools.

GRAPHIC OR IMAGE



VTAG - 'TAGLESS' ITEM LEVEL TRACEABILITY

NARESH MENON

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Item level traceability is needed in tracking components and subassemblies during system maintenance. Current methods include bagging and tagging parts with visible labels that can often be separated from the part during busy maintenance cycles. This results in considerable costs in re-working and re-creating chain of custody. Furthermore, when components are replaced, it is critical to know the provenance of the part in order to protect the assembly from substandard/counterfeit components.

Covisus is an emerging industry-leader in tracking and tracing solutions for products in the global supply chain. Current methods for tracking products rely on physical tags, such as bar codes, QR codes, direct part marking and RFID. Through its proprietary, patented vTag® technology, Covisus offers the only "tagless" tracking technology that does not require any physical marking or tag. A vTag uses intrinsic micrometer scale surface features (texture) of an item to identify it from all other items of its kind. Like a fingerprint, a vTag is unique, unforgeable and intrinsic to the part. It can be applied to individual items of any size or shape made from virtually any material – on parts as small as 4 mm in size. They are invisible, covert and cannot be modified. The vTag system enables parts to be traced back to their origin to verify authenticity or detect tampering.

The vTag® technology was built with funds from the DoD to meet IUID and microelectronics traceability requirements (TRL 8). The technology is in advanced pilots at various DOD (NSWC Crane) and commercial organizations (Boeing, J&J, …)

www.covisus.com

PROBLEM STATEMENT

Maintenance and sustainment requires disassembling, tracking and tracing of components and subassemblies, documentation associated with all work performed and often replacement with parts whose provenance is well known. Currently, the entire process is based on cumbersome manual paper-based steps

Often part/subassembly data is 'lost', require re-working and potential risk of introducing substandard/counterfeits into the full assembly

This is fundamentally because each part/subassembly cannot be easily tracked and traced with existing digital methods.

'Bag & Tag' processes are vulnerable to human error, is slow and arduous

Establishing provenance of replacement components is difficult

BENEFITS

"vTag® creates an intrinsic and immutable link between an item and its data"

vTag® enable cost effective item level traceability.

Because it is based on capturing an image, the process does not require any change to the part and/or packaging.

It works with any part type (metal, ceramic, wood, plastic, rubber, …) and has been validated by DLA to work with a broad range of FSGs

It is rapid (less than 5ms to capture an image), provides complete digital thread, scalable such that one can attach meta-data at the item level

The solution is resilient to normal production/manufacturing environments

TECHNOLOGY SOLUTION

We are a Small Business located in the Los Angeles area who, with pilot funding from the DoD (MDA, DLA, DMEA) have developed 'virtual tags' (vTag®)

vTag® is based on taking a photograph of an item and from it, digitally extracting surface texture. This surface texture is like a 'fingerprint' and is proven to be highly unique to the item level

vTag® is intrinsic to the part, covert, unforgeable, and unique

The technology has been validated by DoD entities as well as the private sector (Boeing, Johnson&Johnson) and has broad applicability at various points in the supply chain

We are compatible with IUID (integrated with DLA database) and meet regulatory standards for DOD microelectronics

TRL 8: In advanced pilots at leading organizations

vTag® solution includes hardware and software
Multiple hardware configurations for different applications

ULTRASECURE INTEGRATED SENSOR PLATFORM FOR MAINTENANCE AND LOGISTICS WORLDWIDE

KEVIN MONTGOMERY

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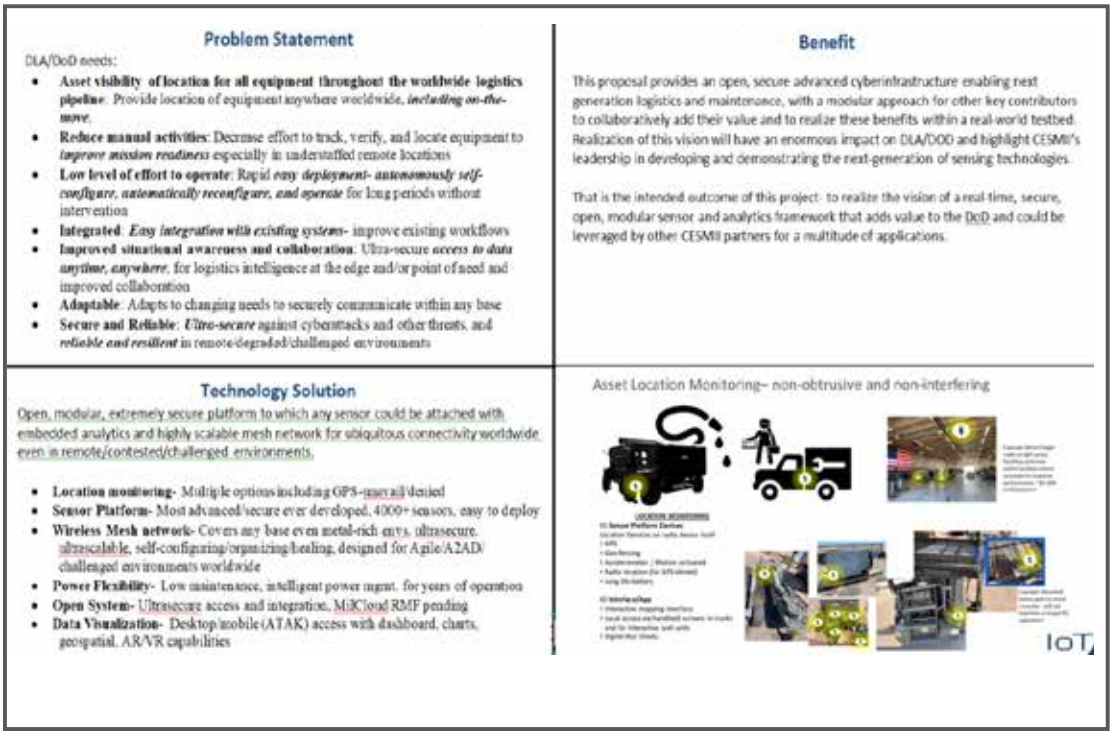
Problem:

DLA/DoD needs:

1. Asset visibility of location for all equipment throughout the worldwide logistics pipeline: Provide location of equipment anywhere worldwide, including on-the-move
2. Reduce manual activities: Decrease effort to track, verify, and locate equipment to improve mission readiness especially in understaffed remote locations
3. Low level of effort to operate: Rapid easy deployment- autonomously self-configure, automatically reconfigure, and operate for long periods without intervention
4. Integrated: Easy integration with existing systems- improve existing workflows
5. Improved situational awareness and collaboration: Ultra-secure access to data anytime, anywhere, for logistics intelligence at the edge and/or point of need and improved collaboration
6. Adaptable: Adapts to changing needs to securely communicate within any base
7. Secure and Reliable: Ultra-secure against cyberattacks and other threats, and reliable and resilient in remote/degraded/challenged environments

Our Solution:

1. Location monitoring: Options include motion activated and time-based location services
   - Fuse sensors (GPS, accel) with geo-fencing, GPS, non-GPS (1-2m), and motion detect natively with layered location techniques
2. Sensor platform: Most secure and advanced ever developed- Supports 4000+ sensors, edge analytics, and transmits on-schedule, event (burst transmit, movement), or demand.
   - Deployed in challenging environments worldwide. Easy, rapid deployment and operation
3. Wireless Mesh Network: Covers any base and supports mobile sensors/tracking. Secure uplink via major military/commercial systems for worldwide coverage
   - Novel radio is extremely difficult to detect or jam, cannot be cracked/spoofed, ultrasecure (TS-level encryption), long-range (10+ miles between stations), highly scalable (up to 10k+ nodes). dynamically-resilient (self-configuring/healing), designed for A2AD/Agile Combat/stealthy/disconnected operations worldwide
4. Energy/Power flexibility: Multiple recharge methods for low maintenance
   - Intelligent power mgmt with keep alive, motion, geo-fencing, and other techniques to improve battery life to years without need of human intervention
5. Open system for integration: Ultrasecure access via Collaborate.mil system
6. MilCloud-based system (NIPR RMF ATO pending) beyond TS security, used by multiple agencies
   - Data Visualization/Interface: Desktop/mobile multi-stakeholder secure access
   - Dashboards, tables/charts, and geospatial features (incl AR/VR). Support for ATAK mobile SA tool for secure, mobile operations anywhere



Status: System TRL 8, comms TRL 9, deployed worldwide incl Balad, JBER, Hickam AFB

Data: Independent validation by Army JVAB, TENCAP, and SLAD labs. Whitepapers avail on performance in industrial (metal-rich), urban, forested, field, and rugged environments

Impact: Open, modular, secure framework has enormous impact and forms a nucleus of innovation for other groups to collaboratively add value

PROCUREMENT WORKFLOW AUTOMATION FOR RESILIENT DOD SUSTAINMENT

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Over the past 30 years, the small to medium-sized US manufacturer has been left behind by the digitization of the supply chain. This resulting bifurcation between large defense contractors and these small mom and pops has resulted in a fragile industrial manufacturing base to support DOD. The dependence and subsequent risk to national security on these smaller manufacturers increases as the average age of the AF aviation fleet matures.

While the small machine shop is struggling to find new business and be discovered, the DOD sustainment apparatus continues to look harder for these same manufacturers. We are developing Sustainment® to address this issue.

Working with the Rapid Sustainment Office (RSO) out of the Air Force Life Cycle Management Center (AFLCMC) at Wright Patterson AFB, OH and the 448 Supply Chain Management Wing (SCMW) and Air Force Sustainment Center (AFSC) at Tinker AFB, OK; Sustainment Technologies has developed an AI-based automated procurement technology to address the issue vendor discovery. The Sustainment® Market Research application is a SaaS-based solution the efficiently connects fragmented ecosystem of 20K+ US machine shops and automates the FAR-based Market Research Process.

The Market Research product is at TRL 7 and began testing and validation with key Supply Chain Management Group (SCMG) end-users at Tinker AFB; Hill AFB; and Robbins AFB in Q3 2020. This AI-based automated workflow solution reduces MR lead times from 14 days to 1 minute. It is predicted to save these AF organizations over 1 million manhours annually.

Other benefits from the technology are a collaborative workflow tool that incorporates messaging, notifications, and resource/best practices library. It also provides in-product analytics to understand and manage market research as a system. Sustainment eliminates swivel time in current processes and encourages collaboration between SMEs. The result is a single-source repository to learn from and build upon prior sourcing and market research activities.

As Sustainment's platform grows, so too will the benefits it provides DOD towards the sustainment mission. Future phases of product growth incorporate an advanced cyber-physical manufacturing procurement system that create a fully networked system of domestic manufacturers. This eventual CNC-based Industrial Internet of Things (IIoT) will allow the entire procurement process from a depot-level demand signal starting the Market Research process to rapid Source Approval Request (SAR) for qualification to automated unit-level part pricing to immediate manufacturing-on-demand that satisfy the requirement and eliminate the mission impaired capability awaiting parts (MICAP) event.

PROBLEM STATEMENT

Sustainment addresses the manual, inefficient systems at the back-end of DOD's manufacturing industrial base. Specifically:
- Manufacturers need to reduce dependencies on foreign suppliers to secure supply chains
- There is no coordinated way for US manufacturers to find the critical suppliers they need at home

This issue manufacturing industrial base fragility is evident by issues facing the 448 Supply Chain Management Wing, Air Force Life Cycle Management Center at Tinker AFB, OK:
- Conducting vendor discovery (i.e., Market Research) takes 14 days per sourcing event on average
- Estimate $1 million per day lost due to excessive lead times
- Estimate 1 million manhours per year lost to inefficient search process

BENEFITS

Immediate benefits of the Sustainment platform:
- Drastic reduction in sole source or no bids (which represents 60% of all sourcing events at Tinker AFB)
- Collapse market research lead times from 14 days to instant
- Automated way to find and engage with small/medium manufacturing vendors
- Identifies set-aside vendors not previously discovered (SDVOSB; WO; HUB; etc.)

Long Term benefits of the Sustainment platform:
- Improved readiness levels
- Predictive analytics of the entire supply chain
- Minimum 20% cost saves on parts via increased competition
- Faster Source Approval Request (SAR) turn-around
- Better ITAR data security via encrypted data transfer protocols

SUSTAINMENT'S SOLUTION

Our technology is a SaaS platform supported by the USAF that efficiently connects the fragmented ecosystem of 20k+ US machine shops with their enterprise customers to enable efficient, secure, onshore, America-first supplier networks.

Sustainment uses AI & an encrypted database to aggregate the demand & supply in the manufacturing processes. This data also creates a real-time geographical visualization of the industrial base and supporting ecosystem.

TECHNOLOGY USE CASE

PARTNERS

RSO · OKLAHOMA Commerce · OKLAHOMA MANUFACTURING ALLIANCE

WORK IN PROGRESS SYSTEMS (WIPS)

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Problem Statement: The success of maintenance and repair facility operations is determined by accountability and efficiency. Every maintenance and repair organization (MRO) is faced with similar challenges to job and work order status tracking, but few MROs have the organic analytical and data management skills to support the systematic translation of raw data into the actionable productivity metrics needed for continuous improvement. Every MRO has a tracking system or work in progress (WIP) systems with a primary function of collecting and track specific details at each stage in the maintenance process. However, most WIP systems alone are not sufficient to address the challenges of the MRO and often lead to additional burdensome tasks for maintenance personnel. The keys to an effective WIP system are transparency for the technician and process optimization. That is what ASI's WIPS solution delivers; an easy to use, data analytics multiplier with minimal disruption in the maintenance flow.

Technology Solution. ASI is pleased to introduce its hands-free work in progress (WIP) system that features minimum infrastructure coupled with radio frequency identification and can address:

- Workload forecasting (and associated resources) based upon supply chain notification
- Where a job is
- How long it takes (at each step)
- Who worked on it
- Backlog monitoring
- Estimated time to completion
- Workload allocation
- Rule-based flexible routing
- Verification of time-sensitive steps such as curing or baking
- Expedited mission critical items

WIPS employs a network of micro-zones and beacons that link the item under repair to the process router (wirelessly) throughout the maintenance process. As a repair component enters the system, the item is tagged with the physical paperwork the item requires throughout the repair process. The beacon network provides a unique ID which links the physical item with sensors to the database. ASI WIPS solution tracks the repair item throughout the repair process and records data in the WIPS database. It also captures status, time in/out at each step, monitors staging areas, and alerts staff when delay thresholds are triggered.

Current Development Status. ASI's WIPS prototype is complete and ready for testing. Early prototypes were successfully demonstrated at Warner-Robins and CCAD.

Proposed Performance Data. Proof of concept implementations have demonstrated to potential for the following:

- 10-15% Improved productivity
- 15-20% Reduction in misrouted components
- 25% Reduction in throughput time
- Improved and additional data availability for continuous performance improvement

Potential Benefits. Andromeda Systems Incorporated (ASI) proposes integration of the Work in Progress (WIP) technology (hardware and software) with DoD maintenance management systems to realize proven benefits from existing users and implement advanced data analysis for continuous performance improvement.

PROBLEM STATEMENT

- Maintenance and Repair Organizations (MROs) require Work in Progress Systems (WIPS) that will improve:
  - Process optimization
  - Data collection at the point of performance
  - Work order status tracking
    - Reduce lost orders, incorrect builds, and delays
  - Provide a means to improve management of items as they move through a facility

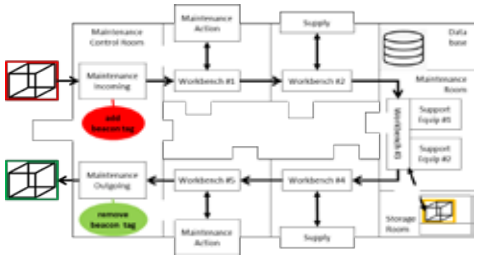
BENEFITS

- Previous implementations have demonstrated the potential for the following:
  - 10-15% Improved productivity
  - ~20% Reduction in misrouted components
  - 25% Reduced throughput time
  - Improved and additional data availability for continuous performance improvement
  - Hands-Free, with no additional burden to the maintenance technician
- WIPS monitors staging areas and alerts staff when thresholds are triggered for shop quality and delays
- ASI WIPS realizes proven benefits above & leverages advanced data analysis for continuous performance improvement, see graphic below for an illustration of WIPS
- WIPS meets the CTMA challenge!

TECHNOLOGY SOLUTION

- ASI's WIPS solution delivers:
  - A network of beacons that wirelessly link the item under repair (wirelessly) to the management database throughout the repair process
  - A tagged component at induction & follows the physical paperwork attached to the item throughout the repair process
  - A transparent repair process
  - Vital information inside & outside the network impacting downtime & availability from the point of performance

GRAPHIC



ADVISOR-GPS DRONE GEOLOCATION SYSTEM

ROB UFFORD

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Problem Statement: Maintenance activities today are faced with managing a multitude of fixed and mobile assets, such as ground support equipment and power stations. Due to size , many of these assets are stored outdoors in distant yards, fields, or lots. Therefore, the task of locating, inventory, and determining the status of these assets is an extremely time consuming and resources intensive task. Traditionally, maintenance and repair activities in every service (USA, USAF, USN, USMC, and USCG) conduct annual wall-to-wall inventories to account for assigned assets. This antiquated inventory process is time-consuming, laborious, fraught with errors and also routinely fails to satisfy the guidelines and mandate of OSD's Financial Improvement Audit Readiness (FIAR) Program.

In addition, most activities use storage yards for maintaining critical assets that can be hundreds of acres in size, too big for electronic management infrastructure and too time-consuming/costly for personnel to physically manage. Andromeda Systems Incorporated's (ASI) Advisor GPS drone-based solution reduces time, improves accuracy, improves resource utilization, and reduces cost associated with asset management for maintenance and repair activities,

Technology Solution: ASI offers a series of drone-based services for both outdoor and indoor operations. Our outdoor solution, ADVISOR-GPS, augments Auto ID data collection with GPS location services. At the time of the auto-id reading, the current GPS coordinates are appended to the data record. ADVISOR-GPS offers two data collection versions:

A. Barcode: ASI utilizes the latest in machine vision, adapting specialized decoding software used extensively in the medical industry. The solution simply taps into an off-the-shelf drone imaging and GPS system for the data collection.
B. RFID: ASI augments a drone with 1) RAIN RFID reader (UHF RFID) (reads passive UHF tags including long-range on-metal tags) and 2) HGA RFID antenna. The GPS coordinate will be paired with the RFID read.

Current Development Status: The underlying vision decoding software has been widely deployed in the medical lab testing industry tracking over twenty million items per year. ASI's ADVISOR-GPS version is currently undergoing pre-market testing and quality control.

Supporting Performance Data: Initial testing has demonstrated GPS accuracy +-4 meters. Real-time asset visibility from autonomous vehicles is projected to be a major part of the digital innovation enabling a new logistics paradigm called "Logistics 4.0".

Next Steps / Potential Benefits: Andromeda Systems Incorporated proposes to integrate the ADVISOR-GPS solution for yard management and logistical support. Detailed analytics for collected data will also be supplied along with anomaly management actions. The real-time asset visibility will enable optimized utilization and management of assets, both in garrison and deployed environments.

PROBLEM STATEMENT

- Maintenance and Supply facilities are faced with managing a multitude of fixed and mobile assets. Assets are often located outdoors in distant yards, fields, or lots. It is a challenging and resource intensive task to locate, inventory, and assess the status of these assets.
- Storage lots can be hundreds of acres in size, too big for electronic management infrastructure and too time-consuming/costly for personnel to physically manage. In addition, manual inventory efforts are often inaccurate.

BENEFITS

- Until recently the most prevalent approach to managing trailers, vehicles and other high-value assets in the yard has been to depend on all-manual, resource-intensive processes to track their location and status, often leaving the integrity of data compromised due to human error and the non-real-time nature of such processes
- ADVISOR-GPS is able to geo-mark field assets to less than 4 meters. It can also interrogate on-board sensors in a SWST (speak-when-spoken-to) architecture. Additionally, t he real-time asset visibility will enable optimized utilization and management of deployed assets.

TECHNOLOGY SOLUTION

ADVISOR-GPS offers two data collection versions:

- Barcode: ASI utilizes the latest in machine vision, adapting specialized decoding software used extensively in the medical industry. The solution simply taps into an off-the-shelf drone imaging and GPS system for the data collection.
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GRAPHIC

Options for active sensors; passive RFID; and barcode (through machine vision).

DEVELOP A DIGITAL TWIN OF A WEAPON SYSTEM

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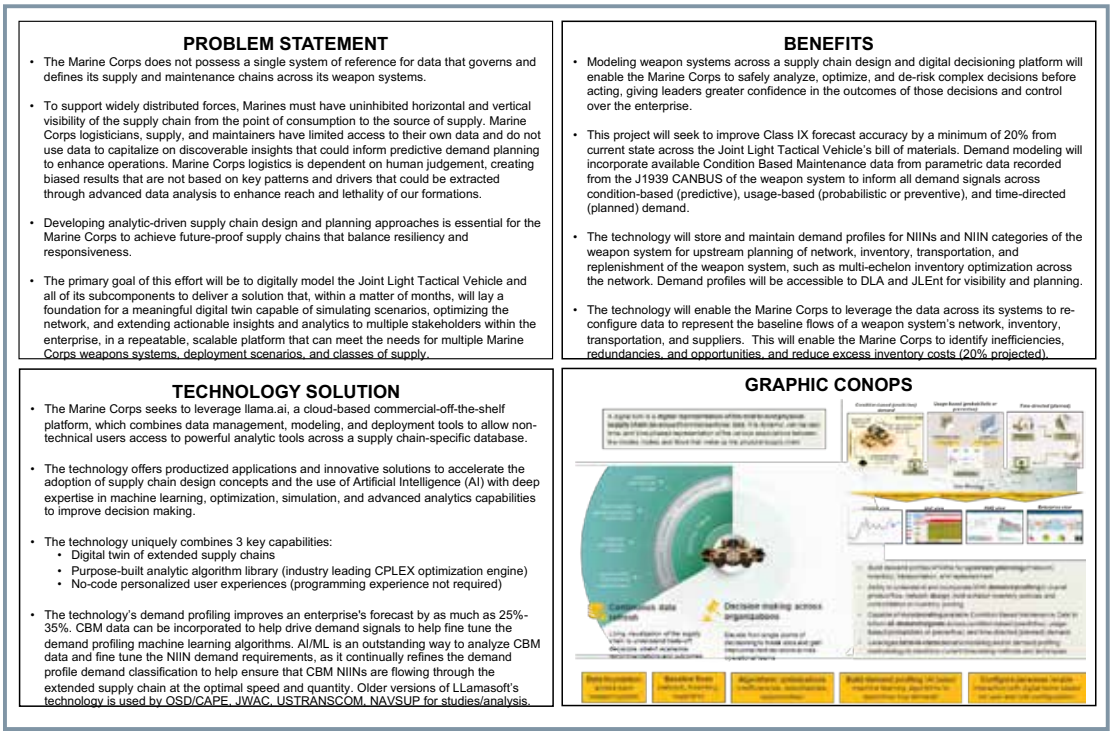
Overview: The USMC has achieved an operationalized state across the full spectrum of Condition Based Maintenance (CBM) (collect, transmit, analyze, act) for 10 Joint Light Tactical Vehicles (JLTV). To realize the benefits of CBM across the CL IX supply chain, an end-to-end supply chain digital twin and AI-enabled demand modeling effort will be synchronized with JLTV CBM data collection efforts to maximize operational availability while reducing overall sustainment costs across the entire network of JLTVs.

Goal: The primary goal of this effort is to demonstrate how a supply chain design and modeling technology can lay a foundation for a meaningful digital twin capable of simulating scenarios, optimizing the network, and extending actionable insights and analytics to multiple stakeholders within the enterprise, in a repeatable, scalable platform that can meet the needs for multiple weapon systems.

Technology: The USMC will leverage llama.ai, a cloud-based supply chain design and modeling technology, which combines data management, modeling, and deployment tools to allow non-technical users access to the power of modeling and analysis. Data across enterprise, DLA, and suppliers will be brought together into a single, unified, supply chain-specific database. This curated data describes the sustainment supply chain of CL IX repair parts and forms the basis for creating a digital twin of the real-world supply chain through enumeration of the designed network in context of designated policies, constraints, and other details of the JLTV acquisition and sustainment chains. This technology will enable a true end-to-end view of the global supply chain where analysis, scenario testing, and decisions are conceived and executed across strategic, operational, and tactical time horizons across a weapon system's Total Life Cycle Systems Management.

End state: Given a curated data foundation, the USMC will use llama.ai to visualize the end-to-end supply chain of the JLTV, develop network, inventory, and simulation models of the supply chain, and develop deployable, persona-based apps to exploit the power of modeling and analysis to aid decision making across the spectrum of stakeholders.

Benefits: Demand modeling will help the USMC with its CL IX forecasting challenges. A possible outcome may be predicting the CL IX blocks to be generated as a result of deployments and exercises. This can potentially revolutionize the planning and management of repair parts forecasting to DLA, 3PL providers, OEMs, and joint partners. A second outcome is the USMC will build demand profiles by NIIN using AI/ML based algorithms to determine the true demand of the various components of the weapon system; incorporate available CBM data to inform all demand signals across condition-based (predictive), usage-based (probabilistic or preventive), and time-directed (planned) demand. This may lead to predictive insights and understanding for a variety of future state conditions.



PROBLEM STATEMENT

- The Marine Corps does not possess a single system of reference for data that governs and defines its supply and maintenance chains across its weapon systems.
- To support widely distributed forces, Marines must have uninhibited horizontal and vertical visibility of the supply chain from the point of consumption to the source of supply. Marine Corps logisticians, supply, and maintainers have limited access to their own data and do not use data to capitalize on discoverable insights that could inform predictive demand planning to enhance operations. Marine Corps logistics is dependent on human judgement, creating biased results that are not based on key patterns and drivers that could be extracted through advanced data analysis to enhance reach and lethality of our formations.
- Developing analytic-driven supply chain design and planning approaches is essential for the Marine Corps to achieve future-proof supply chains that balance resiliency and responsiveness.
- The primary goal of this effort will be to digitally model the Joint Light Tactical Vehicle and all of its subcomponents to deliver a solution that, within a matter of months, will lay a foundation for a meaningful digital twin capable of simulating scenarios, optimizing the network, and extending actionable insights and analytics to multiple stakeholders within the enterprise, in a repeatable, scalable platform that can meet the needs for multiple Marine Corps weapons systems, deployment scenarios, and classes of supply.

BENEFITS

- Modeling weapon systems across a supply chain design and digital decisioning platform will enable the Marine Corps to safely analyze, optimize, and de-risk complex decisions before acting, giving leaders greater confidence in the outcomes of those decisions and control over the enterprise.
- This project will seek to improve Class IX forecast accuracy by a minimum of 20% from current state across the Joint Light Tactical Vehicle's bill of materials. Demand modeling will incorporate available Condition Based Maintenance data from parametric data recorded from the J1939 CANBUS of the weapon system to inform all demand signals across condition-based (predictive), usage-based (probabilistic or preventive), and time-directed (planned) demand.
- The technology will store and maintain demand profiles for NIINs and NIIN categories of the weapon system for upstream planning of network, inventory, transportation, and replenishment of the weapon system, such as multi-echelon inventory optimization across the network. Demand profiles will be accessible to DLA and JLEnt for visibility and planning.
- The technology will enable the Marine Corps to leverage the data across its systems to re-configure data to represent the baseline flows of a weapon system's network, inventory, transportation, and suppliers. This will enable the Marine Corps to identify inefficiencies, redundancies, and opportunities, and reduce excess inventory costs (20% projected).

TECHNOLOGY SOLUTION

- The Marine Corps seeks to leverage llama.ai, a cloud-based commercial-off-the-shelf platform, which combines data management, modeling, and deployment tools to allow non-technical users access to powerful analytic tools across a supply chain-specific database.
- The technology offers productized applications and innovative solutions to accelerate the adoption of supply chain design concepts and the use of Artificial Intelligence (AI) with deep expertise in machine learning, optimization, simulation, and advanced analytics capabilities to improve decision making.
- The technology uniquely combines 3 key capabilities:
  - Digital twin of extended supply chains
  - Purpose-built analytic algorithm library (industry leading CPLEX optimization engine)
  - No-code personalized user experiences (programming experience not required)
- The technology's demand profiling improves an enterprise's forecast by as much as 25%-35%. CBM data can be incorporated to help drive demand signals to help fine tune the demand profiling machine learning algorithms. AI/ML is an outstanding way to analyze CBM data and fine tune the NIIN demand requirements, as it continually refines the demand profile demand classification to help ensure that CBM NIINs are flowing through the extended supply chain at the optimal speed and quantity. Older versions of LLamasoft's technology is used by OSD/CAPE, JWAC, USTRANSCOM, NAVSUP for studies/analysis.

GRAPHIC CONOPS

AUGMENTED REALITY TECHNOLOGY

CHRIS BLUE

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ITHENA has been developing State-of-the-Art Augmented Reality Applications, (AR), for more than 7 years. With our expertise in AR, MR and VR, our applications bring future into the palms of our users. Built on PTC's Vuforia platform, our AR suite is Device Agnostic and works on a wide variety of devices like Smartphones, Tablets, Smart Glasses, Head Mounted Displays, etc. The efficiency that our AR technology brings to our clients is highly valuable. Your team can work together 'as if they were together,' which saves time, money and subject matter expert's time as well.

iAssist – AR Application for Remote collaboration. iAssist brings you the help when you need it the most. The possibility of getting assistance in the field from a Remote Expert enables instant knowledge exchange. The technology enables better and faster decision making, thereby reducing downtime and enhancing Customer Experience. The business benefits include reduction in operational expenses, travel expenses and enables exchange of tribal knowledge.

iInspect – iInspect, is Ithena's AR solution that is used for Service, Repairs and Maintenance Operations. The key features include Guided Repairs + Maintenance. iInspect, is our solution that provides Electronic Work Instructions to operators to follow Standard Operating Procedures to conduct repairs and maintenance activities. This also includes OTS Training, (On-the-Spot), by providing guided instructions with 3D Models and Videos.

Our application provides many ways for remote collaboration between the distant expert, and local operators or technicians. This replaces traditional ways of providing support & training to field technicians. Other benefits include:

- Reduced human errors
- Reduced execution time
- Reduced breakdowns
- Reduced downtime
- Reduced cost
- Increased productivity
- Accelerate problem resolution
- Improve up-time
- Increased compliance
- Increased profit
- Empower your workforce to solve issues!

PROBLEM STATEMENT

- What problem or need does this technology solve?

Maintenance plays a very important role in the industrial sector. Since it has a direct influence on performance, productivity and product quality (not to mention profit and reputation), maintenance is a craft that is always being improved and perfected over time. And, rest assured, the current innovation in maintenance is **augmented reality technology.** Augmented reality, (AR), in a nutshell, allows users to enhance their field of view with real-time superimposed digital information. But, more than that, it is a valuable solution for many of the challenges which surround industrial maintenance, repair, and operations.

BENEFITS

- Reduced human errors
- Reduced execution time
- Reduced breakdowns
- Reduced downtime
- Reduced cost
- Increased productivity
- Increased operation speed
- Increased fix rates
- Increased compliance
- Increased profit

Facts and Results from AR Suite

- 25% reduction in Production Time
- 15-20% Avg efficiency improvement
- 46% increase in warehouse productivity with ITHENA AR Suite

TECHNOLOGY SOLUTION

ITHENA AR Suite is AR engine Agnostic, meaning it supports both, Licensed as well as Open Source AR engines, ranging from Vuforia, Unity, Wikitude, etc.
The Solution has 4 main applications –
iInspect – Guided Repairs and Maintenance. Provides Electronic Work Instructions to follow a set of SOPs. Includes 3D models and CAD Designs.
iAssist – Remote Collaboration and Service. Access to Remote service technician and SMEs by utilizing full-duplex audio communication as well as Video Communication along with chats, on-screen annotations, etc.
The AR Suite works on more that 90% modern devices, ranging from Smartphones, Tablets/iPads, Smart Glasses(Vuzix, Hololens, RealWear, Epson, etc.)

GRAPHIC

BILL OF MATERIALS (BOM) PDF SCRAPER

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Within his planning guidance, the 38th Commandant of the Marine Corps, General David Berger, states "For the Marine Corps, meaningful innovation is not just having great thoughts and concepts rather, it is about translating great thoughts and concepts into action." As this pertains to maintenance operations, any actioned "great thought" should be one that saves resources (e.g. time, money) while still completing required tasks at the appropriate output and quality level. This innovation is one which pairs practicality with modernity, allowing our artisans more time to focus on maintenance operations rather than manually scanning technical manuals to consolidate the parts information required to do their work.

The necessity to generate accurate Bills of Material (BOM) prior to conducting maintenance operations presents an additional time burden for each different maintenance process, contributed largely the requirement to reference multiple Technical Manuals (TM) and other related publications. This project, a collaborative effort between the Marine Depot Maintenance Command (MDMC), Marine Corps Logistics Command (MARCORLOGCOM), and Georgia Technical Research Institute (GTRI), originated as an opportunity to automate data extraction for special-case documents in support of Depot Maintenance operations.

The technical approach for this project began with the design of a Java-based, easily installed application, compatible with target PCs. The application, which requires minimal user orientation or training, parses PDF copies of technical manuals and other maintenance-related documents in order to identify and extract tabular data. While extracting the tabular data, the goal is to identify the useful tables (e.g. parts lists) vs non-useful tables and filter them out as part of the automated process, while also re-formatting tables into a unified format, filling in various input fields. When perfected, this tool will automate this selection, thereby reducing required steps for the user. The design and implementation of a Graphical User Interface allows the tool's user to verify, adjust, and/or correct the automated data extraction as required, in order to consolidate into a singular BOM. Upon completion, the data is compiled into a signed exportable file for use by artisans.

Moving forward, with additional testing feedback from MDMC staff, the prototype application will continue to be refined for improved functionality. Additional applications for this tool would include the similar consolidation of SL-3 publication's data, documents that list all associated parts for an end item. Further, the BOM Scraper functionality has potential applications at the intermediate level of maintenance.

PROBLEM STATEMENT

The necessity to generate accurate Bills of Material (BOM) prior to conducting maintenance operations presents an additional time constraint associated with each job, as well as a potential requirement to reference multiple Technical Manuals (TM) and other related publications.

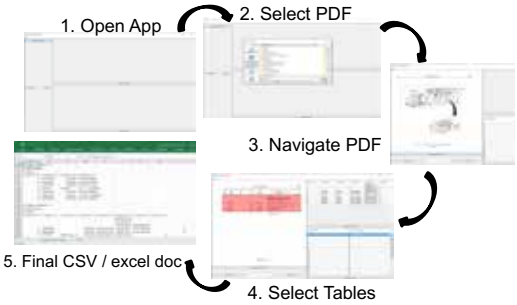
BENEFITS

- Final application will automate the manual process of extracting parts lists from technical manuals and other maintenance-related publications
- Parts list will be consolidated into a machine-readable spreadsheet.
- Reduction of labor hours associate with reverse engineering publications and technical manuals to create a BOM
- Improve the speed and accuracy of parts forecasting and procurement

TECHNOLOGY SOLUTION

- Design of an Operations Research (OR) tool that extract unclassified PDF text and deliver it in CSV or Microsoft Excel format
- Design and implement a Java application that parses PDF documents, extracts tabular data, and exports formatted BOM information
- Design a Graphical User Interface (GUI) that allows user to verify or correct automated data extraction for special-case documents

GRAPHIC OR IMAGE



USING AI/ML TO FORECAST DOD MAINTENANCE COSTS

ANTHONY BROWN

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Problem Statement: Maintenance costs are unpredictable, making planning and budgeting difficult. Teams are often overwhelmed with data, rapid market changes and resource constraints.

Organizations need resources to better forecast and predict maintenance cost and resource needs in a way that improves accuracy, scales to meet organizational needs and improves human productivity.

Description of the Technology: Complete Intelligence's (CI) technology platform uses advanced artificial intelligence and machine learning (AI/ML) to forecast costs and revenues. It combines enterprise data in a secure environment with billions of data points across global economic, market, industry, and other data

Current Development Status of the Technology: CI is an early stage firm with one commercially available product, CI Futures, that forecasts 800+ commodities, currencies, and equity indices. Based on its mature technology platform, CI is developing two other products: CostFlow™ and RevenueFlow™. CI plans to apply its technology platform knowledge from CI Futures to DoD specific cost or data points. CI has been funded with $1.125m. CI has Co-Sell Partnerships with Microsoft, Oracle, Bloomberg and Refinitiv.

Test Data Supporting Performance Claims: We have tracked our accuracy for three years vs consensus (industry experts, economists, and banks) forecasts. 84% of our forecast has less than <5% error and 97% has less than 10%.

Potential Benefits: The objective of this engagement is to demonstrate CI's key capabilities to improve accuracy of DoD maintenance cost planning through our AI/ML-driven technology platform. Working with CI will enable the DoD to utilize existing data sets to better plan and identify revolutionary, accurate, and practical approaches to maintenance cost decisions. This will help the Maintenance Executive Steering Committee and Joint Group on Depot Maintenance apply new technology for more agile, effective, and affordable resourcing strategies and business practices.

Next Steps: We recommend testing a limited number of maintenance and resourcing cost areas and developing a limited statement of work. We will identify source data and receive data by integrating directly with DoD's historical data. Once data sets are received, CI will run its technology platform to test and validate for completeness, process, and forecast the in-sample results, and compare against actual data to identify error rates. Upon conclusion of this discovery pilot, CI will produce a report outlining the methodology and approach, findings from the discovery pilot, conclusions, and recommendations, as well as next steps.

Cross-Service Applicability: The mature technology platform can not only be applied to maintenance, but the CI Futures can be specifically applied to DoD purchases such (e.g. rubber, gas, oil, food, steel, raw materials, components, etc.)

PROBLEM STATEMENT

Maintenance costs are unpredictable, making planning and budgeting difficult. Teams are often overwhelmed with data, rapid market changes and resource constraints. Organizations need resources to better forecast and predict maintenance cost and resource needs in a way that improves accuracy, scales to meet organizational needs and improves human productivity.

BENEFITS

The objective of this engagement is to demonstrate Complete Intelligence's (CI) key capabilities to improve accuracy of DoD maintenance cost planning through our AI/ML-driven technology platform. Working with CI will enable the DoD to utilize their existing data sets to better plan and identify revolutionary, accurate, and practical approaches to maintenance cost decisions.

TECHNOLOGY SOLUTION

Complete Intelligence's technology platform uses advanced artificial intelligence and machine learning (AI/ML) to forecast costs and revenues. It combines enterprise data in a secure environment with billions of data points across global economic, market, industry, and other data. It performs hundreds of millions of calculations to deliver a continuously updated view on an organization's specific cost expectations factoring in impacts of millions of relationships, seasonality, periodicities, and volatilities across geographies, industry sectors, economic concepts, currency markets and global price factors.

Asset Name	Consensus Error			CI Error		
	Jun-19	Sep-19	Dec-19	Jun-19	Sep-19	Dec-19
Brent Crude	16.1%	19.6%	19.2%	0.3%	1.5%	2.0%
WTI Crude	15.3%	11.5%	12.3%	3.9%	4.5%	4.5%
Natural Gas	32.0%	19.6%	18.5%	11.8%	1.2%	9.2%
Coal	32.6%	36.5%	33.0%	11.0%	3.3%	6.6%
Uranium	22.9%	21.0%	25.5%	0.6%	2.4%	1.9%
Aluminum	19.1%	19.4%	21.1%	2.2%	0.6%	0.6%
Copper	21.6%	26.2%	24.0%	0.3%	1.5%	0.8%
Nickel	11.7%	22.1%	8.1%	21.6%	10.9%	5.6%
Lead	11.9%	1.6%	4.7%	5.0%	2.0%	0.2%
Zinc	6.1%	12.1%	11.5%	4.1%	3.4%	1.3%
Tin	4.9%	19.9%	23.7%	10.2%	2.6%	0.4%
Steel	4.9%	4.2%	15.6%	2.8%	0.1%	0.3%
Iron Ore	39.5%	32.5%	24.2%	16.0%	3.2%	7.6%
Gold	7.6%	15.1%	11.9%	9.3%	2.1%	0.8%
Silver	3.6%	12.0%	6.0%	5.7%	3.9%	5.7%
Platinum	7.7%	5.8%	0.8%	2.3%	5.1%	3.1%
Palladium	23.5%	31.0%	38.1%	11.5%	3.4%	12.2%
	16.5%	18.2%	17.5%	7.0%	3.0%	3.7%

RAPID ASSET CONSTRAINT RESOLUTION (RACR)

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Problem statement: Depot maintenance success is determined by how well it sustains warfighter demand through delivery of quality products on time, and at cost. A governing factor in meeting that need is the ability to identify and resolve constraints. Unresolved constraints (UC's) are the greatest barrier to throughput, effectiveness, efficiency, and they restrict capacity. UC's conceal true proficiency and are demoralizing apathetic culprits of logistical entropy. Conservative estimates suggest an economic toll greater than $5M per year due to UC's, while those buried beneath remain undiscovered and are an incalculable burden.

The technology: Rapid Asset Constraint Resolution (RACR) is a system that facilitates resolution from the perspective of the constraint. The initiator (technician) brings a discrepancy to the Level 1 Agile Cell where it is resolved on-the-spot, or input into RACR as a constraint. The technician then returns to work on a different task, while RACR's tiered algorithm sequentially identifies, characterizes and documents the constraint, then energizes and activates the necessary organizational and prime contract partner resources to develop and achieve resolution at the required level.

Status of Development: After two years of maturation in AMXG, gaining prime partner build-in including DLA, Lockheed, and others, RACR is currently being deployed across all Groups as a Complex initiative. The RACR algorithm has been coded into production software (Impresa) with an agile support framework. Collaborative neural support networks and business rules are growing organically as needed. Users identify deficiencies and propose improvements through a central node to be standardized and flowed to the software support team for update, under guidance of RACR doctrine.

Supporting Data: In 1.5 years of development and demonstration, RACR completely restructured constraint resolution approach, and harnessed workforce ability to 'fix bad things'. Six month prototype beta test returned 178 days of aircraft availability to the warfighter in one squadron and observed an aggregate increase of ~37% (Based on comparison of days over AMREP prior and post RACR implementation). A years-old unresolved constraint (Egress cannibalizing @ $250k per unit) was input into RACR, elevated to AFSC/CC, and finally resolved.

Next Steps/Potential Benefits: As a climate driver, RACR represents state-of-the-art in continuous process improvement, and is optimized for active duty/civilian/industry environments. RACR increases efficiency through empowering the technician to clear the fog of production by capturing and resolving constraints at the necessary level. RACR aligns and focuses resources at each tier which drives help-chain networking. RACR balances responsibility, authority, and accountability with an automated, documented structure, and has paved a standard path for constraint resolution from shop floor up to Center (AFMC) and beyond. RACR

PROBLEM STATEMENT

- OO-ALC lacks a robust standardized method for identifying and resolving constraints
- Toll of unresolved constraints (UC's) exceeds $5M per year
- (UC's) are demoralizing and impede development
- Constraints buried beneath those unresolved remain undiscovered and incalculable
- Critical shop floor issues can take years (if ever) to bubble up to command level necessary for awareness and resolution to take place
- Problem creep causes significant resolution delay
- Inaccuracies due to the fog of production are challenging to leaders making decisions

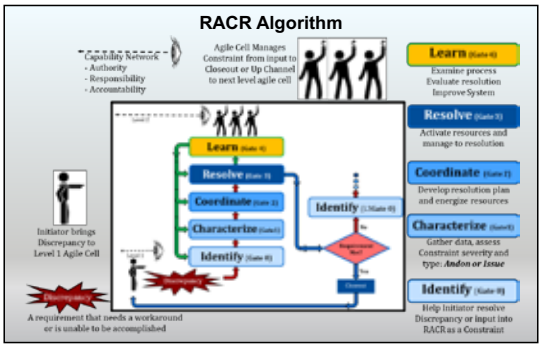
BENEFITS

- Six-month beta test returned 178 days of aircraft availability to the warfighter
- Long term egress cannibalizing @ $250k/unit elevated to AFSC/CC and resolved
- Empowers the technician by facilitating build-in of results
- Clears the fog of production which enhances engagement
- Aligns and focuses resources on constraint resolution
- Balances responsibility, authority, accountability
- Prevents problem creep
- Enhances leadership by increasing organization transparency
- Provides standard path for constraints from floor to AFMC
- Enthusiastic support from OO-ALC/CC & AFMC/CC

TECHNOLOGY SOLUTION

- **RACR** is the OO-ALC standard for resolving constraints
- Gated measured documented problem solving performance
- Captures, communicates, and resolves constraints
- Well-defined intra-organizational collaborative business rules
- Resolution path mapped from constraint perspective
- Standardized help chain from shop floor to AFMC & beyond
- Success is determined by the difference in time

RACR Algorithm



MORE EFFECTIVE USE OF TECHNOLOGY IN SUPPORT OF SERVICE LIFECYCLE MANAGEMENT IS CRITICAL FOR LONG-TERM ASSET UTILIZATION

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CIMdata proposes the definition of a pilot PLM/SLM Augmented Reality environment supported by a robust Digital Twin/Digital Thread concept. The burden of maintaining mission-critical, highly customized, and sophisticated materiel while in theatre is a common challenge across the DoD Services (Armed Forces). Expanding global threats plus the burden technical innovation places adds to the challenges to adapt to new & sophisticated materiel, the technology embedded within the products themselves, and the support infrastructure technology present challenges that cannot be met with technology alone. Service operations and overall approaches to (SLM) are undergoing significant changes. New technologies are provoking stress to SLM. Additionally, initiatives like Industry 4.0 seek to leverage technologies and while examples exist that readily attest to the potential of the individual categories, to effectively use them together for greater effectiveness is rarely found.

Missing piece of the puzzle, key to doing so, is existence of robust, comprehensive end-to-end PLM framework. An end-to-end PLM strategy that spans a product's full lifecycle, from conception to final disposal, is essential to the servicing of the product and optimizing its use while maintaining its availability. A comprehensive PLM strategy addresses and incorporates processes and information from all domains of the extended enterprise, including partners, suppliers, and customers that impact how a product and/or system is designed, developed, manufactured, delivered, operated, and serviced. It ensures that all related information is properly linked and maintained in a valid and consistent manner so that it can be used as needed by whomever needs it to perform their tasks. Without such a strategy no digital thread, necessary for the existence of the digital twin, can be effectively operate from which service personnel can obtain the up-to-date configuration and technical information needed for servicing the product.

Essential to creating the complete digital thread is having closed loop feedback from service (i.e., from in-field use and maintenance) to design, engineering, and manufacturing. Documented performance improvements resulting from the implementation of a comprehensive strategic PLM framework show measurable benefits that range from 10% to 90% improvement in various parts of the product design and engineering tasks when CIMdata's PLM Transformation methodology has been deployed. Access to data that is clear, concise, and valid is equally critical when servicing in-theatre materiel and can result in equipment being returned to reliable service faster and with more confidence. A comprehensive PLM/SLM strategy, and roadmap for its implementation is affordable – and mandatory – to the support of the warfighter community across the DoD Services spectrum.

PROBLEM STATEMENT

- Constant evolution of technology continues to have a major impact on Service Lifecycle Management. As technologies emerge and/or mature the ability to adapt and change, how an organization meets service delivery challenges in what historically has been a reactive and unplanned manner is critical.
- Integrating new technology into a dysfunctional supporting product development framework sub-optimizes the investment itself.
- As the technology landscape continues its rapid evolution every aspect of materiel and its lifecycle is impacted.

BENEFITS

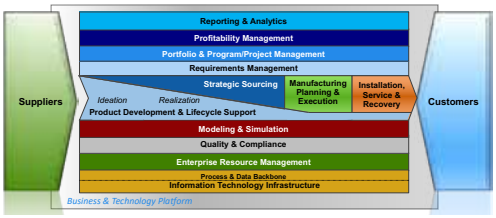
- A more effective service organization that meets the warfighters' needs and expectations.
- Reduced cost and time to "return to duty" status.
- Better "in-service" up-time and thus a better ROI.

TECHNOLOGY SOLUTION

- The well thought out implementation roadmap of new SLM capabilities into the existing communication framework will allow a connected data flow and an integrated view of an asset's data throughout its lifecycle across the traditionally siloed functional perspectives.
- Proven Enterprise Application Architecture (EAA) concepts enable both the SLM strategy, as well as providing improved product performance, and thus serviceability, for future products that support the warfighter.

GRAPHIC

- The correct EAA configuration for the operational entity is critical (CIMdata's EAA model is depicted here).



VIRTUAL MANUFACTURING & DATA INTEGRATION TOOL

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The U.S. Air Force's Air Logistics Complexes have over hundreds of repair and overhaul processes. Management needs to improve productivity of repair and manufacturing product lines to reduce costs and increase material availability. Management would like to benchmark repair process performance, conduct "what if" analyses of proposed changes, have more data to aid strategic decisions, and adopt "Advanced Manufacturing" technology. Challenges: No existing manufacturing process models; Process data is stored in data systems that make the data hard to use. Data is not accurate enough to be reliable; Manual data collection processes; Tight integration of process steps makes on-the-fly modifications or experimentation difficult.

The Virtual Manufacturing & Data Integration Tool (VMDIT) is a 3D virtual model of the manufacturing environment with integrated manufacturing/overhaul process simulation. This tool's models are a platform for a "smart factory" & advanced manufacturing technologies. The virtual environment enables rapid digital and physical transformation of manufacturing operations using Siemens Tecnomatix Plant Simulation software tools. Functionality includes process benchmarking, process simulation experiments, test scenarios to improve the manufacturing system, virtual commissioning, reconfigure manufacturing facilities, social distancing simulations.

Benefits include: Reduced investment in planning of new or reconfigured facilities and processes; Improve productivity of existing facilities and processes; Increase responsiveness to changing conditions; Evaluate arrangements and configurations of the machines and how they affect the system's productivity; Build quantitative business cases for proposed process and facility changes using simulation data; 3D model becomes a virtual asset for the entire organization enabling AR/VR capabilities; Reduces engineering planning time; Improves communication of changes; Enables virtual commissioning of new equipment / processes; enables virtual and remote work capabilities.

This project is currently in a Phase II SBIR at WR-ALC and is being used to benchmark and improve the C-130 propeller overhaul process, which is a multi-service repair and overhaul line which has recently been redesigned with many additional processes and inspections added. These added process steps have increased the complexity of the process, but no physical reconfiguration of the manufacturing assets on the floor of the 402nd Commodities Maintenance Group was contemplated. The result is a disjointed process requiring the movement and transportation of blades and barrels across the facilities to complete various process steps.

The VMDIT tool is being used to study and document the business case for relocating dedicated machines involved in this overhaul process to one contiguous area withing the 402nd CMXG. The tool has shown how the average distance a blade travels throughout the facility can be reduced by 91%, from 6,195 meters.

PROBLEM STATEMENT

The U.S. Air Force's Air Logistics Complexes have over hundreds of repair and overhaul processes & management needs to improve productivity of repair and manufacturing product lines. Management would like to benchmark repair process performance, conduct "what if" analyses of proposed changes, more data to aid strategic decisions, adopt "Advanced Manufacturing" technology. Challenges:

- No existing manufacturing process models
- Process data stored in data systems that make the data hard to use. Data is not accurate enough to be reliable.
- Manual data collection processes
- Tight integration of process steps makes on-the-fly modifications or experimentation difficult

BENEFITS

- Reduce investment in planning of new or reconfigured facilities and processes
- Improve productivity of existing facilities and processes
- Increase responsiveness to changing conditions
- Evaluate arrangements and configurations of the machines and how they affect the system's productivity
- Build quantitative business cases for proposed process and facility changes using simulation data
- 3D model becomes a virtual asset for the entire organization
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- Improves communication of changes
- Enables virtual commissioning of new equipment / processes

TECHNOLOGY SOLUTION

- Virtual Manufacturing & Data Integration Tool (VMDIT): a 3D virtual model of the manufacturing environment with integrated manufacturing/ overhaul process simulation. This tool's models are a platform for a "smart factory" & advanced manufacturing.
- Virtual Environment enables rapid digital and physical transformation of manufacturing operations using Siemens Tecnomatix Plant Simulation Software tools.
- Functionality includes process benchmarking, process simulation experiments, test scenarios to improve the manufacturing system, virtual commissioning, reconfigure manufacturing facilities, social distancing simulations.

GRAPHIC OR IMAGE

Public Content

IMPROVS DOCUMENT SCANNING SOLUTION

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Problem Statement: While the DoD is full of sophisticated weapon systems and equipments, much of the information used to manage its parts, repairs, and usage is tracked using good old fashion paper. This technology digitizes the paper transforming it into true digital documents.

Technology: This technology is much more than scanning which is where most solutions stop. Once scanned Improvs processes the document automatically (server based with no personnel involved) on multiple levels:

- Baseline – Document is scanned
- Automated Document Processing – Document is OCR (Optimal Character Recognition), Optimized (reduces file size without impacting quality), Uniformity (cleans common scanning issue like page orientation, de-speckling, clarity, etc). This transforms the scanned image into an uniform document
- Data Capture – Automatically extracts key data within document (serial #'s, dates, etc). Configurable based on document type
- Metadata – Embeds key information (metadata) within document properties enabling programs like SharePoint to immediately search and find document (s) with no data entry
- Labeling – Documents are custom named making them much easier to find when millions of files are stored
- Validation – configurable options to ensure all files are properly processed and never missed
- Pickup/Delivery – Documents can be processed directly onsite enabling clients to maintain complete control or sent to a processing center. Digital documents are returned as Adobe PDF files requiring no propriety readers

Technology Status: Technology is at TRL Level 9. It can be used by establishing its own mini network (no network approval required) with processed files returned via customers approved process.

Implementation: It is being used in private sector with most recognizable client being American Airlines depot operations. Within DoD currently used at RRAD and DLA in Texarkana. It is being evaluated by VA and FAA for medical data which is currently on hold due to Covid.

Next Steps/Benefits: The technology is ready to be deployed. The benefits extend well beyond simply document scanning:

- Embedded metadata ensures document can be immediately used without manual data entry. The metadata using XML makes searching and retrieval much faster
- Optimized documents file size is roughly 25% of scanned document without impacting quality resulting in much less drive space (huge I.T. issue)
- Documents can be scanned onsite and processed via cloud based servers
- No network access

Cost savings at American Airlines Depot exceed $1 million/year over just scanned documents. RRAD/DLA savings exceed $2.5 million with audit savings (ability to quickly find document) an additional $800k.

PROBLEM STATEMENT

While the DoD is full of sophisticated weapon systems and equipments, much of the information used to manage its parts, repairs, and usage is tracked using good old fashion paper. This technology digitizes the paper transforming it into true digital documents.

Improvs automation and configurability delivers higher quality documents and is cost efficient while delivering superior document functionality. Since it is automated it is also much faster and cost effective than manual processing. It is truly digital information that can be updated or added to, enabling single point of focus rather than a snapshot in time like simple scanned documents.

BENEFITS

Technology is at TRL Level 9. It can be used by establishing its own mini network (no network approval required) with processed files returned via customers approved process.

The technology is ready to be deployed. The benefits extend well beyond simply document scanning:
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TECHNOLOGY SOLUTION

This technology is much more than scanning which is where most solutions stop. Once scanned Improvs processes the document automatically (server based with no personnel involved) on multiple levels:
Baseline – Document is scanned using high quality scanner (not local Xerox, etc)
Automated Document Processing – Document is OCR (Optimal Character Recognition), Optimized (reduces file size without impacting quality), Uniformity (cleans common scanning issue like page orientation, de-speckling, clarity, etc). This transforms the scanned image into an uniform document
Data Capture – Automatically extracts key data within document (serial #'s, dates, etc). Configurable based on document type
Metadata – Embeds key information (metadata) within document properties enabling programs like SharePoint to immediately search and find document (s) with no data entry
Labeling – Documents are custom named making them much easier to find when millions of files are stored
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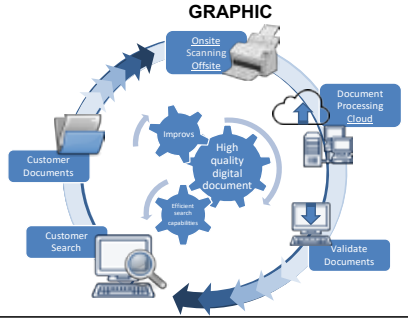
GRAPHIC



CTMA VANGUARD PROPOSAL

RAYMOND LIPA

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This proposal addresses a small but mission-critical part of reshoring US manufacturing in light of the recent health and economic crises faced by our country. The US, through the DOD, needs a contract management, order release, inventory tracking, shipping, barcode, scanning, and accounting system accessible through the NCMS CTMA program for small US manufacturing companies—many of whom are not military contractors currently.

Today, most small US manufacturers are priced out of enterprise-level demand management and supply chain systems due to the years-long tolls of globalism. Also, today there are many missing pieces to our military manufacturing capabilities–many of which could be addressed by small companies with improved public-private efforts. Because the manufacturing computer systems of small-companies are either a) too old and have poor capabilities or b) too expensive from a skilled manpower and operating point of view, the US lacks access to these nimble and innovative companies in responding to crises.

Knovalent proposes supplying its intellectual property and initially its proven Vanguard system to the NCMS, working through the CTMA, to address this mission-critical need. We will work with all parties in a manner to best address this problem area and support the efforts of the DOD. We thank you for your consideration.

PROBLEM STATEMENT

- What problem or need does this technology solve?

For one depot location: this technology, the Vanguard system, enables tracking of contracts, orders, inventory, costing, and delivery/shipping status of products, needed for maintenance, from non-military manufacturers. (Public-side)

For the Defense Logistics Agency: this technology enables the depot information from one location above, as well as other locations, to be analyzed individually or to be rolled up as a whole. (Public-side)

For small manufacturing organizations: the technology (ERP, EDI, barcode, labeling, scanning, etc.) enables suppliers to perform planning and supply-chain roles for US defense and for emergencies that they heretofore could not perform, nor afford (Private-side)

For the NCMS: the technology enables it to expand its long-running, successful CTMA role to help in reshoring needed manufacturing to the US. (Intermediary)

BENEFITS

- List the benefits

Reshoring of needed manufacturing capability is promoted and enabled

Recovery for small manufacturers hurt by current economic and health crises

Reassessment of how to best protect the overall well-being of US citizens and the country from defense, health, small business, and economic threats

Resilience of US defense, economics, and health is improved (future)

Redundancy for US supply chain (future)

A complete list of benefits for each Vanguard module is given on the web pages served when clicking on links at https://knovalent.com/solutions.html. Scroll down the web page to the benefits section. The detailed list of benefits by module is too numerous for this one slide.

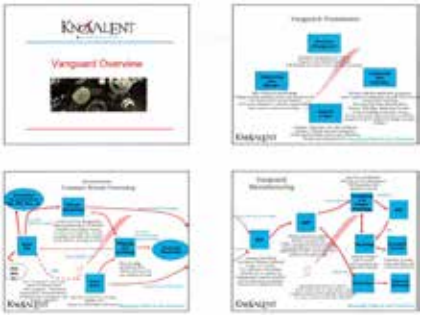
TECHNOLOGY SOLUTION

- Describe the capability

On the Business side: Vanguard is multi-organizational allowing multiple divisions, locations, and work centers within an organization. It also supports multiple currencies and is real time. These capabilities can be changed, added or removed as economic, defense, health, and business conditions change.

Computing architecture: Options are a) Hosted server with green-screen clients b) Web-page transformation of client screens to hosted backend server—recommended for CTMA trial to start and c) Front-end Angular Single-Page Application JavaScript with REST servers backend – for future CTMA deployments, in development

Functional: Order Management via EDI or web with release accounting, order processing, shipping, invoicing, vendor releases; Manufacturing via discrete or repetitive, engineering notices, effectivity dates, master planning, MRP, barcoding and shipping labels with masters; Accounting with GL, AP, AR, costing; Distribution through purchasing, receiving, and inventory management.



MAINTENANCE CAPACITY MODEL

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Understanding maintenance productivity and how it impacts the capacity of an equipment heavy military unit is extremely difficult and discussion on the topic frequently becomes contentious. Efficient management of productivity has a traceable impact on unit readiness.

The complexity of interactions throughout the supply chain and within organizations have made it appear impossible to identify cause-and-effect behaviors of productivity which can be measured and are meaningful from a management perspective.

A study completed in 2018 proposed a method for measuring key behaviors in Marine Aviation units and using the measurements to understand the productivity and operational capacity of the unit. Measurement uses only authoritative source data available from documentation completed when work is completed on aircraft, when aircraft return from flight, and when daily readiness is reported. The data is used to calculate the productive behaviors of workers in Direct Maintenance Man Hours per Worker per Day (DMMH/W/D), number of workers per day (W/D), and the interaction of DMMH per Flight Hour (DMMH/FH). Next a method of calculating capacity was explored along with the impact on readiness of operating at, above, or below that capacity.

The study demonstrated that a method exists to measure behaviors in a way that empowers understanding of what to look for in forming solutions. The study didn't answer "why" because each aircraft (equipment) type faces unique context such as aircraft age, support equipment availability, and quality of technical data.

The study spawned a toolset and management technique known as Maintenance Capacity Model (MCM). An experimental employment of MCM performed at an F/A-18 squadron showed measurable performance improvements. A second employment MCM with improved calculation tools and aligning far more closely with the authors proposed techniques delivered startling results at a CH-53 squadron. By achieving a 200% increase in W/D employment, 20% increase in DMMH/W/D, and effort to control DMMH/FH to a tolerable level; significant performance improvements were achieved in just one year. From FY 2019 averages to second half of FY 2020 the CH-53 squadron achieved the following performance improvements: 72% increase in mission capable aircraft, 35% increase in flight hours, 35% reduction in aviation depot level repairable cost-per-hour, 5% increase in worker job satisfaction, 72% reduction in declined reenlistments, 77% reduction in backlog maintenance on the aircraft.

Maintenance Capacity Model demonstrated that improved management with existing resources can deliver significant improvements for Marine Corps Aviation by delivering more readiness, more flight hours, lower costs, happier Marines, and healthier machines. Strategic application of resources can amplify this technique and over time can improve performance in cost and readiness.

PROBLEM STATEMENT

A lack of consistent and predictable workforce productivity behaviors has had an outsized impact on:

- Poor Aircraft Readiness
- Poor Aircraft Material Condition
- Low workforce experience levels
- Low flight hour production
- Lack of predictability in flight hour generation

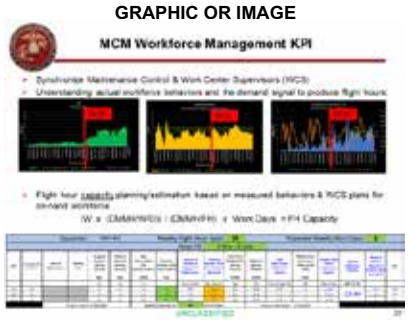
BENEFITS

- Increased productivity of workforce
- Increased aircraft readiness
- Increased flight hours
- Reduced costs
- Increased job satisfaction of workforce
- Reduced declined reenlistments
- Reduced backlog maintenance on aircraft
- Increased understanding & predictability of flight hour generation by unit

TECHNOLOGY SOLUTION

- Information technology is applied to measure and present workforce productivity data to local and mid-level management in order to demonstrate actual performance to combat unproven notions.
- Information technology is applied to calculate flight hour generating capacity based on measured behavior; serving as a fact-based starting point for operational planning.
- Continuous Process Improvement methodologies are used by senior squadron & Marine Aircraft Group maintenance leadership to coach supervisors in identifying and removing constraints.

GRAPHIC OR IMAGE



Approved for public release by HQMC Communication Directorate

CUSTOM ENGINEERING SOLUTIONS (CES) FOR INTERMEDIATE MAINTENANCE ACTIVITY (IMA)

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The Custom Engineering Solutions (CES) for Intermediate Maintenance Activity (IMA) project transformed the workplace to improve shop floor productivity by fostering a culture of rapid innovation. Traditionally, it is challenging for the Naval Undersea Warfare Center (NUWC) Division Keyport Heavyweight (HWT) and Lightweight (LWT) Torpedo IMA to rapidly develop and adopt process improvements. This is due to lengthy annual budgeting cycles to identify and approve funding, lengthy technical review processes, and needs to mitigate any short term production impacts during implementation. Historically, it takes 2-5 years from conception to IMA implementation of non-work stoppage improvement ideas. This project reduces that timeline down to 1.5-years and increases the number of ideas that quickly materialize and are implemented.

In the past, the In-Service Engineering Agent (ISEA) was the primary activity to promote process improvements and as the technical authority, approve those solutions for the IMA. They would work independently to champion an idea with resource sponsors to secure funding, design a solution, identify & contract with manufacturing facilities, then test, evaluate, and qualify new items for the IMA workforce.

The Custom Engineering Solution (CES) for IMA project essentially reverses & compresses that traditional development cycle. The IMA shop technicians are empowered to identify and generate ideas to issues in their workspaces. Collaborating directly with CES (manufacturing) and ISEA (technical authority) personnel, they quickly develop design concepts, use rapid prototyping technologies, test, evaluate, qualify and implement those solutions. The project secures upfront funding for the personnel, material, fabrication, and approval process. This is akin to placing 3-D printers directly in the hands of soldiers in the field to allow them to print material solutions to solve everyday problems.

In FY20, the project supported six distinct efforts to improve IMA shop technician productivity. They include a Fleet Exercise System Tool, Goliath Tool Tray, Torpedo Tray, Tool Shadow Board, Vacuum Stand attachment, and Regulator stand. Four of these efforts have matured from the concept to prototype stage within 6 months. Even with many of these efforts experiencing late-starts and/or suspension due to the COVID-19 Pandemic, ISEA approval is planned in early FY21 to meet the 1.5-year timeline.

This project has demonstrated a significant culture change in the IMA workforce, allowing deck-plate ideas to become reality in remarkably short time, allowing for improved efficiencies, productivity, and empowerment. The success of this project has secured on-going funding through FY22 with expectations that permanent resources will be established to sustain a culture of innovation and collaboration to increase torpedo deliveries to the Fleet.

PROBLEM STATEMENT

- Process improvements take a discouraging long time, historically 2-5 years to be developed & implemented in the Naval Undersea Warfare Center (NUWC) Division Keyport Torpedo Intermediate Maintenance Activity (IMA).
- Lengthy annual budgeting cycles combined with lengthy technical review processes cause impacts and inefficiencies to production until funding and approvals are received.

BENEFITS

- This approach has reduced the time from conception to implementation of deck-plate solutions, from IMA shop floor technicians to 1.5 years.
- Culture shift within the IMA, empowering personnel to conceive & realize rapid improvements within their workspace.
- Increased productivity and torpedo throughput within the IMA with a new culture of innovation and collaboration.

TECHNOLOGY SOLUTION

- Reverse & compress the traditional development cycle.
- Empower IMA shop floor technicians to identify & generate ideas to issues in their workspaces.
- Partner technicians with a collaborative team to design, rapid prototype, test, evaluate, qualify, and implement workspace solutions.
- Secure funding upfront for personnel, material, fabrication, and approval process.

PROTOTYPE TOOLS & FIXTURES

LWT Torpedo Tray

HWT Regulator Stand

LWT Goliath Tool Tray

MAP-BASED MAINTENANCE CONTROL TOWER WITH ARTIFICIAL INTELLIGENCE (AI)[L]

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Problem: DoD has 100's of maintenance depots spread across CONUS and OCONUS as part of its Maintenance and Sustainment complex. These depots operate autonomously with minimal information and capacity sharing (like taxis before Uber). They primarily operate in an analog fashion in an increasingly digital world. The DoD Maintenance and Sustainment complex currently lacks a common operating picture (depot capacity, work center utilization, resource availability, repair parts inventory, potential weather related or other disruptions etc.) which can be especially challenging during a crisis like the current Coronavirus pandemic with potentially grave impact to nation's military operational readiness.

Technology Solution: Murano Corporation is proposing a Map-Based Maintenance Control Tower with Artificial Intelligence (AI) to provide a holistic, integrated, and near real-time common operating picture of the DoD maintenance depots and sustainment activities. Control Tower can fuse different types of information (facilities, spares inventory, vendors, personnel, work orders, platforms, missions, environmental etc.) from multiple sources (legacy applications, new fixed and mobile sensors & cameras, Big Data) to transform depot maintenance from analog to digital, facilitate capacity planning and eventually improve services operational readiness.

Benefits:

- Display all maintenance depot locations and current and operational status on a map with drill-down capability for (think Uber App):
- Current and Pending Work Orders
- Resource Availability
- Repair Parts Inventory
- Work Center Utilization & Average wait times
- Predict future depot operational status, capacity, work center availability, wait times, pending work order completion times, repair parts inventory days of supply, environmental and health disruptions (weather, pandemic etc.)
- Knowledge Portal for Maintenance Best Practices

PROBLEM STATEMENT

DoD has 100's of maintenance depots spread across CONUS and OCONUS as part of its Maintenance and Sustainment complex. These depots operate autonomously with minimal information and capacity sharing (like taxis before Uber). They primarily operate in an analog fashion in an increasingly digital world. The DoD Maintenance and Sustainment complex currently lacks a common operating picture (depot capacity, work center utilization, resource availability, repair parts inventory, potential weather related or other disruptions etc.) which can be especially challenging during a crisis like the current Coronavirus pandemic with potentially grave impact to nation's military operational readiness.

BENEFITS

- Display all maintenance depot locations and current and operational status on a map with drill-down capability for (think Uber App):
  - Current and Pending Work Orders
  - Resource Availability
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TECHNOLOGY SOLUTION

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GRAPHIC

Map-Based Maintenance Control Tower with AI

SIMPLE NETWORK MANAGEMENT PROTOCOL (SNMP)-BASED PROGNOSTICS FOR TACTICAL NETWORK COMMUNICATIONS EQUIPMENT

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Army Predictive and Prognostic Maintenance (PPMx) implementations offer unique opportunities to manage uncertainty in tactical operations by combining accurate identification of incipient equipment anomalies with explanatory power to create actionable, tactical-level, prognoses for network communications equipment. PPMx leverages artificial intelligence (AI), machine learning (ML), and knowledge engineering (KE) processes to develop remaining useful life (RUL) distributions for critical components. These distributions enable a "managed" maintenance approach to increasing network availability. PPMx processes require a source of on-platform data. But capturing data can require a significant investment in PPMx-specific hardware and software, and PPMx programs are evaluated in terms of value streams over tangible (cost) and intangible (readiness) metrics.

The solution is to increase real value by repurposing existing network monitoring data for prognostics.

Simple Management Network Protocol (SNMP)-enabled devices are ubiquitous in tactical networks and SNMP-based software provides the tools for Network Operations (NetOps) monitoring. SNMP Management Information Base (MIB) structures allow device agents to expose a myriad of device variables. But NetOps baselines, typically, do not make full use of available data. SNMP for NetOps involves established processes for polling devices to observe the current state of baseline variables and to assign Green (normal), Yellow (warning), and Red (failure) status to systems at prescribed thresholds. SNMP for prognostics involves understanding the causal relationships between variables and using that context to understand the precursors of failures in time domain. This key difference creates the potential to use SNMP as a de facto PPMx architecture.

SNMP-based prognostics methodology uses a unique ML and KE process to develop complex, probability-based, dynamic models of network component failure modes. The models focus on underlying semi-Markovian processes and on the entropic sensitivity of specific SNMP-variables. The model outputs a set of prognostic markers which, along with Most Relevant Explanation (MRE) algorithms, are used to form logical rule sets, within SNMP-based software tools, that notify maintainers of "pre-yellow" conditions.

SNMP-based prognostics technology is prototyped for select failure modes on Integrated Services Routers (ISR) and Solid State Power Amplifiers (SSPA), both critical components of Army Mission Network platforms. Initial tests proved the capability to fully-execute tactical-level prognostics in SNMP software applications for two critical failure modes:

Detected incipient ISR overheating conditions based on the relative values of two key SNMP temperature curves and packet receive rate (PRR) curves.

Detected incipient SSPA High Electron Mobility Transistor (HEMT) pair failures based on drain current values relative to temperature and power.

PROBLEM STATEMENT

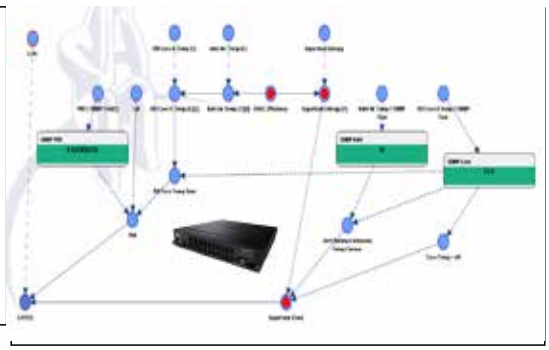
Army Predictive and Prognostic Maintenance (PPMx) implementations offer unique opportunities to manage uncertainty in tactical operations by combining accurate identification of incipient equipment anomalies with explanatory power to create actionable, tactical-level, prognoses for network communications equipment.
But the upfront investment costs associated with implementing PPMx for legacy network communications systems make it difficult to justify value streams, even if the overall impact on readiness is positive.

BENEFITS

- The SNMP-based approach significantly reduces PPMx investment costs by repurposing **existing** the SNMP network monitoring architecture - data, hardware, and software – for prognostics
- Prognostics enables "managed" repairs and increased A_0
- The SNMP architecture provides a rich source of data and very granular views of electronic device parameters
- The methodology provides the mathematical underpinning for codifying the relationships *between* SNMP variables
- The technology enables detection of minute state changes to ensure optimum prognostic distance (sensitivity and accuracy)
- Prognoses are built into the existing Network Operations (NetOps) tool set as customized alerts for actionable intelligence

TECHNOLOGY SOLUTION

- SNMP-based prognostics uses a unique Operations Research (OR) - based process, combining Machine Learning (ML), Artificial Intelligence (AI), and Knowledge Engineering (KE) processes, to develop probability-based, dynamic models of network failure modes.
- The models focus on underlying semi-Markovian processes and on the entropic sensitivity of specific SNMP-variables.
- The model outputs a set of prognostic markers which, along with Most Relevant Explanation (MRE) algorithms, are used to form logical rule sets, within SNMP-based software tools, that notify maintainers of "pre-yellow" conditions.



DISTRIBUTION STATEMENT A. Approved for Public Release.

INTERMITTENT FAULT DETECTION SYSTEM INCREASES AIRCRAFT READINESS

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Today's defense environment requires responsive and affordable solutions to global weapon system support challenges. As operations and near peer threats from China and Russia increase, the Department of Defense's (DoD's) ability to economically sustain weapon systems has become increasingly challenging. The high, sustained operations tempo over the past two decades in harsh environments has eroded weapon system readiness and reduced expected life span.

No Fault Found (NFF) test results in Line Replaceable Units (LRUs) / Weapon Replaceable Assemblies (WRAs), and weapon system Electrical Wiring Interconnect Systems (EWIS) primarily driven by intermittent faults, have become a significant concern and huge maintenance and life-cycle cost driver, and an operational readiness degrader within the DoD. For many DoD weapon system components driven to the depot for repair, less than half have the actual root cause of the problem identified and repaired. The other half tests NFF. Conventional Automatic Test Equipment (ATE) and automated wiring test sets were not designed to detect intermittent faults and are incapable of detecting and isolating momentary intermittent failures that cause NFF. The undetected and unrepaired intermittent faults cause many DoD weapon systems to malfunction during operation because these faults are not detected and hence not repaired at O-level, I-level, the depot, or contractor repair facilities. Instead, the NFF systems continuously cycle between the field and depot resulting in over 278,000 days (760 years) of end-item system non-availability and approximately $3 billion in non-value-added sustainment costs annually.

The Intermittent Fault Detection & Isolation System 2.0™ (IFDIS 2.0™) and portable Intermittent Fault Detector™ (IFD™) are purpose built to detect and isolate intermittent faults in LRUs / WRAs and EWIS and are working very effectively across the Services and commercial aviation. According to the January 2020 GAO Report (GAO-20-116), "Navy Fleet Readiness Center Southwest, California, implemented an Intermittent Fault Detection System on its F/A-18 aircraft generators. According to officials, the depot reduced repair time from 90 days to 30 days and quadrupled the generators' time between failures". The GAO Report continues, "using the Intermittent Fault Detection and Isolation System, the mean time between failures for the generators has increased, according to officials, from 104 flight hours to over 400 flight hours and recovered out-of-service assets generating about $62 million in cost savings". In conclusion, the GAO Report states, "Finally, the Office of the Assistant Secretary of Defense is providing specific guidance in implementing best practices and lessons learned, such as the memorandum issued in April 2019 on the Intermittent Fault Detection and Isolation System directing the military services to adopt this best practice."

PROBLEM STATEMENT

No Fault Found (NFF), Cannot Duplicate (CND), No Evidence of Failure (NEOF), and A-799 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 across 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 these faults unrepaired. These NFF sub-systems continuously cycle between the field and depot accounting for 278,000 days of end-item system non-availability and approximately $3 billion in non-value-added sustainment costs annually.

BENEFITS

- Improve Materiel Readiness by 50%
- Reduce maintenance costs by $3 billion annually
- Reduce No Fault Found (NFF) test results
- Increase operational readiness
- Reduce MICAP rates
- Improve maintenance effectiveness
- Reduce repair cycle-times
- Achieve MC 80
- Accomplish Congressional directive
- TRL 9

TECHNOLOGY SOLUTION

The Intermittent Fault Detection & Isolation System 2.0 (IFDIS 2.0), and portable Intermittent Fault Detector (IFD) are purpose built to detect and isolate intermittent faults, enabling these faults to be repaired. The difficult task of detecting and isolating intermittent faults is accomplished by monitoring all circuit paths simultaneously and continuously –no scanning or sampling. By identifying and correcting the root causes of random intermittent failures, reliability dramatically increases on the diagnosed systems and sub-systems. According to the January 2020 GAO Report (GAO-20-116), the IFDIS 2.0 and portable IFD will increase readiness by 50% on average and provide an annual maintenance cost savings between $2 to $10 billion.

GRAPHIC OR IMAGE

IFDIS 2.0

Portable IFD

SOLVING THE DATA PROBLEM FOR CBM+ USING PHYSICS INFORMED MACHINE LEARNING

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Conditioned Based Maintenance+ (CBM+) aims to "increase combat power expressed in terms of operational and materiel availability and readiness, throughout the weapon system's life cycle." A key enabler to achieving this are predictive maintenance (PDM) machine learning (ML) algorithms that use data to predict the remaining useful life (RUL) of a military asset. Traditional PDM ML algorithms require lots of data (i.e. "big data") to accurately predict RUL. Useful data is difficult and expensive to obtain. It needs to be collected, processed, transmitted, aggregated, cleaned, warehoused, post-processes, etc. Having the right data to use in PDM ML algorithms is arguably one of the biggest obstacles to achieving the goals of CBM+.

Front End Analytics has developed a new class of algorithms called Physics Informed Machine LearningTM (PIML). PIML PDM algorithms can in real-time, accurately, and reliably predict the RUL of an asset with only a small fraction of the data (i.e. "small data") that would have been otherwise required with traditional ML algorithms. Moreover, there are certain problems that can only be solved using PIML PDM. For instance, it may be impossible or impractical to instrument an asset with enough sensors required by the traditional algorithms. Finally, PIML PDM can be integrated into model-based control to modify machine operating parameters to in real-time optimize the RUL of the asset.

PIML PDM algorithms combine physics-based simulations with ML methods to predict the RUL of an asset. The details of these algorithms are proprietary. However, in general, these algorithms transform the problem into "physics space" and use physics-based simulations and multi-stage reduced order models to capture what we call the physics critical path. Different ML techniques are integrated to calibrate the physics path and the overall prediction. The result is that PIML PDM require very little data to produce highly accurate predictions. Moreover, PIML PDM gives insights as to how to improve predictive capability, can extrapolate to an unseen environment, and can be integrated into data fusion frameworks.

PIML PDM predictive speed, accuracy and reliability was successfully validated to predict thermal mechanical fatigue for an engine of a Fortune 50 industrial equipment manufacturer. This complex problem would not have been solvable with traditional ML techniques due to the amount of data that would have been required, and the impossibility of instrumenting the engine accordingly. Internal benchmarks have shown that PIML PDM reduces data requirement by more than 90%. For this type of application, PIML PDM algorithms were successfully validated to be at TRL 5.

Next steps for this technology are to demonstrate it more broadly on military assets and to quantify its capability for system-level asset RUL prediction. PIML PDM algorithms can significantly reduce the "data problem" and substantively advance the goals of CBM+

PROBLEM STATEMENT

Traditional predictive maintenance (PDM) algorithms require significant amounts of data to make accurate and reliable predictions. Useful data is difficult and expensive to obtain. Data needs to be collected, processed, transmitted, aggregated, cleaned, warehoused, post-processes, etc. Moreover, sometimes it may be physically impossible or impractical to instrument an asset with enough sensors to obtain data that would be used to feed these algorithms.

Obtaining the right data to feed into PDM algorithms is arguably one of the biggest obstacles to achieving the goals of DoD's Condition Based Maintenance Plus (CBM+) initiative.

BENEFITS

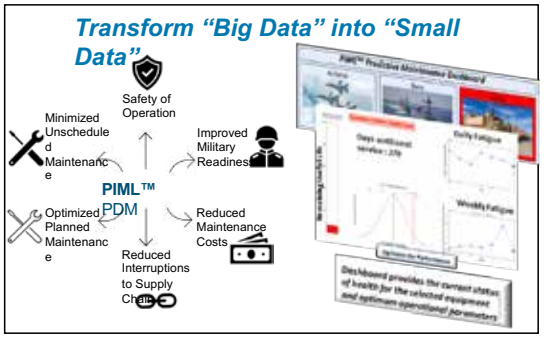
PIML PDM will significantly reduce the "data problem" and substantively advance the goals of CBM+. It can:

- Accurately predict in real-time RUL of military assets with very little data; thus reducing the number of sensors and onboard computational power required in military assets
- Be integrated in to model based control to modify a machine's operating parameters to optimize its performance for a given environment or mission
- Optimize maintenance schedules to reduce overall costs and improve operational and material availability of weapons systems
- Reduce or eliminate unplanned maintenance events ensuring weapons achieve their missions, while reducing casualties and disruption to the supply chain

TECHNOLOGY SOLUTION

Front End Analytics had developed a new class of algorithms called Physics Informed Machine Learning (PIML™). PIML™ PDM can in real-time, accurately, and reliably predict the remaining useful life (RUL) of an asset with only a small fraction of the data (i.e. "small data") that would have been otherwise required with traditional machine learning algorithms.

PIML™ PDM can be integrated into model-based control frameworks to modify a machine's operating parameters to in real-time change and optimize the RUL of the asset. PIML™ PDM gives insights as to how to improve its predictive capability, can extrapolate to an environment it has not seen before, and can be integrated into data fusion frameworks.



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

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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

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 detected abnormalities in DFDR and AIRCAT engine and trend data. We then fuse with faults flagged in Debrief and AIRCAT engine 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 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. DF&NN has already converted the historical C-130 engine to be ingested by our DCPM/GCPM software. 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
- Trust NNs
- Improve confidence in automated maintenance with the user on-the-loop.

PROBLEM STATEMENT

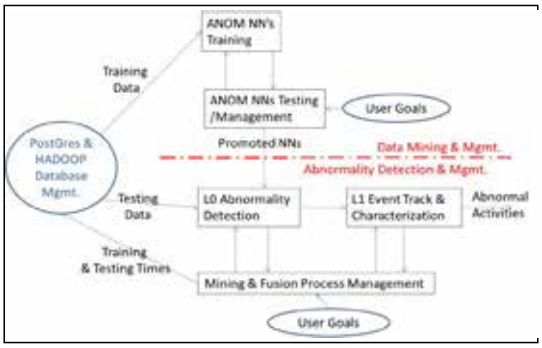
Increase aircraft availability by developing automated Condition -Based Maintenance Plus (CBM+) turnkey capabilities
Detect abnormal precursors in C-130 Digital Flight Data Recorder (DFDR) and Automated Inspection Repair Corrosion and Aircraft Tracking (AIRCAT) engine data
Fuse abnormal behavior detections 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 outperforming 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



DEMOCRATIZATION OF FIBER SENSORS FOR ENABLING ARTIFICIAL INTELLIGENCE, PREDICTIVE ANALYTICS AND DATA VISUALIZATION

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In the near future, artificial intelligence, predictive analytics and data visualization will enable modern tools that will be used to support near real time decision-making. Full realization of these techniques is limited by availability and accessibility of quality data. To overcome these limitations, investments need to be made in sensor systems that provide constant surveillance and notifications of potentially damaging conditions. The monitoring system also needs signal processing and decision toolboxes that could be implemented on multiple platforms. A truly next generation sensor system is adaptable to a variety of mission priorities, while also providing flexibility for upgrades as technology and sensor data evolve.

In a joint project with NASA Armstrong Flight Research Center, Naval Surface Warfare Center-Port Hueneme is deploying a fieldable fiber brag grating (FBG) optic system (microFOSS) with the same accuracy of traditional sensors at a fraction of installation footprint and comparable cost. MicroFOSS is set apart from other fiber-sensing units because of its innovative, low-cost, laser, unique algorithms and use of commercial off the shelf hardware. Measurements of wavelength shift induced by physical acts on the fiber are processed to calculate 2D and 3D shape, position, temperature, liquid level, strain, pressure, etc. MicroFOSS drives down the cost of the electronic sensor suite from $32k to $3k. While the cost of the laser interrogator remains $18K, each laser can pulse thousands of sensors along a fiber string, making the cost per sensor $20. FBG sensors possess an extremely high density to weight ratio, a 10^4 increase over electronic alternatives and are approximately the diameter of a human hair diameter (165 µm). FBG sensors provide key advantages over many other sensors for operation in harsh environments, they are immune to electromagnetic and radio frequency interference, corrosion resistant, able to withstand high temperatures and there is little potential for electrical sparking. FBGs are easily deployed under coatings or in inaccessible areas.

A recent project with the Naval Research Lab and PMS-377 demonstrated fiber sensor deployment on the cargo deck of a landing craft air cushion during routine operations. The approach allowed for the ability to use in-situ measurements to match physical models for prediction of hull deflection and assessment of lifetime reliability. MicroFOSS is also being installed on an additive manufacturing machine for qualifying machine parameters. Near future efforts are focused on embedment of fiber sensors in material during the manufacturing processes.

The main goal of this initiative is to democratize this offset sensing technology. Fiber optic sensing platforms provide an adaptable, nondestructive instantaneous assessment of material conditions in the field. We believe this tool will enable independent sensor data streams, enhancing model-based designs and maintenance analytics.

PROBLEM STATEMENT

In the near future, artificial intelligence, model-based systems engineering, predictive analytics for condition-based maintenance, and data visualization will enable modern tools to support near real time decision-making. Full realization of these off-set technologies will be limited by availability of both quality and quantitative datasets.

To overcome dataset gaps, next generation sensor systems will need to be accessible and reconfigurable to provide constant surveillance and near real time notifications of potentially damaging conditions. These monitoring systems need signal processing and decision toolboxes that are platform agnostic, easily installed and flexible.

A truly next generation sensor system is capable in a variety of mission priorities, while also providing flexibility for upgrades as technology and modernization evolves.

BENEFITS

Strategic partnerships enables sensing technology development and transfer into ever expanding and diverse DoD platforms. The current developed system cut costs by an order of magnitude. Fiber sensors possess an extremely high density to weight ratio, a 10^4 increase over electronic alternatives and are approximately 165 µm diameter. Fiber sensors have a high spatial density, up to a 1000 sensors can be multiplexed within a ¼". They are immune to electro-magnetic interference, corrosion resistant and well suited for hazardous areas.

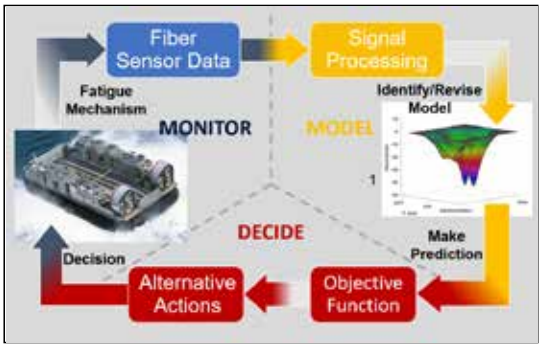
Fiber systems are extremely adaptable, able to continuously monitor, record, assess environmental conditions and equipment status. Continuous streaming data reimagines physical models to predict and generate statistics for analysis in lifetime reliability. Fiber Optic sensors establish independent data streams that enable AI, Predictive Analytics and the Digital Twin.

TECHNOLOGY SOLUTION

Utilizing partnerships with NASA Armstrong and other Governmental agencies, ruggedize a low-cost fiber optic sensing system for both shipboard and aircraft environments. The fieldable fiber system is able to calculate 2D and 3D shape, position, temperature, liquid level, strain and pressure for indication of static and dynamic conditions.

Current efforts are focused on installation of the monitoring system on a variety of platforms to provide constant surveillance and provide real time notification of potentially damaging conditions.

Near future efforts are focused on embedment of fiber sensors in material during the manufacturing processes. Fiber sensor embedment has been shown possible with polymers during extrusion techniques; exploratory efforts are underway for both metal and ceramics.



SIMULATION ENHANCED ELECTRONICS CBM+

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Condition based maintenance (CBM) is a central enabler to improving system availability and mission capable rates. Advances are being made in mechanical and rotating machinery component families as sensor data is compared to historical wear trends.

Electronics typically lack a practical way to measure degradation. In fact, the dominant failure mechanisms in electronics hardware, solder joint and plated through hole failure, are indetectable until the moment of failure. This detection gap when coupled with the increasing electronics content in Air Force systems presents an opportunity to achieve significant benefit from a method to apply predictive CBM to electronics.

Typical predictive methods require high fidelity design information and a time-history for stresses applied to individual assemblies. While this may be achievable in the future as sensor data and digital twin capabilities mature. However, using Ansys Sherlock, predictive models can be built without technical data today and applied to the whole population, and an approximated lifecycle stress profile applied to predict a relative order of failure at the piece part level.

This prediction can be applied to streamline maintenance processes to focus troubleshooting, failure localization and allow maintainers to identify component solder joints that are nearing failure. Proactive repair of components and solder joints prior to failure will extend time in field and prevent future repair cycles.

The USAF is currently exploring this capability for implementation at their Warner Robbins ALC, and the purpose of this effort would be to extend the benefits seen by Air Force throughout all government electronics repair facilities. The proposed research and development effort will:

- map the range of repair processes across the DoD
- deliver a proposed deployment plan to transition the capability throughout the DoD
- transfer of tools and process capability to designated DoD operators
- recommend decision making methods and documentation practices.

The program will allow DoD to take advantage of the latest reliability physics prediction methods and tools to implement a CBM+ program for electronics that will eliminate between 25 and 50% of unplanned downtime and repair costs.

PROBLEM STATEMENT

Electronics repair has historically been a reactive process. The accelerating increases in electronics content in DoD systems, coupled with long life requirements, have led to a greater impact of electronics failure to mission readiness. Additionally, aging electronics repair is complicated by the replacement of components with DMSMS challenges. A lack of TDPs, and stress histories have traditionally prevented any alternative strategy to a reactive maintenance process for electronics, forcing mission systems to endure unexpected failures as a matter of course, with the attendant cost, planning and mission risks.

BENEFITS

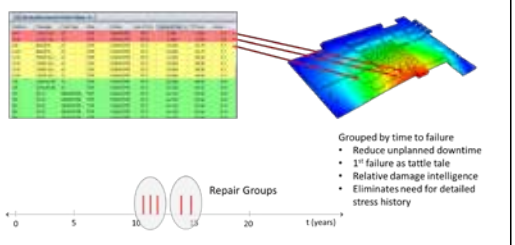
For each component that is identified and repaired before failure, an entire repair requirement is eliminated. Implemented programs are expected to extend the time between failures for aging electronics to pre-wearout levels and increase mission readiness by reducing unplanned downtime by 2/3.

Because repair of these aging electronics typically involve solder joint repair, component replacement can be drastically reduced, extending the inventories of obsolete parts and reducing the costs and risks associated with sourcing replacements.

TECHNOLOGY SOLUTION

Applying commercially available reliability prediction software (Sherlock) to obtain order of failure can allow maintainers to identify and repair undetectably damaged components.

Use of image import into the Sherlock tool allows for predictive models to be created without the TDP. Since first failure acts as a canary in the coalmine, only a generalized stress profile is needed to create a relative order and time to failure prediction. These predictions can be used by maintainers to repair ahead of field failures.



REALIZING CBM+ BENEFITS THROUGH THE DIGITAL LOGBOOK (DLB)

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Reliability-Centered Maintenance (RCM) initiatives, including Condition-Based Maintenance (CBM), have not realized the expected improved readiness, reduced training burden, and rapid continuous improvement. Effective application of CBM+ will exploit machine learning and artificial intelligence.

The Digital Logbook (DLB) tools integrate applications already familiar to the warfighter to provide condition/fact-based guidance for maintenance actions (condition-based, preventive, and corrective). The DLB ensures secure information sharing in disconnected, intermittent, and limited-bandwidth environments to increase readiness through accurate auto-population of records (eliminating manual data entry), automatic maintenance prioritization (reducing downtime), and data-driven workflow automation of fault confirmation, Interactive Electronic Technical Manual (IETM) troubleshooting, and repair procedures (minimizes training). An RCM-based "digital twin" creates a machine learning and artificial intelligence foundation for continuous improvement tailorable to any weapon platform and maintenance process. The DLB can accomplish same-day deployment of process improvements (e.g. IETM updates) over DoD networks. The DLB is customizable in appearance, navigation, terminology, and data collection for all DoD maintenance organizations.

The DLB employs mature software components developed and sustained by Ricardo Defense to integrate a complete vehicle platform to enterprise solution. The DLB automatic record keeping, service activity tasking, and RCM-based workflow guidance is executing a PM Transportation Systems pilot at the National Training Center (NTC) for TRL level-8 validation. The micro-services for the DLB are provided by a joint program office deploying the Joint Data Management Services (JDMS) under an ATO for collecting, distributing, and aggregating CBM+ data and technical manuals. The DLB integrates the IETM Viewer for the Electronic Maintenance System (EMS) with US Army and USMC ATO as well as the IADS4 IETM viewer and PDF viewing. Ricardo Defense developed a commercial tool for populating the RCM "digital twin" that received an IATT for a pilot program applied to generator maintenance by the Army CECOM Logistics Readiness Center (LRC).

A CASCOM summary report from a technical exercise at Joint Base McGuire-Dix-Lakehurst stated the DLB "has the potential to revolutionize how maintenance personnel triage equipment faults, integrate data, and gain efficiencies" saving a half-day on unit return. The DLB "has the ability to significantly enhance the automation process from when equipment faults are detected, through the diagnostic process, recording of the resolution, and ultimately feeding that data back to the dashboard."

Next steps are to simplify the capture of the RCM "digital twin" model, reduce the soldier burden in deploying and configuring the DLB tool suite, and increase machine learning and artificial intelligence process exploits.

PROBLEM STATEMENT

Reliability-Centered Maintenance (RCM) engineering and Condition-Based Maintenance (CBM) initiatives have not realized the expected benefits of increased readiness, reduced training burden, and rapid continuous improvement. Effective application of CBM+ will allow for exploitation of machine learning and artificial intelligence to make it more powerful over time

BENEFITS

- Eliminates manual entry
- Reduces downtime
- Minimizes training
- Recommends fact-based maintenance actions
- Resilient on unreliable networks

TECHNOLOGY SOLUTION

The **Digital Logbook (DLB)** tool suite integrates applications already familiar to the warfighter to provide condition/fact-based guidance in performing maintenance actions (preventive, reactive, and corrective). The DLB ensures that applications share information securely in disconnected, intermittent, and limited-bandwidth environments, and supports increased readiness through accurate auto-population of records (eliminating manual data entry), prioritization of maintenance activities (reducing downtime), and data-driven workflow automation with direct links from faults to pertinent Interactive Electronic Technical Manual (IETM) troubleshooting and repair procedures (minimizes training).

GRAPHIC

DIGITAL-TWIN DRIVEN SMART MANUFACTURING ASSET MANAGEMENT

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Warner Robins Air Logistics Complex (WR-ALC), located at the Robins Air Force Base, Georgia, serves as the primary modernization, sustainment, and depot maintenance center for a variety of aircraft, including the U-2, C-5, C-17, all models of the C-130, E-8, and F-15, and other strategic special aircraft. WR-ALC manufacturing facilities at their depot maintenance center is state-of-the-art, largely automated and comprise of various types of high-value assets in various configurations working synergistically as part of complex manufacturing processes such metal cutting, shaping, finishing and quality checks.

While full automation of the complex manufacturing process lead to significant benefit in workplace safety and environment, the large number of manufacturing processes that are supported with their associated high-value infrastructure-critical equipment, their controls, their timing and orchestration that comprise the manufacturing process, often make it a significant challenge for determination of root cause(s) and corrective maintenance when any of the high-value assets degrade or fail.

Qualtech Systems, Inc. (QSI) and WR-ALC is addressing the above challenge with the adaptation and deployment of TEAMS® technology for designing and implementing a consistent, systematic and repeatable digital-twin driven process for manufacturing asset Fault Management Analysis, Design and Operational Deployment for Asset Monitoring, Condition-based Maintenance and Guided Troubleshooting. The QSI technology with the use of the proposed adaptations can also be readily deployed with rapid benefits realization at other process-oriented complex manufacturing facilities that leverage industrial automation capabilities.

The key benefits to the WR-ALC end-users are:

- QSI's TEAMS® technology has allowed WR-ALC to determine critical failure modes of the manufacturing processes and that of the corresponding equipment assets that serve those processes
- Reduced mean time to diagnose and repair all process and equipment-failures at their manufacturing facilities
- Increased First Time Fix Rate and thereby increased availability of the manufacturing asset
- Improved inventory management of critical repair parts of various manufacturing assets
- Consistent improvement and updates of the digital-twin as part of the overall digital thread of the manufacturing asset and its maintenance process based on the analysis and processing of root-cause failure and repair information, equipment usage and maintenance steps that are all captured and logged by the TEAMS® software.

The above benefits lead to the overall benefit in terms of improved turnaround times for aircraft parts and return to service for the aircraft sent for depot maintenance at WR-ALC.

PROBLEM STATEMENT

- ❑ Complex equipment and processes comprise manufacturing and depot maintenance at Warner-Robins.
- ❑ While full automation of the manufacturing process lead to significant benefit in workplace safety and environment, the large number of processes that are supported, the associated different types of equipment, their controls, their timing and orchestration that comprise the entire manufacturing process, often make it a significant challenge for determination of root causes and remedy when any of the acceptance tests for the finished aircraft part fails
- ❑ Ensuring critical infrastructure manufacturing equipment uptime and rapid return to service is a significant challenge for any large manufacturing facility

BENEFITS

- ❑ Improving the operational availability of complex mission-critical depot maintenance infrastructure equipment at the Warner Robins Air Logistics Complex (WR-ALC)
- ❑ Allow WR-ALC to plan manufacturing operations based on asset availability more effectively. WR-ALC personnel have a clear visibility into the health status of the machine shop equipment through the TEAMS dashboard
- ❑ WR-ALC technicians, using TEAMS guided troubleshooting are able to perform like experts for both scheduled and unscheduled maintenance events
- ❑ Significant Improvement in Cost of Service and improved decisions for parts inventory

TECHNOLOGY SOLUTION

- ❑ QSI TEAMS® COTS technology products provides a digital-twin driven engineering methodology for Process and System-level fault management design and use of the same digital-twin for equipment health monitoring, prognostic health assessment and intelligent guided troubleshooting
- ❑ QSI is deploying TEAMS technology for smart manufacturing equipment (e.g. MAKINO T4) and the Advanced Metal Finishing Facility (AMFF) as part of Warner-Robins Smart Manufacturing Initiative
- ❑ QSI's TEAMS Designer is being used for digital-twin development and process and equipment FMECA
- ❑ QSI's TEAMS-RDS is being used for Asset Health Monitoring and Guided Troubleshooting using the digital-twin

SCALABLE SELF CLEANING WATER FILTER & PURIFICATION & DESALINATION SYSTEM

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The Problem: There are currently two (2) main categories of systems that supply military potable water, evaporate/condense (EC) and reverse osmosis (RO). Both of these systems (EC and RO) have annual maintenance costs averaging about 5% of the system value. EC systems collect large amounts of scale which reduces efficiency, and RO systems are essentially filters that clog with particulates during operation. Some environment situations, such as algae blooms at sea, force the shutdown of both EC and RO systems which allow algae cyanobacterial toxins to pass on into the potable water supply. Further, system down time related to failures, operator errors, and availability of replacement components can place both military personnel and operations at risk.

The Technology Solution: This solution combines a first stage centrifuge style self-cleaning filter (coarse and fine) to provide a turbidity with less than 10 microns average particle size (typically less than 7 microns). The second stage of the solution utilizes a high energy E-field plasma and ultraviolet-B to super oxidize the water, which destroys micro-organisms, essentially sterilizing the water, without the use of toxic chemicals or filters, and creates highly reactive OH radicals (e.g. hydroperoxl, hydrogen peroxide, super oxide O2) that break down organic contaminants and toxins into carbon dioxide and water. The third and last stage is an ionic separator, similar to a high speed electrophoresis separator, that removes salt and any remaining contaminants.

The Current Development Status of the Technology Solution: All of the components of the first stage filter are commercially available as standard parts. The main components of the second stage are also commercially available, but require custom mounting. The third stage ionic separator is still in the design phase.

Test/Simulation Data: Filter cut size versus water feed pressure test data and E-coli survivability data make power point file tool large to upload, but are available.

Next Steps: The remaining steps include the completion of the design, the simulation and testing of the ionic separator, and the construction of a complete working prototype, which would include all sensors and programming the computer controller and real time display unit.

The Benefits: The centrifugal style self cleaning filters require almost no maintenance.

The high E-field plasma and UV-B super oxidizer neutralize and destroy organisms and toxins.

The ionic separator removes salt and any remaining toxins.

The sensors and computer controller monitor water purity in real time.

The system is small and compact, and will fit on a 20-foot ISO container frame.

The system is expected to require almost no yearly maintenance, with the possible exception of the plasma electrodes, which can be replaced during operation, no shutdown required.

PROBLEM STATEMENT

- Potable Water is Vital to Military Personnel & Mission Effectiveness.
- The Current Evaporate/Condense & Reverse Osmosis Systems Exhibit Maintenance of 5% of System Cost.
- Toxins from Algae Blooms Can Force the Shutdown of Both Systems.
- System Failure and Component Replacement Endanger Mission Effectiveness.
- These EC & RO Systems Can Exhibit Large On-Going Costs for Chemicals.
- These Systems are Not Compact & Only Produce 50% Through Put on 20-Foot ISO Frames.

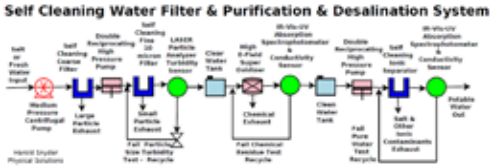
BENEFITS

- The centrifugal style self cleaning filters require almost no maintenance.
- The high E-field plasma and UV-B super oxidizer neutralize and destroy organisms and toxins.
- The ionic separator removes salt and any remaining toxins.
- The sensors and computer controller monitor water purity in real time.
- The system is small and compact, and will fit on a 20-foot ISO container frame. Scalable.
- The system is expected to require almost no yearly maintenance, with the possible exception of the plasma electrodes, which can be replaced during operation, no shutdown required.

TECHNOLOGY SOLUTION

- A multistage, scalable, high flow rate, self cleaning water filter, plasma/ultraviolet purification, and ionic separator.
- Filter Turbidity Particle Size Less Than 10 microns.
- High E-Field Super Oxidizer destroys organisms and breaks down toxins.
- Ionic Separator Removes Salt & Remaining Contaminants.
- Sensors & Computer Controller Monitor Real Time Water Purity & Recycle Water to Pass Requirements.

GRAPHIC OR IMAGE



ENHANCING READINESS WITH EFFECTIVE DECISION SUPPORT UTILIZING SINGLE PAGE APPLICATIONS (SPAS)

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ANSOL has first-hand experience with one of the most prevalent issues we have seen…the lack of readily available quality data. Even with 20 years of central databases, 16 years of SOA and 8 years of cloud technology, this problem not only continues to exist but has proliferated. Central database apps do not meet the needs of individual users which leads to disparate offline spreadsheets/ tools, inaccurate data and analytics, manual workflows, inefficient processes, and poor issue identification and response times. Collectively, these issues adversely affect maintenance, sustainment and production processes across many organizations.

Description: ANSOL has successfully developed and implemented the use of highly customizable SPAs, utilizing existing enterprise content management systems (e.g., SharePoint, AWS), to combat this problem. SPAs demonstrate SOA and provide in-memory, cloud-enabled user interfaces, business intelligence, and analytic tools for spreadsheets and data services. They perform like a desktop or mobile app with user friendly drag-and-drop displays, efficiently using infrastructure bandwidth and delivering fast user experiences.

SPAs can integrate multiple data sources real-time, while leveraging all DoD security and encryption controls, enabling effective decision support. They promote data sharing and can be a collaborative solution spanning many activities. ANSOL has the ability to configure and deploy SPAs for ATO production use within a few hours.

Development Status: The POM Tool(TM) is a lightweight, commercially built, TRL-9 analytically rich, interactive decision support SPA currently in use.

Test Data: Since 2009, metrics have been collected as ANSOL employees utilized the POM Tool in performance of support contracts to provide engineering services for the Navy. 16 areas of functionality within 5 modules were tested using data for: 1,600 Navy afloat/ashore platforms, 32,000 maintenance periods, 500 products, 3,000 alterations, and 200,000 requirements.

Efficiencies gained: Detailed reviews of submarine maintenance and modernization data that typically took 3 analysts 3 days to compile, compare and manipulate now took only 1 analyst 1-2 days using the POM Tool.

In April 2020, we configured a classified Navy production SharePoint site for Commander, Submarine Force, deployed an SPA and migrated legacy data in two hours.

Potential Benefits: SPAs enable data standardization, simplified data management, enhanced data analytics, collaboration, scenario-based planning, schedule and budget management, reduced IT maintenance costs, more efficient maintenance and sustainment processes, and decision support. The SPA architecture allows for rapid rollout of capabilities and supports multiple security enclaves. Affordable local tools with local data ownership leads to accurate and readily available data to be analyzed and shared across organizations enabling a proactive posture for readiness and maintenance capabilities.

PROBLEM STATEMENT

- There is no established method of modernizing legacy IT systems to meet the increased demands for higher quality products and services. With 20 years of central databases, 16 years of SOA, 10 years of web services and 8 years of cloud technology, the lack of readily available quality data not only continues to exist but the problem has proliferated. Central database applications do not meet the needs of the individual user which leads to disparate offline spreadsheets/tools, inaccurate data and analytics, manual workflows, inefficient processes, and poor issue identification and response times. Collectively, these issues adversely affect maintenance, sustainment and production processes across a wide variety of organizations.

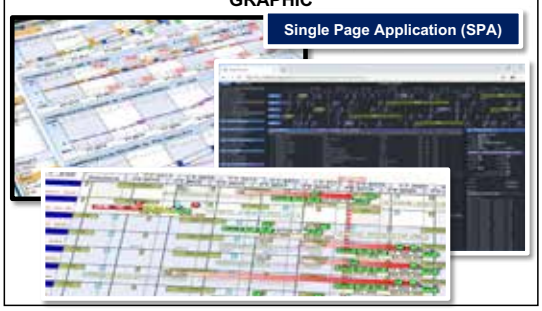
BENEFITS

- Enables more effective and predictable maintenance systems
- Reduces infrastructure and legacy IT maintenance costs
- Visual alerts and graphically rich views allow for more effective decisions, thereby increasing productivity and efficiency
- Promotes data standardization and data sharing
- Simplifies data management, allowing for more time spent on analytics and issue response/resolution
- Enhanced data analytics, including scenario-based planning
- Data collaboration within and between organizations utilizing existing Application Programming Interfaces (APIs)
- Robust schedule and budget management
- New SPA capabilities deployed in hours/days vs. weeks/months
- Compatible with all modern web browsers, operating systems, and platforms (i.e. desktops, laptops, tablets, smartphones)

TECHNOLOGY SOLUTION

- Deploy a cloud-based, customizable Single Page Application (SPA) that has state-of-the-art qualitative and quantitative analytical tools and enhances collaboration, data management and decision support. SPAs are graphically rich, cost-effective applications that run in a web browser. ANSOL will utilize existing DoD enterprise content management systems (e.g., SharePoint, Azure, AWS) and leverage their existing IT infrastructure to demonstrate SPA implementation and maintenance cost savings and efficiencies.

GRAPHIC



CONDITION BASED MAINTENANCE+ DEVELOPMENT ENVIRONMENT (CBM+DE)

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The Condition Based Maintenance+ Development Environment (CBM+DE) has profound connotations. The implications are new methods to improve the quality of Test/Repair and refine the methods of Test/Repair.

The No-Fault-Found (NFF) chain of events could be as follows: (1) It is a chain of events that starts, chronologically, with the end user experiencing a fault symptom. (2) The chain of events might progress from a sortie abort to reporting of the fault to the relevant technicians, through to diagnosis and rectification activity. (3) If the diagnosis is a success then the genuine root cause of the fault is isolated and rectified and the weapon system is signed off serviceable having been made fit-for-purpose and airworthy once more. (4) However, if the root cause cannot be found – in other words, the activity has resulted in diagnostic failure – you are dealing with a NFF situation.

There are times when test/diagnosis on certain Units Under Test (UUT) becomes extremely time consuming, manpower intensive and absolutely frustrating. It is at these times when a new AI and/or Algorithm technology can be useful.

Essentially CBM+DE Software System technology addresses real world problems which can include a vast array of issues like: Certain components never reach a diagnostic conclusion depending on circuit design and Test Program Set (TPS) quality, Prognostics is important to increase Mean-time-between-failure (MTBF) and/or identify defective parts. NFF problems can be extreme and very elusive, Test voids can be an issue and Limit Settings are critical, Intermittent failures are very elusive, Can be perceived as SYSTEM failures that ATE does not normally detect - If TPS mainline can't detect the problem then diagnostics cannot work, The inability to reproduce the symptom during maintenance/diagnostic activity, need to detect the root causes of intermittent faults, Technology needed to streamline the repair process, Hone in on specific test and specific diagnostics, Determine the actual cause of failure, No probing techniques programmed, Limit deviations, skewing, average versus actual measurement, Fix problems in real time, Technology needed to reduce wear and tear on UUTs, Replacing good components occurs quite often - replacing good parts can cause other problems, Technology to utilize IEEE standards so information can flow.

Real world problems include a vast array of issues. CBM+DE Software technology is designed to address the many issues associated with the Test/Repair process of UUTs. CBM+DE will collect data, move data, store data, clean and analyze data, and feed back to users and expand data across the enterprise. Propose the development of the CBM+DE to turn data into something meaningful.

PROBLEM STATEMENT

- 50% readiness not acceptable
- Readiness and Lethality are prime importance
- Turn data into something meaningful
- Smart data decisions, data gathering, Open Architecture
- No-Fault-Found (NFF) – 50% NFF
- Probably 75% out the door with Intermittent faults
- Prognostic: collect data, move data, store, analyze, back to users - Expand data across the enterprise
- Maintenance based on evidence: not only fix but prognosticate to increase MTBF
- Cost: maintenance test and repair - ATE replacement
- Cost driver 35% O&M
- Develop new capability for Automatic Test Systems

BENEFITS

- Aid in solving elusive Intermittent Failures
- What causes the intermittent failures?
- Test Void solutions
- No-Fault-Found solutions
- Automated Test Diagnostics does not work solutions
- RTOK – Re-Test Okay and Bad Actors addressed
- Provide solutions for the inability of test equipment to detect the root causes of failures.
- Predicting Cause of Failure based on Evidence
- Predicting Failures that will occur
- Needed to test some components
- Needed to find actual cause of failure
- Increasing Mean Time Between Failures

TECHNOLOGY SOLUTION
CBM+DE

- Build or Reconstruct to clean databases for Intermittent, No-Fault-Found and Prognostics
- Unlock and utilize the data chain
- Utilize – Where, When, What, How criteria
- Develop AI, Algorithms, and an Ontology
- Fit data into something meaningful
- Maintenance based on evidence
- Predictive analytics - Improve diagnostics
- Real time performed diagnostic decisions

INNOVATIVE "IN-SITU" NDI SENSOR BASED SYSTEMS FOR REAL-TIME DIAGNOSTICS AND CONDITION-BASED MAINTENANCE

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Problem statement: Current Non-Destructive Inspection (NDI) methods for DOD aircraft platforms are very labor intensive and often require structural disassembly and downtime. Acellent provides Structural Health Monitoring (SHM) based NDI systems that utilize sensors integrated with the structure, eliminating the need for structural disassembly. SHM systems leverage modern low-cost sensors and data acquisition combined with powerful signal processing algorithms and fast data transfer mechanisms to detect and track damage over time allowing for timely, targeted and cost-effective maintenance of the structures with minimal or no human interaction. Sensors can be easily installed in areas that are otherwise difficult or impossible to inspect without extensive structural disassembly. Structural inspection can be performed for an entire structural area (example wing, fittings etc.) in minutes. SHM can enable maintenance based on actual material condition instead of current periodic inspection schedules, thereby reducing maintenance downtime, increasing platform availability and readiness, and enabling Condition Based Maintenance.

Technology Description: Acellent provides complete SHM systems that include -

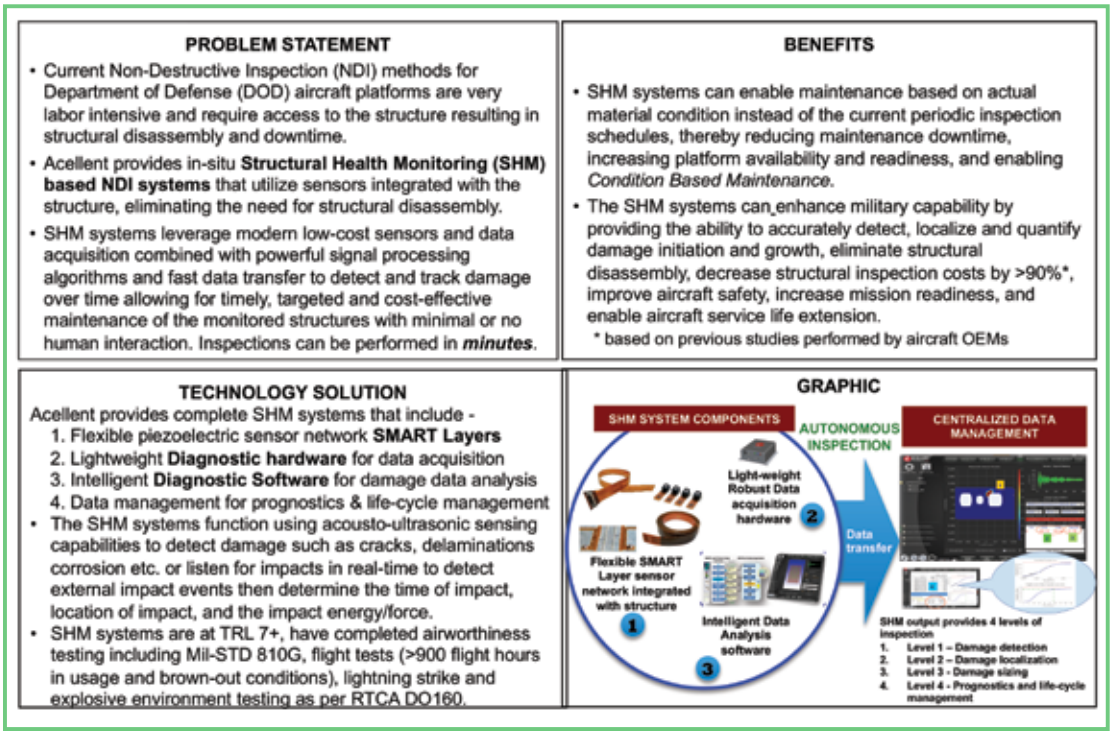
1. SMART Layers - a network of miniature distributed piezoelectric (PZT) sensors and actuators embedded on a thin flexible film and surface mounted or embedded in a structure (metal or composite). The novel sensor network eliminates the need to individually place and wire each sensor and allows the user to monitor an entire area for damage and not just a single point.
2. Diagnostic hardware that are lightweight and have been especially developed to interface with the SMART Layer for data acquisition. The hardware can be located on-board or off-board the platform.
3. Intelligent Diagnostic Software for data analysis to obtain damage information in real time.

The SHM systems have dual acousto-ultrasonic sensing capabilities. The Active SHM system is analogous to a built-in ultrasonic NDE using a network of miniaturized piezoelectric sensors to detect and quantify damage such as cracks, delaminations corrosion etc. The Passive SHM system is set up to be continuously 'listening' acoustically for external impacts in real-time to provide time of impact, location of impact, and the impact energy/force.

Current development status : SHM systems are currently at TRL 7+

Test/simulation data: Completed major testing required for deployment including Mil-STD 810G testing, flight tests (>900 flight hours in usage and brown-out conditions), lightning strike and explosive environment testing as per RTCA DO160.

Potential benefits: The SHM systems can enhance military capability by providing the ability to accurately detect, localize and quantify damage initiation and growth, decrease structural inspection costs by >90%*, improve aircraft safety, increase mission readiness, and enable aircraft service life extension. * previous studies by aircraft OEMs.



FILTERS IMPROVEMENTS FOR US ARMY: MAINTENANCE, REPAIR & OPERATIONS COST SAVINGS USING HIGH QUALITY LEVEL METALLIC FILTERS

JEFFREY LECLAIR

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The solutions for our Nation's military need to be of the latest technological advancements that improve operational readiness. We offer game changing concepts that should significantly improve our Nation's mobile equipment operations and enhance equipment availability. This allows the equipment to stay in the field longer and be maintained by the same military t/m's in the field, not only improving operational efficiency but also reducing logistics movement and time and overall costs.

We believe our engineering and using high quality level metallic filters will further improve the operating systems of our mobile equipment. By partnering with the military to understand the maintenance enhancements of a superior filtering system we shall develop the best product design. We have improved technologies and materials, and engineering by working with our partners in this design. Our built-in quality approach is a step by step process control process that is critical to achieving the expected efficiency improvements that our military demands.

The design will be a collaborative approach to engineer and manufacture a superior product design using our leadership first-hand military combat knowledge collaborating with military design groups. This can lead to further improved opportunities where the weight and size of the equipment can be tested for downsizing for easier maintenance and stronger, longer lasting materials. If the maintenance to achieve these high levels of equipment is targeted and optimized, wasteful spending can be eliminated. Costs are greatly decreased while achieving a highly efficient filter, that have high permeability combining high porosity and thin filter layers at high mechanical strength.

Through the testing phase, we will optimize together the filtering improvements to the equipment vehicles. This is accomplished through the development of technologies combined with resourcing strategies, improved business and production processes, and any other transformative capability. By incorporating the maintenance activity reviews at the same time this new product design will make maintenance more sustainment, more agile, effective, efficient, and affordable.

The field trails will focus on maintenance and sustainment where the military equipment end user will get the opportunity to try it before you buy it to ensure maximum impact. Their feedback in critical to our team's success in ensuring we have optimized the improvement in safety as well as quality. Their buy-in is critical because of their hands-on experience.

Our operational materiel readiness submission around product design improvements along with high quality level metallic filters are to make maintenance more sustainment, more agile, effective, efficient, and affordable.

PROBLEM STATEMENT

- Current filters breaking down prematurely
- Excessive downtime and costly repairs of M1 Abrams battle Tank, resulting in being changed out often
- Safety concerns to soldier due to filters heat events
- Maintenance costs very large
- Fleet readiness not optimized
- Current Filters allow excess foreign objects resulting in wear in the forward mod, ultimately Catastrophic Failure of the AGT 1500 Engine
- Excessive media in current filters results in operator level preventive maintenance providing minimal value
- Moisture allows larger particulate to enter jet engine turbine.

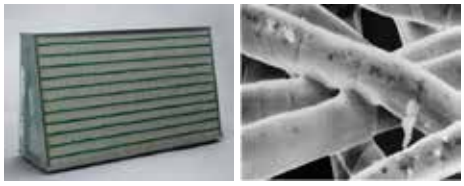
BENEFITS

- Total cost of ownership approach results in filters lasting from 7X longer than current.
- Enhances operational readiness, and maximizes results from operator level PMCS tasks.
- Abram's Tank Inlet Air Filter (VPAC) will have improved air flow, will capture and retain foreign bodies.
- Burn resistance due to high heat capacity that prevents overheating and fires.
- By connecting the maintenance program with the filters, the tanks reliability, availability, yield, quality and safety will increase.
- Increases meantime between failures, mitigate and eliminate engine failures.

TECHNOLOGY SOLUTION

- Our team will design, engineer and manufacture a superior product design using our leadership first-hand military combat knowledge collaborating with military design groups.
- The filters are manufactured of metallic filter media produced using randomized metal fibers, that are highly efficient in both gases and liquids, that have high permeability combining high porosity and thin filter layers at high mechanical strength.
- These mechanical strength fibers enable a mechanically strong network that maintains its integrity under high vibration and pressure and with low pressure drops, high flow rates.
- The metal filter elements are thermal and corrosion resistance and have a very high heat capacity.

GRAPHIC OR IMAGE



Element is from a family of random metal fiber filtration medias
Consisting of sintered SST metal fibers
Highly efficient in both gases and liquids
Characteristics unmatched by other filtration medias

SYSTECON'S TACTICAL AUGMENTED OPTIMIZATION

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Today, maintenance techniques and follow-on supply chain processes are conducted in a reactive posture. Maintenance troubleshooting and corrective actions are triggered by a failure of a component or subsystem or a failure or exceedance of a Time Based Operational (TBO) limit. Demands are created and supply chains react in response to a component removal. This reactive posture continues throughout the entire logistics enterprise and is aggravated by high re-work rates associated with incorrect troubleshooting. Manhours are wasted conducting incorrect maintenance techniques and increase Non-Mission Capable rates during servicing. Supply chains are negatively impacted as parts are removed in error, new parts are purchased, and removed components incur costly No Fault Found charges. Sparing models are built with this incorrect information and costs continue to rise over the life cycle of a vehicle.

Systecon' s TAO puts fleet maintenance and supply chain personnel into a proactive position. TAO leverages operational and health and usage data currently generated by most sophisticated weapon systems and is integrated with cutting edge modeling and simulation modules to optimize operations. This data contains telemetry data, system state data (temps, torques, and pressures), and vibration analysis data which TAO consumes to provide the current state of the weapon system and proactively identifies negative degradation and potential failure. TAO constantly monitors each component "between the operational limits" allowing potential failure to be identified. This stops the negative impact of reactive maintenance across the greater ILS environment, reducing cost and increasing Operational Readiness rates.

TAO is a fully developed commercial off the shelf application and exhibited proven performance via Proof of Concept's (POC) conducted with USG and commercial OEM's. PEO Aviation, US Army, conducted a 60-day POC in 2020, TAO was given 18 aircraft and asked to identify 6 aircraft experiencing a nose gear box failure. Data was masked and no data schema was identified. TAO successfully identified 5 of 6 aircraft, considered to be a great success. In a follow-on test, TAO was given 6 aircraft and identified all 3 aircraft experiencing a nose gear box failure. TAO is applicable for any USG weapon system across all services producing the appropriate level of operational data.

TAO operates in a government cloud or on-premise environment providing clients the flexibility to scale across a single vehicle or multiple fleets. TAO is autonomous, no data scientists are needed to train the algorithms, actionable information is delivered in near real time to all consumers of data across the maintenance and logistics enterprise, leveraging existing data download procedures or replacing them to move data in real time into the network environment.

TAO is the future of maintenance, transforming maintenance and supply chain processes from a reactive to a proactive posture.

PROBLEM STATEMENT

Maintenance techniques and the resulting supply chain processes are conducted in a reactive manner. Maintenance troubleshooting and corrective actions are triggered by the failure of a component or subsystem, literally waiting for failure or an exceedance of a Time Based Operational (TBO) limit.

The Department of Defense and commercial industry are unable to harness the full power of Artificial Intelligence and Machine Learning techniques due to the complex nature of mobile weapon systems. Data identification, collection, and normalization challenges limit potential solutions from being implemented and scaled to solve the demanding maintenance and logistics challenges they face today.

BENEFITS

Maintenance
- Reduce Man Hours
- Predictive Maintenance Alerts
- Reduce Unscheduled Maintenance
- Increased Root Cause Identification

Supply Chain
- Reduce False Demands
- Limit No Fault Found
- Optimized Sparing
- Automated CS&S Planning
- Provide "Just In Time" Processes

Engineering Analysis
- Dynamic FRACAS
- Individual Vehicle FRACAS
- Safety of Flight Profiling
- Configuration Management
- Digital Twin Generation

Mission Impacts
- Increased Readiness Rates
- Higher Mission Success Rates
- Reduce Training Timelines
- Optimize O&M Budgets
- Pure Fleeting Capabilities

TECHNOLOGY SOLUTION

TAO leverages an unsupervised machine learning algorithm to provide an ability to "learn" how the vehicle is being operated, what are the "current" mission requirements, and what performance variables are impacting availability today.

Regime Identification is at the core of the Systecon solution. The algorithm independently identifies and catalogs operational regimes at the individual vehicle level. This approach is in stark contrast to historical deep dives of past performance requirements to predict future failure modes and apply them in aggregate across an entire fleet of vehicles.

As regimes are identified for each vehicle, TAO provides an unprecedented level of context and insight into future and past component failures and moves this analysis across the Integrated Logistics Support ecosystem. This improves all areas of support from future acquisition, engineering, maintenance, and supply chain functions.

MACHINE LEARNING FOR THE LIFE CYCLE

INTEGRATED, RAPIDLY DEPLOYABLE "PLUG & PLAY" LIFE-SUPPORT SYSTEM FOR EXTREME SUBSEA/TERRESTRIAL ENVIRONMENTS

WILLIAM MESSNER

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The current life-support technology – now use in every "extreme environment" (subsea & terrestrial) - is ancient. Current system design remains pre-WWII. Today's world is filled with ubiquitous, highly advance technologies – virtually NONE of which are deliverable to maintenance / inspection people working in confined hazmat spaces subsea and terrestrial.

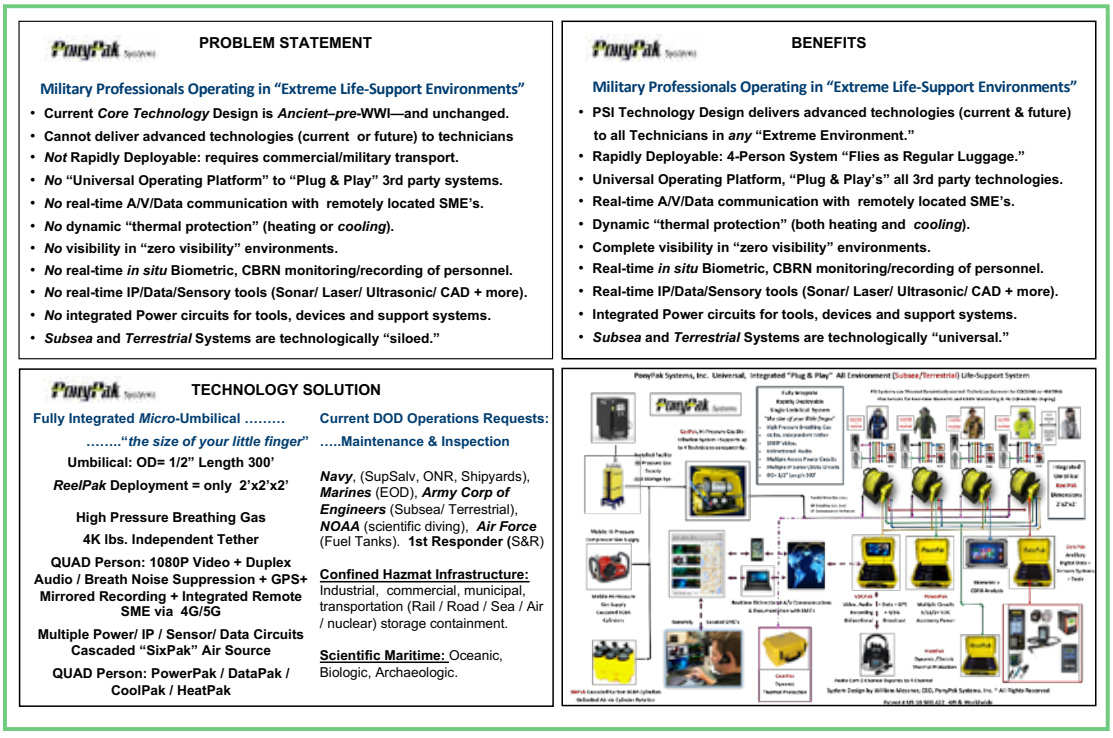
The key innovation within PSI's universal operating platform solution, is our fully-integrated micro-umbilical ("the size of your little finger") which is smaller than the current gas only line now used by ALL DoD. PSI's disruptive technology supports four (4) technicians concurrently with all the following:

- Breathing Gas (30 cf/m)
- Safety Tether (4,000 lbs. test)
- 1080P Video with Switchable integrated LED Lights
- Duplex Audio
- Ancillary Circuits for Power, Devices & IP Data Tools/Sensors
- Integrated, Real-time Remote SME's A/V communications + mirrored (local & remote) recording + GPS
- Dynamic Thermal Protection: Both Heating & Cooling
- Supports Biometric & CBRN Monitoring + Heads Up Display (3rd party)
- Supports all current and FUTURE technologies to be developed for personnel safety and work efficiency.

PonyPak Systems, Inc. (PSI) has developed the only system solution: a complete, integrated, universal "operating platform," upon which every current and future technology may operate, "plug & play." Importantly all life-support system "solutions" going forward, must support a continually evolving universe of future technical requirements (and advancements) in technician safety and work efficiency. Current global technology not only cannot support all future technologies, it is incapable of supporting the most basic of current technologies. This is because (except for materials) it is unchanged in 100 years!

PSI's technological innovations are supported and protected by fifty (50) patents in thirty (30) territories, worldwide. For review, see US Patent #10,500,422 B2,."Integrated Umbilical Delivery System for Gas, Data, Communications Acquisition/ Documentation, Accessory Power and Safety for Users in Adverse Environments," Issued December 10,2019

PSI's *Universal Life-Support Platform*, will support a myriad of new, creatively designed safety systems, tools and devices, by 3rd party companies, to support the brave technicians who work in dangerous confined hazmat spaces.



CONDITION-BASED MAINTENANCE (CBM) FOR VEHICLES

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Problem: Vehicles maintenance in the DoD currently involves two very broad concepts of maintenance: preventive and corrective maintenance balancing operational readiness with total lifecycle costs. Preventative maintenance attempts to act before defects become system failures. The actions are often subjective, consume resources and reduce the time a system is available. Inconsistent checks, inadequate and unnecessary maintenance drives up fleet costs. Corrective maintenance actions are performed for run to failure items or those that fail in an unplanned or unscheduled manner. Even though items may be scheduled for preventative maintenance, if they fail prematurely, they will require corrective maintenance. This approach saves the burden of preventative maintenance but results in variability in availability and can drive cost if a failure causes secondary damage.

Condition-Based Maintenance (CBM) is a conscious effort to shift equipment maintenance from excessive preventive and unscheduled maintenance to a more proactive and predictive approach driven by condition sensing and integrated, analysis-based decisions.

Significant challenges in CBM include development of accurate physical, material science-based methods that utilize existing and unique sensors to determine equipment condition.

Proposed Solution: CBM for DoD vehicles through failure mode damage models (digital twins) of drive system components with damage models continually updated through existing and new real-time sensors. This solution will transition powerful prognostic data analysis and new real-time sensors used on USAF F22 and F35 to vehicles to maximize operational readiness, increase reliability, reduce logistical footprint, and minimize lifecycle costs. Existing sensor data will be fused with new real-time data, supplemented by digital simulations and robust failure mode damage models to avoid unplanned failure of DoD vehicles.

This approach uses proven TRL9 sensors, failure prediction methods, and DPHM (Diagnostics, Prognostics & Health Management) principles already in use on the USAF's F22, F35, and over 4500 commercial aviation engine programs. GasTOPS' real-time oil debris sensor is the gold standard of the F35 DPHM solution, eliminating unplanned events on the engine and Liftfan.

Benefits: CBM brings the ability to meet mission requirements and increase system availability giving commanders and logistics providers information that enables better maintenance decisions. This solution provides earliest indication and prediction of critical drivetrain component damage. Health status from fused real-time data and modeling decades of knowledge in drive system failure modes translated to Remaining Useful Life (RUL) of components. Open data architecture facilitates integration with secure vehicle health management system. This solution will provide increased vehicle readiness, crew safety, operational reliability, reduced logistical footprint and lifecycle cost.

PROBLEM STATEMENT

Reliability-Centered Maintenance (RCM) engineering and Condition-Based Maintenance (CBM) initiatives have not realized the expected benefits of increased readiness, reduced training burden, and rapid continuous improvement. Effective application of CBM+ will allow for exploitation of machine learning and artificial intelligence to make it more powerful over time

BENEFITS

- Eliminates manual entry
- Reduces downtime
- Minimizes training
- Recommends fact-based maintenance actions
- Resilient on unreliable networks

TECHNOLOGY SOLUTION

The **Digital Logbook (DLB)** tool suite integrates applications already familiar to the warfighter to provide condition/fact-based guidance in performing maintenance actions (preventive, reactive, and corrective). The DLB ensures that applications share information securely in disconnected, intermittent, and limited-bandwidth environments, and supports increased readiness through accurate auto-population of records (eliminating manual data entry), prioritization of maintenance activities (reducing downtime), and data-driven workflow automation with direct links from faults to pertinent Interactive Electronic Technical Manual (IETM) troubleshooting and repair procedures (minimizes training).

GRAPHIC

TOBYHANNA ARMY DEPOT COMMUNICATIONS SECURITY FORWARD REPAIR ACTIVITY VAN

JAMES RILEY

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Problem Statement: When deployed, the U.S Army lacks in theater Communications Security (COMSEC) support. If a COMSEC device becomes nonfunctional, the responsible unit is required to order a new device through standard supply channels and must ship the nonfunctioning COMSEC device to Tobyhanna Army Depot (TYAD) in Pennsylvania for repair or disposal. The process is costly, high risk, and could take as long as six months for a unit to get new equipment. This lead-time results in the inability to have secure electronic communications, which hampers unit operations and makes the U.S and its allies vulnerable to enemy forces.

Description: The TYAD COMSEC Forward Repair Activity (FRA) Van is a forward deployed depot support vehicle that enhances Warfighter COMSEC readiness by bringing TYAD COMSEC supply and maintenance capabilities to the operational theater. Each COMSEC FRA Van maintains pre-determined stock to offer unit customers for direct exchange (DX). The DX process permits the Warfighter to have functioning equipment immediately vice having waiting for assets to arrive through standard supply channels. Minimal downtime occurs during a DX action and units can continue their mission and not risk enemy forces accessing sensitive communications. In addition, the COMSEC FRA Van technicians can receive and repair COMSEC items in a timely manner.

Current Development Status: TYAD COMSEC FRA Vans were deployed to support U.S Army Forces in Germany, Korea, Kuwait, and Afghanistan. At this time, COMSEC FRA operations only occur in Germany and Korea. The deployed TYAD COMSEC FRA Vans ensure that the Warfighter has functioning COMSEC equipment at all times. In addition, TYAD COMSEC FRA Van technicians identify COMSEC equipment failure causes. Identified equipment trends in the FRA reports result in recommendations to the unit customers to prevent damage.

Test/simulation data supporting performance claims: Since 2005, the TYAD COMSEC FRA Vans DX'd or repaired over 23,000 COMSEC items. On average, the TYAD COMSEC FRA Van technicians repair over 500 COMSEC items and DX over 200 COMSEC items each month.

Next steps/potential benefits: The TYAD COMSEC FRA Vans have consistently demonstrated operational value in various theaters The Army will continue operations in Europe and South Korea. The Army should develop potential plans to deploy vans at a variety of locations, including reestablishing operations in Kuwait and Afghanistan.

PROBLEM STATEMENT:

When the U.S Army was deployed, it lacked in theater Communications Security (COMSEC) support. If a COMSEC item became nonfunctional, the responsible unit ordered a new device through standard supply channels and shipped the nonfunctioning COMSEC device to Tobyhanna Army Depot (TYAD) in CONUS for repair or disposal. The process was costly, high risk, and could take as long as six months for a unit to get equipment. While a unit awaited the replacement COMSEC equipment to arrive, mission activity ceased because of the inability to have secure electronic communications. When mission activity stopped enemy forces were able to gain respite and threaten the United States and its allies.

BENEFITS

- Total turnaround time same day typically less than 24-hours versus 6-8 weeks; eliminates long lead times; and increases operational availability.
- Equipment is repaired or exchanged in the Theater of Operations ensuring supportability for secure communications for critical networks.
- Repair capacity of 500 each COMSEC items per month and direct exchange capacity of 200 each COMSEC items per month.
- Worldwide deployment capability. The van has been deployed in desert, mountain, and temperate environments.

TECHNOLOGY SOLUTION

- The COMSEC Electronic Repair Vehicle-Mobile (CERV-M) is a deployable, self-contained retrofitted 10-ton semi-trailer van that provides Forward Repair Activity (FRA) and Depot maintenance capability for controlled cryptographic devices in operational environment. .
- Mobile repair center with specialized depot data center for COMSEC supported by two qualified COMSEC electronic technicians.
- Approved storage for cryptographic devices and classified support equipment, power, heating, cooling, and Local Area Network
- Electrostatic repair and test benches capability.

CERV-M Forward Repair – Depot Maintenance

PROGNOSTICS AND HEALTH MONITORING OF COMBAT VEHICLES USING ACOUSTIC MICROPHONE DATA

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Monitoring the health of combat vehicles presents numerous challenges, including harsh conditions, dynamic modes of operation, and data quality, as well as challenges with adding instrumentation to the vehicle, such as reliance on add-on instrumentation for data collection and/or added expense for such systems.

The proposed solution for prognostics and health monitoring of combat vehicles addresses many of these challenges by using acoustic microphone data and focusing specifically on issues related to a lack of fault sensitivity caused by using only can-bus data.

In-vehicle microphones are a cost-effective solution for detecting error states or anomalies from multiple sources. Utilizing existing in-vehicle microphones, along with contextual data from the can-bus, could significantly reduce the cost, by leveraging the existing data, and improve upon the current predictive monitoring solutions for combat vehicles which only use can-bus data. However, this approach is challenging and requires sophisticated AI. The application of domain specific methods for vehicle audible error states and anomalies has not been fully explored for combat vehicles.

Realizing success with this approach in the commercial vehicle industry, Predictronics has been able to deliver application-specific, open-source solutions for acoustic signal processing, feature extraction, and anomaly detection.

In addition to the general benefits of employing prognostics and health management in combat vehicles, such as increased uptime, improved mission readiness, optimized maintenance scheduling, reduced costs, and more, there are many specific benefits of this approach, including a reduced need for additional instrumentation, lower cost implementation of an AI-based solution, and broad applicability across a vehicle fleet.

PROBLEM STATEMENT

- Monitoring the health of combat vehicles comes with numerous challenges, however, the proposed work focuses specifically on issues related to lack of fault sensitivity caused by using only can-bus data. In addition, there are challenges with adding instrumentation to the vehicle including the reliance on add-on instrumentation for data collection and the added expense of such systems.

BENEFITS

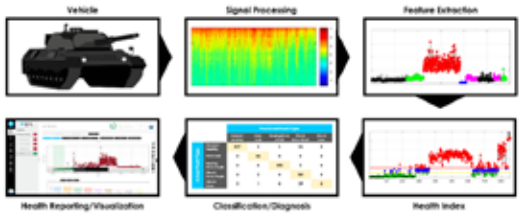
- Utilizing existing in-vehicle microphones along with contextual data from the can-bus could significantly reduce cost by leveraging the existing data and improve upon the current predictive monitoring solutions for combat vehicles that only use can-bus data.
- Specific benefits:
  - No additional instrumentation required
  - Broad applicability across vehicle fleet
  - Low-cost solution
  - AI-based solution
- This approach is already being piloted with a commercial vehicle OEM with promising results.

TECHNOLOGY SOLUTION

- Utilizing existing in-vehicle microphones, along with contextual data from the can-bus, could significantly reduce the cost, by leveraging the existing data, and improve upon the current predictive monitoring solutions for combat vehicles which only use can-bus data. However, this approach is challenging and requires sophisticated AI. The application of domain specific methods for vehicle audible error states and anomalies has not been fully explored for combat vehicles. Leveraging existing success in utilizing this approach, Predictronics is able to deliver application-specific open-source solutions for acoustic signal processing, feature extraction, and anomaly detection.

GRAPHIC OR IMAGE

Overview of solution for vehicle health monitoring.



INTERACTIVE DIGITAL TWIN OF EQUIPMENT OPERATIONS & MAINTENANCE MANUALS

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Problem: Legacy and unconnected devices still rely on paper manuals and drawings to maintain, service and repair. This process is very time consuming and sometimes dangerous, especially in the battle times. This Digital Twin technology solves this problem by making every equipment Operations & Maintenance O&M manuals interactive and smart.

Technology Solution: This is a commercial software platform using the latest technologies such as Digital Twin 3D/AR, AI and ML to convert Operations and Maintenance manuals for any legacy or IoT equipment, smart and interactive and delivers them on mobile or wearable smart glasses for hands free operation.

- Digital Twin, 3D/AR parts identification and procurement capabilities.
- AI built troubleshooting wizard to help identify the problem.
- ML on-boarding system by scraping pdf manuals to extract procedures, warnings, step by step instructions and drawings.
- Video assist by remote experts to help guide the service.
- Step-by-step instructions in writing, video or animation formats to complete tasks.

Benefits:

- Real time access to mission critical data and interactive experiences that engage and educate personnel. Improve safety, compliance and performance by integrating 3D visual tools.
- Reduced Maintenance, Repair and Service times.
- Increase efficiency of operations.
- Increase safety, by providing safety instructions and protocols before the service is started.

PROBLEM STATEMENT

- What problem or need does this technology solve?
- Legacy and unconnected devices still rely on paper manuals and drawings to maintain, service and repair. This process is very time consuming and sometimes dangerous, especially in the battle times. This Digital Twin technology solves this problem by making every equipment Operations & Maintenance O&M manuals interactive and smart.

BENEFITS

- List the benefits
- Real time access to mission critical data and interactive experiences that engage and educate personnel. Improve safety, compliance and performance by integrating 3D visual tools.
- Reduced Maintenance, Repair and Service times.
- Increase efficiency of operations.
- Increase safety, by providing safety instructions and protocols before the service is started.

TECHNOLOGY SOLUTION

- Describe the capability
- Digital Twin, 3D/AR parts identification and procurement capabilities.
- AI built troubleshooting wizard to help identify the problem.
- ML on-boarding system by scraping pdf manuals to extract procedures, warnings, step by step instructions and drawings.
- Video assist by remote experts to help guide the service.
- Step-by-step instructions in writing, video or animation formats to complete tasks.

GRAPHIC

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PTC CONDITION-BASED AND PREDICTIVE MAINTENANCE (CBM+) SOLUTION

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Problem: Increasing demand for DoD operational readiness and assets availability puts pressure on organizations to improve systems live, resiliency and operational availability. The challenge to optimize maintenance decisions, minimize repairs, first time fix rates and service levels – is real, without systematic approach, which changes time-based and usage-based maintenance procedures into real predictive and condition-based maintenance – the maintenance performed based on evidence of need (only when it is needed)

Tech Description: The key promise of PTC CBM+ solution is the application and integration of appropriate logistic processes, technologies, and knowledge-based capabilities to achieve the target availability, reliability, operation, support and cost optimization of systems, assets and components across their life cycle. PTC CBM+ solution uses historical, near real-time and real-time data to prioritize and optimize maintenance resources, such as Service Part Management and Demand Forecasting, to enable Predictive Maintenance. The solution uses a digital twin system engineering approach for data collection, analysis and analytics to support the decision-making processes for system acquisition, modernization, sustainment, and operations.

PTC CBM+ solution offering enables connectivity, data exchange and interoperability between:

- Maintenance Information and Planning Systems
- Reliability, Quality, FRACAS and Risk Management Systems
- Depot, Repair and Stock Management Systems
- Warehouse, Warranty and Freight Management Systems
- Procurement, Order Management, Financial and ERP Systems
- PLM Systems for E-BOM, M-BOM and In-Service BOM management

PTC CBM+ solution is based on ThingWorx IIOT Platform, which enables seamless connectivity between the systems, with the PTC mission-critical solution of Service Parts Management (SPM) for Supply-chain planning, Availability-based Inventory Optimization and Demand Forecasting. PTC Augmented Reality (AR) capabilities, (Visual enhancement capabilities) connected into the CBM+ architecture will boost maintenance procedures and training with interactive AR-based work instructions. PTC CBM+ solution is enterprise systems of record agnostic and enables capability to aggregate and synthesize data from various sources – legacy and vendors-supported systems and applications.

Current development status of the technology and Test/simulation data supporting performance claims: The software is commercially available with out of the box functionality and being utilized by the DoD today. No additional test or simulation data is required.

Next steps/potential benefits: PTC's CBM+ solution provides reduction in unplanned downtime, improved first time fix rates, predictive maintenance, reduce maintenance and inventory costs.

PROBLEM STATEMENT

- Improve systems live, resiliency and operational availability
- Optimize maintenance decisions, minimize repairs, first time fix rates and service levels
- Minimize and eliminate cases and risks of assets uptime failures
- Predict assets critical failures, which happen between scheduled maintenance
- Move from time-based and usage-based maintenance to predictive and prescriptive maintenance

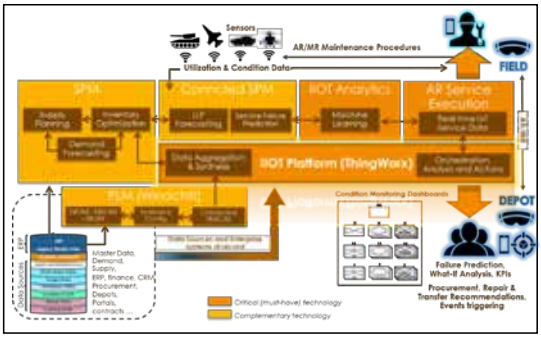
BENEFITS

- Reduced unplanned downtime by 86%
- Predicted impending alarms with 91% accuracy
- Predicted likelihood of part rework with greater than 95% accuracy
- Reduced maintenance costs by 41%
- Improved first time fix rates by 20%
- Predict Common source of unplanned downtime with 90% accuracy
- Predicted impending failures by 89%
- 25% faster wiring harness install with
- 47% faster training instruction comprehension
- 34% faster wiring a turbine control box
- 20-30% Increase in training rates

TECHNOLOGY SOLUTION

thingworx servigistics windchill vuforia

PTC CBM+ solution uses historical, near real-time and real-time data to prioritize and optimize maintenance resources. The solution uses a digital twin system engineering approach for data collection, analysis and analytics to support the decision-making processes for system acquisition, modernization, sustainment, and operations. CBM+ solution is based on ThingWorx IIOT Platform, which enables seamless connectivity between the systems, Service Parts Management (SPM) system and AR (Augmented Reality) technology



SAFE CLEAN AUTOMATED POLYSULFIDE REMOVAL SYSTEM (SCAPRS)

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Polysulfide sealants are critical to the performance of many military systems. Unfortunately, the durability which makes these sealants so valuable also makes them very challenging to remove during maintenance. A clean, high speed, automated solution using atmospheric plasma addresses the limitations of existing mechanical and chemical methods for removing these sealants.

Atmospheric plasma coating removal uses low temperature plasma to convert a coating, such as polysulfide, into water vapor and carbon dioxide. The tool is similar in size to a Dremel allowing it to be easily used in confined spaces such as fuel tanks. Automating this technology maximizes removal speed and process quality and keeps humans out of awkward workspaces where there is a high risk of repetitive stress injury. SwRI has developed a vision system which can identify polysulfide and automatically generating robot paths to remove it. This allows the system to work on a large variety of parts without the need for reprograming by a skilled operator.

Atmospheric plasma has been successfully used to remove polysulfide both manually and on a gantry system. It proved significantly faster than manual removal with a scraper and did not negatively impact the aluminum substrate. It is a commercially available product from Atmospheric Plasma Solutions so there is not a significant development challenge before it can be deployed. SwRI's technology to automatically generate robot paths from vision system data has also been used on several successfully deployed products. These include systems for automatically detecting and removing slag from large castings and systems for automatically de-painting aircraft. The challenge will be the integration of these components into a fieldable system.

The proposed system would offer significant benefits over existing methods for polysulfide removal. It is significantly faster than manual methods using scrapers and eliminates the repetitive stress injuries that these methods can cause on maintenance crews. The environmentally friendly nature of atmospheric plasma makes the system far safer and cleaner than chemical stripping methods for polysulfide. The flexibility of SwRI's automated path planning technology allows the system to work on a large variety of parts and adapt to where the polysulfide sealant is in each case. Automatic quality checks from the vision system validate that the removal process is completed to a high standard improving safety and performance.

PROBLEM STATEMENT

Polysulfide sealants are a critical to the performance of many systems in the aerospace, marine and chemical industries. Unfortunately, the durability which makes these sealants so valuable also makes them very challenging to remove. Existing methods rely on either mechanical removal through methods such as scraping or chemical removal using a dissolving agent. These methods are slow, ergonomically challenging and environmentally unfriendly. Automated plasma coating removal is clean, fast and prevents human operators from incurring repetitive stress injury.

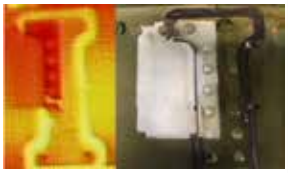
BENEFITS

- **Safe:** Keeps humans out of confined spaces and prevents repetitive stress injury
- **Clean:** Uses no chemicals and produces no toxic byproducts
- **Fast:** Significant speed advantage over manual mechanical removal
- **Flexible:** Mobile platform and scan and plan technology allows system to detect and remove polysulfide automatically without preprogramed paths
- **Proven:** System uses existing technology and approaches. While the integrated system is novel the components are already developed

TECHNOLOGY SOLUTION

SwRI proposes a flexible, confined space capable system for polysulfide removal using proven technology. Atmospheric Plasma Solution's PlasmaBlast™ PB-7000 will be used for coating removal while SwRI's proven path planning and sensing software will be used to scan an area for polysulfide, execute a robot path to remove it and check that removal is complete. Each of these systems has been independently used and verified on previous projects which significantly reduces program risks compared to a clean sheet design. The system will be on a mobile platform to enable it to work on a large variety of systems.

PlasmaBlast™ PB-7000 (Left) and Polysulfide detection using SwRI vision system (Right)



FLEXIBLE STRONG SAFETY COATINGS FOR HARSH ENVIRONMENTS

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Problem Statement: Why are military and aerospace parts and systems categorized as mission-critical?

Because SAFETY must be the top consideration at every stage of research, design, and development. Aerospace Engineers designing parts and systems are responsible for selecting precise materials that solve corrosion issues, eliminate electrical system failures, prevent microbial growth, as well as preserve these assets for as long as materially possible.

Nycote Laboratories Corporation manufactures strong, flexible, easy to use coatings systems that have been trusted in aerospace and defense since the 1960s. Our formulations deliver unique coatings that are applied to increase the safety of critical assets. Your engineers asked and we listened. Over the decades aerospace and defense engineers have asked us to deliver custom coatings that help solve unique challenges and to protect proprietary parts in harsh environments. Nycote coating technology extends the life of parts and we create customized solutions when needed.

Success for Nycote is the creation of products that keep you safe when you fly.

What is Nycote Coating Technology?

We manufacturer unique clear light-weight nylon-polyamide epoxy coatings that provide single-source protection against Skydrol®, JP 4, 5, 8, & 10, salt spray oxidation, conductivity, and other corrosive elements. The aircraft MRO sector is in need of replacing chome and heavy metal products. We believe we can provide solutions to replacing outdated technologies or products that are no longer available or acceptable.

More About Nycote Technology

- Proprietary uniquely clear liquid-nylon thin film that creates a tough, yet flexible barrier and cures pinhole-free, providing complete encapsulation.
- Performs in extreme environments (high and low temperatures)
- Adheres to a large array of substrates, metals, plastics, carbon fiber, glass, and fabrics.
- Offers easy to use one or two-part coating products that perform to a plethora of industry standards.
- Self-levels over a surface allowing for uniform pinhole-free coverage
- Continuous film for 100% corrosion protection
- Chrome and heavy metal-free
- Single-pass solution for easy application. Can be applied by brush, spray, dip, or roll-on methods
- Clear coating that can be custom tinted

EU/IATA/ REACH regulatory compliant

Company Benefits

- Nycote Laboratories Corporation, a small business with worldwide distribution (4 to 6 day lead time)
- ISO 9001 2015 & AS9100D Certified Quality Management System
- Proprietary, crosslinked polyamide-epoxy-nylon thin, lightweight advanced coating tech.
- 60-years experience formulating coatings and trusted by OEM's, MRO's and engine

PROBLEM STATEMENT

Why do we categorize military and aerospace parts and systems as mission critical? Because SAFETY must be the top consideration at every stage of research, design and development. ***Aerospace Engineers*** designing parts and systems are responsible for selecting precise materials that solve corrosion issues, eliminate electrical system failures, prevent microbial growth, as well as preserve these assets for as long as materially possible.
Nycote Laboratories Corporation is a ***SAFETY*** company, creating unique coating systems that are applied to increase safety to critical assets in Aerospace and Defense.
For 60-years Nycote Laboratories Corporation has collaborated with major OEM's, MRO's and Engineers worldwide to provide mission critical coating solutions. Nycote coating technology extends the life of parts and we go above and beyond to create customized solutions.
We are excited to participate in the maintenance Innovation Challenge because we want to help bring solutions to complex challenges and collaborate with and learn from your engineers.

BENEFITS

Product Benefits

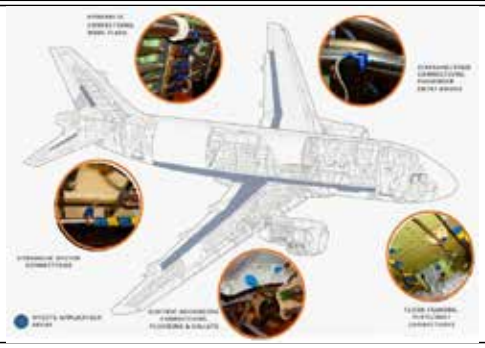
- Protection of Electrical Systems: partnered with MRO's and OEM's to create coatings to exact requirements or specification.
- Corrosion and Chemical Resistance: Partnered with Airbus, Collin AS, Honeywell, Raytheon and many more to meet exact requirements for chemical and corrosion resistance on their critical parts/systems
- Impregnated materials:-Nycote coatings used to impregnate other materials, such as, military and ballistic fuel bladders for tanks & aircraft .Exceptional bonding capabilities.
- Microbial range: We are partnering with two major Aircraft interiors companies to bring new antimicrobial products inside the cabin as a solution for high-touch surfaces, And to create new antimicrobial parts. Nycote meets the requirements for Antimicrobial surface protection per ISO 22196 as well as fungus resistance to SAE-AMS-S-4383 & ASTMG21.(currently testing to Human Corona Virus) (test data provided with NDA)

TECHNOLOGY SOLUTION

Nycote's unique nylon coatings provide single source protection against Skydrol®, JP 4, 5, 10, salt spray oxidation, conductivity and other corrosive elements.

- Proprietary uniquely clear liquid-nylon thin film that creates a tough, yet flexible barrier. Cures pinhole free providing complete encapsulation.
- Performs in extreme environments (high and low temperatures)
- Adheres to vast array of substrates, metals, plastics, carbon fiber, and fabrics.
- Offers easy to use one or two-part coating products that perform to a plethora of industry standards.
- Self-levels over a surface allowing for uniform pinhole-free coverage
- Continuous film for 100% corrosion protection
- Chrome and heavy metal free
- Single pass solution for easy application. Can be applied by brush, spray, dip or roll-on methods
- Clear coating that can be custom tinted

EU/IATA/ REACH regulatory compliant



LASER SURFACE FUNCTIONALIZATION

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Every active service member relies on industrial materiel, in everyday operations and in active conflict situations, in energy, tools and transportation. Protective coatings are applied to this materiel and when they inevitably fail due to rust, fouling, or ice, the warfighter bears the risk. Every year defense spending is over $20B on rust alone. Cleaning and reapplying coatings also takes critical equipment out of service.

FLITE has a new technology that protects all materials using lasers instead of temporary coatings. Without changing the basic properties of metal, glass, plastic and other materials, our technique crafts a surface texture that cleans and protects itself without a coating. This technique, pioneered at the University of Rochester's Institute of optics, uses femtosecond laser pulses to melt the surface of a material and evoke a specific functional pattern. The patterns, such as the familiar lotus leaf, change the liquid interaction with the surface in a non-chemical and non-energetic effect. This change in surface interaction causes water droplets to be driven away rapidly from the surface in a dramatic effect, whether the material is tilted by only a few degrees, exposed to air currents or vibration. Other textures can attract water to the surface – even pulling it against gravity – or repel or attract oil-based liquids, or change the color of materials. Early tests show the effect to have surprising permanence and durability on a wide variety of solid substrates, including metals, glass, plastics, ceramics, semiconductors and composite materials.

There are two approaches to this technique emerging from the fundamental work at Rochester, referred to as laser-induced periodic surface structures (LIPSS) and direct laser interference patterning (DLIP). FLITE is licensing innovations from both camps to be able to prescribe the right technique for the right material and challenge. At the same time, FLITE is engaged in two parallel design tracks; (a) integrations to embed as a manufacturing process technique into the supply chain, and (b) integration with other laser improvement techniques, such as peening (hardening), cleaning and rust removal, for field maintenance and in-situ infrastructure treatment.

The published papers and patent applications describe the use of this technique and refer to broad applications in marine, solar, and aviation sectors, each of which are being pursued by FLITE Material Sciences. FLITE continues to pursue licenses and develop innovations to bring this process from TRL-4 to TRL-8 and reasonable MRL levels over the next 2 years. Our 2020 defense projects are to prevent ice on helicopters and drones, keep sensors and cameras clear, and make better solar panels and body armor. Commercial opportunities include early adopter customers include global companies, including aerospace, marine transportation, automotive, oil and gas, medical devices, food and beverage, and durable goods manufacturers.

PROBLEM STATEMENT

- Coatings suffer from overall fragility against environmental conditions, substrate adhesion problems and a tendency to begin a cascade of failure when small damage occurs.
- Taking materiel out of service for removing and reapllying coatings is expensive and removes critical equipment from mission service.
- Despite the cost of coatings and their maintenance cycle, rust, ice and fouling create catastrophic loss, risk and damage borne by service members
- The $100B coatings market has not offered solutions better expressed than "this is what you have to live with."

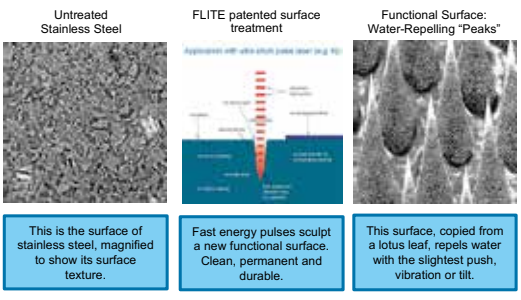
BENEFITS

- A non-chemical, weightless, permanent layer of protection
- In a repellent technique, since liquid can't dwell on the surface, then rust does not form, ice does not adhere, and contaminants (dust, smoke) are washed away easily
- In an attraction technique, paints, glues and lubricants are held tightly to the surface; in combination with the right coatings, it can improve adhesion without the use of a primer
- The process is 100% clean to apply with no toxic effect during manufacturing, in the field, or at end-of-use
- Documented benefits in aviation, solar, sensor and water applications

TECHNOLOGY SOLUTION

- Apply a patented laser technique to the surface of the material before or after a coating is applied
- The laser creates a microscopic texture that is designed to attract or repel water or oil based solutions
- This laser technique can be applied to glass, metal, plastic, ceramics, semiconductors and composites – and tailored quickly with confidence to new materials
- The technology can be combined with other laser improvement and maintenance techniques, such as laser peening (hardening) or cleaning and rust removal

GRAPHIC OR IMAGE



ROBOTIC LASER COATING REMOVAL (F-16 AND F-35)

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F-16 Problem: USAF F-16s typically have 8-15 mils of coatings that have been applied to them. De-painting an F-16 AC is primarily done using plastic media blast (PMB). Per AC, this process generates 2000 lbs. of PMB dust that contains Hexavalent Chrome and Cadmium, which in turn has to be treated and disposed of as Hazardous waste. PMB requires workers to be in full PPE with breathing air as it is a very dusty and hazardous environment to work in. PMB also degrades the fatigue life of the AC skins as it imparts mechanical stresses on the surfaces. This is why the F-16 Program Office has limited the number of times that an F-16 can be de-painted with PMB to 3 times. PMB is also very labor intensive requiring well over 500 man hrs. and 10 Flow days to complete.

F-35 Problem: F-35 needs to remove 2-3 mils of coating from the entire outer mold line of the AC and then reapply the same amount to keep the coatings on the AC within specifications. The only currently available method to accomplish this is hand sanding. This is estimated to take 500-800 man hours and 12-15 Flow days. The other challenge of this is that it is very difficult to precisely remove the correct amount of coating. The coated surfaces do not have uniform thickness and the process will require the tedious task of taking thousands of measurements over the AC while sanding.

RLCRS uses high power LASERS to put energy into the coating, causing it to release and ablate into dust. Temperatures are controlled well below critical AC skin thresholds via use of multiple control systems to work in real time to discern coating locations and types.

Data driven benefits of RLCRS for F-16 are proven and the system is in place de-painting production F-16s since 2017. The system saves 2000 lbs. of hazardous waste per AC. It removes the worker from the Environment. It has no negative impact to the AC airworthiness so there is no limit on how many times it can be used. It saves an average (depending on coating thickness) of 150-250 man hours per AC and reduces 3-5 flow days from the process.

OO-ALC is in the process of upgrading the RLCRS to read precise coating layer thicknesses on metals and composites. This will afford an even more improved ability to achieve the precise coating removal needs for F-35 in order for them to refresh the coating (Take 2 mils off, put 2 mils on) without having to take all of the AC coatings off. RLCRS technology can, conservatively estimating, remove the 2 mils of coating and afford the AC to be ready to paint in 5 days vs. 15.

OO-ALC is currently evaluating all data regarding feasibility of this application and conservatively estimates $15M/yr. of annual savings as planned workloads hit their stride. Hazardous waste and worker stress/strain related to this process will be significantly reduced or eliminated.

PROBLEM STATEMENT

Plastic Media Blast (PMB) of F-16 AC:
- Generates 2000 lbs. of hazardous waste per AC
- Requires operators to be in full PPE surrounded in hazardous conditions exposed to Hexavalent Chrome and Cadmium.
- Causes significant worker stress strain
- Damages the AC surface substrates
- Requires 500+ man hours, and 10 flow days per AC

F-35 Scuff Sand for Refresh application of Coating:
- Estimated to take 500-800 man hours and 12-15 Flow Days
- Difficult to uniformly remove 2-3 mils of coating from entire AC outer mold line (OML)
- Significant Worker Stress/strain

BENEFITS

F-16 De-paint:
- Generates 10-12 lbs. hazardous waste per AC
- Removes operator from hazardous PMB environment
- Does not impact Airworthiness of the AC substrates
- Saves 150-250 man hours per AC and 3-5 Flow days
- Saves $2.5M per year

F-35 Scuff Sand:
- Estimated eliminate 300-500 man hrs. and 10 Flow days
- Accurately and uniformly remove coatings to yield much better surface to recoat to specified thickness
- Remove worker from hazardous Environment 90%
- Potential to save more than $150K per AC
- One RLCRS can while process up to 100 AC per/yr ($15M/yr. savings)

TECHNOLOGY SOLUTION

Robotic LASER Coating Removal System (RLCRS)
- Use of multiple high fidelity control systems that deliver specified LASER power and precision to various areas, substrates, and coatings on the entire OML of the AC.
- Utilized new control technology to accurately measure and remove desired amount of coating thickness from all areas of a non-uniformly applied coating.
- High power vacuums capture 99% of affluent keeping the process area clean and safe for Personnel and the Environment.

GRAPHIC OR IMAGE

APELLIX AERIAL ROBOTIC SYSTEMS FOR THE WAR ON CORROSION

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Apellix is a five-year-old robotics company specializing in precision flight control that allows unmanned aerial systems (UASs) to function as industrial tools for cleaning and fabric maintenance (CFM) of capital-intensive infrastructure. We maintain a predetermined flight path within +/-3cm, allowing our aircraft to perform observational inspections, contact-based inspections, pressurized cleaning, and airless coating of elevated structures up to 150' in height. Apellix is a winner of the 2017 NACE Corrosion Innovation of the year and has been awarded four patents covering much of the technology surrounding the use of UASs to perform some of the dangerous, physical work currently performed by people on scaffolding, ropes, and manlifts, or performed in certain confined spaces.

Many elevated structures are difficult to access and exist in environments that expose the fabric to salt, moisture, and environmental factors that can reduce the effectiveness and longevity of protective coatings. The accumulation of mold, salt, and other contaminants can reduce the lifespan of the coating as well as create aesthetic issues. A small defect or damage can sometimes impair a coatings protective abilities, accelerating localized corrosion well in advance of all other areas of the structure.

Apellix proposes a tethered aerial robotic system capable of performing 1) visual inspection and contact-based measurements, 2) limited spot chemical wash with limited blasting, and 3) limited application of protective coating. This would consist of NDE with contact-based NDT capabilities as well as using a pressurized high-volume flow of water or chemicals (e.g., NaClO, H3NSO3, Chlor-RidTM, etc.) to clean exterior structures. Should a defect be found requiring repair of the coating, the system would be capable of limited blasting to roughly NACE No. 4/SSPC-SP 7, then coating the repaired area with a protective coating such as Interzone 954 from International Paints.

The system would operate with Apellix' existing autonomous features but remain under the direct supervision and control of a pilot and corrosion engineer positioned safely out of harm's way, on the ground. The UAS would be equally adept operating at a tank terminal, a refinery or offshore.

We believe this system can be developed within six months of the award using discreet applications already commercialized or currently in field trials with Apellix.

The resulting system can be developed to incorporate the unique global safety and environmental demands of the industry, including environmental monitoring sensors and integration with any proprietary data reporting/data management systems. We also believe with additional development this system could be re-configured and developed for use in confined spaces, allowing unmanned entry inspection, cleaning, and repairs.

PROBLEM STATEMENT

Many elevated structures are difficult to access and exist in environments that expose them to environmental factors that can reduce the effectiveness and longevity of protective coatings. The accumulation of mold, salt and other contaminants can reduce the lifespan of the coating as well as create aesthetic issues. A small defect or damage can sometimes impair a coatings protective abilities, accelerating localized corrosion well in advance of all other areas of the structure.

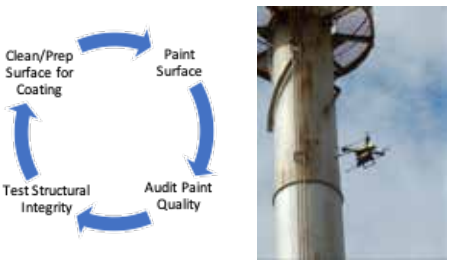
BENEFITS

Cleaning & fabric maintenance of capital-intensive infrastructure such as storage tanks, pressure vessels, process piping, and their associated supporting infrastructure is costly and dangerous and often requires the asset be taken out of service. An aerial spot repair system for inspection, testing, cleaning, surface preparation, and painting could save millions of dollars, reduce risk to workers, and enable more sustainable operations of the assets. This tool is needed for the ongoing war on corrosion. Estimates are that direct and indirect costs of corrosion are 6% of the US GDP.

TECHNOLOGY SOLUTION

An aerial spot repair system for inspection, testing, cleaning, surface preparation, and painting. The aerial robotic system will be capable of performing 1) visual inspection and contact-based non-destructive testing 2) chemical washing and limited spot blasting, and 3) limited application of protective coating. Should the system detect an area requiring repair of the coating it would be capable of limited blasting to roughly NACE No. 4/SSPC-SP 7, then coating the repaired area with a protective coating such as Interzone 954 from International Paints.

GRAPHIC OR IMAGE



NON-LOSS DRAIN PLUG

DOUG HAGEDORN

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Problem Statement: Drain plugs on the bottom of military vehicles are a simple device that are threaded into the hull and removed when water accumulates inside and needs to be drained out. This plug is often removed and misplaced while the water is allowed to drain out. Water is then able to enter the vehicle from this exposed hole and gets trapped into areas below the floor plates allowing corrosion and rust to take place more frequently.

Technology Solution: Armatec has developed a form fit and function drain plug that screws into common drain ports on vehicles but then has a secondary opening and closing screw allowing the user to open the drain for water egress and then close it again without physically removing anything from the vehicle preventing the loss of the plug. The unit can be adapted to any drain size and is made of stainless steel to prevent corrosion.

Status: The system is designed, manufactured and ready for purchase.

Benefits: The benefits would be reduced costs due to replacement of lost drain plugs and the reduction of maintenance due to corrosion damage.

Next Steps: The next steps would be to get them into the hands of the users and validate that they would be of use.

PROBLEM STATEMENT

Drain plugs on the bottom of military vehicles are a simple device that are threaded into the hull and removed when water accumulates inside and needs to be drained out.

The plug is often removed and misplaced while the water is allowed to drain out over time. It is often forgotten to be replaced leaving the vehicle open to water and debris entry from the exposed hole.

Water is then able to get trapped into areas below the floor plates allowing corrosion and rust to take place more frequently

BENEFITS

- Reduced costs due to replacement of lost drain plugs
- Reduced maintenance due to corrosion damage

TECHNOLOGY SOLUTION

- Armatec has developed a form fit and function drain plug that screws into common drain ports on vehicles but then has a secondary opening and closing screw allowing the user to open the drain for water egress and then close it again without physically removing anything from the vehicle preventing the loss of the plug.
- The unit can be adapted to any drain size and is made of stainless steel to prevent corrosion.

GRAPHIC OR IMAGE

PART NUMBER: ACXXX

GRAPHENE AS A NEXTGEN PAINT ADDITIVE

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Problem: Corrosion due to paint failure negatively affects equipment and infrastructure availability and performance, increasing maintenance costs of weapon systems and infrastructure, causes environmental damage and loss of capital investments, and can create safety hazards for personnel. A study contracted by the DOD reported the cost impact of corrosion as $20.6 billion in fiscal year 2016.

Description of the Technology: Graphene nanoplatelets can enhance paint performance by imparting anticorrosive, antimicrobial, antiviral and antifungal properties, increasing strength, durability, and barrier protection, improving UV resistance and thermal (and electrical) conductivity.

What is graphene? Graphene is a one atom thick layer of carbon atoms arranged in a hexagonal "honeycomb" pattern. Harder than diamond, and 200 times stronger than steel, the two-dimensional carbon-to-carbon bonds in graphene are the strongest bonds known to science. Professors Geim and Novoselov won the 2010 Nobel Prize in Physics for isolating graphene in 2004 but, until recently graphene production has been too small and expensive for industrial use.

Current Development Status: Our scalable manufacturing process produces high quality, low cost graphene in industrial volumes.

- Renewable, sustainable biomass feedstock
- Carbon-negative process
- No toxic solvents or co-products
- Current monthly production capacity of 150MT

Test Data: The following is a summary of testing conducted by outside companies on the benefits to various applications by our graphene.

- Polymer reinforcement

  Nite Technology added 1% ProCene® to 75% carbon fiber reinforced epoxy

  25% increase in strength and elastic modulus

- Lattice Composites added 0.05% ProCene® to their high performance molding compound

  Increased strength by 18%

  Increased elastic modulus by 21%

- Ford Motor Company showed the addition of 0.025% ProCene® to polyurethane foam:

  Increased compressive strength by 28%

  Increased tensile strength by 23%

  Increased tensile modulus by 21%

  Increased tear resistance by 21%

- Paint for Marine Applications

  Quantum Paint added 5% ProCene®

  Dries 330% faster

  100% effective in anti-fouling

  Better coverage area

- Armor

  MEP Consulting Engineers

  1% ProCene® added to their basalt/ polymer defeated a Level 3 threat to both body armor and helmet

PROBLEM STATEMENT

Corrosion due to the degradation and failure of paints negatively affects equipment and infrastructure leading to:

- Reduced asset availability
- Deteriorated performance
- Increased costs to maintain weapon systems and infrastructure
- Environmental damage and loss of capital investments,
- Safety hazards for servicemembers.
- A study contracted by the DOD reported the cost impact of corrosion as $20.6 billion in fiscal year 2016.

BENEFITS

Benefits of adding Graphene nanoplatelets to paints include:

- 330% faster drying
- Improved coverage
- Anticorrosive properties
- Antimicrobial, antiviral and antifungal
- Increased strength, durability, and barrier protection
- Improved UV resistance
- Thermal (and electrical) conductivity
- Anti-fouling in marine applications

TECHNOLOGY SOLUTION

What is Graphene?

- A one atom thick layer of carbon atoms arranged in a hexagonal "honeycomb" pattern.
- Graphene is harder than diamond, and 200 times stronger than steel.
- The two-dimensional carbon-to-carbon bonds in graphene are the strongest bonds known to science.
- Andre Geim and Kostya Novoselov won the 2010 Nobel Prize in Physics for isolating graphene in 2004

Next Steps/ Potential Benefits: Next steps in developing graphene for coatings include additional testing of paints enhanced with graphene-liquid dispersions in various applications and environments to determine optimal dispersants, effective loadings and application methods as well as adjust performance characteristics and benefits.

Potential benefits include improved coverage area, faster drying times, enhanced barrier protection, UV resistance, and increased surface life. Anti-fouling benefits are also expected in marine applications. Additional benefits may be realized in advanced coatings and applications such as LO (Low Observable) aircraft coatings.

AIRCRAFT PRESERVATION MATERIAL

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It is a fundamental truism, that all refined metals, if left unprotected from the environment, will revert to their natural states. This is also true at 309 AMARG (Ogden Air Logistics Complex, Hill AFB, UT – located at Davis Monthan AFB, AZ), where one of its primary missions is to inhibit this reversion of the component parts of aerospace assets.

Since 1947, two systems for protecting assets have been developed and employed at 309 AMARG. Each of the legacy systems proved economical and effective for about 30 years, until overtaken by technological advances in both material science and application techniques. 309 AMARG has, once again, modernized the process, using lessons learned and the application of emerging material technologies, to make the preservation of aerospace assets yet more effective and economical. In addition, 309 AMARG had been reliant on a sole source provider for its preservation materials. At one point the provider was unable to produce, leaving AMARG with no method of preserving aircraft for multiple months.

The new materials were created primarily to generate competition. In doing so technical advancements were also included that made the new materials superior to the old. The new base layer and top layer can both be applied in one coat vs two. The new top layer contains heat rejecting ceramic beads that keep the interior surfaces of the aircraft approximately 10 degrees F cooler; extending the life of electronic components stored inside. These new materials have been approved for DoD aircraft and are currently being used at AMARG. In parallel the new materials are being tested by the Navy for use in shipyards.

PROBLEM STATEMENT

- For the past 30 years 309 AMARG has been reliant on a sole source provider for its aircraft preservation mat'ls.
- The application process for these legacy materials required 2 coats of base material and 2 coats of top material for each aircraft.
- The Navy has been reliant on this same material for preservation of their ships' propellers.
- The DoD is not a major customer for this company and approximately 2-3 years ago they were unable to produce the material; causing AMARG to halt preservation activities for several months until production resumed.

BENEFITS

- Elimination of sole source reliance.
- New materials can be applied with 1 coat of base material and 1 coat of top material; saving cycle time, calendar time, and material cost.
- New materials apply similarly to legacy materials; minimized training time.
- New top material contains heat rejecting ceramic beads which provide improved thermal protections of undercoat and aircraft; leading to longer reclamation windows for electronic components.
- New mat'l approved, and in use, on DoD aircraft. Currently in approval process for Navy ship propellers.

TECHNOLOGY SOLUTION

- Working with industry partners AMARG developed a new set of preservation materials (base material and top material) consisting of modern ceramic technologies.
- New materials can be applied via airless technologies, have been approved for application on aircraft, and are currently in use at AMARG.

LOTRAX (LORA-BASED ASSET LOCATION AND INVENTORY SYSTEM)

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Problem Statement: Maintenance and supply chain operations typically have enormous challenges in identifying, locating, and tracking the status of valuable assets (such as Engine and Electronic Component ISO containers). Additionally, the corrosion and environmental damage to the components inside results in extensive repair costs each year, as well as removing critical components from the logistics chain. The challenge is incorporating low cost, long lasting sensors, with minimal infrastructure to provide maintenance and supply operations with accurate and timely asset location and environmental conditions.

Technology Solution: ASI is providing, LoTRAX, a GPS-based location system for high value assets in outdoor locations. It is quick to deploy with minimum infrastructure requirements. The communication mechanism is Long Range (LoRa), a wireless technology developed to enable low data rate communications over long distances using sensors and actuators for Internet of Things (IoT) applications. LoTRAX can upload specific sensor data such as temperature and relative humidity, (i.e. Jet Engine containers). LoRa range is over a mile in urban environments and over three miles in rural areas. To date, over 80 million LoRa end nodes (tags) have been deployed, including smart cities (streetlights, meters, ports (containers, support equipment), and numerous suites of sensor relay activities.

Examples of solutions now available to address these issues include:

- Monitoring the location of reusable transport materiel such as trailers, trucks, rail cars, and shipping containers so that these assets will be readily available when needed.
- Monitoring fleets of vehicles and drivers and integrating with the supply chain Enterprise Resource Planning (ERP) system to optimize capacity utilization, delivery times and maintenance periods.
- Monitoring the health (temperature, vibration, sear) of engines or other equipment to enable predictive and condition-based maintenance.

Current Development Status: The ASI LoTRAX system features Tracker tags (GPS + LoRaWAN data radio + accelerometer + battery). The technology is demonstrable and currently in low rate sample manufacturing. The business-card size electronics can be packaged in many form factors including IP68 enclosures.

Supporting Performance Data: The solution is readily demonstrable with GPS accuracy of 3 meters or less. Data can be forwarded on either 1) regular cycles, 2) state change such as in motion, or 3) upon demand (supports SWST (speak when spoken to) protocols).

Next Steps / Potential Benefits: Andromeda Systems Incorporated proposes to integrate the LoTRAX system for high value asset tracking, fleet tracking, logistical support and condition-based maintenance. Detailed analytics for collected data will also be supplied along with anomaly management actions. Real-time asset visibility will enable optimized management of maintenance resources and assets.

PROBLEM STATEMENT

- DoD faces enormous challenges in tracking and monitoring high value assets, i.e. aircraft engines, APUs, radar systems, etc. packaged in containers or ISO containers. DoD also incurs millions of dollars in repair and replacement costs each year due to damage from corrosion and environmental damage. Factors include:
  - Challenges in identifying locating and tracking the status of valuable assets
  - Visibility into the asset condition (temperature, vibration, sear) with minimal infrastructure
  - An analytical foundation for predictive and condition-based maintenance

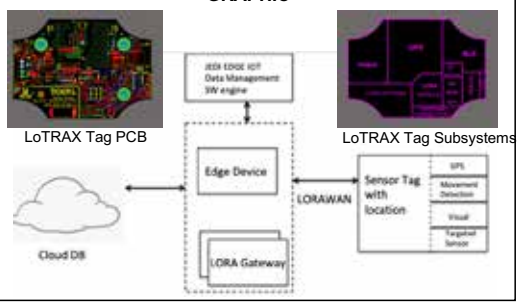
BENEFITS

- ASI's LoTRAX solution enables predictive maintenance practices by transferring asset location, identification, state information (performance sensors), and temporal reasoning for real time assessment and alert notification. Predictive maintenance structures such as LoTRAX are able to reduce overall maintenance costs by ten to forty percent.
- Other benefits from LoTRAX for predictive maintenance:
  - Optimizing planned downtime
  - Minimizing unplanned downtime
  - Optimizing equipment lifetime
  - Optimizing employee productivity

TECHNOLOGY SOLUTION

- ASI is providing, LoTRAX, a GPS-based location system for high value assets in a bounded outdoors location. It is quick to deploy with minimum infrastructure requirements.
  - LoRa is a wireless technology that has been developed to enable low data rate communications to be made over long distances by sensors and actuators for Internet of Things (IoT) applications
  - LoTRAX can upload specific sensor data such as temperature and relative humidity. LoRa typically travels over a mile in city environments and over three miles in rural areas. To date, over 80 million LoRa end nodes (tags) have been deployed

GRAPHIC



IMPROVED MILITARY READINESS THROUGH AN AI-ENABLED RESPONSE TO COVID-19 PANDEMIC

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The COVID-19 pandemic not only a public health emergency, but it also poses a significant threat to military readiness and operations. Military leaders have had to make critical decisions based on incomplete information and without the means to clearly assess the impact that such decisions would have on the spread of the virus and its impact on military readiness, force health protection and command integrity. Moreover, military bases and installations pose a special risk, where young recruits may be asymptomatic and interacting with a more susceptible population of senior officers.

ADVICE (AI powered, Decision Support for Virtual City Environment) is a platform that allows military leaders to create scenarios and assess the impact of mitigation strategies on the spread of COVID-19 within a military base or other facility with high degree of granularity (street/building level). This platform provides AI driven recommendations as to the best way to mitigate the virus spread, while preserving military readiness, force health and command integrity. ADVICE has four modes of operation: Descriptive (What is happening?), Diagnostic (Why did it happen?), Predictive (What is likely to happen?) and Prescriptive (How to act in response?).

ADVICE will provide military leaders with: (1) An early warning system of potential "hot spots" within a military installation. (2) Scenario-based prediction as to the spread and likely impact on military readiness; (3) Recommendations as to the best mitigation effort that will reduce virus spread, while minimizing force disruption; (4) A granular street level view, allowing laser focused decisions that minimize the disruption of operations; (5) a continual learning platform that utilizes advanced AI methods to improve its predictions and prescriptions over time.

ADVICE uses a system of systems approach and includes an epidemiological layer that predicts the spread of the virus based on the movement of agents (mobility layer), susceptibility, geographic location, etc. This platform utilizes advanced simulation techniques such as agent-based modeling (ABM) combined with machine learning (ML) techniques such as deep reinforcement learning (DRL).

ADVICE leverages a platform called FORESIGHT created by Georgia Tech for its smart campus initiative. FORESIGHT is a multi-scale, integrated environment that provides Georgia Tech's management with decision-making capabilities targeted towards energy, infrastructure, safety and mobility. ADVICE is at TRL 2, but it leverages the FORESIGHT technology which is at TRL 8. Next steps for this technology is a TRL maturation program where it is demonstrated in a military base or other facility.

PROBLEM STATEMENT

The COVID-19 pandemic not only a public health emergency, but it also poses a significant threat to military readiness and operations. Military leaders have had to make critical decisions based on incomplete information and without the means to clearly assess the impact that such decisions would have on the spread of the virus and its impact on military readiness, force health protection and command integrity. Moreover, military bases and installations pose a special risk, where young recruits may be asymptomatic and interacting with a more susceptible population of senior officers.

BENEFITS

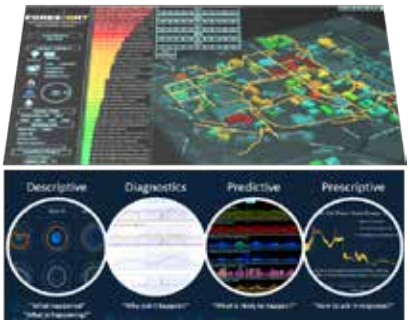
Provides military leaders with:

(1) An early warning system of potential "hot spots" within a military installation.
(2) Scenario-based prediction as to the spread and likely impact on military readiness;
(3) Recommendations as to the best mitigation effort that will reduce virus spread, while minimizing force disruption;
(4) A granular street level view, allowing laser focused decisions that minimize the disruption of operations;
(5) A continual learning platform that utilizes advanced AI methods to improve its predictions and prescriptions over time.

TECHNOLOGY SOLUTION

ADVICE (**AI** powered, **D**ecision Support for **Vi**rtual City **E**nvironment) provide military leaders with an environment to create scenarios, assess the impact of mitigation strategies, and receive recommendations to mitigate the virus spread, while preserving military readiness, force health and command integrity. ADVICE has four modes of operation: Descriptive (What is happening?), Diagnostic (Why did it happen?), Predictive (What is likely to happen?) and Prescriptive (How to act in response?). Its AI driven recommendations

ADVICE uses a system of systems approach to predicts the spread of the virus based on virus transmission (epidemiological layer), movement of agents (mobility layer), susceptibility, geographic location, etc. This platform utilizes advanced simulation techniques such as agent-based modeling (ABM) combined with machine learning (ML) techniques such as deep reinforcement learning (DRL). ADVICE leverages a platform called FORESIGHT created by Georgia Tech for its smart campus initiative.



EYEMYND CORONAVIRUS PHOTON BLASTER

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Problem: COVID-19 is showing the world that we are ill-prepared to quickly and efficiently address a global-scale biological threat like the Coronavirus. Each and every precious human being is both a potential carrier of the deadly Coronavirus particles, and a potential new victim.

Technology Solution: We need to quickly destroy each Individual Coronavirus Particle while it is still several feet away from us.

We are designing a very powerful new Coronavirus Photon Blaster with a uniquely-tailored smart-pattern of Coronavirus-Shaped Ultraviolet light particles to find, disrupt, and quickly (in a few milliseconds) destroy every Individual Coronavirus Particle as it floats in midair at a distance of several feet.

Operates as briefly emitted specially structured light to a volume or surface. Embodiments: smartphones, light bulbs, and small photon-field emitters that can be easily integrated into human smart-glasses, sunglasses, goggles, and helmets.

Benefits:

- The Individual Coronavirus Particles are quickly neutralized in mid-air, within one inch from the human nose & human mouth.
- All Coronavirus Disease Transmission via Human Respiration is Eliminated. Coronavirus Airborne Transmission and Coronavirus Surface Transmission is Eliminated with a number of Unique Photonic Wave-Shapes suited and tailor-made for each type of Coronavirus Environment.
- Precise Ultraviolet Lightfield Shape Matching and Ultrasound Shape Matching to optimally resonant with the unique Coronavirus shape and the unique Coronavirus size of each type of Coronavirus Particle.
- The Coronavirus Photon Blaster is Safe for human skin, and human eyes, and helps all people be safe and able to conduct their normal activities. The Coronavirus Photon Blaster will be shaped and sized to retrofit to existing light sockets and smartphones, and will be made to be efficient, low-cost, with low power, small size, high-speed, and with a very high level of human safety.

This new Coronavirus Photon Blaster Invention will save many human lives.

See EyeMynd.com for more detailed information about this Coronavirus Photon Blaster.

PROBLEM STATEMENT

COVID-19 is showing the world that we are ill-prepared to quickly and efficiently address a global-scale biological threat like the **Coronavirus.** Each and every precious human being is both a potential carrier of the deadly Coronavirus particles, and a potential new victim.

A fully proper **defense strategy** requires **novel solutions** to find, disrupt, and destroy each and every Coronavirus Particle **quickly, in milliseconds**, before it can reach anyone else.

A good robust ***Coronavirus Photon Blaster*** solution will make it impossible for a Coronavirus Particle Pathogen to travel through the air even ***one inch*** away from a person's ***nose or mouth***, before being photon-blasted, destroyed, incapacitated, and effectively neutralized.

BENEFITS

- *Super Fast Mid-Air Coronavirus Photon Blasting* - in just a **few milliseconds**
- The Individual Coronavirus Particles are quickly neutralized in mid-air, *within* ***one inch*** *from the* ***human nose & human mouth***.
- All Coronavirus Disease Transmission via Human Respiration is Eliminated. Coronavirus Airborne Transmission and Coronavirus Surface Transmission is Eliminated with a number of ***Unique Photonic Wave-Shapes*** suited and tailor-made for each type of Coronavirus Environment.
- Precise ***Ultraviolet Lightfield Shape Matching*** and ***Ultrasound Shape Matching*** to optimally resonant with the unique Coronavirus shape and the unique Coronavirus size of each type of Coronavirus Particle.
- The Coronavirus Photon Blaster is *Safe for human skin, and human eyes*, and helps all people be safe and able to conduct their normal activities. The Coronavirus Photon Blaster will be shaped and sized to retrofit to ***existing light sockets and smartphones***, and will be made to be efficient, low-cost, with low power, small size, high-speed, and with a very high level of ***human safety***.

TECHNOLOGY SOLUTION

- **Coronavirus-Shaped Ultraviolet (UV) Photonic Light Field Energy Packets** that are intelligently designed, structured, shaped, tailored, customized, sized, and uniquely fitted to specifically interact with, resonate with, and effectively destroy each individual Coronavirus Particle in milliseconds as it leaves the human nose.
- The "smart" energy packets employ multiple advanced energy-shaping methods and are specially designed to travel several feet through the air, to **find and explode each Coronavirus Particle in just a few milliseconds.**
- These Smart Coronavirus-Shaped Light-field Wave Packets are carefully designed to cause ***disruptive resonant vibrations*** in the ***structure of the Coronavirus wall***, resulting in the destructive explosion and neutralization.
- Operates as briefly emitted specially structured light to a volume or surface. Embodiments: ***smartphones, light bulbs, and small photon-field emitters*** that can be easily integrated into human ***smart-glasses, sunglasses, goggles, and helmets***.
- Visit ***EyeMynd.com*** for more details about this ***Coronavirus Photon Blaster***.

EYEMYND CORONAVIRUS SELF-PROTECTING HUMAN DNA SHIELD

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We urgently need to fully protect all our precious human cells from each and every type of dangerous mutation that may possibly emerge from the growing family of Coronavirus-Type Particles that will continue to mutate and evolve during 2020, 2021, and into the future.

We are designing a Coronavirus Self-Protecting Human DNA Shield that will biologically encode a number of powerful new human cell wall guarding capabilities that will fully block and prevent any type of current or future Coronavirus from binding to any type of human cell wall membrane and injecting its RNA into the cell cytoplasm to infiltrate and hijack the natural human cell RNA Transcription Mechanisms.

This new Coronavirus Self-Protecting Human DNA Shield Invention, when properly installed pre-birth, will completely prevent any new human beings from ever becoming infected with any type of Coronavirus.

See EyeMynd.com for more detailed information about this powerful new Coronavirus Self-Protecting Human DNA Shield Technology Solution.

PROBLEM STATEMENT

COVID-19 is showing the world that some types of viral agents, like the deadly 2019-2020 **Coronavirus**, even with relatively low fatality rates, can cost nations trillions of dollars, strain healthcare systems to the breaking point, and even put national security at risk.

A ***completely powerful permanent Human DNA Shield solution*** that prevents any type of Coronavirus RNA (or any other type of dangerous RNA or DNA) from invading and hijacking *any type of precious human cell* is required and urgently needed right now in 2020. This type of very advanced Human DNA Shield Technology will *require many years to develop completely*. However, if we begin working diligently right now to quickly start developing this technology in 2020, then we can begin to create some ***really good solutions for all mankind by 2025***.

A powerful new ***Coronavirus Self-Protecting Human DNA Shield*** is needed to block, prevent, and neutralize each Coronavirus Particle before it has *any chance whatsoever to breech any type of any human cell wall membrane.*

BENEFITS

- This *Powerful Self-Protecting Human DNA Shield* will be ***Fully Deployed Months Before Each Human Birth.***
- This is a ***Permanent Complete Intelligent Human DNA Solution***.
- The Self-Protecting Human DNA Shield will work to ***fully block*** and neutralize any type of Coronavirus, and also any other type of pathogen containing ***any combination*** *of malicious RNA and malicious DNA.*
- This Powerful New Human DNA Shield will be ***easy to strengthen and extend each year*** to *protect the human body from an increasing array of potential threats.*
- This ***Self-Protecting Human DNA Shield*** is an ***Ultimate Technology*** because there is *no way* to create any technology that is *any greater*.

TECHNOLOGY SOLUTION

- We are designing a powerful new type ***of DNA & RNA Event Resolution Imaging (ERI) Artificial Intelligence (AI)***, that can run on specific combinations of Classical Computers and Quantum Computers, to completely map and decode All Human DNA and All Coronavirus RNA to discover the ***key upgrades needed to strengthen Human DNA*** to code properly for a number of *novel defense mechanisms* to ensure that no human cell can ever be invaded and hijacked by any Coronavirus RNA.
- We are designing a *new type of quantum computer* to fully enable a powerful new ***ERI AI human DNA transcoding schema*** to help *nurture human cell wall membranes* to grow properly with many powerful ***self-protecting properties*** to ensure that no Coronavirus can invade them. These self-protecting properties can be tuned to properly handle the *specific RNA* of the Coronavirus that causes COVID-19, or any other pathogen.
- See ***EyeMynd.com*** for more detailed information about this ***Coronavirus Self-Protecting Human DNA Shield***.

EYEMYND BRAINWAVE VR HEADSET FOR CORONAVIRUS SOCIAL DISTANCE TELEPRESENCE

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We human beings need to take a number of powerful proactive steps to better avoid transmitting the Coronavirus Particle to each other. One such important proactive step is to fully create and completely support a greatly-enhanced socially-satisfying human-to-human Social Distancing Virtual Reality (VR) experience with a much-improved new type of VR Headset.

For many years, we have been designing, developing, and prototyping some powerful new types of Human Brainwave VR Headsets, with some novel types of embedded human brainwave sensors, to enable a hands-free, facial-expression rich, brainwave VR experience that is much more enjoyable and virtually satisfying than what is possible with current VR technologies.

Our complete brainwave VR system is designed to read in your personal human brainwaves, interpret your brainwaves accurately with our advanced new artificial intelligence software, and then animate in real-time, your personal Human VR Avatar that lives inside a virtual environment. All this is done automatically, and effortlessly, as it is all driven by your very own spontaneous human brainwave activity.

Our new Optical Brainwave VR Headsets will provide maximal immersion in VR environments, with complete human comfort, optimal social enjoyment, and high VR tolerance for long, satisfying, fully-immersive human VR experiences.

Visit EyeMynd.com for more detailed information about our new Human Brainwave VR Headsets.

PROBLEM STATEMENT

The **COVID-19 Pandemic** has caused the whole world to appreciate a stronger need to more quickly accelerate the development of many different kinds technologies to greatly facilitate ***telepresence capabilities for human-to-human teleconferences*** across large distances.

Better types of ***Virtual Reality (VR) technologies*** are needed to help human beings feel like they are very close to one another in a virtual sense, even when their real human bodies are very far apart, and ***safe from the Coronavirus.***

The right type of ***Human Brainwave VR Headset for Coronavirus Social Distance Telepresence*** can grow and evolve over time into an ***Ultimate Human Headset*** for almost all types of human interaction that will be *needed in the future*.

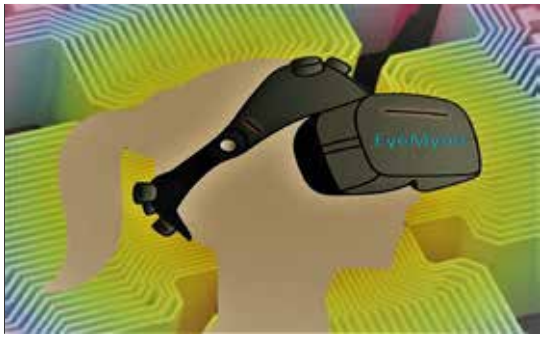
Presently VR is limited by ***having to use the human hands*** to control a set of VR controllers. Current VR is also limited in that it is ***difficult to see each others human facial expressions***. VR is also presently limited in that human beings ***still have to speak*** with their own human vocal cords. What is really needed is a powerful new type of *Human Brainwave VR Headset that* ***fully solves*** *all of these many problems.*

BENEFITS

- Our new ***ROL Optical Human Brainwave VR Headsets*** will allow human beings to *freely communicate* with one another virtually just as if they are only inches or feet apart, even though their real bodies may be many miles apart. This will people to do what they want to do, while providing for good social distancing to keep us all safe from the COVID-19.
- These new *ROL Optical Human Brainwave VR Headsets* will be very ***comfortable and lightweight*** and will allow users to see each others natural ***human facial expressions*** with high accuracy and excellent authenticity.
- Our new *ROL Optical Human Brainwave VR Headsets* will allow the user to ***control her virtual hands and feet with just her brainwaves alone.***
- These advanced new Human Brainwave VR Headsets will also ***open the door*** to many new types of ***human virtual interactions*** and human virtual industries in a *new sub-mortal level* of virtual reality that is ***just one level below this mortal human level.***

TECHNOLOGY SOLUTION

- For ***many years*** we have been *inventing, creating, developing, prototyping, patenting*, and testing some advanced new types of ***Electric Brainwave VR Headsets*** that contain multiple soft human ***electrical brainwave sensors*** that are ***so comfortable*** that you cannot even feel them while you are wearing them.
- We have also been designing some very advanced new types of optical human brainwave sensors (that are strategically placed inside our new ***Optical Brainwave VR Headsets***) that employ ***combinations of red and orange light***, with ultrasensitive photon detectors, and special artificial intelligence software to effectively measure the ***mean firing rates*** of individual functional ***groups of neurons*** inside the human brain.
- We expect that future versions of our new ***Red&Orange Light (ROL) Optical Brainwave VR Headsets*** will eventually be able to measure the ***unique firing patterns*** of each and every ***individual neuron*** inside the human brain from really large numbers of our new ***ROL Human Brainwave Sensors,*** that do not need to even touch the human skin.
- Visit ***EyeMynd.com*** for more details about our new ***ROL Optical Human Brainwave VR Headsets for Coronavirus Social Distance Telepresense***.



EYEMYND BRAINWAVE VR FOR TELEPRESENCE TELECONFERENCES WITH HUMAN FACIAL EXPRESSIONS

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The most fully satisfying human social-distancing Virtual Reality (VR) Experiences rely upon the proper real-time animation of human facial expressions as visual physical cues of social emotions. Without this high-fidelity VR representation of human facial expressions and human feelings and emotions, human to human communication is incomplete and potentially mis-interpreted. These potential mis-interpretations can lead to misunderstandings. Therefore, accurate human facial expressions need to be fully present in VR for all of us. These Accurate Human Facial Expressions in VR are made possible by our advanced Human Brainwave Operating System (Human BOS).

Our Human BOS acts as a personalized and self-optimizing brainwave signal interpretation engine that animates the backbone of a completely natural-feeling VR experience. We have been developing our Human BOS for many years. The Human Facial Expression Component of our Human BOS is designed to eliminate the blank stares of typical VR avatars, and replace these blank stares with high-accuracy human facial expressions as shown in our EyeMynd Avatar Video at EyeMynd.com. From your own spontaneous human brainwave activity, our Human BOS reads even subtle human facial expressions, and then animates, in real-time, your own Human VR avatar. Your Human VR Avatar can then communicate and interact face to face with other live VR avatars anywhere in the world.

Our Human BOS creates intimate VR Telepresence experiences that make you feel like you are really in the presence of the other human avatars.

The Human BOS provides maximal human facial expressiveness in artificial virtual environments, so that the human-to-human communication experience becomes as reliable as actually being there in person. It also creates a psycho-physical experience that causes long-term VR immersion to become more comfortable and more natural-feeling to the user.

Visit EyeMynd.com for more detailed information, and to view our EyeMynd Avatar Video, which shows Human Brainwave VR Facial Expressions, including lots of avatar winks and smiles.

PROBLEM STATEMENT

The COVID-19 Pandemic is increasing the need for good high-quality ***human facial telepresence*** for ***face-to-face teleconferences*** across great distances.

Current Virtual Reality (VR) Headsets do not allow proper recording of a persons' facial expressions such as ***smiles, winks, eye movements,*** and other ***human facial expressions*** that help human beings fully understand one another while ***communicating and socializing inside*** virtual environments.

A new type of ***Brainwave VR Headset*** is needed, with embedded ***comfortable brainwave sensors*** to accurately measure ***human facial*** expressions to enable more effective virtual teleconferences between human beings worldwide.

BENEFITS

- ***Experience Real Human Facial Expressions inside Virtual Worlds***
- ***Animate your own VR Avatar*** using just ***your own human brainwaves***
- Experience the *Most Fully Immersive* and Realistic Feeling VR Experiences
- *Increases human appreciation and enjoyment of VR immersion*
- ***Soft Comfortable Human Brainwave Sensors***
- High performance with no perceptual lag times
- Can be employed as an ***advanced human brainwave developer tool***

TECHNOLOGY SOLUTION

- For many years we have been developing the ***most advanced human brainwave signal processing system on the planet.***
- Our cloud-enabled system includes a ***self-tuned personal Human Brain Operating System (BOS) platform*** that provides accurate real-time interpretation and translation of any individual's brainwaves..
- We have been developing our system for high-resolution recording of brainwave signals for human facial and body movements to create a very enhanced ***human avatar telepresence experience.***
- We have also created the most advanced system to record and accurately interpret ***human mental and physical emotions*** from personal brainwave patterns.
- Visit ***EyeMynd.com*** for more detailed information about our *Brainwave VR for Telepresence Teleconferences with Human-Facial Expressions,* and to watch our ***EyeMynd Human Avatar Video.***

EYEMYND SMARTPHONE CORONAVIRUS SCOPE

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To maximize safety, Every Individual Coronavirus Particle needs to be accurately identified, located, and seen from a safe distance of several feet. By first seeing all the Coronavirus Particles located in a particular room, and thereby knowing beforehand exactly where all the Coronavirus Particles are at, an informed person can wisely and safely avoid contact.

We are designing a Smartphone Photonic Coronavirus Scope that will scan an environment to find, identify, and locate all the Individual Coronavirus Particles (from their unique ultraviolet photonic micro-reflection patterns) as they float in midair (or reside on a surface) several feet away. Our advanced scanning and detection methods (including ultraviolet photonic light field reflection pattern interpretation and reflection-event localization) will provide an accurate and safe means of detection.

As an accessory for a smartphone, this new Smartphone Photonic Coronavirus Scope will become a very useful smartphone companion device to help people scan their personal environmental surroundings to help them safely avoid any contact with the deadly Coronavirus Particles. This Smartphone Photonic Coronavirus Scope can be used and appreciated in both widespread commercial applications and in personal consumer applications.

Visit EyeMynd.com for more details about our Smartphone Photonic Coronavirus Scope.

PROBLEM STATEMENT

There is a strong need to make each and ***every Coronavirus Particle easily visible to everyone.***

There does not yet exist a Smartphone Attachment that can help us see Every Coronavirus Particle, at a ***distance of several feet***.

Most Coronavirus Particles are Spherical Pathogens with *diameters of 60 to 140 nanometers*. This ***small size*** is way too tiny for the un-aided human eye to see.

A Smartphone Attachment Coronavirus Scope, that acts somewhat like both a *Coronavirus Microscope and a Coronavirus Telescope*, needs to be developed to ***help us all easily see the exact location of every Coronavirus Particle.***

BENEFITS

- ***Easily See the Exact Location of every Coronavirus Particle from several feet away***
- *Quickly detect every Coronavirus Particle's* ***Location in milliseconds***
- Simply ***scan your environment with your own smartphone***
- See Coronavirus Particles ***before*** you get near them
- *See all the Coronavirus Particles so you can avoid them*

TECHNOLOGY SOLUTION

We are designing an advanced new ***Smart Photonic Emission, Reflection, and Detection System*** that ***emits structured ultraviolet light energy packets*** that interact with a single Coronavirus Particle in a way that generates ***tiny unique micro-reflection patterns of light particles*** that can be detected by very sensitive ***single photon counters***.

The ***reflected ultraviolet photon count patterns*** are analyzed and interpreted by our advanced ***Photonic Pattern Event Resolution Imaging (PP ERI) Artificial Intelligence (AI)*** software to detect the presence and location of each and every individual Coronavirus Particle at a distance of ***several feet.***

We are designing our ***advanced PP ERI AI system*** to *detect reflected resonant photonic energy micro-signatures* to quickly identify the ***exact location*** of ***every Coronavirus Particle*** in the scanned environment. We expect our advanced signal processing will make it possible to ***detect, decode, and visualize the exact locations*** and numbers of Coronavirus Particles.

Visit ***EyeMynd.com*** for more details about our ***Smartphone Coronavirus Scope***.

EYEMYND QUANTUM COMPUTER TO DECODE CORONAVIRUS RNA

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To create a full range of robust Coronavirus solutions, we need to fully understand the Coronavirus Particle's RNA code that tells it precisely what to be, and what to do. We are designing an advanced new type of qubit-qubit relative phase-controlled Deterministic Quantum Computer to do many useful things, including decoding the Coronavirus RNA.

Our Deterministic Qubit-Qubit Phase-Controlled Quantum Computers will enable an entirely new regime for quantum computing, where quantum states are sustained for long useful periods of time, qubit relative phase is incrementally mastered, and the elusive probabilistic nature of current quantum computers gradually transforms into increasingly deterministic systems, as we develop increasing control over the fine details of the inner nature of qubit wavefunction collapse.

This will change our world. This will open up some good new doors to give us a deep and complete understanding of the Coronavirus RNA, and also a deep understanding of our very own Human DNA, and many other things.

Visit EyeMynd.com for more details about our Quantum Computers to Decode Coronavirus RNA.

PROBLEM STATEMENT

Ribonucleaic Acid (RNA) lies at the heart of every ***Coronavirus Pathogen***. *RNA is the biological computer code* that tells each and every Coronavirus enemy exactly what to do.

The 2019-2020 COVID-19 Pandemic demonstrates the worldwide need to be properly prepared to confront and ***handle all types*** of global-scale human biological threats, like the current *Coronavirus Mutation* that causes COVID-19.

A Strong Defense requires that we fully understand the ***hidden RNA code that lies deep within this tiny enemy.*** Proper mitigation requires solutions that first fully decode and map the molecular structure of the pathogen RNA.

Advanced Quantum Computing Coronavirus RNA Mapping will enable powerful new useful proactive solutions to combat COVID-19.

BENEFITS

- Our ***Advanced New Quantum Computers*** will open the door to the ***Ultimate Way*** to solve for pathogen identification and eradication
- Our *New Quantum Computers* will create solutions exceptionally quickly and robustly
- Our ***Quantum Computer AI Algorithms*** will *decode Coronavirus RNA* to yield a robust understanding of ***Coronavirus Structure*** and behavior.
- Our ***RNA-Event Related Imaging (ERI) Artifical Intelligence Algorithms*** can be run on both *Classical Computers* and on *Quantum Computers*.

TECHNOLOGY SOLUTION

- Our advanced ***new Quantum Computing Technology*** is enhanced by special application of the ***Aharonov-Bohm Effect*** to detect, alter, and *control the relative phase of individual Quantum Bits (qubits)* to stabilize these qubits to achieve ***very long and useful coherence times***.
- Our special implementation of advanced ***Dirac Strings for Photonic Quantum Computers*** to attain full control of ***qubit-qubit relative phase relationships*** to stabilize quantum coherence to help transition from *probabilistic quantum computing* into ***deterministic quantum computing.***
- We are developing practical *programming bridges* that merge conventional classical software programming with programming for quantum computers employing ***quantum logic gates***.
- Visit ***EyeMynd.com*** for more details about our designs for our ***Quantum Computers to Decode Coronavirus RNA.***

EYEMYND QUANTUM ARTIFICIAL BRAINS IN ROBOTS TO COMBAT THE CORONAVIRUS

DAN COOK
LARRY PACE

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We need to create a robust new type of AI to provide the general-purpose brain-like processing power and artificial intellect for future humanoid robots who will do the work that would be unsafe for human beings. We human beings can find many ways to safely avoid interactions with Coronavirus Particles by having smart robots perform many necessary human labors.

We are designing a new type of Quantum Computing Artificial Intelligence that will allow us to create a powerful new type of Artificial Brain that will closely mimic real human brains to carefully learn to perform almost all of the repetitive human labors that we the people currently do. This Artificial Brains will both save many human lives, and become the General Purpose AI that animates the robotic brains of the future.

Visit EyeMynd.com for more details about our Quantum Artificial Brains in Robots to Combat the Coronavirus.

PROBLEM STATEMENT

COVID-19 has helped to reveal that the world needs an ***intelligent robotic workforce*** to ***combat the Coronavirus*** and other pathogens, sparing human exposure and infection.

There are many *jobs that human beings do not enjoy doing*.

Artificial Brains that mimic real human brains need to be developed to properly *animate the humanoid quantum computing robots* of the future that will soon perform almost all human labor.

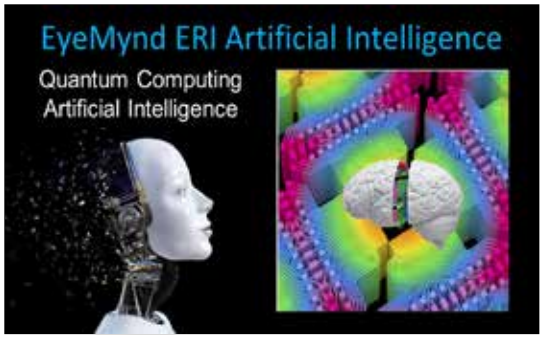
This will ***free real human beings*** for better pursuits.

BENEFITS

- Our ***Quantum Artificial Brains*** will be able to learn how to *mimic real living human brains* to ***perform almost any task a human can do.***
- These Artificial Brains can be used to *animate a broad variety of humanoid robots* of the future to ***perform almost all human labor.***
- These Artificial Brains will help solve *many difficult problems for mankind, and* will ***free humanity for better pursuits***.

TECHNOLOGY SOLUTION

- We have been designing a really new powerful type of ***Event Resolution Imaging (ERI) Artificial Intelligence (AI)*** that can run on both *classical computers and on quantum computers.*
- Our ***new ERI AI Algorithms***, when fully ported to appropriate quantum computers, include a powerful method of *learning from experience to mimic living human brains* to create a type of ***ultimate General Artificial Intelligence (AGI).***
- This ***new AGI*** will be at the ***heart*** of the new ***Artificial Brains*** that will animate the *world's labor robots of the future*.
- See ***EyeMynd.com*** for more details about our ***Quantum Artificial Brains in Robots to Combat the Coronavirus.***



EYEMYND QUANTUM ROBOTS TO STOP THE CORONAVIRUS AND SERVE HUMAN BEINGS

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Humans can avoid interaction with Coronavirus Particles by having Intelligent Robots do activities that would otherwise be risky to accomplish. We are designing our advanced Quantum Robots to initially function as mechanical avatars, driven in real-time by human pilots. These high-performance Quantum Robot Drones will save many human lives, and do work at rates and with performance that exceeds human capacity and capability.

Later, our fully-autonomous Quantum Robots will be animated by our Artificial Brains that will learn to mimic the behavior of real human brains to enable our Quantum Robots to perform almost all human labor. This will free humankind for better pursuits.

Visit EyeMynd.com for more details about our Quantum Robots to stop the Coronavirus and serve Human Beings.

PROBLEM STATEMENT

COVID-19 is showing the world that we need ***intelligent robotic machines*** to perform every type of work that could possibly put a *valuable human being at risk*.

Precious Human Beings are not meant to slave away at *dangerous jobs* or be ***forced to perform menial work they do not enjoy.***

Super Intelligent Humanoid Robots of *every size and shape* are needed to learn to perform all the ***difficult labors*** that are currently being done by *precious vulnerable human beings.*

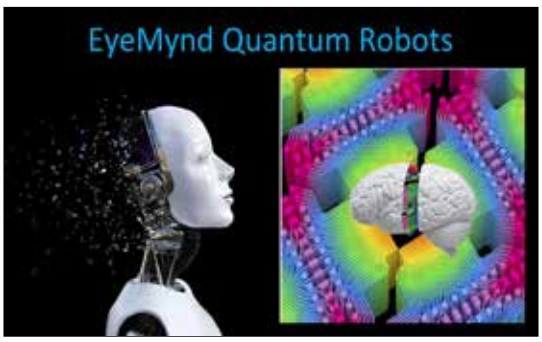
Very Powerful and ***Intelligent Artificial Brains*** are need to animate these ***Amazing Robots of the Future.***

BENEFITS

- Our ***Quantum Robots*** will work in many types of ***dangerous environments*** that are *not safe for human beings.* Our Quantum Robots will also perform the ***menial labors that no human being desires to do.***
- Our Quantum Robots will be able to ***work faster*** and longer that humans to build more useful things quicker. Our Quantum Robots will be able to understand how to execute a task, and how to *adapt to new environments* and situations, while working on the overall mission.
- In the beginning, until our Quantum Robots can work with complete autonomy, human beings will need to *animate the robots*, as extensions of their human bodies.
- Our Robotic Human Avatars will be fully capable of providing ***full replication of human activities***. Our *Quantum AI* will provide the ***core computational capabilities*** of these powerful Robotic Human Avatars.

TECHNOLOGY SOLUTION

- We are designing a new type of ***Quantum Event Resolution Imaging (ERI) Artificial Intelligence (AI)*** that will sit at the heart of the ***Artificial Brains*** learn to *mimic human brains* to animate future robots that will perform almost all human labor.
- This will *free humankind* for better pursuits.
- We are designing a powerful new type of Quantum Computer that will provide many orders of magnitude increases in computational capability to provide the necessary speed for our ***Quantum ERI AI Algorithms*** at the heart of our ***Artificial Brains*** that will animate our *Quantum Robots.*
- Visit ***EyeMynd.com*** for more details about our ***Quantum Robots to stop the Coronavirus and serve Human Beings.***



ENHANCING CONDENSER TUBE CLEANING THROUGH INNOVATIVE TECHNOLOGY

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Problem statement: Aircraft carrier condensers and heat exchangers require regular cleaning to remove fouling in order to operate effectively. Condenser cleaning is often the critical path for completion of carrier availabilities. Current process is to hand-feed a lance pressured with water through condenser tubes. This requires multiple people, is time consuming, and involves a safety risk to operators. The optimized solution will result in safer and faster tube cleaning, and eliminate condenser cleaning as a constraint on availability.

Solutions for this application will have the following: Reduced cleaning time, increased cleanliness of the tubes (no re-work associated with inadequate cleaning), mitigation of safety risk to the operator.

The number of tubes to be cleaned on a single project can be up to 60,000. Minor inefficiencies in the process can result in significant increases in work duration. This project seeks to validate an alternative method and process to alleviate this problem and to position this technology to be available for a range of condensers/heat exchangers on Navy ships.

Description of Technology: The technology is designed to enhance cleaning methods, removing "hands-on" end-users from harsh working conditions by the use of a robotic lance feeding and positioning system. This project takes an industry-leading solution for confined space condenser cleaning and optimizes it for performance on naval vessels. Improvements include:

- Wireless remote operation with tablet computers, eliminating risk of operator injury from contact with high-pressure spray
- Automatic positioning to condenser tubes, with the single press-of-a-button, mitigating human error
- Robotic lance feeding: Allowing for predetermined and consistent feed-rates throughout shifts to optimize cleaning performance (mitigating deficient clean and human fatigue). Feeding two lances simultaneously, doubling cleaning capacity per stroke by energizing water during both forward and reverse feeds (mitigating deficient clean).

Current development status of technology:

- Technology currently performs at TRL-6 level
- Test/simulation data supporting performance claims: Phase 1 prototype has successfully cleaned condensers on aircraft carriers in Bremerton and San Diego.

Next steps/potential benefits: Cleaning system is expected to reach TRL-9 phase by 3rd quarter 2020, which will include 100% Fully Automated Cleaning. Robotic system will automatically perform both positioning and feeding sequences without individual commands from end-users. Additional customization and improvements based on lessons from Phase 1 prototype. Benefits of this technology are not limited to aircraft carriers. Because of its adaptability, this technology can apply its increased safety and productivity, and reduced cleaning time for better performance in: All naval and commercial vessels containing heat transfer devices, shipyard equipment, chemical, power generation, and food processing plants.

PROBLEM STATEMENT

Cleaning condensers on aircraft carriers is a significant job that takes months to accomplish and often becomes the critical path for the aircraft availability. Additionally, several individuals have been injured in the corporation over the last year by high pressure spray lances used in cleaning condensers

BENEFITS

- Tubes to be cleaned quicker—schedule savings and cost savings. Improved operational readiness for Naval vessels
- Reduced cost of maintenance
- Reduced down time, and maintenance of equipment aboard ship
- Improved safety to operators and safety features
- This technology can be applied to DoD facilities that require condenser tube cleaning
- Eliminate injuries to mechanics from high pressure spray lances.
- Benefit aircraft maintenance at all shipyards with potential for application to other vessels.

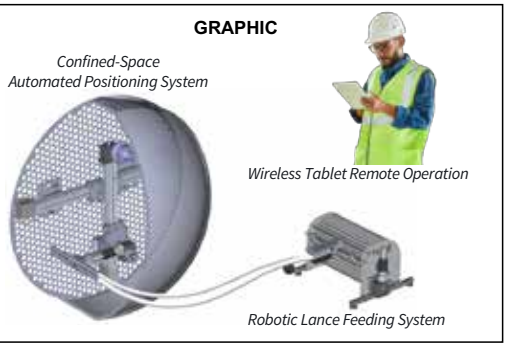
TECHNOLOGY SOLUTION

Use of an automated technology to position and feed lances will result in quicker cleaning time and will prevent injuries by taking the lance out of the mechanics' hands

Primary Federal Sponsor
- Puget Sound Naval Shipyard, Jeff Brimhall, Technology Insertion Manager, PSNS&IMF

Potential Application(s):
- Enterprise capability which will benefit all four Naval Shipyards
- Food processing plants, power plants, hospitals, manufacturing facilities

GRAPHIC



IN-HOUSE MANUFACTURE OF PLY-METAL PANELS FOR PAYLOAD TRANSPORTER III TRAILERS

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The 309 MMXG (Ogden Air Logistics Complex, Hill AFB, UT) Sheet Metal Shop manufactures Environmental Covers for Payload Transporter III Trailers. The trailers are used to transport Minuteman III nuclear payloads, missile guidance systems, Propulsion System Rocket Engines, and nose cones. The manufacturing of the Environmental Covers requires ply-metal panels. The smaller panels were purchased from a vendor, and the larger ones were manufactured in-house. The manufacturing process of ply-metal was labor intensive, and of poor quality. Voids and delamination were inherent to the manufacturing process. The environmental Covers of two trailers delaminated. One of the trailers had finished depot maintenance operations and was in route to be delivered to the field, and the other trailer was close to (refurbishment) completion when the problem was discovered.

The team, composed of the Sheet Metal Shop and Process Engineering, developed a process to manufacture all ply-metal panels in house using a vacuum process. The new process requires the use of a large plastic sheet, tacky tape, breathing material, and two vacuum pumps. When validating the manufacturing process, the materials used cost less than $20 dollars, and the vacuum pumps were borrowed from the Air Conditioning Shop.

The manufacturing process proved to be successful, and has now been updated to use three-four Venturi pumps that use the in-house shop air to perform vacuum, rather than the traditional vacuum pumps. The new process eliminated the need to place 70 x 60 lbs. sandbags on the aluminum sheets during the curing process. It allows the mechanic to adhere both sides at the same time, reducing the manufacturing time of each panel by 14 hours. It also allows the mechanic to manufacture up to three small (5'x9') panels at the same time. The new process also reduced the manufacturing time by two weeks, rework time by three days, and saves the program approximately $50K per trailer.

PROBLEM STATEMENT

Ply-metal panels are manufactured to produce Environmental Covers for Payload Transporter trailers. Due to manufacturing process, aluminum skin of Environmental Covers delaminated from center plywood core. Environmental Covers on two trailers were re-manufactured due to delamination, one trailer was re-called from the field.

BENEFITS

- Improved safety of mechanics
- Eliminated use of sand bags to apply pressure on aluminum sheet during bonding process
- Eliminated voids in epoxy
- Ensures uniform bond line
- Eliminated delamination
- Eliminated two weeks in manufacturing process
- Eliminated three days of rework
- Saves approximately $50k per trailer

TECHNOLOGY SOLUTION

Developed vacuum process to laminate ply-metal panels.

SAM SCALING TOOL

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Problem Statement: Nonskid surface coating is difficult to remove uniformly, efficiently, and safely. The popular Aurand MP6 surface scaler removes failing nonskid surface on carrier decks, but injury rates among maintainers are high, and the process is slow. Currently maintainers recline, kneel, or sit while using the scaler.

Maintainers who use the Aurand MP6 suffer serious injuries due to poor postures as well as exposure to vibration and high grip forces. Injuries include musculoskeletal disorders, repetitive stress injuries, and respiratory ailments due to dust inhalation. Staff unavailability due to injury impacts production schedules, budget, and morale. Though consistency in removal of nonskid is critical to meet requirements, achieving consistent results is impaired by excessive fatigue.

Description of the Technology: The Temple Allen SAM (Standup Abrading Machine) Scaling Tool takes the already-proven Aurand MP6, mounts it on an ergonomic and vibration-dampening control handle, and adds an integrated dust collection system and carry handle. This configuration enables maintainers to confidently wield the MP6 while standing comfortably. The patent-pending SAM Scaling Tool maintains uniform pressure on the surface resulting in a uniform finish. Responding to feedback from maintainers at demonstrations, Temple Allen added an adjustable cut height feature to accommodate pitted areas.

Current Development Status of the Technology: The SAM Scaling Tool, featuring the Aurand MP6, is available for commercial sale to government and private sector clients. Configurations are available with or without vacuum capability. The SAM Scaling Tool is one of a family of SAM Tools for use across a wide spectrum of surface preparation applications.

Test Data Supporting Performance Claims: Onboard demonstrations of the SAM Scaling Tool received positive feedback – NavSea observers called this technology a "game-changer." The Aurand Tool has been in use since 1937 and the SAM technology has been in regular use at commercial and military locations since 2014. SAM customers report meeting or exceeding internal targets for productivity, consistency, and safety since implementing SAM tools.

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

Potential Benefits: Use of the SAM Scaling Tool yields a consistent high-quality surface finish by all maintainers. Using the SAM Scaling Tool can improve predictability for maintenance schedules by boosting "trigger-on" time uniformly for all maintainers. By eliminating exposure to vibration, high grip forces, and poor postures, the SAM Scaling Tool protects maintainers from injury as well as supports a constant rate of work. The vacuum and debris shroud reduce exposure to toxic dust.

PROBLEM STATEMENT

Nonskid surface coating is difficult to remove uniformly, efficiently, and safely.

Current procedure to remove failing nonskid surface on carrier decks employs handheld pneumatic scaling tools. Handheld tools pose significant risk of injury because they subject maintainers to excessive vibration, high grip forces, and poor postures.

Injured personnel impose high costs to morale, budget, schedule, and mission readiness. Fatigue, short of injury, can result in inconsistent surface finish that requires rework.

BENEFITS

The SAM Scaling Tool is proudly made in the United States and offers many benefits, including:

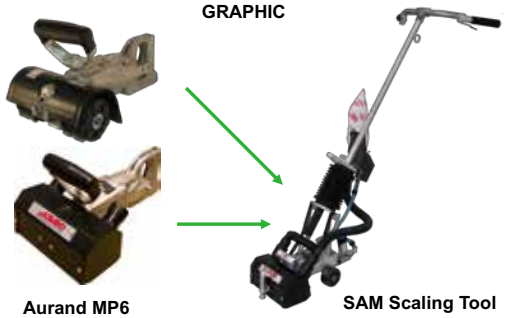
- Reducing injuries and fatigue
- Achieving consistent results from all maintainers
- Increasing trigger-on time during removal of surface coating
- Promoting sustainability because it is a durable tool
- Attracting and retaining skilled labor
- Improving debris capture

TECHNOLOGY SOLUTION

Temple Allen's SAM Scaling Tool removes nonskid surface coating efficiently, uniformly, and safely by:

- Incorporating the already-approved Aurand MP6 scaler
- Eliminating poor postures, vibration, and high grip forces
- Capturing debris with included shroud and vacuum
- Producing a more consistent, higher-quality finish
- Incorporating the ability to adjust cut height
- Using a pneumatic system (95 psi)
- Increasing "trigger-on" time

GRAPHIC



CHROMIUM MITIGATION TECHNOLOGIES

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Hexavalent chromium is 8x more carcinogenic than asbestos and is an IARC Group 1 Agent, alongside arsenic, mustard gas, and plutonium. It is used extensively throughout the DoD and industry in paint, plating, and welding operations, and exposes many personnel to toxic airborne dust. Workers who are exposed to hexavalent chromium are at increased risk of developing lung cancer, asthma, or nasal damage.

With the Air Force, Figure Engineering has developed three novel technologies to mitigate chromium and cadmium exposures, specifically from abrasive blasting, while drastically reducing energy consumption. Dust Migration Mapping (DMM) creates a heat map of a facility to visualize migration paths and correct problems at their source. Figure's Continuous Hazardous Environment Monitor (CHEM) sensor speciates and quantifies chromium and cadmium dust in real time. The CHEM sensor provides feedback to Figure's Advanced Continuous-Time Adaptive Ventilation (ACTAV) system, which automatically ramps up or down big ventilation systems to match the present hazard, keeping workers below the PEL and saving up to a measured 70% energy costs.

Currently, the TRL 7+ technologies are showcased in the world's most advanced blast booth, a tractor-trailer-sized booth in Building 844 at Hill AFB, which was installed with the help of the Rapid Innovation Fund (RIF), which chose Figure to be featured in a RIF success story. The technologies are also installed at Hill's B507 plating shop, controlling a 1000hp critical ventilation system. Figure currently has patents pending for each of the three technologies. Figure recently completed an initial Navy contract to integrate ACTAV with it's Collective Protection Systems, ship-wide ventilation protecting sailors during CBRN attacks.

The technologies were developed with experimental design, input, and oversight from world-renowned cardiopulmonary toxicologist Dr. Vincent Castranova, former acting Director at NIOSH and distinguished professor of toxicology at WVU. At Dr. Castranova's NIOSH lab, Figure demonstrated repeatedly that CHEM's measurements fell within the OSHA method's statistical error, providing reliable results in 5-10 minutes, rather than the legacy method's typical 2-3 weeks. This was tested and validation by parallel monitoring with Hill's Bioengineers over the course of 18 months. DMM has successfully identified secondary unknown chromium sources that went years undiagnosed. ACTAV has demonstrated the ability to maintain operator PELs below the action limit while delivering a measured energy savings of up to 70% during production.

Figure's technologies are commercially available through Veteran Equipment and are now propagating to Robins, Tyndell, Corpus Cristi, PACAF, Pittsburgh Air Reserve Station, and Boeing's Osprey depot, among others. Next, Figure is packaging these technologies into rapidly deployable don/doff and decontamination units to immediately benefit existing depot facilities, forward repair centers, and other maintenance sites.

PROBLEM STATEMENT

- Hexavalent chromium is 8x more carcinogenic than asbestos
- Chromium compound agents are in the same IARC Group as arsenic, mustard gas, and plutonium.
- It is used extensively throughout the DoD and industry in paint, plating, and welding operations, and exposes many personnel to toxic airborne dust.
- Workers exposed to Chromium are at increased risk of developing lung cancer, asthma, or nasal damage.

BENEFITS

ACTAV, CHEM, and DMM are increasing fleet readiness by preserving maintainers' health, increasing equipment up time, and freeing cash.

- Workers stay below OSHA Permissible Exposure Limits (PELs)
- PELs are reprogrammable and expandable to easily meet future OSHA PEL compliance
- Rapid detection of primary and unknown sources of Cr & Cd for elimination
- Extended equipment life with reduced wear and tear
- Less hazardous waste from less media lost through ventilation
- 70% energy savings over constant-velocity booths.
- Cr/Cd exposure measurement in 5-10 min instead of 2-3 wks

TECHNOLOGY SOLUTION

With the Air Force, Figure Engineering has developed three novel technologies to mitigate chromium and cadmium exposures, specifically from abrasive blasting:

- Dust Migration Mapping (DMM) creates a heat map of a facility to visualize migration paths and correct problems at their source.
- Continuous Hazardous Environment Monitor (CHEM) sensor speciates and quantifies chromium and cadmium dust in real time.
- Advanced Continuous-Time Adaptive Ventilation (ACTAV) system uses CHEM feedback to autonomously ramp ventilation systems to match the present hazard

Peace of mind for worker and manager to focus on the mission!

THE SARCOS® GUARDIAN® XO® FULL-BODY, POWERED EXOSKELETON

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Logistics Service Members (SM) must perform physically demanding and high-risk activities manipulating heavy equipment, tools, materiel, and supplies in complex and often high-risk environments like shipyards and airfields. Sarcos' Guardian® DX robot will uniquely add to the Department of Defense's (DoD) transformative investments in material readiness and the modernizing of its maintenance and sustainment forces. Delivering a cost-effective solution with a high return on investment, the Guardian® DX will facilitate greater productivity, faster turn-times, lower cost, higher precision, fewer injuries, and a more agile and capable workforce. No other product or technology like the Guardian® DX robot is available today, giving the DoD a substantial advantage over near-peer competition and adversaries.

The Guardian® DX robot leverages the core state-of-the-art technologies and capabilities of Sarcos' Guardian® XO® and Guardian® GT to develop a new class of dual-use human-scale tele-operated highly dexterous robots. The Guardian® DX will work as a real-time tele-operated robotic system that is kinematically-equivalent to the human user, facilitating dexterous manipulations. The robot arms will move with human-like motions, ranges of motion, and dexterity and the operator will receive real-time sensory feed-back information from the remote-robot. The operator will be equipped with a Virtual Reality Headset (VR) to see what the remote-robot sees and hear what the robot hears, delivering an immersive workspace experience – a telepresence to the operator. A modular system-architecture will facilitate later installation on different ground and aerial work platforms. The integration of a human operator controlling a remotely located robot results in a system with the resourcefulness and experience of the human operator combined with the strength, stamina, repeatability, and precision advantages of robots.

Sarcos will demonstrate a prototype system for a commercial customer in October 2020 and is developing the system as part of a contract with the U.S. Navy.

Sarcos is leveraging investments made in Sarcos-designed exoskeletons and other mobile dexterous robotic systems to accelerate the critical path of the Guardian® DX. In addition to an increase in productivity, quality of work, and reduction in occupational injuries, the deployment of the Guardian® DX is expected to: enable an individual who performs physically demanding work to do so consistently over longer periods, have skilled people stay in the workforce longer, and equalize work and career opportunities by enabling people of all ages and body types to perform physically demanding work which has traditionally been reserved for a small portion of the population that meet certain physical capability requirements. The Guardian® DX will bolster overall readiness as a direct result of modernization that exceeds the current capabilities of near-peer competitors and adversaries.

PROBLEM STATEMENT

- Logistics Service Members must perform physically demanding activities manipulating heavy equipment, repair parts, tools, materiel, ammunition, supplies and dunnage
- Common logistics tasks: must efficiently and safely lift, push/pull, transport and manipulate loads in both structured and unstructured environments
- Heavy lifting tasks result in numerous short/long-term injuries
- Injuries tend to reduce useful timespan for worker utility
- Must reduce strain, increase endurance, create safe work environment
- Cost in lost man-hours and useful work life results in immediate and enduring readiness issues and massive medical costs

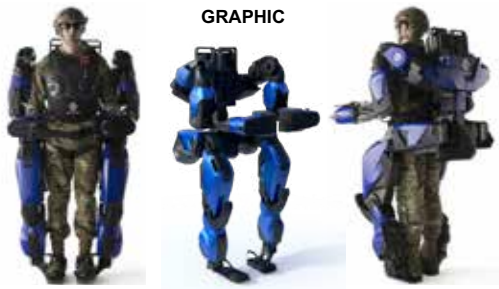
BENEFITS

- Human performance: augment strength and endurance
- Reduce operator strain and injuries
- Optimize productivity; reduces physical and cognitive burden
- Extend useful life of worker capability
- Open aperture: more people to qualify for physically demanding jobs
- Easy, natural and intuitive to use, requiring minimal training (a few hours) before it can be used in its basic mode
- Safe to use – integrating fail-safe modes of operation and damage tolerant design features
- Usable by a large cross-section of the healthy adult population
- Energetically autonomous

TECHNOLOGY SOLUTION

- Full body, fully powered exoskeleton (XO®)
- Actuated arms, torso, and legs designed to transmit a significant portion of the load to the ground
- Actuation modules contain combinations of an electric motor, an elastic element, and/or a braking mechanism
- Power pack consists of hot-swappable rechargeable batteries; each battery stores approximately 650 Wh
- 24 Degrees of Freedom managed by a control and sensing network
- XO® POD is a reusable and durable shipping/transportation container, which is also used for charging, donning and doffing, data acquisition and communication

GRAPHIC



Sarcos® Guardian® XO® (Alpha Unit) Full-Body, Powered Exoskeleton

AUGMENTED REALITY HEADSET TO DISPLAY COMPLIANCE DATA

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Problem Statement: mechanic/technicians, working at US military overhaul centers and depots, are wasting over 14.5 million hours annually, as they research, gather, and reference technical data. Whether using paper or notepad computers, the mechanic's hands are not free to work. Consequently, the current engineering data compliance system is a safety hazard. Lastly, over 60,000 indirect labor hours are wasted as personnel reconcile compliance reports. Personnel must review each task to ensure tech data compliance.

Technology Solution: The VPS solution will use an augmented reality headset to display VPS's highly unique virtual Process Control Document (vPCD), which is a holographic checklist of all the tasks required in order to perform a maintenance operation on a piece of equipment. Within each task are links to all the required technical data, drawings, specifications, and orders that must be complied with. Also, through immersive collaboration, technicians have immediate access to quality assurance (QA) specialists, engineers, lead workers, and administrators, each with the ability to see what the mechanic is seeing, including both the actual hardware and the virtual technical data supporting it. Consequently, VPS will provide the mechanic with the required technical information, when needed, hands free!

Benefits: safety issue is mitigated. The holographic image of the process control documents and technical data are provided hands free, activated through voice recognition. Safety is enhanced. With spatial recognition, the system can warn the mechanic before he cracks his head. Time currently wasted researching, gathering, and referencing tech data can be used for higher value-added activities. Collaboration with other mechanics/technicians, engineers, supervisors, parts maintenance technicians is facilitated. Time is no longer wasted reconciling task compliance as data is stored digitally. There is a significant return on investment. Mechanics will save one hour per day. Sixty-thousand mechanics would save 14.5M hours per year, based on a 1,670 hour-yearly yield.

Development Status of Technology: level 6 to 9 AR technologies are the driving force behind ship and boat MRO (MRO-market). The two most technologically advanced AR systems are HoloLens 2, made by Microsoft, and Magic Leap 1, made by Magic Leap. With AZURE cloud services, HaloLens can display holographs up to 100 million polygraphs (Headset Comparison) Data input and output modality of AR headsets is astonishing. AR headsets allow spatial computing, allow the headset to understand what is around them. They know where the user's head is and the position the head is in. They can read hand, head, and eye movement. (ML-input-design). Air Force has developed 3 notepad eWCD systems. Navy is also developing a notepad system eTCD technical control document.

Next Steps: select device, develop document linking protocol, write software to cloud, test software on devices.

PROBLEM STATEMENT

US Military Overhaul Centers and Depots
- Mechanics/technicians waste 14.5 m hours annually
  - Handling/referencing engineering compliance data (based on observations) estimate 1.1 hours/day/tech
- Safety hazard – hands are not free
- Indirect labor wastes over 60K hours annually
  - Reconciling compliance lists for engineering data
  - All engineering compliance data, mostly handwritten, must be reviewed
  - Hundreds of thousands of tasks must be reviewed to ensure technical data compliance

BENEFITS

Enhanced Safety for Depot Mechanics/Technicians
- Continually returning to reference data no longer required
- Finding safe place to store documents and/or notepad NA
- Spatial recognition warns mechanic of impending danger
- Holographic data provided on demand
  - Regardless of body position
  - Regardless of location
- Research, Gather, & Reference tech data NA
  - 1.1 direct labor hours/data/mechanic saved
- Reconciling takes minutes vs days
  - Data/reporting is digital
- Facilitates collaboration – stakeholders can see and hear what technician sees and hears, both data and actual hardware!

Technology Solution

Use Augmented Reality (AR) headset to display compliance data
- Link all engineering data, process orders, tech manuals, drawings, and specifications to process control document
  - Headset becomes voice activated data portal
  - Holographic data provided on demand
  - Images provided regardless of body position
- Facilitates collaboration – supervisors, QA, engineers, planners, coworkers
  - Collaborators can see same thing technician sees
  - Actual hardware and virtual hardware at same time
- Use AR capabilities to enhance safety
  - Spatial recognition identifies objects and position
  - Recognizes, head, hands, and eyes position & movement

Picture

UV COMPLETE LIGHT EMITTING AUTONOMOUS NAVIGATOR

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Our Company, Botley Robotics, has developed a UVClean germicidal elimination system designed to assist in the fight against our current global pandemic. The COVID-19 pandemic has left us with a new normal that is not only impacting our health and social lives but is also wreaking havoc on businesses and economies globally. Organizations face many challenges ahead while utilizing traditional cleaning methods, including user error, chemical exposure, performance variation, complicated requirements of high-touch areas, and availability/cost of increased manpower.

Our UVClean unit autonomously follows the desired cleaning path and automatically adapts to environmental changes utilizing the latest advancements in self-guided technology, as our technology employs unique scanning software and equipment to create a virtual map of your facility.

We have currently produced 10 units and are receiving quotes for testing/certification from multiple nationally recognized labs. We also have 5 programmers working around the clock coupled with our hardworking team in the shop to create human detection software, as safety remains at the forefront of our concern.

We plan to resume production coupled with a well-timed marketing campaign following completion of our human detection software, unit certification, and quality/effectiveness testing. UVC light is the future of cleaning, and we believe our UVClean unit can be utilized for numerous other applications that may arise in the future along with UVC disinfection needs such as material handling, schools, and varied logistics needs across a multitude of industries.

PROBLEM STATEMENT

- We are currently engulfed in a global pandemic that has altered every aspect of our lives. Our country is currently implementing various technological advances that will allow us to return to 'normal'.
- Organizations face may challenges utilizing traditional cleaning methods, including constant variation in performance of individual cleaners, chemical exposure, inappropriate use of disinfectants/chemicals, unstainable increases in workforce, and complicated disinfection requires of high touch areas.

BENEFITS

- Industry exclusive arms to focus UVC light on various surfaces
- Easily preprogrammed autonomous unit that will kill 99.9% of all germs and bacteria
- Kills germs 3x faster than liquid chemicals; meanwhile, improving efficiency and efficacy of your disinfecting procedures.
- Works on any surface, covering a 16ft span and 10ft high cleaning area in a single pass
- Our UVClean unit autonomously follows the desired cleaning path and automatically adapts to environmental changes utilizing the latest advancements in self-guided technology, as our technology employs unique scanning software and equipment to create a virtual map of your facility.

TECHNOLOGY SOLUTION

- The sanitizing effects of UV lights have been seen with other coronaviruses, including the one that causes severe acute respiratory syndrome (SARS). Studies have shown that it can be used against coronaviruses. One study found at least 15 minutes of UVC exposure inactivated SARS, making it impossible for the virus to replicate.
- Botley plans to focus its current efforts towards the fight against our current global pandemic; meanwhile, remaining steadfast in the belief that this is the future of disinfecting.

GRAPHIC

FLAT RACK/C.R.O.P. ROTATOR

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Problem: Sierra Army Depot uses a container rotator developed and designed to rotate shipping containers. When used with a flat rack or CROP (Container Roll on/off Platform) the center of balance is much lower than when a container is used. This causes the hydraulic ram to work harder than needed and creates a rotating hazard if/when the rack is lowered into the resting position. During the day to day Maintenance operations the team identified some hazards in the process.

Solution: The repair program was for several hundred assets and each time the task was performed the team had to utilize additional equipment to assist. So the team quickly began to work on solutions, both to improve the process and the final product. Quite quickly they came up with some ideas that would/could help eliminate the potential for accidents in the future. Sierra Army Depot personnel modified existing equipment and built a rotator specifically for performing maintenance on Flat Racks and CROPS. By moving the pivot point higher, in line with the deck of the rack, the load was significantly reduced. Allowing for much easier rotation and a much slower move to rest action.

Benefits:

- This solution reduced the overall stress on equipment, which will prolong the life of hydraulic jacks, pins and associated rotating components.
- This new design allows for increased rotation and will prevent the need to utilize additional equipment to assist in rotating.
- Above all, this solution helps to make this process safer. The reduced load is much more controlled and in the event of failure the speed and weight of the falling material is greatly reduced.

PROBLEM STATEMENT

The current rotator developed/used at SIAD was designed to rotate Shipping Containers. When used with a flat rack or CROP (Container Roll on/off Platform) the center of balance is much lower than when a container is used. This causes the hydraulic ram to work harder than needed and creates a rotating hazard if/when the rack is lowered into the resting position.

BENEFITS

- This solution reduced the overall stress on equipment, which will prolong the life of hydraulic jacks, pins and associated rotating components.
- This new design allows for increased rotation and will prevent the need to utilize additional equipment to assist in rotating.
- Above all, this solution helps to make this process safer. The reduced load is much more controlled and in the event of failure the speed and weight of the falling material is greatly reduced.

TECHNOLOGY SOLUTION

The team in the Metal Fabrication Branch at SIAD designed and developed a rotator specifically for performing maintenance on Flat Racks and CROPS. By moving the pivot point higher, in line with the deck of the rack, the load was significantly reduced. Allowing for much easier rotation and a much slower move to rest action.

GRAPHIC OR IMAGE

AIR MONITORING BUILDING VENTILATION ENHANCEMENT SYSTEM

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Ambilabs LLC & Conservant Systems have joined forces for the purpose of development of enhancements to air handling systems in Dept of Defense (DoD) buildings, to facilitate a reduction in operational maintenance requirements, in combination with improvements in workplace indoor air quality. Operational maintenance enhancement capabilities for DoD building air handling & circulation systems are a heightened requirement because of the global covid-19 pandemic. Ambilabs is an innovator company with extensive experience in air sensor technologies, & in combination with Conservant's HEDS (High Efficiency Dehumidification System) technology, we offer a unique solution to facilitate operational maintenance enhancements across DoD buildings. Ambilabs was recently selected as a US Air Force Small Business Innovation Research awardee, and Conservant was recently chosen as a finalist in the USAF AFWERX global technology competition for the "Base of the Future".

We can supply our proven combined integrated technology for the DoD to enable building cooling load reductions & reheat energy reductions for Relative Humidity (RH), and to facilitate biological and corrosion control improvements in buildings based upon overall air quality verification, & improvements to air quality. The anti-viral version of our combined solution can capture or kill 99.9% of COVID-sized particles, enhancing life safety as well. The system can be added on to most types of current building HVAC and air handling systems, thereby ensuring substantially less capital expenditure requirements, yet enabling an immediate improvement in indoor air quality within a DoD building. Additional operational benefits are reduced air handling system maintenance and lower energy consumption costs. But even more importantly it also means better health & wellness & improved productivity for military personnel working in each building where our systems get deployed.

Our systems can also be utilized in production work facilities where air quality conditions can impact quality control procedures; for example, implementation of our system can ensure that aircraft maintenance procedures occur in an improved air environment, resulting in better quality maintenance processes & reduced requirements for rework, such as strip & recoats of aircraft undergoing maintenance in CCF's (Corrosion Control Facilities). Our solutions are also effective for maritime applications in reducing condensation & corrosion.

The technology represents an innovation in building air handling & air circulation operations, & our immediate goal is to establish a "pilot" system at a DoD facility which can be monitored, & then replicated across multiple DoD facilities. The Ambilabs Conversant system is also designed such that military personnel can deploy & install & self-maintain, enabling a faster & more widespread rollout of the air handling systems enhancement technology.

PROBLEM STATEMENT

- ❑ DoD's cost of building air handling maintenance runs to billions of dollars per annum.
- ❑ Airborne contaminants and pollutants are of increasing concern in the workplace due to covid-19 and other potential future virus and bioaerosol adaptations
- ❑ DoD has a critical workforce to protect in the interest of the nation's security, as well as individual military and civilian personnel safety, health, and well being.
- ❑ Complete replacement of all current HVAC and air handling systems is not feasible in terms of time, manpower, or budget.

BENEFITS

- ❑ Accurate measurements; easy to maintain; easy to deploy & scalable to building size; Fast real-time results
- ❑ Solution can be systemized & integrated across the DoD
- ❑ Substantially lower cost of integration compared to full HVAC systems replacement costs
- ❑ Various locations within building can be monitored concurrently, using same technology
- ❑ Military personnel breathe better quality air = improved work productivity within a safer work environment.
- ❑ Maintenance processes can also be performed in a cleaner work environment, resulting in higher quality finishing work.

TECHNOLOGY SOLUTION

- ❑ A Real-Time Continuous Solution to accurately monitor & help control Relative Humidity & Particulate Levels throughout building air handling systems
- ❑ Particulate measurement + Energy Recovery RH control solution is designed for the DoD maintenance environment
- ❑ Solution can be integrated as an additive to current HVAC and building air handling systems
- ❑ Systems operation and calibration is simple and is easily performed by current Buildings Operations personnel
- ❑ The Only Specifically Named Air Handling Systems Advanced Technology in the 2019 DoD "High Performance and Sustainable Buildings Report to Congress"

SYSTEM IN OPERATION at a Federal Lab, Puerto Rico

IDF AMMUNITION STOCKPILE SAFETY AND RELIABILITY SURVEILLANCE AND MANAGEMENT SYSTEM

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IDF ammunition stockpile consists of various items with different technical characteristics, from 5.56" bullets to large caliber missiles and rockets. The stockpile is divided between storage sites and field units, with different maintenance conditions. The age of the items in the stockpile varies between 70 years and one year. Until 2019, the main stockpile management system of the IDF has been an outdated Mainframe system which was connected to main SAP R3 ERP. The system was extremely basic with mainly stockpile data and extremely limited technical information. Safety and reliability of the stockpile was assessed by a complex program of testing and inspections, managed through the mentioned above system.

In 2019-2020 the old Mainframe system was scrapped, and a new SAP ERP system was introduced with advanced capabilities. IDF Ground Forces Technological Division and Missile and Ammunition Center conducted an analysis of the stockpile to define eight groups of ammunition with common technical parameters. New sampling, testing and analysis methodology, based on the eight new ammunition groups, was defined. The methodology was implemented through new SAP-based stockpile management system as the Ammunition Periodic Examination Module (APEM). The APEM takes advantage of the ERP system capabilities by automatically scanning the stockpile and creating the required testing and inspection plans, monitoring and analyzing the examination status, producing reports etc.

Since 2020 the new system with APEM module is operational in IDF. The new system enables to manage from end-to-end all the aspects of ammunition stockpile between the Central Logistics Command, Ground Forces Technological Division, Missiles and Ammunition Center and the field units. The system provides increased reliability of stockpile safety and shelf-life analysis. The probability of human errors and untested ammunition items is reduced. The system provides improved cost-effectiveness of the surveillance program due to elimination of double-testing and full automation of the process.

PROBLEM STATEMENT

- IDF ammunition stockpile consists of various items with different technical characteristics, from 5.56" bullets to large caliber missiles and rockets.
- The stockpile is divided between storage sites and field units, with different maintenance conditions.
- The age of the items in the stockpile is variable between 70 years and one year.
- Safety and reliability of the stockpile was assessed by complex program of testing and inspection, managed through complicated and outdated legacy data system.

BENEFITS

- Increased reliability of stockpile safety and shelf-life analysis.
- Decreased probability of human errors and untested ammunition items.
- Improved cost-effectiveness of the program due to elimination of double-testing and automation of the process.
- End-to-end approach to management of all the aspects of ammunition stockpile between the Central Logistics Command, Ground Forces Technological Division, Missiles and Ammunition Center and the field units.

TECHNOLOGY SOLUTION

- IDF Ground Forces Technological Division and Missile and Ammunition Center conducted an analysis of the stockpile to define 8 groups of ammunition with common technical parameters.
- New sampling, testing and analysis methodology, based on 8 new ammunition groups, was defined.
- The methodology was implemented through new SAP-based stockpile management system as the Ammunition Periodic Examination Module (APEM). The APEM takes advantage of the ERP system capabilities by scanning automatically the stockpile and creating the required testing and inspection plans, producing reports and many more advanced management features.

SMARTREPAIR

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Foreign Object Damage (FOD) causes 18-20% of unscheduled engine removals per year in 4th generation fighter engines. The 5th generation engines (F-119 & F-135) that power the F-22 and F-35 are more susceptible to FOD costing the USAF $250K-$1.0M/engine due to the level of damage and repair/service. 5th generation engines utilize Integrally-Bladed-Rotors (IBR). Engineering assessments of IBRs use paper instructions and illustrations explaining complicated decision trees to define the repair rules for specific damage. There are 20 different damage classifications with their own set of repair rules containing damage geometry, location, relation to other damage, and historical data. A successful repair is time consuming and requires highly skilled maintainers using complex work instructions to perform conservative damage assessments.

Our solution optimizes IBR repair from initial damage assessment to final prescription of repair procedures. SmartRepair™ builds AI based predictive repair models of damage and repair rules and injects these as 3D visualizations using Augmented Reality (AR) directly onto the component enabling rapid repair decision-making at the point of maintenance. The AI can tailor repair rules to specific damage scenarios maintaining adherence to engineering process controls. The algorithms draw historical and present damage/repair data from other IBRs allowing maintainers to view and make repair predictions.

Example: After a 3D whole field edge scan of the damaged IBR is added to the database, the system will identify FOD and automatically display the most likely damage condition with a confidence level and alternatives. The engineer will see a 3D map of damage specifications and the repair rules needed reducing misinterpretation of technical data and complex repair maps. Once the damage parameters are confirmed, the database enables automatic real-time comparisons with historical data and current repaired conditions viewable on the IBR being repaired. The engineer has now done an engineering analysis at the point of maintenance.

Our solution can reduce the current average engineering analysis time of 3 weeks to 1 day, reduce the decision risks of error by 80% improving component reliability, and reduce labor burden on maintainers and technical SMEs. Future work will combine repair maps and blade harmonic tuning data that can predict the impact of repaired damage on blade frequency. In addition, this can be expanded to other high value DoD components.

ARCTOS customers at the OC-ALC are currently supporting this solution and have selected the F119 1st stage hollow fan blade IBR as the pilot launch product. With Avatar developing TRL 8, military-grade AR job execution aids for customers including the US Navy, USAF, and US Coast Guard, our solution combines the latest AR hardware and vision science technology with whole field/edge scanning equipment and predictive analytic methods using machine learning algorithms.

PROBLEM STATEMENT

Foreign Object Damage to Integrated bladed rotors cause 18-20% of unscheduled engine removals in F119 and F135. Costs of repair/service ranges from $250K-$1.0M per engine due to damage level.

Repairs are complex. 20 different damage classifications have their own set of repair rules containing damage geometry, location, relation to other damage, and historical data.

A successful repair is time consuming, requires highly skilled maintainers utilizing complex work instructions to perform potentially overly conservative damage assessments.

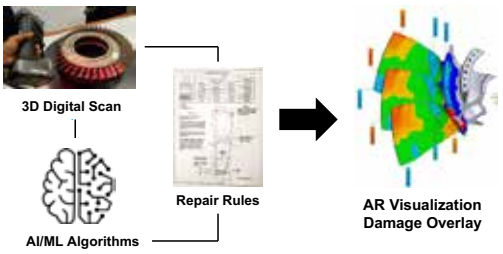
BENEFITS

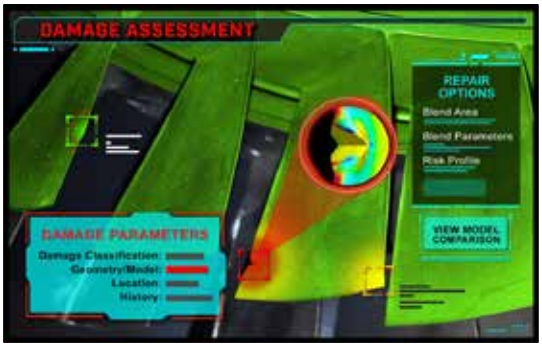
Faster turn-around-time from improved process speed of damage assessment and optimization of repair options.
3 weeks to 1 day

Reduced risk higher fidelity tailored repair process and high-quality technical decision-making, reducing error rate once damage from use has occurred.
80% error rate reduction

Reduced labor burden on maintainers and technical SMEs.
Highly scalable across DoD.

TECHNOLOGY SOLUTION
Engineering Analysis at the Point of Maintenance





VIRTUAL SHIP-CHECKS OF NAVAL SUBMARINES

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The Portsmouth Naval Shipyard Innovation Projects Scan Project (PNS-IPX Scan) produced a 3D scan of USS Cheyenne and developed a process to scan future fast attack submarines. The PNS-IPX Scan Project has saved engineering downtime, reduced project costs, reduced radiation exposure, and produced a virtual model of USS Cheyenne for future reference.

Planning for major CNO availabilities starts two years before a submarine enters the drydock. Preplanning uses numerous tools to ensure time spent planning produces thorough and meaningful work products. Multiple ship-checks are performed on every ship before the ship availability is planned to start. Ship-checks provide preplanning engineers and project leadership with information about the ship's current condition for a given system or component. Each ship-check requires PNS project teams to send individuals to the current location of the submarine, spend significant capital pursuing answers for pre-planning, and confirm that each answer sufficiently meets the requestor's need. Issues that arise after the ship-check must wait until the ship arrives at the maintenance activity for the major availability.

The PNS-IPX Scan Project has performed a ship-wide scan of USS Cheyenne as well as sections of USS Virginia, USS California, and USS Santa Fe. Virtual ship-checks (ScanChex) have been utilized by engineers and the project team to eliminate work on RC Cooling Coils, plan new round hull cut locations, verify various nameplates, plan refueling support systems and interference removal, trace pipe runs, confirm ship conditions, and assess viable routes to move components shipboard. ScanChex has added an incredible tool to the pre-planning tool belt. Engineers have said that ScanChex has provided answers that were otherwise challenging to find and increased certainty in the products that preplanning has produced. The virtual model of USS Cheyenne produced by the PNS-IPX Scan Project avoided unnecessary costs by increasing access to a higher quality preplanning toolset, reducing the bow wave of work caused by limited asset availability, reducing disruptions to shipboard operations, reducing radiation exposure to personnel, and decreasing contact between personnel from different geographic regions which limits the transmission of Coronavirus. As of September 2020, the USS Cheyenne FY22 project team has saved more than $250,000 and 70 mandays, all directly attributed to the efforts of the PNS-IPX Scan Project.

During FY21 and FY22, the PNS-IPX Scan Project plans to scan sections of USS Texas and USS Newport News. The PNS-IPX Scan Project is working with NAVSEA 07TR to produce 3D Renderings for use in Navy trainings as well.

PROBLEM STATEMENT

Ship-checks provide preplanning with the means to confirm ship conditions prior to ship arrival at the maintenance activity. Each ship-check is constrained to within the dates of a minor availability. Pre-planning work that requires verification of current ship conditions must be put on hold until a ship-check or the ship arrives at the maintenance activity. Ship-checks are a logistical bottleneck, require substantial resources to support, increase contact between personnel, and are limited by asset availability.

BENEFITS

- Avoid unnecessary costs by increasing access to a higher quality preplanning toolset
  - Reduce travel costs
  - Provide access to high accuracy measurement capabilities
- Reduce the bow wave of work caused by limited asset availability and decrease precautionary planning steps
- Reduce disruptions to shipboard operations
- Reduce radiation exposure
- Decrease contact between personnel from different geographic regions (COVID-19)

TECHNOLOGY SOLUTION

Perform ship-wide scan of USS Cheyenne as a proof of concept. Use 3D Scanners, High Resolution Cameras, and related software to produce a virtual model of the submarine's interior spaces. Provide easy, local access to the virtual model of USS Cheyenne in support of all preplanning efforts at Portsmouth Naval Shipyard. Upon proof of concept, expand scanning efforts to include other assets and increase access to virtual models for future virtual ship-checks (ScanChex).

GRAPHIC OR IMAGE

CHEMICAL MAINTENANCE INNOVATIONS FOR ADDITIVE MANUFACTURING+

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Problem: Additive Manufacturing's potential in maintenance cannot be achieved without reliable, repeatable, scalable quality measures.

Technology: Spectroscopy offers chemical analytical capability, including non-destructive instant field validation and authentication. Handheld off-the-shelf instruments are insufficiently quantitative – unless a multivariate match model is created for predictive analytics. Currently TRL-3.

Data: InfraTrac's experiments, including an America Makes award, two refereed publications and additional client work, show 100% accuracy distinguishing pure polymer prints by material composition using near-infrared spectroscopy. For metals, InfraTrac shows 100% material quality verification via x-ray fluorescence spectroscopy for atomic numbers between 13 and 42, with additional elements possible with analytic support. Detection of a taggant spot (to authenticate a genuine part) in directed energy deposition (DED) AM titanium alloy is shown below.

Authentication via taggant, by XRF spectroscopy, in 3DP Ti64:

		Composition (%)			
Line	Column	Ti	TagA	V	Au
	1	91.75	3.94	4.32	0.00
	2	94.15	1.74	4.01	0.09
1	3	94.80	1.13	4.07	0.00
	4	85.05	10.05	4.72	0.18
	5	86.47	8.85	4.48	0.19
	1	93.79	2.13	4.09	0.00
	2	90.83	4.85	4.32	0.00
2	3	87.90	7.35	4.63	0.11
	4	93.38	2.39	4.24	0.00
	5	90.13	5.80	4.05	0.01

Next Steps: Establish spectral test protocols and design reference repositories, so materials and finished parts can be validated with quick-check non-destructive chemical analysis.

Maintenance impact: Quality is the biggest challenge limiting embrace of AM, and counterfeiting looms even beyond electronics. Anyone can use a 3D printer, and it will not all be MIL-STD. Conventional tracking relies on labels and promises; chemical validation adds trust.

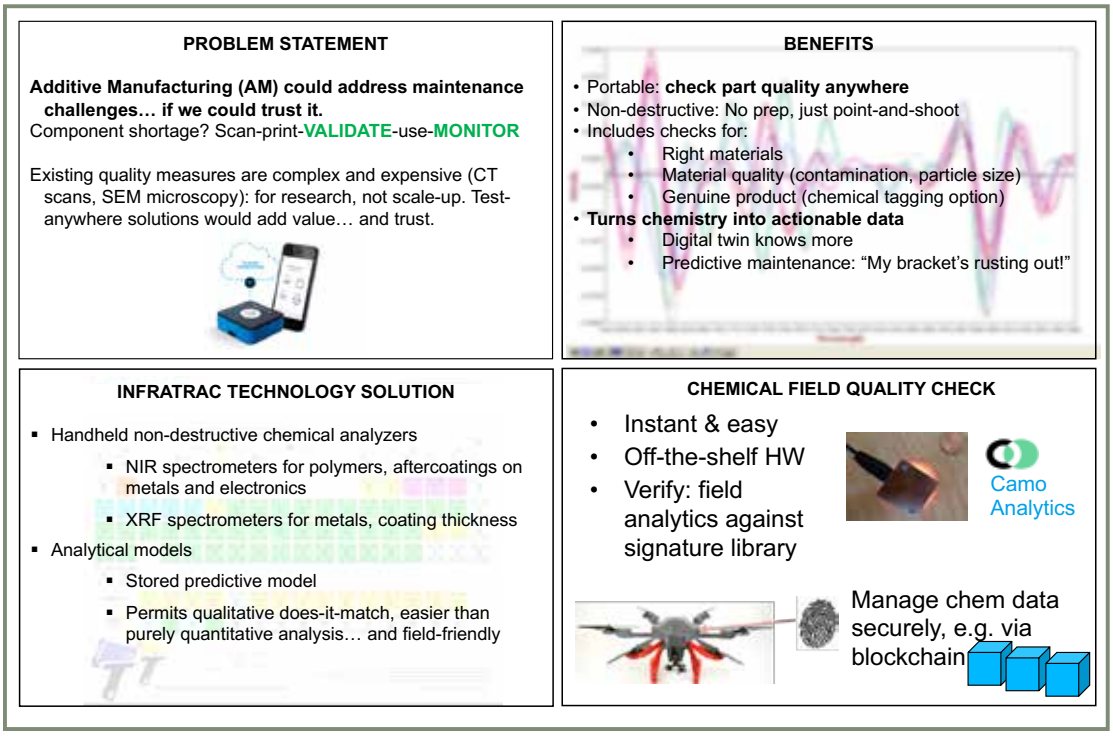
Originality: No one else has applied spectroscopy – or handheld chemical analysis – to AM quality. InfraTrac's chemical anti-counterfeiting is covered by multiple patents, issued and pending.

Avoidance of commercialism: Techniques come from agritech, pharmaceutical manufacturing, and geology; hardware is off-the-shelf.

Maturity: Replicated in lab conditions and in multiple locations with multiple printer types and dozens of different material types.

Cross-service: Tested on AM parts compatible with fighter jets, this technology helps AM lighten warfighter loads, repair vehicles, helicopters, shipboard elements, and more, along with electronics, with an anti-counterfeiting option.

Feasibility/practicality: The test instruments are process-compatible and COTS and, for polymers, cost less than a phone; XRF handhelds cost $15-25K and falling, as technology and adoption improve. Spectral data are (x,y) pairs, easily managed in existing data systems.



3D SCANNING FOR IMPROVED MAINTENANCE, SUSTAINMENT AND READINESS

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Defense Engineering Services (DES) proposes to employ recent developments in 3D scanning technology, to quickly and cost effectively capture the geometry of legacy and current defense related systems, to mitigate obsolescence and improve documentation.

Recent 3D Scanning Improvements:

- Object tracking - The DES scanner uses the objects own geometry to track scanner movement. This alleviates the requirement to place target stickers on the object.
- Resolution and color - The scanner can digitize hard to scan textures and even capture color.
- On-board processer - New 3D scanners have an onboard processer, allowing them to operate without being tethered to a computer. This allows the operator to move freely.
- On-board video display - DES's 3D scanner is equipped with a video display that allows the operator to see the scan, ensuring scan quality.
- Large format - With an on-board processor and video display, DES's 3D scanner can be used on large objects to include a full military vehicle.
- Improved file clean-up and manipulation - Historically, the data files created by a 3D scanner were difficult, if not impossible, to work with. They were useful to create representative geometries in 3D space, which could be designed around, but could not be changed, corrected, or made into a useful solid 3D part file. Cleaning-up the file was a tedious process that cost time and money. Today, files created by a 3D scanner can be manipulated, converted, corrected, and merged together. Holes, surfaces, threads, and even blemishes can be modified, added, or removed with just a few clicks.

Benefits and Uses:

- Capturing geometry for obsolete parts, components or systems. This allows for modern techniques to be used to reverse engineer or create alternatives.
- Creating 3D geometry for items that are currently only documented via 2D drawings (common DLA problem).
- Capturing as-built conditions for complex systems with high degrees of variability.
- Capturing damage, wear, or deformation of items to indicate the need for replacement, track lifecycle performance of components, or to conduct studies to establish maintenance practices.
- Capturing geometry of interfacing items, so that new solutions or upgrades can be integrated.
- Rapid prototyping systems can directly use the files created by 3D scanning to make prototype parts.
- For systems with high variability, individual items can be scanned by serial number, and tailored solutions created.

These developments in 3D scanning have created an opportunity to efficiently and accurately create solutions to sustain and keep ready defense-related systems. These systems are often unique, specialized, and expensive. It is worth the time and effort to keep systems maintained and ready. This task got much easier with the latest 3D scanning technology. DES has invested in this technology because we have seen the improvements, and have benefited greatly from the increase in speed, accuracy, and usefulness are valuable. Senvol is continuing to develop new capabilities (e.g. transfer learning).

PROBLEM STATEMENT

- Obsolescence remains a concern for many legacy and current defense systems.
- Manufacturers, OEMs, and suppliers may not be available, capable, or willing to support legacy systems.
- Some military systems were produced by more than one manufacturer, increasing the logistical burden.
- Legacy technical data packages are often not available, not complete, not accurate, or not current, thus not able to support sustainment, repair or new development.
- Manufacturing variability is not typically captured through production. Each serial number may be different.
- Tracking wear on components can greatly improve maintenance and head-off catastrophic failure.

BENEFITS

- Obsolete parts, components, and systems can be captured, cleaned-up, and corrected quickly.
- Drawings and other documentation can be created quickly.
- Replacement parts or retrofit solutions can be engineered more quickly using modern techniques.
- Replacement parts can be rapidly prototyped based on existing geometries or interfaces.
- New designs for legacy systems can be completed quickly and accurately with minimal touch-time required.
- For systems with high variability, individual items can be scanned by serial number, and tailored solutions created.
- Replacement pipes, ducts, hoses, and routings are made much more easily.

TECHNOLOGY SOLUTION

- Defense Engineering Services (DES) recently acquired the latest generation 3D scanner and software with many new features, improvements, and new capabilities.
- Object tracking, structured light, laser/optical overlay, and full color scanning create high fidelity 3D models.
- Scanner has on-board processing and video display greatly improving the speed, quality, and accuracy of the scan activity.
- Complex or simple geometries are captured easily, including large format (full vehicle), no need for a computer to scan.
- Recent software developments greatly improve speed, accuracy, and usefulness of the files created by 3D scanners.
- The 3D files created by the scanner can now be manipulated, corrected, and modified directly in the CAD software.

GRAPHIC

ENTERPRISE QMS WITH INTEGRATED ERP

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Over our 30+ year history, we have seen countless organizations struggle with delays in maintenance and production life cycle because disparate systems do not present an enterprise view. TIP Technologies eliminates delays by allowing business units real time visibility to parts/materials availability, quality and supplier data, and mitigation of counterfeit parts in the supply chain. TIPQA Quality Management, is an integrated commercial off the shelf software solution, comprised of 15 web-based modules. These software modules support the complete range of quality functions and the complex requirements facing organizations-from Receiving Inspection, Non-conformances and Corrective Actions to final product disposition. Clients chose TIPQA to achieve continuous and measurable improvements while advancing productivity, service, and time to market. TIPQA offers a seamless interface to ERPs like Costpoint, Oracle, SAP, Microsoft and can be configured for use with other ERPs and business systems. TIPQA can also be stand-alone quality solution, is highly configurable and scalable.

TIPQA provides the following: Automation of critical quality processes, Real-time access to quality and manufacturing data, Effective processing of nonconformance and corrective actions, Supplier Metrics and Control Over User Access. TIPQA automates processes focusing on compliance, traceability for all material, parts, and finished goods. The solution allows for information exchange across the enterprise and drives continuous improvement.
The following is a list of standard quality assurance initiatives that can be effectively completed using TIPQA: First Article Inspection, Complete Product Genealogy/ Traceability of Parts, Automation of Audits, Modernized MRO Tracking, support a Lean Manufacturing Environment, Supply Chain Management, Mission Assurance and Industry Compliance, and Minimized Risk of Counterfeit Parts. TIP Technologies has a long record of success helping Aerospace and Defense companies meet and exceed industry compliance. The TIPQA web-based solution was released in mid-2019 and commercially available since. We continue to grow, support, and successfully expand the client base.

Prior to implementing TIPQA, a client had a hold on supplier part deliveries. Their legacy system was labor intensive and required duplicate data entry. Since their Quality and ERP systems were not integrated, they also required duplicate entry of nonconformances. Receiving inspectors were spending more time on data entry, than inspecting parts. Another customer was using a series of spreadsheets for traceable configuration. This process was time consuming and inefficient. They wanted to find a way to streamline critical quality processes and gain visibility into problems and avoid delays. Serialized parts including traceable configurations at receiving inspection needed to be automated. This is just a small sample where TIPQA provides a solution. Live Software Demo focusing on your priorities and how TIPQA provides a total solution.

PROBLEM STATEMENT

- Lack of visibility across the enterprise, causes delays in the manufacturing life cycle.
- Manual process for inspections and audits are time consuming.
- Tracking/traceability of materials, how/when/where is the info captured and how easy is it to retrieve, audit and generate reports.
- Counterfeit Parts in the supply chain, are a serious risk to quality and performance of final product. Especially with second & third tier suppliers this can be a major issue.

BENEFITS

- TIPQA integrates with ERP Systems, which allows for an enterprise wide view of parts, materials, current state and other critical production data.
- TIPQA automates the inspection process, from first article inspections to in process, and then to non-conformances and corrective actions. By automating these functions the info is readily available, and with bi-directional communication with ERPs this info may be shared across business units.
- TIPQA makes it easy to determine which parts/materials were used on what product-saving time and helping ID problems (& problem suppliers) sooner.

TECHNOLOGY SOLUTION

- TIPQA generates complete product configuration for organizations that require sophisticated configuration mgmt. and provides complete genealogy of all material throughout the process.
- TIPQA is designed to meet the most stringent compliance standards in industries such as Aviation, Space & Defense.
- TIPQA integrates with almost all ERP Systems to synch real time quality & manufacturing data for a complete view of the enterprise.

GRAPHIC

SMART LAYER BASED STRUCTURAL HEALTH MONITORING SYSTEMS

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Problem statement: Current Non-Destructive Inspection (NDI) structural inspections of Department of Defense (DOD) aircraft platforms are very labor intensive and require access to the structure resulting in structural disassembly and downtime. Acellent provides Structural Health Monitoring (SHM) based NDI systems that utilize sensors integrated with the structure, eliminating the need for structural disassembly. SHM systems leverage modern low-cost sensors and data acquisition combined with powerful signal processing algorithms and fast data transfer mechanisms to detect and track damage over time allowing for timely, targeted and cost-effective maintenance of the monitored structures with minimal or no human interaction. Sensors can be easily installed in areas that are otherwise difficult or impossible to inspect without extensive structural disassembly and structural inspection performed in minutes. SHM, if implemented, will enable maintenance based on actual material condition instead of the current periodic inspection schedules, thereby reducing maintenance downtime, increasing platform availability and readiness, and enabling Condition Based Maintenance.

Technology Description: Acellent provides complete SHM systems that include:

- SMART Layers – a network of miniature distributed piezoelectric (PZT) sensors and actuators embedded on a thin dielectric carrier film and surface mounted or embedded in a structure. The novelty of the SMART layer lies in its networking capabilities with any type of sensor eliminating the need to place each type of sensor individually on the structure.
- Diagnostic hardware that are lightweight and have been especially developed to interface with the SMART Layer for data acquisition.
- Intelligent Diagnostic Software for data analysis to obtain damage information in real time.

The SHM systems have acousto-ultrasonic sensing capabilities. The functioning of the Active SHM system is analogous to that of a built-in ultrasonic NDE with a network of miniaturized piezoelectric sensors to detect damage such as cracks, de-laminations corrosion etc. In the Passive SHM system is set up to be continuously 'listening' acoustically for impacts in real-time to detect external impact events then determine the time of impact, location of impact, and the impact energy/force.

Current Development Status: SHM systems are currently at TRL 7+

Test/Simulation Data: Acellent has completed major testing required for deployment including Mil-STD 810G testing, flight tests (>900 flight hours in usage and brown-out conditions), lightning strike and explosive environment testing as per RTCA DO160.

Potential Benefits: The SHM systems can enhance military capability by providing the ability to accurately detect, localize and quantify damage initiation and growth, decrease structural inspection costs by >90%*, improve aircraft safety, increase mission readiness, and enable aircraft service life extension.

* previous studies

PROBLEM STATEMENT

- Current Non-Destructive Inspection (NDI) structural inspections of Department of Defense (DOD) aircraft platforms are very labor intensive and require access to the structure resulting in structural disassembly and downtime.
- Acellent provides **Structural Health Monitoring (SHM) based NDI systems** that utilize sensors integrated with the structure, eliminating the need for structural disassembly.
- SHM systems leverage modern low-cost sensors and data acquisition combined with powerful signal processing algorithms and fast data transfer to detect and track damage over time allowing for timely, targeted and cost-effective maintenance of the monitored structures with minimal or no human interaction. Inspection can be performed in *minutes*.

BENEFITS

- SHM systems can enable maintenance based on actual material condition instead of the current periodic inspection schedules, thereby reducing maintenance downtime, increasing platform availability and readiness, and enabling *Condition Based Maintenance*.
- The SHM systems can enhance military capability by providing the ability to accurately detect, localize and quantify damage initiation and growth, eliminate structural disassembly, decrease structural inspection costs by >90%*, improve aircraft safety, increase mission readiness, and enable aircraft service life extension.

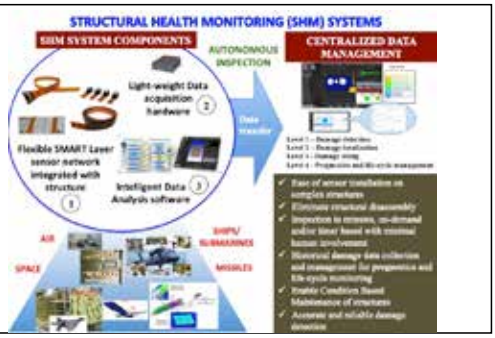
  * based on previous studies with Boeing

TECHNOLOGY SOLUTION

Acellent provides complete SHM systems that include -

1. Flexible piezoelectric sensor network **SMART Layers**
2. Lightweight **Diagnostic hardware** for data acquisition
3. Intelligent **Diagnostic Software** for damage data analysis

- The SHM systems function using acousto-ultrasonic sensing capabilities to detect damage such as cracks, delaminations corrosion etc. or listen for impacts in real-time to detect external impact events then determine the time of impact, location of impact, and the impact energy/force.
- SHM systems are at TRL 7+, have completed testing including Mil-STD 810G, flight tests (>900 flight hours in usage and brown-out conditions), lightning strike and explosive environment testing as per RTCA DO160.



C-27J DE-ICE BOOT TEST KIT

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A team from the US Coast Guard developed a leading edge deicing test kit for the C27J Spartan aircraft to assist in troubleshooting faults. The C27J has 11 total leading edge boots, four per wing, two on the horizontal stabilizer and one on the vertical stabilizer. The innovative approach to testing the deice boots significantly reduces troubleshooting time and increases the accuracy of correctly identifying faulty components, specifically pressure regulating valves internal to the wing structure.

Prior to the development of the kit, testing consumed a large amount of time and resources (both time and staffing) but yielded little information. Aircrews could test the system in two ways.

The first option was to check the aircraft's ice protection control panel and dual timer system monitor (DTSM). The ice protection control panel and DTSM are used to inflate the boots in flight but are limited in their ability to detect faults and low pressure. This method necessitated engines must be running to provide bleed air for boot inflation. Removing the need for engines running, reduced the requirement of a four member maintenance team by 50% and significantly increased safety.

The second option was to use a DC power supply and meter to manually inflate the boots and check each boot's pressure switch individually. In either case troubleshooting took anywhere between 10 to 50 hours and results were often confusing without in-depth system knowledge.

The kit coupled with clear procedure slashed the time to identify faulty components to less than two hours. The test kit, coined 'Bootalyzer' (boot + analyzer), includes an engine bleed air adapter, a manifold pressure gauge adapter and a test set control panel and is stored in a 4x4 Pelican Box. Built with the technician in mind, a simple set up of the adapters and a flip of a switch inflates two boots at a time. From there a light on the switchboard illuminates if the valves are working properly. Three kits were built at the Coast Guard's Aviation Logistics Center in Elizabeth City, NC and are currently being used by maintenance personnel on the service's 14 C-27Js.

PROBLEM STATEMENT

- US Coast Guard lacked a reliable, efficient way to test discrepancies within the leading edge de-icing boot system

BENEFITS

- Reduces personnel requirements for troubleshooting (since engines do not have to be running)
- Slashed troubleshooting time from 30 hours (average) to 2 hours
- Increased accuracy of identifying faulty components
    - Deleting a faulty regulator (lowering pressure from engines to de-ice system) is extremely difficult without the kit

TECHNOLOGY SOLUTION

- Portable kit consisting of the following:
    - an engine bleed air adapter
    - A manifold pressure gauge adapter
    - Test set control panel

GRAPHIC OR IMAGE

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

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Imagine rapidly scanning a part, looking at its internal properties, and determining if it is good or bad – all before machining it. Envision the quality assurance potential with that level of data and intelligence. The mashup of two tried and true technologies – non-destructive testing (NDT) and portable scanning arms – has evolved into a completely new approach to inspection and dimensional control.

Portable measuring arms are used extensively in the manufacturing environment for on-demand measurement and inspection. Their ability to instantly adapt to applications as a measure-ready tool without the need for re-calibration is the reason for their industry adoption. The integration of an NDT sensor with this portable device has wide-ranging possibilities for manufacturing, engineering, and scientific applications.

Combining technologies from both Hexagon and Pragma can effectively create a digital twin for maintenance operations with exact scanning for dimensional accuracy and exact location of flaw detection for preventative actions. This pinpointing of the location of flaws and defects in a part before it becomes critical is instrumental in doing targeted maintenance on the areas that absolutely require repairs now and provides a mechanism for closely monitoring other flawed areas when they become critical over time. This enables the maintenance operations to more quickly turn the asset back over to the warfighter, after repairing the most critical areas.

PROBLEM STATEMENT

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

BENEFITS

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

TECHNOLOGY SOLUTION

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

AI ENABLED DEFECT DETECTION FOR VISUAL INSPECTION

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Visual inspections are critical in aircraft maintenance, repair, and overhaul operations. They are often the primary defense against premature failures caused by unresolved surface defects. Analysis of inspection data is labor intensive, time-consuming, costly, and subject to potential bias. Deep learning algorithms, such as convolutional neural networks (CNNs), paired with imaging devices have the potential to provide accurate and reliable defect recognition for visual inspections. Automated inspections result in significant cost savings, improved efficiency, and reduced cognitive workloads for human technicians.

The Automated Inspection with Deep Learning (AIDL) software tool was developed for the borescope inspection of C-130 propeller blades at Robins AFB but is applicable across numerous manual visual inspections across the DoD and commercial aerospace. The software consists of a system of state-of-the-art convolutional neural networks (CNNs) that are trained to detect instances of cracks, corrosion, and other surface defects within images taken during the inspection process. AIDL assigns a classification and confidence level to the full image set and passes any images below a user-defined threshold to the human technician for further review. Errors and misclassifications are logged through the user interface and stored for future retraining. This allows the algorithms to correct for past mistakes and adapt to new image conditions and defect types. Additionally, due to the transferability of CNNs, the system can be applied to a new inspection task with minimal engineering.

Analatom is enhancing AIDL for deployment in production at Robins AFB. With a human-in-the-loop implementation, the software demonstrated 99.9% accuracy in the borescope inspection task. RAFB predicts a 75% reduction in inspection times resulting in $70,000 in cost savings per month. Following success in the borescope inspection, a downstream fluorescent penetrant inspection process provides an opportunity for further integration within the workflow. Analatom is also pursuing commercialization through the AWS Partner Network and NVIDIA's GPU Cloud.

PROBLEM STATEMENT

- Nondestructive inspection for defects is critical in many maintenance and overhaul operations. Analysis of data is labor intensive, time-consuming, costly, and subject to human errors. Deep learning algorithms, such as convolutional neural networks (CNNs), paired with imaging devices have the potential to improve efficiency and enhance inspection capabilities.

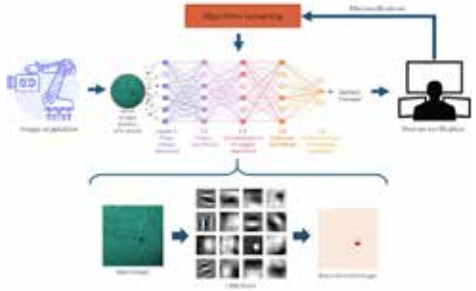
BENEFITS

- Reduction in maintenance costs
  - WR-ALC estimates **75% reduction** in inspection time and between **$17,500 and $70,000 per month** for a single inspection procedure
- Increased throughput and reduced costs of errors
- Improved inspection quality and consistency
- Increased flexibility and adaptability of maintenance systems
- Improved efficiency and effectiveness of users within the system
- Enhanced data collection in support of Industry 4.0 and Smart Factory initiatives

TECHNOLOGY SOLUTION

- Automated Inspection with Deep Learning (AIDL) software tool uses deep learning algorithms to detect and classify surface defects in images taken for visual inspections
  - Detects cracks, corrosion, and other surface defects
  - Initiates human review for images with low prediction confidence
  - Tracks errors internally to trigger algorithm relearning – corrects for misclassifications and preserves performance for dynamic inspection environments

GRAPHIC OR IMAGE



3D-PRINTED C-130 NEGATOR SPRING TOOL

LCDR BRIAN SEEKATZ

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The U.S. Coast Guard employs HC-130H and J-model aircraft as long range surveillance assets in the support of search and rescue and law enforcement missions. Safe and efficient aircraft maintenance ensures these aircraft are ready at a moment's notice, and working on the C-130 paratroop doors has been a chronic challenge to maintainers. C-130 paratroop doors weigh approximately 350 lbs. and rely on a negator spring system to enable crewmembers to easily and safely raise and lower the doors on the ground and in flight. Replacement of the negator spring requires a technician to remove tension on the system using the paratroop door negator spring rewinding special tool. This legacy tool is difficult to use and contacts nearby equipment. Additionally, technicians have been injured while winding or unwinding the highly-loaded spring.

AMT1 James Sullivan of the U.S. Coast Guard's Long Range Surveillance (LRS) division at the Aviation Logistics Center (ALC) led the design, manufacture, and testing of a new negator spring rewinding special tool that streamlines paratroop door negator spring replacement and significantly enhances the safety of the evolution. The tool interfaces with the spring steel output drum and allows a technician to maintain positive control of the tension at all times. The tension is then securely held by the tool while the negator spring is removed and replaced.

After drafting the initial design, an aluminum prototype was machined and tested. The design was then modified to enable 3D printing of the hub of the tool. The 3D-printed tool and hardware costs only $35 to make and is compatible on both C-130H and J-model aircraft. At this time, the design is fully implemented and incorporated into the CG supply system. All C-130 field units should receive their tools by the end of the year. Additionally, there is a patent pending for this novel solution to a problematic and hazardous C-130 maintenance procedure.

PROBLEM STATEMENT

- C-130 paratroop doors weigh 350 lbs and rely on a negator spring to enable the door to be easily opened/closed.
- Servicing the paratroop door and negator spring requires the tension of a highly-loaded spring to be held by a special tool.
- The legacy special tool is difficult to use, often contacts nearby equipment, and is susceptible to releasing tension prematurely and injuring the technician.

BENEFITS

- Redesigned tool ensures positive control of negator spring tension throughout the maintenance procedure.
- Does not contact nearby equipment
- 3D-printed hub and associated hardware cost only $35
- Compatible on C-130H and J-model aircraft

TECHNOLOGY SOLUTION

- The tool was redesigned to interface with the negator spring output drum in a way that permits winding by hand through the use of removable handles.
- The use of four handle installation points enables winding in 90 degree increments, rather than 180 degree increments with the legacy tool.

Fig 1: Legacy Tool

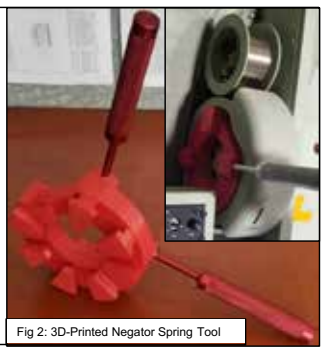

Fig 2: 3D-Printed Negator Spring Tool

FLIGHTLINE TEST INNOVATION REDUCES TEST TIMES AND EXPANDS CAPABILITIES

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Problem Statement: Today's flightline armament maintainer faces the challenge of performing O-Level test and maintenance with legacy armament test sets that greatly limit the ability to quickly and efficiently verify armament system readiness, diagnose failures, and return the aircraft to FMC status.

Legacy O-Level test sets commonly only perform limited functions supporting armament on a single aircraft, while others perform a single function supporting multiple aircraft. The logistics and sustainment cost challenges are clear when faced with supporting a broad range of test sets. The impact from these challenges includes reduced mission readiness, long test and repair times, training inconsistencies, and increased proficiency requirements for the maintainer.

Technology Description: Marvin Test Solutions designed, developed, qualified, and deployed a hand-held universal O-Level armament test set, the MTS-3060A SmartCan™, that supports both legacy and smart weapon system test on any 4th/5th Gen aircraft and combines the capabilities of multiple O-Level armament test sets. In addition, the MTS-3060A incorporates test capabilities of the current large footprint test sets into a rugged, compact test set that drastically reduces test times.

The SmartCan™ weighs less than 4 lbs., yet incorporates more than 35 measurement channels, Squib measurements, active communications test interfaces, three arbitrary waveform generators, multiple electronic loads, discrete outputs, data logging, cybersecurity, BIT, selftest, automated calibration, cable ID, remote control operation, sunlight-readable LCD display all powered by six standard AA batteries. Data storage and transmission enables trend analysis for predictive maintenance. In fact, the entire kit including selftest, adapters, cables, and storage case weights less than 50 lbs.

Development Status: The MTS-3060A is a TRL 9, deployed, and non-developmental item available for immediate purchase and use. The MTS-3060A is applicable to all branches of the US and FMS Armed Forces and DLA.

Test / Simulation Data: The MTS-3060A is currently deployed supporting F-16, F-15, TA-50, FA-50, Hawk, F-18, and F-5 as well as on a UAS and in 2 SILs. Qualification data validates the capabilities identified in the Technology Description section.

Maintenance Impact & Benefits: The MTS-3060A significantly improves readiness while reducing maintenance costs. F-16 fleet maintenance savings, based on a fleet size of 790 aircraft, are projected to be at least $935,882 annually due to drastically reduced setup and test times. These savings are solely based on scheduled maintenance activities and do not reflect additional savings realized from addressing unscheduled activities more efficiently. Similar savings are projected for the F-15 fleet.

F-16 test setup time is reduced from 45 minutes to 4 minutes (91% reduction). Similarly, test times for a pylon utilizing MIL-STD-1760 and for a LAU-129 is reduced from 20 minutes to 3 minutes (85% reduction), and 35 minutes to 4 minutes (89% reduction) respectively.

Additionally, further savings will be realized through test set consolidation, simplified logistics, and standardized training for all aircraft armament specialists. One FMS customer was able to replace a large number of desperate test sets on the flightline across their F-16 and F-15 fleets by procuring the MTS-3060A SmartCan™.

PROBLEM STATEMENT

- Legacy flightline armament test sets significantly reduce the ability to quickly and efficiently verify armament system readiness, diagnose failures, and return 4th and 5th Generation aircraft to full mission capable (FMC) status
- Impact associated with currently deployed legacy test sets:
  - ✓ Reduced mission readiness
  - ✓ Long test and repair times
  - ✓ Maintainer training and proficiency inconsistencies
  - ✓ Logistics / sustainability challenges associated with deploying multiple test sets
- Additional operational issues:
  - ✓ Large flightline footprint (size / weight)
  - ✓ No troubleshooting or predictive maintenance capabilities (reactive only)
  - ✓ Inconclusive test results (false positive / negative)
  - ✓ No commonality across aircraft platforms (multiple test sets required)

BENEFITS

- **$935,888** Annual projected scheduled maintenance savings
  - ✓ F-16 Fleet (790 aircraft)
  - ✓ Similar savings projected for the F-15 fleet
- **85%** to **91%** Test setup / execution reduction times
  - ✓ F-16 / F-15 / A-10, 4th and 5th Generation aircraft
- **One** test set capable across **multiple** aircraft and weapons systems
  - ✓ F-35, F-22, F-15, F-16, F/A-18, A-10, FA-50, F-5, TA-50, Hawk, RPA, ground launchers
  - ✓ JDAM, SDB, AIM-9, AIM-120, AGM-65, Gun, AGM-84/88, AGM-114, Any - 1760 Wpn
- **Simplified** life cycle **support**, **training**, and **maintenance**
  - ✓ 4-year calibration cycle / COTS AA-battery operation
  - ✓ Standardize O-Level armament test set training and rapid maintainer proficiency
  - ✓ Predictive maintenance capability with stored, printable test logs
- Advanced **cybersecurity** features and protection
  - ✓ TPS encryption / removable SD storage

TECHNOLOGY SOLUTION

- MTS-3060A SmartCan™ Universal O-Level Armament Test Set
- Innovative, state-of-the-art design delivering the most advanced handheld flightline test set available; **active** measurement capabilities include:
  - ✓ > 35 measurement channels, multiple electronic loads, discrete outputs
  - ✓ Active avionics communications test interfaces, squib measurements
  - ✓ Weapon emulation, data logging, cybersecurity, BIT, selftest, automated calibration
  - ✓ Cable ID, remote control operation, sunlight-readable LCD display
  - ✓ Rugged package, weighs < 4lbs., powered by 6 standard AA batteries
  - ✓ Data storage and transmission for trend analysis and predictive maintenance
- Supports both legacy and smart weapons preload armament test and measurement on any 4th or 5th Generation aircraft
- Supports multiple manned and unmanned aircraft, as well as ground systems, their armament and munitions

EAGL (ENGINEERING AGILE GLOBAL LIFECYCLE) LABORATORY

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Problem: A strategic gap exists between new systems being introduced, such as the F-35, and old systems being used well past their expected life span, such as the B-52. These platforms have parts that are out of production by the OEM or are missing complete Technical Data Packages. Often a part cannot be transported or removed from its location for inspection, making it impossible to obtain critical measurements and evaluations needed to complete the missing technical data required to manufacture the part, therefore a means of acquiring the data on site is needed.

Description of Tech: The EAGL (Engineering Agile Global Lifecycle) Laboratory is the nation's most comprehensive on-site reverse engineering mobile facility developed to perform critical analysis of materials, finishes, measure geometric characteristics and dimensions of parts which must remain secured or are otherwise unavailable for transport. A 2019 Ford Transit-350 was fully outfitted with tooling and inspection instruments such as a portable hardness tester, fluke voltage tester, caliper set, radius gauges, thread gauges, scale set, micrometer set, ID gauges, depth gauges, and more. The 3D DNTVG printer produces samples for drawing verification and 3D model analysis for form and fit. The Keyence 3D optical scanner takes dimensions of a part in high resolution and can take data in ultra-high resolution for inspection of angles, surface finish, length, diameter, and more. The X-ray fluorescent scanner (XRF) is utilized to determine metallic composition of parts. The Fourier-transform infrared (FTIR) scanner is used for the analysis of organic compounds which provides key data to determine chemical makeup of compounds accurately for reverse engineering.

Current Status: The EAGL Lab is currently located at the Parts Life, Inc. facility, and plans are to schedule site visits to help maintain fleet readiness of parts that are approaching obsolescence.

Test/Simulation Data supporting performance claims: The EAGL team visited Tinker Air Force Base to do on-site inspection of parts for reverse engineering and developed technical data for various SBIR items. Next the EAGL team visited NAS Oceana to investigate a Tool Set, Dome Nut for a Phase I SBIR. The goal was to verify existing technical data against a sample and to address deficiencies in its TD Package. Also, the team visited the Naval Undersea Warfare Lab in Newport, RI to reverse engineer an elbow fitting. The fittings points of failure were analyzed, and modifications were recommended.

Next steps/potential benefits: Benefits are to create full TD Packages from government samples on-site, 3D print samples for form and fit checks, complete chemical analysis and material verification for components and finishes, and reverse engineer parts without taking possession.

PROBLEM STATEMENT

Often legacy platforms do not have access to OEM parts or complete technical data packages to manufacture parts. Many of these parts cannot be moved or transferred from their original location for a variety of reasons, making reverse engineering for manufacturing offsite impossible.

BENEFITS

- Benefits are to create full TDP from government samples on-site
- 3D print samples for form and fit checks
- Complete chemical analysis and material verification for components and finishes
- Reverse engineer parts without taking possession.

TECHNOLOGY SOLUTION

- The EAGL (Engineering Agile Global Lifecycle) Laboratory is a comprehensive on-site reverse engineering mobile Lab developed to perform critical analysis of materials, finishes, measure geometric characteristics and dimensions of parts which must remain secured or are otherwise unavailable for transport.

GRAPHIC OR IMAGE

REMOTE INSPECTION, SCENARIO PLANNING & AI-DRIVEN PREVENTIVE MAINTENANCE

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The need for maintenance personnel to go onsite for every inspection prevents frequent monitoring and timely maintenance that can act as preventive measures, and also ends up costing more.

For the damaged parts or area that need to be repaired or replaced, someone has to visit onsite to inspect and take measurements, which increases both repair cost and duration. Existing solutions are expensive, time consuming, and require sophisticated equipment, which prevents them from being adopted at scale and from being used frequently.

Everyone carries a smartphone these days and most people use their smartphones as a camera, rather than a phone. Imagine if you asked any DoD personnel onsite to take few photos (from their phones) of the DoD assets that need to be inspected or repaired. Using our proprietary technology, we will build 3D models and floor plans of the area of interest and DoD maintenance personnel can remotely inspect, take measurements from the captured photos and conduct scenario plannings.

Our AI-driven image detection will detect signs of deterioration early on and offer early warnings that will prevent damages that usually occur from lack of timely maintenance. We will also help DoD estimate repair cost estimates remotely.

Some of the benefits that the DoD will realize are:

- Reduces cost and cycle time
- Cross-service applicability
- Improved safety and productivity

PROBLEM STATEMENT

No easy and cost-effective way to get a 3D Model of the DoD assets - on demand, real-time and within minutes - that require **periodic maintenance, monitoring and inspection**. The need for maintenance personnel to go onsite for every inspection **prevents frequent monitoring** and **timely maintenance** that can act as **preventive measures**, and also ends up **costing more**.
For the damaged parts or area that need to be repaired or replaced, someone has to **visit onsite to inspect and take measurements**, which increases both repair cost and duration. Existing solutions are expensive, time consuming, and require sophisticated equipments, which prevents them from being adopted at scale and from being used frequently.

BENEFITS

- **Reduces cost and cycle time**: The DoD maintenance personnel:
  - Have to make fewer onsite visits,
  - Can conduct more tasks remotely, and
  - Don't have to wait until they are onsite, to inspect
- **Cross-service applicability**: Our Solution can be applied to other service branches, such as military, the US Air Force, Defense Logistics Agency, etc for remote inspections, maintenance, scenario planning, etc.
- **Improves DoD safety and productivity:** Due to fewer onsite visits and DoD's ability to utilize their maintenance personnel anywhere, regardless of their geographic location.

TECHNOLOGY SOLUTION

Everyone carries a smartphone these days and most people use their smartphones as a camera, rather than a phone. Imagine if you asked **any DoD personnel onsite to take few photos** (from their phones) of the DoD assets that need to be inspected or repaired. Using our proprietary technology, we will build **3D models** and **floor plans** of the area of interest and DoD maintenance personnel can **remotely inspect**, **take measurements from the captured photos** and conduct scenario plannings.
Our AI-driven image detection will detect signs of deterioration early on and offer early warnings that will **prevent damages** that usually occur from lack of timely maintenance. We will also help DoD **estimate repair cost estimates remotely**.

GRAPHIC OR IMAGE

CCAD OVEN AUTOMATION

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CCAD is the world's largest maintenance depot for rotary wing repair and has large industrial ovens used for heat treating, relieving hydrogen embrittlement, or curing powder coatings on an array of parts. Ovens are mostly operated manually and monitored via chart recorders to ensure the baking "recipes" are implemented correctly. Since manual operation depends on personnel capabilities and equipment reliability, large numbers of parts are rejected or need reprocessing due to non-conforming control factors. This results in increased labor, parts, equipment runtime, and utility costs.

Currently, oven maintenance is performed at fixed times regardless of actual operational time since runtime is only documented sporadically. Thus highly used equipment is being under serviced, and less used equipment is being over serviced, leading to unplanned failures and excessive maintenance costs.

In 2017, CCAD implemented a small project in the heat treat shop to automate several ovens with PLC-based controls tied into a central workstation. Operators can pre-program unique recipes (heating and cooling) based on part specs, thereby increasing manufacturing consistency and quality control. Systems operate on a daily schedule and allow ovens to be shutoff at night and automatically pre-heated in the morning before operators arrive. The upgrades resulted in a Year 1 energy savings of $4,000, production increases by 15%, and reduction on parts rejection by 20%. Performance monitoring and reduced runtimes have decreased oven maintenance costs by 47% and has given CCAD the ability to prioritize maintenance of critical equipment.

The proposed project will expand automation efforts and focus on high priority production equipment, including additional industrial ovens, industrial freezers, various CNC machines and test stands. The ability to remotely monitor equipment performance will allow for properly scheduled preventative maintenance and provide for predictive maintenance.

Optimization will also include centralized workstations with customized graphical user interfaces (GUI) for both operations and maintenance personnel. Operational GUI focuses on real-time operational parameters, with systems auto-programmed and monitored to ensure desired conditions are achieved per recipe without manual intervention. Alarms will notify operators of non-conformance. Maintenance GUI focuses on key parameters such as runtimes, non-conformance logs/alarms, sensor drift, etc. This is used to schedule preventative maintenance at intervals based on equipment operational performance, preventing unplanned failures.

The proposed factory optimization supports increased workload/plant expansion at any time, by accommodating future changes in process workflows and required productivity. Overall, worker safety will improve, and the integrated diagnostics and production analyses will yield reduced time to market and minimize equipment downtime. This project will increase productivity, and reduce labor and maintenance costs.

PROBLEM STATEMENT

Problem: Industrial ovens are operated manually leading to large amounts of rejected parts. Re-processing of parts is extremely expense in the forms of labor, parts costs, equipment runtime, and utility costs. Maintenance is performed on fixed time intervals regardless of actual operation time resulting in higher than necessary maintenance costs.
Objective: Reduce maintenance costs via predictive maintenance and reducing reactive repair/replacement. Automate the baking "recipes" eliminating the manual operation of the ovens and reducing the re-processing of parts.

BENEFITS

Reduced run times result in a reduction in overall equipment maintenance and a longer life expectancy of the equipment

Operating parameters can be programmed in time based intervals. Monitoring of the key performance parameters also allows predictive maintenance

Equipment can be pre-programmed to turn on and achieve required operating conditions during the pre-dawn hours (prior to employees scheduled start time), therefore enabling additional manufacturing throughput in the course of any single day without leaving equipment operating at night

Pre-programmed sequence of operations can be programmed to implement a recipe with no manual requirements. Automated alarms identify when parameters or times exceed tolerances, therefore minimizing part rejects and improving worker safety

TECHNOLOGY SOLUTION

PLC-based controls tied to centralized workstation with two graphical user interface (GUI)

• Operational GUI focuses on real-time operational parameters and allow for systems to be automatically programmed and monitored ensuring the desired conditions are achieved throughout a process without manual intervention during the "recipe". Alarming would notify operators of non-conformance so issues could be resolved on-the-fly without affecting production output.

• Maintenance GUI focuses on key performance parameters such as runtimes, non-conformance logs/alarms, sensor drift, etc. These metrics would be considered for scheduling preventative maintenance prior to unplanned failures and at intervals based on equipment operational time as opposed to time-based intervals.

GRAPHIC OR IMAGE

TOUCHSTONE: RUGGED, CONFIGURABLE HAPTIC TOUCHSCREEN OVERLAY

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Touchscreens are increasingly being utilized as a flexible alternative to traditional button panels for many industrial and military applications. However, haptic technology used in current touchscreens does not provide sufficient feedback for operators working in harsh environments and wearing heavy gloves. This requires the user to close the loop by looking at the display, distracting them from their environment. There exists a need to provide stronger and more information-rich haptic feedback such that users in noisy, distracting, and dangerous environments are able to navigate touch-based controls without turning away from the situation at hand.

Midé Technology, through a NAVAIR Phase II SBIR, is developing a high performance haptic feedback touch screen overlay, dubbed "Touchstone", which allows for the emulation of realistic pushbutton sensations when interfacing with "virtual" software-defined buttons on computer displays. The system, currently at TRL 4 for shipboard use, features a ruggedized touch panel overlay that is affixed and driven by an array of haptic feedback modules nested around the display unit. A haptic background service designed by Midé is installed on the device and provides a link between onscreen software controls, touchscreen sensing data, and the haptic actuators themselves. An API developed to interface with the service allows for a software designer to easily pre-configure software buttons with different responses and patterns, and can allow users to adjust the haptic sensation similar to a volume control. The actuator modules leverage Midé's patented haptic bus technology (originally designed for wearable vibrational alerting systems), which interconnects each addressable actuator node together to form an intelligent array around the display, and provides both coarse-scale and fine-scale actuation resulting in rich, nuanced effects.

Early tests with NAVAIR personnel show great promise for the efficacy of the system. Next steps include further ruggedization, environmental and endurance testing, refining of control "clicks" and "buzzes" to better identify onscreen controls by feel alone, and end user evaluations. Midé's Touchstone touchscreen system, as well as our wearable haptics technologies, can provide a valuable means to improve situational awareness and performance of manufacturers interfacing with industrial equipment, sustainment professionals in the depot, on-site construction and maintenance workers in the field, and for many other users that need improved verification of touchscreen software actions to do their job safely and efficiently. The modular, scalable approach to both software and hardware could be useful for legacy or new systems of various physical display sizes and aspect ratios, device architectures, operating systems, and programming languages, saving development time and aiding adoption across the DOD enterprise.

PROBLEM STATEMENT

- Conventional button panels are expensive to redesign and reconfigure for the military. Touch panel systems allow for easy reconfigurability.
- Typical forms of haptic feedback in touch panel systems are inadequate for gloved hands and harsh environments, or for navigating the controls blindly.
- Operators need to be able to identify buttons with gloved hands and without looking at the screen, so that they can maintain attention on their surroundings.
- Midé's Touchstone system is rugged and provides strong indication when a user's finger or stylus is on a button and when the button has been successfully pressed.

BENEFITS

- Reconfigurability for simulation consoles and operator interfaces
- Hardware can be repurposed for different tasks, or uses (ie simulation and training tools) → cost savings
- Scalable, modular design. Actuators can be fitted to different touch panels. More can be added for larger displays by simply appending to the actuator bus
- Provides a simple, human-readable programming interface for configuring the haptic behavior of the UI
- Improves maintenance and manufacturing accuracy.
- Enhanced HMI, safety, and situational awareness, allowing the operator to control panel by feel, and gives reliable tactile confirmation that software button has actually been registered in challenging usage cases.

TECHNOLOGY SOLUTION

- Modular actuators interface with a touch panel to provide configurable forms of haptic feedback in a rugged environment, including large displacements to simulate buttons and small vibrations to provide various indications
- Leverages Midé's patented haptic bus technology, originally designed for wearable garment based tactile feedback arrays.
- A haptics service provides the link between the onscreen controls and the haptic actuators
- An API allows for easy integration of the haptics service with user-designed interfaces, as well as simple configuration of the type of haptic response associated with each onscreen control

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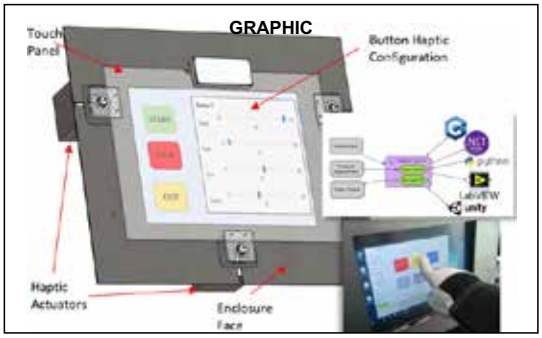
GRAPHIC



SURFACE TREATMENT SYSTEM (STS)

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It is well documented that compressor fouling of gas turbines is responsible for the majority of engine performance losses. Solids and condensing particles can precipitate on the stationary and rotating components affecting aerodynamic efficiency with the potential to result in secondary mechanical reliability issues. The cost of performance deterioration can manifest itself with lower power output, increased fuel burn and decreased component reliability thereby culminating in a higher cost of life cycle ownership/maintenance.

This solution combines several pre-existing independent technologies into a system to achieve a level of performance previously not realized.

The first step is the rapid and simultaneous removal of surface contaminants, including metal-oxides and corrosion products while not effecting the underlying substrate material. By utilizing a high intensity radiant heating process (laser), that is pulsed at ~10,000 times per second, the heat conduction is small preserving the underlying substrate while vaporizing the contaminants thereby realizing a substantial reduction in the waste stream. This FAA approved, controlled surface prep process has been demonstrated on both metal and composite materials and used in production today.

The second step is to process the surface to achieve a roughness of ~5 nm. This is done through the use of a process known as Rill Tech Micro-Finish. This improved performance through the reduction of skin friction is directly proportional to aerodynamic losses. This process is currently used in many racing applications.

The final step is the application of a thin film (Plasma Enhanced Chemical Vapor Deposition-PECVD), hydrogenated amorphous carbon coating, called Diamond-Like Carbon (DLC). This system has a very low coefficient of friction (more than 10X lower than Teflon), which is known for wear-resistance and tribological properties. In addition to the physical properties some of these coatings have been optically matched to infrared glass to eliminate front surface reflections, which makes the coating ideally suited as a protective outer surface for lenses used in thermal sighting imaging systems currently deployed on production military aircraft.

The combination of these technologies is a very hard, non-porous, compliant system that exhibits a hydrophobic behavior. These physical properties enable it to act as an effective surface treatment for gas turbine components, which are susceptible to accumulation of fouling debris during flight/operation.

The next steps for the Surface Treatment System (STS), is to process targeted engine parts, verify part resonant response, perform a cascade fouling test, and then evaluate in actual engine operation.

PROBLEM STATEMENT

Engine fouling is a significant concern for all types of gas turbines. However, it is more significant for aircraft gas turbines since they operate in a "non-filtered environment. Meaning that there is no inlet filter system as in power generation units. The following summarizes the problems caused by fouling:

- Reduced engine inlet mass flow and engine power output
- Negatively impacts compressor aerodynamic efficiency
- Chloride buildup accelerates airfoil corrosion/pitting
- Foreign particle erosion from ground debris or detritus, hail, volcanic ash, soot, other organic materials, etc.
- Primary source of secondary engine component damage due to Bill of Material Object Damage (BMOD),

BENEFITS

- Increased compressor efficiency
  Lower fuel consumption (Increased SFC)
- Greater vehicle range
- Reduced compressor BMOD
- Increase hot section durability due to reduced cooling temperature and CMAS (Calcia-Magnesia-Alumina-Silicate)
- Improves compressor stall and surge margin
- Less thrust/power deterioration
- Reduces unscheduled overhauls for improved fleet readiness
- Significantly reduced impact of foreign material accumulation due to lube system oil leaks causing "glue like" adherence
- Enables "Laminar Flow" aerodynamics for significant performance improvement

TECHNOLOGY SOLUTION

- The opportunity to solve this on-going condition can be eliminated through the combination of a unique three step Surface Treatment System (STS). The first step is an FAA approved laser ablation system that completely eliminates any surface contamination. The second step results in a surface finish (Rz) down to 5 µm. This step is necessary due to the thinness of the Diamond Like Carbon (DLC) coating. The typical airfoil surface has numerous surface imperfections that would penetrate the DLC coating that could result in a local nucleation point for further coating attack. The Plasma Enhanced Chemical Vapor Deposition (PECVD) process is conformal and will apply a uniform coating no matter what surface contour. DLC coating has proven it's durability as it has been used a long time on military aircraft missile sensor dooms, specifically for sandy environments.

GRAPHIC

FOAM FILLED TIRES

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Standard pneumatic air-filled tires are problematic in three areas: maintenance, acquisition, and reliability. Pneumatic tires require everyday routine maintenance for tire pressure checks and are subject to failures such as blowouts and flats. Replacement tubes are difficult to procure due to the specific geometry of tire tubes and air valve location. The tubes are difficult or undesirable for OEMs and other companies to replicate due to small quantity or the companies that are willing to reproduce the tubes are not specification compliant. The ideal situation would be to remove the pneumatic tubes and eliminate the chance of flats. Due to strict requirements of armament support equipment, the tires must be 100% design compliant.

DeVal Lifecycle Support has developed a special compound of elastomeric foam¬– a flexible foam known for its resiliency often used in industrial and airline industries. Elastomeric foam exhibits properties of low thermal conductivity and is flexible and easy to insert into tires and retains long term performance. We substitute the air with our compound, which duplicates the cushioning of air, while eliminating the failures associated with the routine maintenance of pneumatic tires. The foam can be injected into any size tire with any tube available. Once the tube is filled with foam through the valve port, the foam solidifies and is cured from that point forward. Once complete, the fill valve is cut off, and the foam makes the tire virtually indestructible. Foam density can be adjusted to cover heat resistance, speed and capacity depending on application and size. Essentially, there is only need for change if the tread is worn past the safety point.

These tires are used in applications such as aircraft tow tractors and industrial forklifts.

This process can be used for any DoD required tire. Size isn't restricted since current aircraft tractors have extremely large tires (6' diameter). We have removed pneumatic tires from munitions trailers, foam filled them, and finally tested them on the trailer. These tires have been tested for over 1.5 years in hot and cold environments, various loads and speeds up to 20 mph, including steering system tests and had no failures. The MHU 230 trailer will these tires going forward. DeVal is manufacturing a set of tires for an additional first article and is currently under contract.

Elastomeric foam contains the same resiliency as air without requiring pneumatic pressure checks and can be injected into any size tube. Tubes of generic geometry and valve stem location are used since the tube only retains the foam. Future applications are extensive for all rolling stock across all branches of the DoD that require pneumatic tires. Since the DoD must do more with less, foam filled tires completely fits this model.

PROBLEM STATEMENT

- **Problem:** Standard pneumatic air-filled tires are problematic in three areas: maintenance, acquisition, and reliability. Replacement tubes are difficult to procure due to the specific geometry of tire, configuration of tubes and air valve location.

BENEFITS

- Elastomeric foam contains the same resiliency and cushioning as air without requiring pneumatic pressure checks and can also be injected into any size tire tube. The foam filled tires require zero maintenance and are virtually indestructible. There will be no flat tires or blow outs during operation and no required daily maintenance pressure checks

TECHNOLOGY SOLUTION

- DeVal Lifecycle Support has developed a special compound of elastomeric foam– a flexible foam known for its resiliency often used in industrial and airline industry.

GRAPHIC OR IMAGE

SMART SUSCEPTOR HEATING BLANKET FOR COMPOSITE REPAIRS

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Problem: Within the aerospace and defense industry, composite repair was a $4.1 billion dollar industry in 2018 and this number is only going to grow as composites become more prevalent across all branches of the US military. Repairs of these materials, however, have their costs.

- Repairs significantly reduce combat and asset readiness.
- Incorrectly made repairs are not immediately obvious but can cause greater damage to composite structures.
- The quality of the repair is highly dependent on the quality of the cured joint which depends largely on the heating of the repair zone.

Considering the material advances and the capital investments required to create and maintain these advanced works of engineering, it is mind boggling that the repair industry is still curing composite repairs with the same resistance heating blanket technology developed in the 1980s. Traditional heating blankets output a fixed amount of heat over the entire area of the blanket. There is no method of accurately or repeatably controlling the temperature during a repair. For instance, advancement in the wings of composite aircraft have produced entirely composite aero-skins bonded to composite ribs and spars with each component having an engineered thickness to maximize strength and minimize weight. To make a repair by placing a traditional heating blanket over the structure and turning it on results in cold spots where the material is thick and ribs and spars draw away heat. In order to cure the resin to make a repair, a traditional heating blanket must be turned up to raise the temperature. However, the areas next to these structures, where the composite is thin and has no heat sink, are now overheated. This significantly compromises the material's integrity. Therefore, it requires a very skilled and experienced technician to make quality repairs to composites without inadvertently causing greater damage.

Technology Solution: A heating blanket capable of self-regulating across its entire area. This is possible through the use of smart susceptor technology. The technology uses induction with a unique self-regulating heating element called a smart susceptor. The susceptor is made from a metal that becomes non-magnetic at a specific temperature called the Curie temperature. At this temperature, the heating element no longer accepts energy from the induction system and the heating stops. Regardless of the energy input into the system, the smart susceptor levels off at the same temperature. But if any point drops below the Curie temperature, that specific point becomes magnetic and begins to heat until it becomes non-magnetic. This enables incredibly even temperature distributions and requires no software monitoring or temperature control. The results of this technology are:

- Temperature regulation to within ±4 °F, Demonstrated on over 300 sq ft of area
- Virtual impossibility of overheating.
- No specialized knowledge of the structure being repaired.

PROBLEM STATEMENT

Composite materials are becoming ever more prevalent across all branches of the US military, however, repairing composites has its problems.

- Downtime due to repairs reduces combat readiness.
- Repairs made incorrectly can create additional damage without being obviously visible.
- Successful repairs depend of the skill of the technician.
- Quality of the composite repairs depend on maintaining a narrow temperature band in which the resin cures.
- Heat sinks caused by engineered features (ribs, spars, multi-thickness panels) make even heating with traditional heat blankets difficult if not impossible.

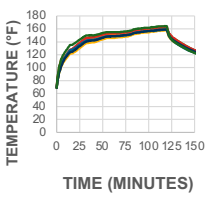
BENEFITS

- Increased combat and asset readiness.
- Quality repairs made with confidence.
- Less risk of damage to costly composite structures due to operator error or sensor malfunction.
- Highly trained technicians are not mandatory for repairs.
- Decentralizes repair network by enabling standard warfighters to make repairs.
- Proven operation in a production environment.
- No constant monitoring, increasing technician productivity.
- Multiple blanket systems can be synced for large repairs.
- Installed systems have proven robust with 600+ debulking cycles and not a single failure.

TECHNOLOGY SOLUTION

The solution is a smart heating blanket capable of curing a composite without overheating or otherwise damaging the rest of the structure.

- Smart susceptor heating blankets maintain a ±5 °F curing temperature band without any input or software control.
- Smart susceptor heating blankets cannot heat beyond a specified temperature regardless of inputs or power applied.
- Smart susceptors automatically stop heating in areas where the target temperature is reach while continuing to heat in cooler areas without input from thermocouples or other control devices.
- Temperature ranges up to 375 °F with multiple temperature set points are possible.



PORTABLE COMPOSITE SCARFING UNIT

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Composite manufacturing is a relatively young discipline in comparison to metallic manufacturing. Due to the high load bearing capacity of composite materials and stringent requirements of structural components, composite repair is subject to tightly controlled procedures with regards to accuracy and customization of repair material in order to guarantee continued function of these components. The majority of the existing repair processes are currently manual and operator dependent without a digital thread traceability. In a previous NCMS funded development project, GFM established the concept of an IRPC (Inspection & Repair Preparation Cell). This project successfully performed inspection and repair of composite components taken from aircraft. Components were processed in a system with primary functions of digitizing the component followed by non-destructive inspection to determine location and limits of any defects in the component.

GFM would like to further develop a holistic approach to repair composite structural parts. GFM's approach seeks to utilize Industry 4.0 methodologies to track part and defect information to form the digital thread from the start of the process. The fully automated process will also include generation of CNC programs for scarfing components in order to remove defects and prepare component for repair. Special databases in the background provide basics for necessary repair strategies that will be developed with our project partner WSU NIAR, Wichita, KS. Main focus of this development effort is to create a portable gantry-based high precision 5 axis GFM CNC scarfing unit. With a portable machine, it is possible to repair components that are in the field, or in-service, and cannot practically be brought to repair depots. Historical approaches to portable repair machines have been around for several years, however, these approaches often proved to be unsuitable. Machines based on robotic processes have historically failed to achieve the required accuracies. Other systems were characterized either by shortcomings in the work envelope or a high complexity in the set-up, making practical use impossible.

The technical advantages of this innovative portable scarfing machine, among other things, is due to its split design. Functional separation of attaching to the defective part and scarfing is implemented in a two-piece independent machine design. Lightweight frame functions to connect to defective part, is a stable, rigid carrier of actual CNC processing machine, which is only fixed to the frame, with high precision, in the last step of set-up.

Total process of the repair is given by an intelligent software system, and allows generation of necessary repair plies from recorded actual data of the surface of defective part, plus creation of processing path of scarfing machine and automatically generated repair concept. In combination with a GFM CNC ultrasonic cutting machine these repair plies can be cut automatically. This will result in a digital thread that can be incorporated in digital twins of aircraft systems, which can facilitate future quality in field repairs. Our partner WSU NIAR, will co-develop this system, and is committed to furthering this development together with leading industry users.

PROBLEM STATEMENT

- The frequency of minor accidental damage during the service life of composite structures has become high, and the resultant repair work has a significant impact on maintenance costs
- Existing manual repair procedures are outdated, error prone and exhaustive
- The repair method is not suitable for on-site repair because of lack of knowledge, skills or equipment, which is a time, cost or logistical burden
- A validation of the repair to predict the further service life is not possible either simply due to missing data, records or due to quality fluctuations of repair work

BENEFITS

- GFM high-precision CNC technology eliminates the effects of human error
- Complex task, but easy to use, facilitated by automatic repair program and geometry of repair plies generation
- Versatile and affordable equipment with small footprint and low weight broadening the range of repair applications
- The portable unit allows on-site and/or off-site repair and eliminates the need for transportation to the workshop
- Effective and automatic application of the best practice repair strategy due to WSU NIAR's commitment for long-term development efforts
- By creating a digital thread, recording and tracking of the history enables future predictability of the further life cycle

TECHNOLOGY SOLUTION

- GFM Portable Advanced 5-axis milling/scarfing machine with advanced CNC machining and programming capabilities
- After machining, the machining path is used to determine the exact geometry of the required repair plies
- Open control to add all necessary functions (e.g. digitizing) to the editing and process recording functions
- Integrated database for repair philosophy and continuous further development of best price concepts due to the long-term development commitment of the project partner WSU NIAR

GRAPHIC OR IMAGE

HEATCON SMART SUSCEPTOR COMPOSITE REPAIR SYSTEM

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Composite materials have become the dominant choice for high-performance aerospace structures. These materials must be cured under controlled conditions to achieve optimal properties. While autoclaves serve this function well during manufacturing, repairs are often performed outside of an autoclave. Maintaining the required temperature uniformity, often ±10° F, can be challenging or sometimes impossible using traditional techniques. Design features such as structural stiffeners, cross sectional thickness changes, and metal component interfaces increase thermal complexity. The result is uneven heating within the structure.

Uneven temperature distribution within the repair area is often mitigated using techniques such as insulation placement, thermal surveys, application of secondary heat sources, and use of multiple control zones. When these techniques are unsuccessful, the resulting material properties may not meet design requirements, which could lead to in-flight failure of the repair patch. Heat blankets using electrical resistance wire have been the standard for composite repair since the 1980's with minimal design changes.

Although they generate even heat, this does not always translate to even temperature in the repair area. This can work well on general repairs, but when repairing a thermally complex structure, the results may not be acceptable.

In contrast, a Smart Susceptor heat blanket actively manages temperature uniformity to improve repair quality, enhancing in-flight safety. A Smart Susceptor heat blanket uses an engineered susceptor alloy as the heating element. The susceptor element receives electromagnetic field energy (generated by the inductive power supply) and converts it to heat. A Smart Susceptor alloy is custom engineered to have a Curie point at the cure temperature. This creates "self-regulating" behavior—as the Curie point of the alloy is reached, it loses magnetic susceptibility, preventing cure temperature overshoot. Every point of the Smart Susceptor blanket physically reacts to the localized temperatures of the repair area to manage temperature uniformity. Cold regions continue to heat while hot regions maintain and limit temperature. This mitigates effects of heat sinks to improve final material properties.

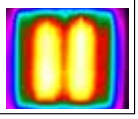
Testing on thermally complex structures has shown temperature uniformity improvements often exceeding 300% over traditional resistive blankets. Additional benefits include:

1. Reduced risk of thermal damage through overheating
2. Higher probability of meeting design requirements
3. Reduced need for operator training
4. Elimination of time-intensive thermal surveys

Heatcon has a COTS Smart Susceptor repair system available. It has the same familiar interface as previous Heatcon bonders, which have supported sustainment of military composite aircraft structures for decades. Future developments in work include networked multi-zone capability, additional temperature alloys and complex 3D heat blanket shapes.

PROBLEM STATEMENT

- Composites are the material of choice in high-performance military aerospace structures, but many repair processes continue to create challenges
- Maintaining stiffness and strength in repaired composite structures requires a narrow cure temperature range
- Temperature uniformity can be difficult to achieve using conventional heat blankets for "thermally complex" structures with:
  - Stiffeners
  - Thickness changes
  - Metal components



Thermal image of composite panel with stiffeners, heated by conventional (resistance) heat blanket, outside acceptable temperature range

BENEFITS

- Over 300% improvement in temperature uniformity, for improved material properties
- Reduced risk of thermal damage through overheating
- Reduced need for operator training or expertise
- Elimination of time-intensive thermal surveys
- Same intuitive interface used by existing fleet equipment
- Multiple alloys available including 250 and 350 °F Curie points
- Multi-zone networking, additional temperature alloys, and 3D shaped blankets in development
- TRL8

Thermal image of Smart Susceptor heat blanket heating evenly

TECHNOLOGY SOLUTION

- Smart Susceptor technology combines inductive heat with custom-designed heater alloys, providing "self-regulating" performance:
  - Engineered heating alloy loses ability to create heat above cure temperature (Curie effect)
  - Cold regions continue to heat, hot regions hold temperature
  - Greatly improved uniformity
- Smart Susceptor heating wires embedded in a heat blanket
- Inductive power supply integrated into a Heatcon bonder

IMAGE

Smart Susceptor on F-18 wing

Smart Susceptor hot bonder

Smart Susceptor heat blankets

TRAINING ARMOR

DOUG HAGEDORN

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Problem Statement: Currently military training exercises and learning in peace time are done using expensive real armor systems mounted to their military vehicles. During these exercises the armor systems get damaged and require costly repair or in most cases requiring replacement. This is a huge logistic, maintenance burden, and spares cost.

Technology Solution: Armatec can implement an exact replica training armor kit that is form, fit, weight, equivalent system, at a fraction of the cost of real armor, has Infinite durability, and provides equivalency to the real thing for training purposes. The training kit is installed for everyday peacetime usage while the real armor kit is in storage. Once the vehicle needs to be battle ready the training kit is replaced for the real thing for deployment.

Benefits: The benefits of this system is a reduction of spares/ maintenance of armor in training and peacetime to $0, and due to weight equivalency the vehicle still behaves the same as it would with the real kit for training. The system has been fully designed for a Stryker but can be implemented for any platform.

Next Steps: The next steps would be to get the kits onto a brigade of Stryker's and analyze the cost savings from training the next recruit of soldiers to realize the cost savings potential.

PROBLEM STATEMENT

Currently military training exercises and learning in peace time are done using expensive real armor systems mounted to their military vehicles. During these exercises the armor systems get damaged and require costly repair or in most cases requiring replacement. This is a huge logistic, maintenance burden, and spares cost.

BENEFITS

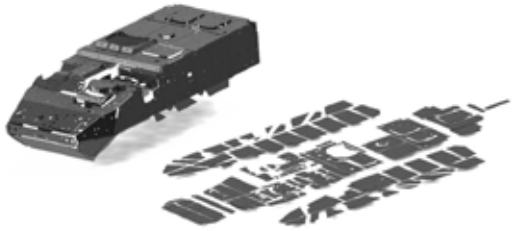
- Reduction of spares/ maintenance of armor in training and peacetime to $0
- Due to weight equivalency the vehicle still behaves the same as it would with the real kit for training.

TECHNOLOGY SOLUTION

- Armatec can implement an exact replica training armor kit that is:
  - Form, fit, weight, equivalent
  - Fraction of the cost
  - Has Infinite durability
  - Training compatibility to the real thing
- The training kit is installed for everyday peacetime training and use while the real armor kit is in storage.
- Once the vehicle needs to be battle ready the training kit is replaced for the real thing for deployment.

GRAPHIC OR IMAGE

Below is the training kit for STRYKER as an example



TOWING INDICATOR

DOUG HAGEDORN

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Problem Statement: The Stryker vehicle has no definitive way to indicate that the vehicle tow release is fully disengaged and ready for towing. If the system isn't fully disengaged and the E-brake is still engaged, towing the vehicle causes the e-brake to heat up and cause fires and in some cases burning the entire vehicle to the ground due to a runaway fire.

Technology Solution: Armatec has developed a simple bolt on indicator that will provide clear 100% feedback to the user to allow them to know exactly when the tow release is indeed fully disengaged.

Benefits: The benefits of the unit allows for clear feedback to the user that the system is disengaged a reduction in maintenance costs due to fire damage repairs and no loss of asset due to a runaway fire.

Next Steps: The next steps would be to get the system implemented on a brigade of Stryker's to validated its function.

PROBLEM STATEMENT

- The Stryker vehicle has no definitive way to indicate that the vehicle tow release is fully disengaged and ready for towing.
- If the system isn't fully disengaged and the E-brake is still engaged, towing the vehicle causes the e-brake to heat up and cause fires.
- In some cases the vehicle is burnt to the ground due to a runaway fire.

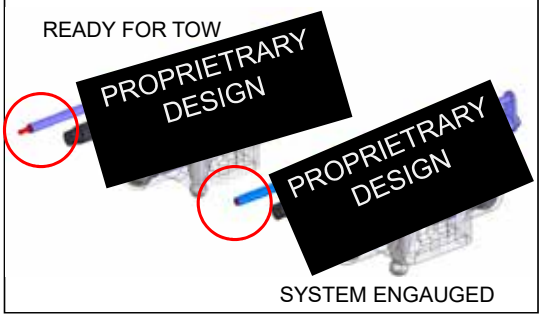
BENEFITS

- Clear feedback to the user
- Reduction in maintenance costs due to fire damage repairs
- No loss of asset due to a runaway fire

TECHNOLOGY SOLUTION

- Armatec has developed an indicator that will provide clear 100% feedback to the user to allow them to know exactly when the tow release is indeed fully disengaged.
- Simple bolt on replacement

GRAPHIC OR IMAGE



ELEVAT MACHINERY OPTIMIZATION SOLUTION

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Elevāt is software that enables machinery owners, users, and builders to remotely (via the cloud), monitor equipment anywhere in the world in real time and provide that information as determined by the users, securely to anywhere in the world. Data collected while a machine is disconnected is stored and uploaded once a connection is reestablished. Equipment fails because parts fail, and most machines worldwide are not connected to the cloud meaning users are blind to critical data and information such as machine location, machine health, environmental conditions, machine efficiency and service requirements all of which lead to downtime costing billions annually.

Elevāt makes connecting any critical machine data to the cloud easy, inexpensive and relatively quick. Elevāt does not provide hardware, however our worldwide distribution partners do. Elevāt distributors can provide installation and connection services or they can teach users how to connect their equipment to the Elevāt cloud using standard industrial components.

Elevāt provides enhanced machine performance by enabling secure and safe remote software upgrades, making it possible for machines years old to have their software updated and improved versus when first put into service. With Elevāt, parts can be supplied just-in-time (JIT) thereby building a virtuous cycle of machine insight, predictive maintenance and to deliver the right parts to the right location, just in time, reducing inventory worldwide. Elevāt enables machine operators to leverage data and make real-time business decisions, reducing downtime and optimizing productivity.

Elevāt is a combination of software components running on the Edge and in the Cloud. Elevāt combines software with industrial technology to collect data often formatted as CANBUS J1939 protocol and via a proprietary compression technology, and streams that data while minimizing data transfer costs. The Elevāt CORE technology runs on major cloud platforms and provides multi-tenant organizations the ability to customize their data visualizations. Elevāt's industry-leading management team has deep domain experience and a proven ability to execute.

PROBLEM STATEMENT

- Military in service operations and supply chain lack visibility to machine health, location, performance, uptime, and upcoming maintenance and service requirements.
- Machinery is not connected to the cloud, and fails at inappropriate times This applies to all equipment requiring any kind of maintenance, used on land or at sea worldwide
- Military is unable to remotely monitor, upgrade, optimize performance, accurately predict parts demand and equipment readiness and in field effectiveness
- Operations lacks real-time location, equipment health for each piece of machinery.
- Equipment does not remain current if software is not upgraded.

BENEFITS

- Connect any machine to the cloud easily and quickly
- Uses standard industrial commands, no specialized technical requirements
- Provide all the data required by the user (command or in field)
- Access Over the air software updates
  - Machines years old can be continuously improved via OTA operational software updates
- Smart Parts
  - Anticipate parts requirements
  - Manage logistics for to "The right part at the right place at the right time." all the way to supply chain
  - Increase machine uptime & productivity
  - Geolocation of machines (type and status)
  - Networked enabled machine and parts exchange

TECHNOLOGY SOLUTION

GRAPHIC OR IMAGE

HC-144 FAIRING ACCESS DOOR & ELECTRICAL TEST GEAR CONNECTION POINTS

CDR ASH LOVEJOY

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The U.S. Coast Guard (USCG) operates a fleet of 18 HC-144 Ocean Sentry aircraft from four air stations to perform its eleven congressionally mandated missions. The USCG's unique mission spectrum poses a variety of maintenance challenges not seen by any other operator of similar type aircraft in the world. In particular, high annual usage rates in all-weather maritime conditions is very demanding on the aircraft due to the increased stress from buffeting and operational maneuvering coupled with the constant threat of corrosion.

The Coast Guard's readiness posture and mission spectrum is often limited due to the HC-144's engine inlet anti-ice and propeller de-ice system reliability issues and component locations. System components are located on the exterior of the fuselage behind large fuselage fairings. Removal of the 10.5' long fairings to troubleshoot faulty components was considered a major inconvenience and was circumvented due to the level of effort required and the inherent risk of both fairing and airframe damage. Furthermore, once the large fairing we're removed, technicians had to remove electrical tray covers, and insert bare test set wires into terminal ends of the electrical tray. The combined impact of these problems caused deferred maintenance, limited aircraft operations in cold weather, and required excessive man labor hours to troubleshoot and repair these vital systems. The solution strategy was two-fold: 1) Design and install point-of-service maintenance access doors in the left and right fuselage fairings. 2) Develop organic electrical test gear connection points which complement the access doors providing easy hook-up, and real-time pinpoint testing of system components.

This collaborative initiative solves several maintenance challenges:

- Significant reduction in mission limited assets due to propeller/engine de-ice and anti-ice faults
- Eliminates the man labor hours associated with removing the entire fairings
- Reduced fairing damage and ancillary airframe repairs
- Eliminates installation of faulty replacement parts
- Facilitates pinpoint testing from the safety of the aircraft's cabin
- Eliminates safety concerns of testing with bare wires.
- Restored technician troubleshooting confidence
- Eliminates field repair request for related system failures

Design and prototyping of first articles occurred at the Coast Guard's Aviation Logistics Center while long term sustainment will be outsourced to a composite repair partner. Providing innovative sustainment solutions for the HC-144's all-weather capability highlights the USCG's organic capability to innovate for the betterment of the USCG and to the public which it serves. This best practice solution was shared with the aircraft manufacturer encouraging strategic partnerships and growth. Providing maintenance solutions not considered by the manufacturer delivers selfless transparency and highlights what innovation is all about. - Semper Paratus!

PROBLEM STATEMENT

The Coast Guard's HC-144 aircraft experiences high failure rates of its engine inlet anti-ice and propeller de-ice system components. Cumbersome access to system components and current troubleshooting procedures are inefficient which result in:

- Increased deferred maintenance for anti ice systems.
- Limited ability to fly the aircraft in cold weather.
- Increased likelihood of fairing and/or surrounding aircraft structure damage during cumbersome fairing removal process.

BENEFITS

- Significant reduction in mission limited assets due to propeller/engine de-ice and anti-ice faults.
- Eliminates large labor requirement associated with removing the fairings.
- Reduces fairing damage and ancillary airframe damage.
- Facilitates quick and easy pin point testing from the safety of the aircraft's cabin.
- Eliminates safety concerns of testing with bare wires.
- Restores technician troubleshooting confidence.

TECHNOLOGY SOLUTION

- Fast removal, easy to use point-of-service access doors.
- Organic electrical test gear connection points which complement the access doors providing easy hook-up, and real-time pin point testing of system components.

ADVANCED SINGLE VACUUM BAG COMPOSITE REPAIR

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Polymer matrix composites are increasingly replacing traditional metallic materials in aerospace platforms due to high strength to weight ratio, manipulative properties, and corrosion resistance. However, repair methods for these materials are considerably more complicated. Typical composite flush repairs require machining a tapered or stepped cavity to remove the damaged region, followed by bonding of a high strength, mating composite patch. A repair patch closely matching the strength of the original substrate is necessary to maintain component performance. Autoclave or Double Vacuum Debulk (DVD) processes are currently required to eliminate voids in a composite and thus fabricate high-quality composite patches. However, these process require special tooling, limit the size of the repair, are overly complicated and expensive, and create logistical challenges when repairs are needed on-site.

Luna Innovations Incorporated has developed Out of Autoclave (OOA) composite patch fabrication and application processes that enable repair of high-performance components. Luna's advanced single vacuum bag processes utilize a novel breathable resin barrier (BRB) which permits maximum air permeability but prevents resin penetration. This allows air to be continually evacuated over the entire surface of the laminate patch while achieving uniform vacuum compaction pressure. With the use of the BRB, high-quality aerospace laminates can be produced via OOA fabrication while eliminating prolonged debulking steps, excessive lay-up support materials, and specialized tooling. Luna's unique Single Vacuum Debulk (SVD) process is an alternative method to prepare a semi-cured soft patch without the need for size limiting DVD tooling. This novel process mimics the DVD process, in which voids/volatiles can be eliminated without compaction pressure prior to fully consolidating the laminate. Yet, only a single vacuum bag is required with no additional tooling.

The technologies are in the process of being optimized for commercial transition. Using one or a combination of these processes, void volumes ≤1% have been consistently achieved with both current wet-resin and prepreg repair materials. Luna's repair processes eliminate special tooling, simplify set-up, and remove size restrictions, enabling on-site repairs. Reductions of repair times by more than 50% are achievable. Luna is actively seeking end-users to demonstrate the technology in preparation of commercial transition.

PROBLEM STATEMENT

- A process is desired to perform aerospace flush repairs that meet or improve the quality of the current process, but is less labor intensive and minimizes complex support equipment
- Aerospace flush repairs require machining tapered cavity to remove damage, followed by bonding of mating (scarf) composite patch
- Autoclave or Double Vacuum Debulk (DVD) fabrication processes are currently required to fabricate high-quality patches for composite repair
- These process require special tooling, limit the size of the repair, are overly complicated and expensive, and create logistical challenges when repairs are needed on-site

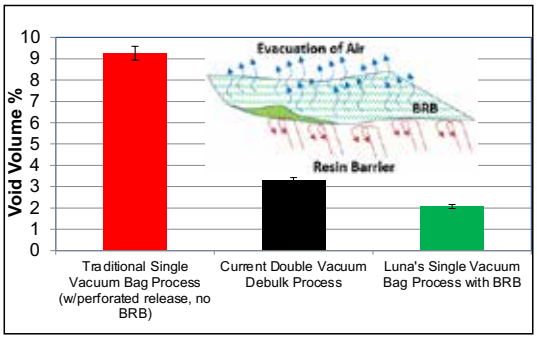
BENEFITS

Luna's single vacuum bag repair processes:

- Can produce autoclave or DVD quality repair patches with simple tooling
- Enable repairs on-site at any facility or location
- Allow for larger repair patches
- Eliminate equipment scheduling bottlenecks
- Lower the cost for repairs
- Can reduce repair times by more than 50%
- Are readily adaptable for rapid integration

TECHNOLOGY SOLUTION

- Luna has developed advanced single vacuum bag repair processes for simplified, efficient composite repair
- For rapid technology insertion, Luna's approaches utilize current composite repair materials - complete requalification is not necessary
- Innovative Breathable Resin Barrier (BRB) enables fabrication of low void volume/high quality composites using standard single vacuum bag Out of Autoclave (OOA) process – the BRB permits air permeability but prevents resin penetration
- Luna's unique Single Vacuum Debulk (SVD) process mimics DVD process and quality using only a single vacuum bag and without required DVD tooling



ROBUST FILTRATION FOR MILITARY AIR AND GROUND VEHICLES

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Working with the US Army, a new filter material has been developed for use in hydraulic, lube oil and fuel filtration which (in the case of the Army) reduced their maintenance on helicopters by ten times. This material is being tested in Air Force aircraft, ground support systems and Navy ships. It has been a phenomenal breakthrough which will allow for more sophisticated hydraulic equipment to be utilized as systems can now be much cleaner than ever before. As well, since this filter material cleans fluids better than new, hydraulic and lube oils can be repeatedly reused saving disposal costs.

PROBLEM STATEMENT

There is a need for more robust, environmentally friendly filtration technology which can reduce aerospace and ground based vehicle maintenance and promote readiness in hydraulic, lube oil and fuel systems for the military. **The US Army, Air Force, and Navy are currently experiencing high levels of oil and fuel contamination in their equipment, costing hundreds of millions of dollars, reducing readiness, and compromising safety for our services.** Current filter technology is over 50 years old and does not provide the cleanliness required for modern technology to be applied to our aircraft and ground vehicles.

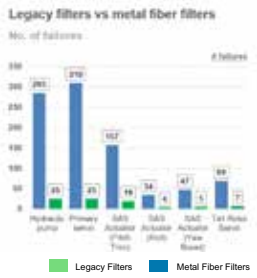
BENEFITS

- Significantly reduces maintenance. Has cut hydraulic maintenance on Army helicopters by **ten times**.
- Can greatly extend the time between maintenance on ground -based vehicles and aircraft. Provides more reliability and readiness during times when maintenance is not available.
- **Reduces fluid disposal frequency.** Hydraulic and lube oils are now cleaner than new oil and does not require disposal, just a filter change.
- Dissipates static charge in hydraulic systems.
- Metal fiber elements can be scrapped as any other metal. No need for environmentally unfriendly dumping.

TECHNOLOGY SOLUTION

Robust, sintered metal fiber filter materials provide the strength to capture and **retain** particulate which greatly reduces maintenance and provides longer life to military equipment. Metal fiber filter media is 100% stainless steel sinter bonded fibers and contains no glues or binders as current paper and fiberglass filter medias. Current filter materials break down and shed particulate during dynamic conditions causing even more damage to the equipment. Metal fiber filter media does not release fibers or contaminant back into the system during dynamic conditions and greatly extends the life of the equipment being protected. This material is now being used in Army helicopters and Air Force aircraft with great success.

GRAPHIC OR IMAGE



REAL-TIME PREDICTION OF INCIPIENT FAILURE IN WORKING FLUIDS

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Working fluids (engine oil, transmission fluid, hydraulic fluid, coolants, etc.) become contaminated in use. To ensure that the equipment is not damaged by the contaminated fluid, the fluid is typically removed and replaced periodically. For large groups of machines, the used fluid is then shipped to an analysis laboratory and a complicated analysis is performed to ensure that the fluid replacement period is correct for each machine and that each machine is not in need of immediate repair. This procedure is costly, time consuming, and does not always work in a timely manner to prevent machine failure.

This proposal presents a new analysis approach to the detection of incipient failure in working fluid. The proposal presented herein demonstrates the value of real-time analysis of the differential electrical admittance of the working fluid in-situ to detect the incipient failure of the working fluid in a large class of machines and devices. Once incipient failure has been detected, the contaminated working fluid can be removed and replaced with new, high quality working fluid, before the machine is damaged. The physical system shown in this proposal has been modeled earlier.

Based on this proposal, a prototype system will be physically developed to demonstrate that the differential electrical admittance changes, as measured in the Frequency Domain, as a function of the shift in the parametric value of the electrical conductivity and/or the relative permittivity, can be employed in real-time to predict the incipient failure of the measured working fluid. The sensor portion of this unit will be so designed as to allow it to be replaced each time the fluid is replaced, much as an oil filter. Replacing the sensor will prevent residual contamination from compromising the measurements of the new replacement fluid and ensure higher real-time accuracy.

The next step in the development of this technology will be to fabricate, at least, a small number of prototype systems (3) and to install those systems in suitable working environments (car, truck, tank, etc.) for duration tests and data acquisition and analysis.

PROBLEM STATEMENT

In many working fluid applications, (e.g. trucks, planes, military vehicles and weapons, submarines, etc.) it is presently standard practice that the in-machine working fluids are nominally to be removed and replaced (oil change, transmission fluid, etc.) with new fluids before any catastrophic event can occur. The removed fluids are then returned to a laboratory and analyzed. Occasionally, the catastrophe occurs first.
Current processing techniques are slow, costly and labor intensive. The end results are influenced by the variability in properties of both different fluids and the differences in the incipient fluid failure mechanisms in different machines.

BENEFITS

Using real-time prediction of incipient failure inherently compensates for the variability of both new fluids and the variability of the incipient fluid failure mechanisms from machine to machine.

Real-Time Prediction of Incipient Failure in a Working Fluid saves both cost and valuable time, as well as being immediately available in critical situations.

TECHNOLOGY SOLUTION

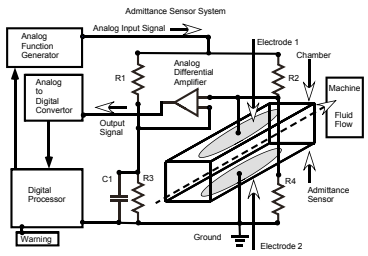
1. Fluid flows through the Admittance Sensor.

2. Analog Input signals at a selected frequencies are applied to the Admittance Sensor System, sequentially.

3. The applied signals are sensed by the Analog Differential Amplifier and sent to the Analog to Digital Convertor (A/D). The output of the A/D Convertor is sent to the Digital Processor for analysis.

4. The Digital Processor stores each analysis result and assembles Admittance response curves. The measured response curves are compared to the reference response curve (measured from a pure fluid). Sufficient deviation of the measured curve from nominal, causes a warning signal.

Admittance Sensor System



NO LEAD TEMPERATURE SENSORS

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Problem: Composite structures require accurate temperature control for processing and repair. Current methods require thermocouple leads that are restricted to trim areas and require heat transfer assessments to critical part locations.

Technology Solution: New sensors can be placed within the part and measured using a magnetic field, eliminating the need for leads and enabling in part measurement.

- Direct temperature measurement using small imbedded sensor (below acceptable flaw size) is available
- Measurement is achieved using a magnetic field that activates and interrogated the sensor without thermocouple leads.

Benefits: Direct measurement of temperatures in critical part and repair locations is:

- Requires less time (less expensive)
- Ensures accurate temperature is achieved at critical locations
- Shortens repair time and return to service by eliminating the heat transfer assessment step.

PROBLEM STATEMENT

- Repair and maintenance of composite structures is a need across the DoD and relies on accurate measurements of temperature. Most structures preclude placement of thermocouples in the part itself and rely on costly heat transfer assessment to ensure a successful repair or replacement part.
- This need for heat transfer assessment:
  - Adds cost
  - Delays return to service
  - Introduces risk because of difficulties in obtaining accurate heat transfer data

BENEFITS

- Direct measurement of temperatures in critical part and repair locations is:
  - Requires less time (less expensive)
  - Ensures accurate temperature is achieved at critical locations
  - Shortens repair time and return to service by eliminating the heat transfer assessment step.

TECHNOLOGY SOLUTION

- Direct temperature measurement using small imbedded sensor (below acceptable flaw size) is available
- Measurement is achieved using a magnetic field that activates and interrogated the sensor without thermocouple leads.

GRAPHIC

- Antenna over sensor in a part

Sensor next to ruler in layup

PORTABLE TACTICAL WELDER

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Power management is the limitation to increasing welder mobility and efficiency. To create a solution, it requires an effective battery management system (BMS) in a backpack unit that can be used quickly and safely in the depot but also have the durability to operate in the field or shipyard. The unit should be easy to use and leverage consumables in the existing supply chain. A backpack welding solution allows the welder to work in remote locations, speeding repairs and eliminating costly power set-up and take down inefficiencies. If incorporated aboard ships for damage control, a backpack solution reduces electrical risk during post-flooding repair which is often necessary to get under way. Fire risk aboard ship can be reduced by eliminating the need to run power through watertight doors such as those conducted during pier side maintenance availabilities.

Effective solutions for welder mobility and power management are the obstacle. The ability to draw and transfer power from the L-ion batteries to provide consistent quality welds in a compact lightweight design. The BMS design should also be intelligent in terms of discharge and recharging the battery bank where power is drawn or restored across multiple cells to ensure maximize battery recharge time, cycle count and premature cell failure.

Duty cycle or number of minutes welding should be competitive to standard welders with safety consideration of a Li-Ion battery bank. The BMS must include both soft and hard shut down configurations. In the event a Welder surpasses the duty cycle, integrating temperature based "soft" shut down programming protects the a redundant "hard" shut down procedure with reset only available by the manufacturer to ensure no damage occurred.

A combination of MIG and FLUX CORE welding offer the broadest capabilities. FLUX CORE welding shares commonality with traditional stick welding and MIG welding allows for thinner materials like sheet metal at lower amp. The portable welder should have an amperage controller that ensures a large range of materials and thickness that can be effectively welded and during maintenance work to maximize welder efficiency especially when working a punch down list that are common during shipyard maintenance availabilities.

The Tactical Welder backpack (TRL 9) is designed around usability and productivity and was awarded a Defense Innovation Award in 2017 for its patented BMS technology. The product was taken to a half dozen private sector shipyards for testing and evaluation in 2018 and underwent a full redesign of the welding gun based on real world feedback making improvements in usability. The Tactical welder earned a Gold Edison Award in the "Portability" category in 2019. Developing a plasma cutting system using the same compact lightweight BMS design is the next research goal.

PROBLEM STATEMENT

- At the depot, time spent tearing down and setting up power scales quickly and may unnecessarily tie up repair bays. In many instances, managing power often takes just as long as doing the repair
- Available power in CONEX based field repair kits is limited
- In the field, repair power may not be easily accessible or otherwise put the recovery vehicle at risk
- Manufacturers in the welding industry market welders as portable, but when factoring power management, fall short on mobility or are limited in terms of capability
- Traditional commercial units are not designed for field use

BENEFITS

- A backpack welder dramatically increases efficiency especially for small to medium welding projects and frees-up repair bays. Reducing time managing power translates into more projects completed (ROI)
- A backpack welder improves time to restore in the field. Grab the welding backpack, welding bag and go
- Increase available power resources for equipment in FOB or other CONEX based repair kits. Re-charge when power isn't being used
- Vehicles may require welding repairs in locations where traditional recovery and repair equipment may not be able to access or in proximity

http://veterantechllc.com/products/tactical-welder/

TECHNOLOGY SOLUTION

- MIG or FLUX CORE welding with the same unit.
- 512kw power BMS. constant power delivery up to 300A
- 30% Duty Cycle with redundant safety systems to prevent overheating or risk of battery damage
- Up to 1lb of wire on a single charge. Partial recharge in less than 1 ½ hours, 2.5 hours with full discharge
- Weld up to ½ inch steel or other metal. (0.030 – 0.052 wire)
- Lightweight (27lb.) compact design with padded backpack intended for industrial or field use
- Battery, patented BMS completed UN certified testing
- Optional programmable Amp controller to ensure quality welds each time.
- Certified ISO 9001 manufacturing processes. Made in the USA

Tactical Welder Capability Demo

GRAPHIC OR IMAGE

DUST SENSOR SYSTEM FOR IMPROVED OPERATIONAL READINESS

STEVE TODOVERTO

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Airborne sand, dust, and volcanic ash ingestion is increasingly a problem for gas turbine and piston engines in both military and civil applications. Ingestion of these materials may accelerate the loss of engine efficiency and also result in a substantial reduction in component life or catastrophic failure. The resulting ingestion adversely affects turbine or engine performance through erosion of compressor components, deposit buildup on turbine airfoils, and blockage of cooling systems. Further complicating detection and quantification of this ingestion, the operational temperature environment often exceeds 125˚C, rendering conventional electronic sensing technologies ineffective.

A method to detect, characterize, and quantify ingestion of these airborne materials is needed to determine immediate and long term effects to the system. The data collected can then be used to develop appropriate condition based maintenance strategies via a prognostic system, thereby increasing overall operational readiness. Some of the benefits to the user of this technology are:

increased engine life; real time mission planning / operational adjustments; power assurance forecasting; filter breach detection; improved safety; vehicle availability; and assessment.

GE and Unified Business Technologies, Inc. have partnered to provide a TRL7+ advanced dust sensing system. The key to this technology is a custom developed Multi Chip Module (MCM) that enables high temperature + 250˚C operation with exceptionally low (≈10-15 A) leakage current. This MCM is combined with sensor probes that utilize electrostatic induction to induce current as dust particles pass by the sensor. These probes are not subject to contamination / debris buildup like other laser based technologies.

The MCM / Sensor probes are mated to additional electronic circuitry such as our magnitude comparator with threshold detection circuitry which integrates complex signal signatures to create a simple digital output for a warning indicator when dust or particulate ingestion exceeds a pre-determined setpoint.

For more detailed analysis and advanced prognostics, a microcontroller based signal processing module allows the user to continuously record sensor data that can be further used to analyze material type and quantify total ingestion. The outputs of these modules can then be adapted to existing platform interfaces such as turbine FADEC, diagnostic busses (J1939, etc), or user displays to provide instant operational feedback to the platform operator. The system can be supplied to the user as a retrofit kit for the platform of interest.

This technology has been in development and has completed operational validation testing and flight testing on military aircraft, resulting in a TRL7+ current state. Full maturation of the technology only requires tailoring of the design to your specific platform requirements and completion of any incremental validation testing to ready it for fielding.

PROBLEM STATEMENT

Airborne sand, dust, and volcanic ash ingestion is increasingly a problem for gas turbine and piston engines in both military and civil applications. Ingestion of these materials may accelerate the loss of engine efficiency and also result in a substantial reduction in component life or catastrophic failure. The resulting ingestion adversely affects turbine or engine performance through erosion of compressor components, deposit buildup on turbine airfoils, and blockage of cooling systems. Further complicating detection and quantification of this ingestion, the operational temperature environment often exceeds 125°C, rendering conventional electronic sensing technologies ineffective.

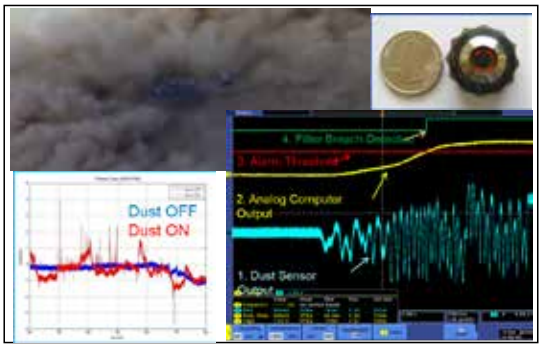
BENEFITS

A method to detect, characterize, and quantify ingestion of these airborne materials is needed to determine immediate and long-term effects to the system. The data collected can then be used to develop appropriate condition-based maintenance strategies via a prognostic system, thereby increasing overall operational readiness. Some of the benefits to the user of this technology are:

- Increased Engine Life
- Real time mission planning / operational adjustments
- Power assurance forecasting
- Filter Breach Detection
- Improved Safety
- Vehicle availability assessment

TECHNOLOGY SOLUTION

- Custom Developed Multi Chip Module (MCM) Technology Enables High Temperature + 250°C operation with exceptionally low (≈10^{-15} A) leakage current
- Sensor probes utilize electrostatic induction to induce current as dust particles pass by.
- Magnitude comparator with threshold detection circuitry integrates signal to create simple digital output for warning
- Advanced signal processing allows for continuous data recording to analyze and quantify total ingestion
- Various interfaces to integrate with platform FADEC, Management systems or diagnostic busses (J1939, etc)



VUFORIA AUGMENTED REALITY

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PTC's Industry leading Augmented Reality (AR) software platform, Vuforia, uses advanced computer vision technology to enable digital content to be placed in real-world environments. With support for handheld and head worn devices, Vuforia includes easy-to-use workflows, SDKs, and cloud services for Unity and other leading development tools. W PTC has assembled several Vuforia packages to create the perfect solution for any problem that maintainers may face.

PROBLEM STATEMENT

- Young, inexperienced workforce
- High turnover rates/low tenure in maintenance MOS
- Rapid introduction of new technology requires constant re training
- Traditional training methods are inefficient and costly to create, manage and deploy.

BENEFITS

Vuforia Expert Capture
Is the **fastest** and **easiest** way to create **powerful** AR-enabled instructions that empower front-line workers

- On board new workers quickly and safely
- Capture precious IP from your most experienced workers
- Create just in time training and job performance aids to improve maintenance execution and safety

TECHNOLOGY SOLUTION

VUFORIA EXPERT CAPTURE

vuforia™

- Effortlessly capture domain expertise to create step-by-step instructions for hands-on training & task guidance.
- Simplify editing, fine-tuning and publishing of AR content in an easy-to-use web-based environment.
- Equip workers with essential instructions at their finger-tips with dynamic content delivery to multiple device types.

GRAPHIC

Utilize the hands-free capabilities of 'say what you see' technology to:

- Rapidly capture expertise anywhere, anytime
- Leverage the "wearability" of light-weight, industrial rated devices

SPALL LINER REMOVAL PROCESS

DOUG HAGEDORN

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Problem Statement: Spall liner removal for a cracked weld or a steel plate replacement is very difficult, labor intensive and a huge maintenance burden. The liners must be removed before the welding process can happen and this can be proven difficult with just mechanical removal methods.

Technology Solution: Armatec has developed a process and training course to be able to train maintenance level personnel on an efficient way to removed spall liner from vehicles. The technique has been proven and used on many of our own spall liners (such as our super spall) for easy and time efficient removal.

Benefits: The benefits of this process include time savings at the maintenance facility depots for spall liner removal, reduction in consumables and mechanical prying and ultimately reduction in manual labor which can lead to fatigue and injury.

Next Steps: The process has been in place at Armatec for over 5 years and is ready for training deployment. The next steps would be to provide our training and manual to maintenance groups to help them with this process.

PROBLEM STATEMENT

Once cracked welding or a steel plate replacement is required on a hull, internally bonded on spall liners can be very difficult to remove, labor intensive, and a huge maintenance burden.

The liners must be removed before the welding process can occur and this can be proven difficult with just mechanical removal methods.

BENEFITS

- Time savings at the maintenance facility depots for spall liner removal
- Tools and techniques for efficiency improvements at the depots
- Reduction in consumables and mechanical prying
- Reduction in manual labor which can lead to fatigue and injury.

TECHNOLOGY SOLUTION

- Armatec has developed a process and training course to be able to train maintenance level personnel on an efficient way to removed spall liner from vehicles.
- The technique has been proven and used on many of our own spall liners (such as our super spall) for easy and time efficient removal.

GRAPHIC OR IMAGE

Below is a caption from the training manual

AUGMENTED REALITY TO IMPROVE MAINTENANCE WORKFORCE PERFORMANCE

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Maintenance processes are generally achieved by following specific, technical steps that ensure standardization, quality, and safety. The workforce accesses these instructions through a 2D method (e.g. paper manual) which limits the situational awareness to words and still photographs. Reducing time on task is key, and with advanced technology, maintainers will be more effective, timely and accurate.

Interactive Augmented Reality (AR) technologies provide the user with extensive amounts of easy to understand context-relevant information. AR integrated into maintenance activities has proven to increase maintenance velocity in carrying out technical tasks, to improve quality, and is able to collect data to support managerial decision making. Leading businesses are already employing AR systems and reaping these benefits.

Our technical approach converts current work instructions to AR format providing step-by-step guidance and 3D overlays and directions. In addition, it converts existing CAD into AR, hosts the system on a Wi-Fi network, provides two-way AR-based expert help system, and optimizes means for the user to benefit and employ the AR technology.

The benefits of using our AR technology are extensive and exceed and existing known abilities to include assist newer maintainers with complex tasks, providing hands-free access to needed information, increasing maintenance velocity, reducing costs, improve quality, reducing errors, and collecting data to support managerial decision making.

Lockheed Martin is firmly committed to this capability integrating the technology for Lockheed Martin's eCASS manufacturing, Orion Space Capsule manufacturing, and numerous remote expert applications. Huntington Ingalls uses AR for ship manufacturing where it is used on the manufacturing floor for planning and for maintenance.

PROBLEM STATEMENT

Provide AR to support the Marine Corps Logistics Command and the Marine Depot Maintenance Command (MDMC) to assist in generating and disseminating suitable technical information to the point of maintenance through hands-free and tablet devices to increase the effectiveness, accuracy, and speed of maintenance activities.

BENEFITS

- Assist newer maintainers with complex tasks
- Provide hands-free access to needed information
- Increase maintenance velocity, reducing costs
- Improve quality, reduce errors
- Collect data to support managerial decision making

TECHNOLOGY SOLUTION

- Convert current work instructions to AR format
  - Step-by-step guidance
  - 3D overlays and directions
- Convert existing CAD into AR
- Host system on WiFi network
- Provide two-way AR-based expert help system
- Optimize means for the user to benefit and employ the AR technology

GRAPHIC OR IMAGE

AUGMENTED REALITY SOLUTION FOR MAINTENANCE AND REPAIRS

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Within the Department of Defense (DoD), many workers skilled in maintenance and repair of government assets are retiring. Maintenance challenges stem from the inefficiency of manual processes in a world that has become increasingly complex and digital. Recording faults on paper forms, manually transferring forms between soldiers, mechanics and clerks, and maintenance procedures requiring the reference of physical technical manuals introduce delays, errors and omissions. The complexity of maintenance and repair work increases with the adoption of new technologies. Existing methodologies leave a skills gap with younger workers and experienced service members.

LCE and Taqtile have partnered on the creation and implementation of Manifest®. Manifest is a released product with end-to-end, cross-platform solution developed with the ideals of simplicity, consistency, and scalability. Subject Matter Experts (SMEs) use augmented reality or iOS devices to capture knowledge and create content that increases team efficiency, effectiveness, and collaboration. Manifest does not require specialized knowledge of 3D, CAD publishing tools, or coding to create guided content.

This solution can be delivered in three ways: 1) Equipment and procedure knowledge capture. SMEs capture step-by-step instructions for equipment operations, configuration, repair, and maintenance using the HoloLens 1/2, Magic Leap, or iPad (and/or PC+web browser) to overlay steps on real-world equipment and in-situ capture audio, video, text, bookmarked documents. These procedures are then saved to a storage location of the customer's choice and can be recalled on the same equipment, another instance of the equipment elsewhere, or on a virtual representation of the equipment anywhere. 2) On-the-job assistance. Technicians can follow step-by-step procedures overlaid on equipment or a digital equivalent. Each step of the process can have pictures, audio, IoT meters, 3D models, video, pen notes, and the digital document to provide additional context to improve the fault verification process. 3) Job preparation. Before attempting a large or unfamiliar job, technicians can pre-visualize the task over real world equipment or digital twins. All applications of this solution include access to a two-way live interaction with a SME, trainees and new recruits can seek guidance on performing difficult tasks or overcoming obstacles.

Taqtile's development of Manifest has been guided by feedback from USAF TSgt Cory Kozlowski since early 2017, when he was stationed at Yokota AFB. He first used Manifest as a tool to capture his 20 years of knowledge and experience as an USAF jet engine mechanic to create augmented work instructions based on USAF Tech Orders (T.O.). TSgt. Kozlowski was able to identify significant benefits in the form of a complete elimination of errors when tasks were performed by new recruits and less skilled staff when using the augmented work instructions.

PROBLEM

Many workers skilled in shipboard maintenance and repair are retiring, leaving a skills gap when younger workers come aboard without the same level of experience. This is having an impact on staffing levels as well as skilled workers to support USN Ship repair. As the majority of the current ship repair work force reaches retirement age it is imperative to have the capability to pass on that knowledge to the next generation of ship repair workers, while still getting the work completed on time and with zero defects.

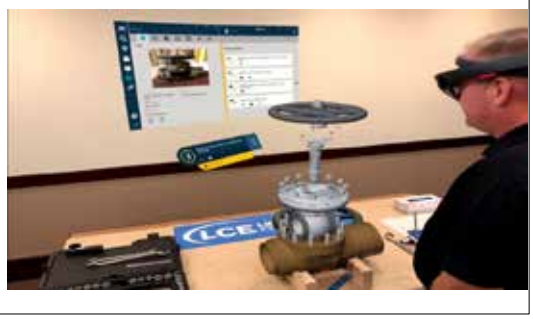
BENEFITS

- Procedures are saved to location of customers choice and can be recalled upon the same equipment, another instance of the equipment elsewhere, or on a virtual representation of the equipment in a classroom or boardroom.
- Unfamiliar equipment, and/or infrequently executed operations can be pre-visualized over real-world equipment or digital twins.
- Trainees and new recruits can contact SME in a live engagement to better understand how to perform a difficult task or overcome obstacles.

TECHNOLOGY SOLUTION

Using Taqtile Manifest software and experience of LCEs Subject Mater Experts (SME) step-by-step instructions for equipment operations, configuration, repair and maintenance using the HoloLens, Magic Leap, Tablet and/or PC+web browser to overlay steps on real-world equipment and in-situ capture audio, video, text, bookmarked documents and more to best describe the task at hand.

GRAPHICS



SKILLS AND QUALIFICATIONS MANAGEMENT SOFTWARE SYSTEMS

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Skills and qualifications management is an absolute necessity within the DOD from the military branches to the civilian workforce. However, a problem exists in regards to the standardization of the skills and qualifications management systems (SQMS). All agencies have an interpretation of a SQMS. Some may use a paper format to track skills and others may use an MS Excel format. Although the various formats may work for individual agencies, standardization is the backbone of the DOD. The DOD civilian workforce consists of a high percentage of prior military service personnel or veterans. Of course, veterans have received the world's best training through the U.S. military. Unfortunately, all of their skills and qualifications are not easily transferred to their next career field within the DOD. By the same token, civilian personnel do not have a vehicle to carry the skills and qualifications into another job series. The only way a potential employee can transfer their skills and qualifications is through a resume submittal via **USAJOBS.com**. Unfortunately, some skills aren't mentioned on a resume for various reasons. Additionally, some resumes are embellished and are not accurate to the actual skills and qualifications which wastes valuable time and resources.

As a resolution for standardization, there are several options of Skills and Qualifications Management Software that have a long and proven track record that manages employee skills and qualifications for an agency and/or eventually the DOD. The benefits of utilizing this software is skills/qualifications transferability, skills/qualifications verification, and overall standardization within the DOD. Several companies are currently available for consideration such Rubix - Employee Skills Mapping, Skills Base or CWA Smart Process. These companies offer test drives of their software for compatibility.

Transferability of skills/qualifications from the military to a DOD civilian position or from DOD civilian inter-agency positions or from job series advancements, the ability to carry and access an employee's skills/qualifications is invaluable to a career and advancement.

Verification of skills/qualifications of a potential employee minimizes time and effort spent scrutinizing resumes for the proper skills/qualifications for a position as well as decreasing the cycle time from job posting to selection. This could also minimize any oversight and inaccuracies for selection. It will improve the efficiency and/or effectiveness of current verification of skill/qualifications.

With the technology and software readily available, a 2 year utilization testbed for feasibility and practicality with a medium sized agency such as the Corpus Christi Army Depot would yield the compatibility and validity of this type of software.

For cross-service applicability, standardization of the skills and qualifications management systems into a single software system would enhance and reinforce the DOD workforce.

PROBLEM STATEMENT

Standardization of a cross-service (military and civilian agencies) skills and qualification management software system does not exist within the DOD which increases time and effort in filling job vacancies with highly qualified personnel due to lack of transferability and verification of skills and experiences.

BENEFITS

- Transferability of skills/qualifications from the military to a DOD civilian position or from DOD civilian inter-agency positions or from job series advancements, the ability to carry and access an employee's skills/qualifications is invaluable to career advancement.
- Verification of skills/qualifications of a potential employee minimizes time and effort spent scrutinizing resumes for the proper skills/qualifications for a position as well as decreasing the cycle time from job posting to selection.
- Standardization and realigning the skills and qualifications management software systems into a single user-friendly system would enhance and reinforce the cross-service applicability across the entire DOD.

TECHNOLOGY SOLUTION

- Rubix Employee Skills Mapping website quote: "Reduces cost and increases effectiveness of enterprise business intelligence, Provides monitorable performance indicators and analyzes cause and contributing factors."
- Skills Base website quote: "a skills inventory management and capability matrix software solution for assessing and recording the skill and interest levels of all staff and employees."
- CWA SmartProcess website quote: "skills are transparently visible in a table and skills matrix. Qualifications can be transferred directly from a course. In skill management software, qualifications from a process role are synchronized directly with an employee's qualification profile."

GRAPHIC OR IMAGE

AUGMENTED REALITY REMOTE MAINTENANCE SUPPORT SERVICE (ARRMSS)

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Augmented Reality Remote Maintenance Support Service (ARRMSS) is an enabling technology for an overarching augmented reality for maintainers framework. ARRMSS is an active research and development effort in the CREATIVE Lab based in NAWCAD Lakehurst NJ.

Augmented reality (AR) is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated content, also known as augmentations, in the users' field of view. Information about the surrounding real world of the user becomes interactive and digitally manipulated. Information about the environment and its objects is overlaid on the real world.

The Navy is very interested in the use and deployment of AR technologies to help the fleet during operation, maintenance and troubleshooting of equipment both ashore and afloat. The CREATIVE Lab is focused on researching and developing AR technologies to support the operation, maintenance and troubleshooting of Support Equipment (SE) and Aircraft Launch and Recovery Equipment (ALRE).

ARRMSS provides the ability for a fleet maintainer to communicate with a Subject Matter Expert (SME) remotely using video/audio/text with the added capabilities of the SME being able to place augmentations/drawings/files onto systems and objects in the maintainer's field of view to help guide them during operation/maintenance/troubleshooting. Allowing the SME to see in real-time what the maintainer sees can exponentially help reduce system downtime and improve fleet performance.

PROBLEM STATEMENT

- Current CONOPS for unresolved maintenance issues involve a Subject Matter Expert (SME)/NATEC representative traveling to a location to help with troubleshooting/repair
  - Increases repair time
  - Increases cost
  - Creates a cascading effect on schedule
  - Negatively impacts equipment and aircraft availability
  - Hinders Fleet readiness

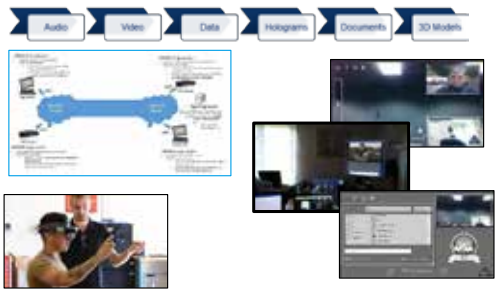
BENEFITS

- Provides the means for a SME to communicate in real-time with a Maintainer deployed in the field
  - SME sees and hears exactly what a Maintainer sees and hears
- Using Augmented Reality capabilities, SME can place Holograms in Maintainers 3D Field Of View to help guide troubleshooting/maintenance steps in real time
- Can share other digital content such as PDF and Text Documents, 3D Models and Images that the Maintainer can use additional reference right in their field of view without having to take their eyes off of the task at hand

TECHNOLOGY SOLUTION

- ARRMSS is an application framework that connects a SME (using a Windows PC/tablet) to a maintainer (wearing a Hololens 1 or 2) and allows for the transfer of applicable data over a DoD network
- ARRMSS supports:
  - Video/Audio/Data Transfer
  - Holographic Augmentations (Holograms) – Arrows, Free Drawing, Text, Beacons
  - PDF and text document sharing
  - 3D Model Sharing

ARRMSS



ECHO INTERACTIVE TRAINING PLATFORM

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Technical training is complex, hands-on, and time consuming to provide to new technicians, regardless of service branch or equipment. Gaps in maintenance and service competencies are rising across the military as equipment becomes increasingly difficult to procure and expensive to maintain in a training environment. Pandemic conditions have accelerated the need for remote interactive training that provides more engagement than is currently available. Because of these factors, the DoD is facing a shortage of combat-ready technicians who require a more adaptable, engaging way to learn.

The Echo Platform was created to solve this emerging problem by deploying remote training for desktop, iOS, Android, and Virtual Reality (VR) implementations. Training content only needs to be developed once but can be deployed limitless times to any device or hardware. Because training built within Echo is designed to be interactive, the realism of physical equipment is retained without the cost of actual equipment and maintenance. By moving training from a physical to digital environment, investment shifts from legacy overhead costs to creating more realistic scenarios that generally cannot replicated in a traditional training environment, like combat and natural disasters.

Benefits of immersive Virtual Reality (VR) training over other types of training are documented in a recent study by PwC, one of the world's leading consulting firms. VR learners were shown to be capable of training four times faster than in a traditional classroom. They were also 275% more confident to apply the skills learned in training on the jobsite. Where the Echo Platform stands out is the integration of interactive training content into any device and any system. Although VR is the gold standard for remote training, it may not be suitable for every training environment. Echo will deploy the same content to a phone or desktop while retaining its interactive features. System integrations such as a Learning Management System, Product Lifecycle Management system, or Enterprise Resource Planning system are built into Echo.

Immersive training is relatively new technology, but its adoption rate has already created several mature products. The Echo platform is developed and has a Technology Readiness Level (TRL) 8. Benefits to learners and the DoD over traditional methods include:

- Unlimited practice in a "no consequences" environment
- Realistic scenarios and actions that cannot be replicated in a classroom
- Deeper memory retention through hands-on interactions
- Variable scenarios, real-time feedback, and learning paths
- Remote training that can take place anywhere without reducing learning impact
- Ability to onboard, train, and deploy more technicians in shorter sprints
- Cross-functional technology that can be utilized across all service branches
- Recommended next steps are providing the NCMS a demo of the Echo platform to validate its TRL and a review of possible pilots within the DoD.

PROBLEM STATEMENT

Technical training is complex, hands-on, and time consuming to provide to new technicians. Traditional training methods rely on resources that are expensive, difficult to procure, and time-consuming to adapt to learning behavior or training updates.

In addition, pandemic conditions have impacted the ability to travel to onsite training, increased risk of human to human contact, and disrupted the delivery of physical equipment manufacturing. All these constraints have created an urgent need for Department of Defense- new technicians are not guaranteed to be combat ready and neither is the equipment they maintain. Remote, interactive training is required to increase combat readiness.

BENEFITS

Technician-specific benefits:

- Detailed guidance in a hyper-realistic environment
- Confidence to learn by failing in a "no consequences" space
- Realistic scenarios that can't be replicated in a classroom
- Stronger memory retention through limitless hands-on practice

DoD-wide benefits:

- Cloud-based platform allows training to take place anywhere
- Reduced need for costly physical equipment during training
- Onboard and deploy more technicians in shorter sprints
- Utilize virtual training across all service branches

TECHNOLOGY SOLUTION

Echo is a fully mature solution that builds technician training in a virtual, digital environment with hands-on interactivity. This in-production solution has two components.

First, training content development creates guided instruction in a hyper-realistic environment. Users interact with digital tools and equipment just as they would physical ones. Required tasks and capabilities are incorporated into training so that technicians are prepared for any eventuality.

Second, an in-house platform pushes the same training content to unlimited users across any device- desktop, phone, tablet, eyewear, or virtual reality headset, anywhere in the world.

GRAPHIC OR IMAGE

The same assets and content can be deployed in any format and to any hardware, depending on the optimal use case.

EXPERT KNOWLEDGE CAPTURE AND TRANSFER FOR MAINTENANCE

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Problem: Skilled maintainers are in high demand and spend more time training new personnel than performing maintenance tasks. Current training methods use standard operating procedures, costly and time-consuming training sessions and work instructions to train staff, ensure safety and compliance, and manage quality, and are painful and expensive to create, maintain, and follow. Give maintainers back time to perform aircraft maintenance, increase training retention and rapidly create cost effective and flexible training aids using Vuforia Expert Capture.

Tech Description: Quickly capture detailed work instructions of technical experts on complex equipment and processes. Enhance training and provide guidance on complex tasks by accelerating knowledge transfer through hands-free and mobile devices adding Augmented Reality (AR) annotations, then publishing a video to thousands of others immediately. No paper manuals. Capture spatial, audio and visual steps of aircraft maintenance procedures utilizing Augmented Reality devices (Wearables or tables) This digital information is combined to create experiences that can be easily edited or modified as steps change. The final experience is a holographic workflow with step by step instructions that maintenance personnel access through Augmented Reality devices such as Apple and Android devices, or head mounted devices. Personnel are led through a process with audio and visual cues, including text instructions overlaid onto physical assets.

Current development status of the technology and Test/simulation data supporting performance claims: The software is commercially available with out of the box functionality and being utilized by thousands of customers around the world to include the United States Air Force. No additional test or simulation data is required.

Next steps/potential benefits: PTC offers free, remote training and value workshops. Our software is available on GSA. The software is delivering huge value; customers are reporting 37% less time training personnel, a 30% increase in knowledge retention, and have reduced the time experts spend documenting procedures, training and away from production activities by 75%.

PROBLEM STATEMENT

- Young, inexperienced workforce
- High turnover rates/low tenure in maintenance MOS
- Rapid introduction of new technology requires constant re training
- Traditional training methods are inefficient and costly to create, manage and deploy.
- Inability to rapidly train or remotely support new works or complex tasks.
- Ever increasing complexity of maintenance tasks.

BENEFITS

Vuforia Expert Capture
Is the **fastest** and **easiest** way to create **powerful** AR-enabled instructions that empower front-line workers

- On board new workers quickly and safely
- Capture precious IP from your most experienced workers
- Create just in time training and job performance aids to improve maintenance execution and safety

TECHNOLOGY SOLUTION

VUFORIA EXPERT CAPTURE

- Effortlessly capture domain expertise to create step-by-step instructions for hands-on training & task guidance.
- Simplify editing, fine-tuning and publishing of AR content in an easy-to-use web-based environment.
- Equip workers with essential instructions at their finger-tips with dynamic content delivery to multiple device types.

Utilize the hands-free capabilities of 'say what you see' technology to:

- Rapidly capture expertise anywhere, anytime
- Leverage the "wearability" of light-weight, industrial rated devices

DEPARTMENT OF DEFENSE MAINTENANCE SYMPOSIUM

DECEMBER 6–9, 2021
MILWAUKEE, WISCONSIN
sae.org/dod

DoD Approved

MAINTENANCE INNOVATION CHALLENGE

CALL FOR INNOVATIONS

Revolutionary or Evolutionary? Showcase your innovations to the maintenance community at the 2021 Department of Defense Maintenance Symposium and shape the future of the enterprise.

The Challenge's objective is to elevate and expand sustainment innovation beyond new technology to include value-added partnerships, resourcing strategies, business practices, processes, and other transformative capabilities that make maintenance more agile, effective, and affordable.

For a second year, the National Center for Manufacturing Sciences has committed to support the demonstration of the winner's innovation in a selected DoD activity by making available $50,000 and necessary in-kind labor to the associated commercial technology provider, to the extent permitted under the existing Commercial Technologies for Maintenance Activities Cooperative Agreement.

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
6. All submissions must be cleared for public release

All abstracts that meet the minimum criteria listed will be posted on a public website and included in a Maintenance Innovation Challenge summary booklet, distributed at the Symposium. From the eligible abstracts, an evaluation board comprised of maintenance subject matter experts will select six finalists to present at the 2021 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 and recognized at a Symposium Plenary Session. Also, a People's Choice Award will be determined by audience voting.

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 2021 Maintenance Innovation Challenge please contact Nori Fought of SAE International at nori.fought@sae.org.

Administrative support provided by SAE International under contract with the U.S. Department of Defense. Reference herein to any non-federal entity, process, service or technology does not constitute or imply endorsement, recommendation or favor by the Department of Defense or U.S. Government.

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NOTES

Richard Crowther, USAF

Aristides Staikos, US Navy NAWCAD Lakehurst

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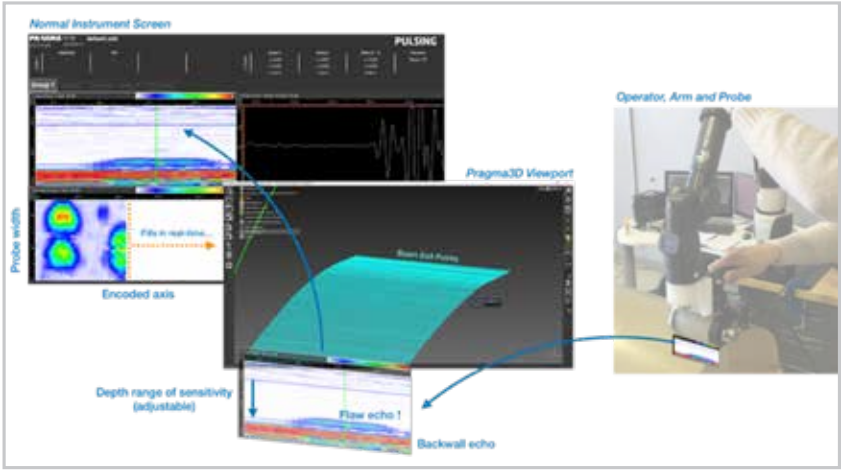
Cory Jamieson, The Pennsylvania State University ARL



Ryan Myers, Hexagon Manufacturing Intelligence

NOTES

LtCol Michael Malone, United States Marine Corps

Naresh Menon, Covisus Inc

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