

# MAINTENANCE INNOVATION CHALLENGE

DECEMBER 12–15, 2022  
ORLANDO, FLORIDA





## OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE

3500 DEFENSE PENTAGON  
WASHINGTON, DC 20301-3500

SUSTAINMENT

### MEMORANDUM FOR 2022 DOD MAINTENANCE SYMPOSIUM PARTICIPANTS

After a one-year hiatus due to the COVID-19 pandemic, I am pleased to announce the return of the highly anticipated Maintenance Innovation Challenge (MIC) as part of the 2022 Department of Defense (DoD) Maintenance Symposium. Aligning with the National Defense Strategy priority of building an enduring advantage and the Deputy Secretary of Defense's focus on reducing sustainment costs by improving performance across key sustainment cost drivers, the MIC provides an outstanding opportunity to highlight and exploit promising innovations and technology.

In keeping with the theme of the 2022 DoD Maintenance Symposium, "Next Generation Materiel Readiness Forged through Data Advantage, Technology, and Innovation," the MIC aims to elevate and expand the call for maintenance innovation beyond novel technology; to include unique partnerships, resourcing strategies, and business practices or processes.

With assistance from the DoD Joint Technology Exchange Group, the submissions were thoroughly reviewed, and six finalists selected. Senior maintenance and sustainment leaders including the Military Services' Sustainment Technology Executives and the organic industrial base commanders selected this year's MIC winner.

The MIC finalists will be presenting their maintenance innovations during the Maintenance Innovation Challenge breakout on December 12, 2022, from 1300-1430 in the Orange County Convention Center, Orlando, Florida. Based on the presentations, the audience will select the MIC "People's Choice Award" winner. The MIC winner and the People's Choice Award winner will be announced and formally recognized during the DoD Maintenance Symposium's plenary session on the morning of December 13, 2022. I encourage your participation in this breakout session to engage with some of the most forward-thinking individuals in our community and to continue the dialogue throughout the DoD Maintenance Symposium and the exhibition hall.

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

Sincerely,

A handwritten signature in black ink, appearing to read "Vic S. Ramdass", is positioned below the word "Sincerely,". The signature is fluid and extends across the width of the page.

Vic S. Ramdass, Ph.D  
Deputy Assistant Secretary of Defense  
(Materiel Readiness)

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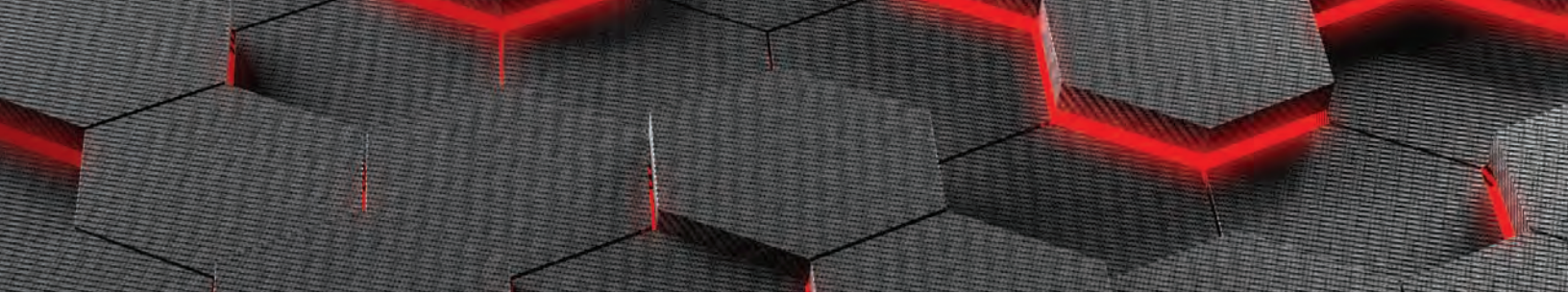
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# THE MAINTENANCE INNOVATION CHALLENGE

The importance of sustainment innovation development and adoption is increasingly relevant as DoD strives to accelerate materiel availability by improving the effectiveness and viability of the Defense industrial base, including our organic capabilities. The COVID-19 pandemic has again illuminated the gaps we have in our domestic resources, industrial capabilities, and supply chain approaches and has highlighted the innovative spirit and world-class capabilities resident in our sustainment community during our response. Novel innovations can provide significant advances in capabilities to our sustainment enterprise and benefit other military and domestic challenges. The Military Services, Defense agencies, industry, and academia, are all actively pursuing innovative technologies and processes to improve maintenance capability, effectiveness, and efficiency.

The objective of the Maintenance Innovation Challenge (MIC) is to elicit and share unique, enhanced maintenance capabilities, to potentially elevate and expand sustainment innovation beyond new technology, to include value-added partnerships, resourcing strategies, business practices, processes, and other transformative capabilities

MIC submissions are reviewed and evaluated by the Joint Technology Exchange Group (JTEG) Principals, composed of DoD logisticians representing each Military Service, the Joint Chiefs of Staff, the Defense Logistics Agency (DLA), and an industry representative. The JTEG selected six finalists from the group of 92 submissions. In the second phase, the six finalists were evaluated by senior DOD logisticians who ultimately selected an overall winner.



The Evaluation Criteria used to judge the submissions are:

- Maintenance Centric—Innovation’s impact on maintenance
- Original Contribution for the State of the Art—Originality of the idea
- Commercialism—Focus on the innovation rather than the company/organization
- Technical Maturity—How ready to implement is the technology/process?
- Cross-Service Application—How many military Services and/or agencies 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 innovation is to transition to DoD maintenance

At the 2022 DoD Maintenance Symposium, the six MIC finalists, will present their new technologies, processes, or business practices to the symposium audience during a breakout session. Attendees at this breakout session will have the opportunity to select the MIC People’s Choice Award based on the six presentations. Additionally, all who submit a qualifying abstract and quad-chart are published in this MIC book.

The MIC winner as selected by a panel of senior DoD logisticians, and the “People’s Choice Winner” will both be announced and receive high profile DoD-wide recognition during a DoD Maintenance Symposium plenary session where they will receive striking trophies. Additionally, the National Center for Manufacturing Sciences has offered to provide each winner \$50,000 of in-kind support.

This MIC book contains the abstracts, quad charts, and contact information for all 92 innovations

submitted, and is a great tool to utilize for information exchange as well as keep as a reference source.

# 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 DoD maintenance requirements for new technology, processes, and equipment.
- Serve as an advocate for new technology or equipment with cross-service potential to increase efficiency

## **JTEG Community:**

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

## **JTEG Monthly Technology Forums:**

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 digital maintenance, additive manufacturing and repair, or advanced wiring inspection capabilities.
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.

## **JTEG Website:**

Industry, DoD, and academic personnel can use the JTEG website, <https://jteg.ncms.org>, to view and share information on new technology, processes, and equipment developments that have proven benefits or potential applications involving depot maintenance. Visitors are welcome to review new and exciting technology posted on the website or reach out and contact the JTEG Principals listed on the website. In addition, all past and future JTEG technology forums are posted on the website.



# THE JTEG PRINCIPALS AND KEY REPRESENTATIVES



## **STEVE MCKEE, P.E.**

Director, Enterprise Maintenance Technologies and CTMA Program Manager  
Office of the Deputy Assistant Secretary of Defense for Materiel Readiness (ODASD(MR))  
OSD JTEG Principal  
+1.571.969.0662  
stephen.e.mckee.civ@mail.mil



## **SEAN COGHLAN**

Division Chief, Engineering, Technology, and Technical Policy  
Directorate of Logistics, Civil Engineering, Force Protection, and Nuclear Integration  
Air Force Materiel Command, Wright-Patterson AFB  
USAF JTEG Principal  
+1.937.904.0855  
sean.coghlan@us.af.mil



## **WILLIAM BAKER**

Lead Engineer, Depot Maintenance Division  
Marine Corps Logistics Command  
USMC JTEG Representative  
+1.229.639.9104  
william.baker@usmc.mil



## **JASON VALCOURT**

Logistics Management Specialist, Depot Maintenance /Inter-service Programs  
HQ Army Materiel Command, G-3 Supply Chain Management Directorate  
US Army JTEG Principal  
+1.256.450.8257  
jason.w.valcourt.civ@mail.mil



## **JOSEPH SPARKS**

Lead, Advanced Technology & Innovation  
Commander Fleet Readiness Centers (COMFRC)  
NAVAIR JTEG Principal  
+1.301.757.3042  
joseph.c.sparks2.civ@us.navy.mil



## **EDILIA CORREA**

Chief/Process Owner, Technical & Quality Assurance, J344  
Defense Logistics Agency, Organic Manufacturing  
DLA JTEG Principal  
+1.571.767.1585  
Edilia.Correa@dla.mil



## **ROBERT E. KESTLER**

Advanced Technology & Innovation (ATI) Lead Engineer  
Fleet Readiness Center - East (FRC East)  
Naval Air System Command (NAVAIR)  
NAVAIR JTEG Representative  
+1.252.720.8516  
Robert.e.kestler.civ@us.navy.mil



## **DEBBIE LILU**

Vice President, Maintenance and Sustainment, Business Development  
National Center for Manufacturing Sciences (NCMS)  
CTMA Program Principal  
+1.734.262.0758  
Debbie.Lilu@ncms.org

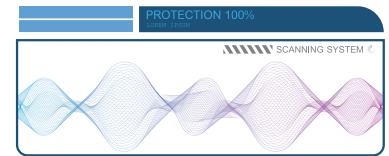


## **JANICE BRYANT**

Sustainment Technology Program Manager  
Naval Sea Systems Command (SEA 05T1)  
NAVSEA JTEG Principal  
+1.360.507.8745  
Janice.k.bryant@navy.mil

# MIC Publicity Leads to Successful CTMA Projects

MIC FINALISTS CAN GO ON TO COMPLETE CTMA PROJECTS



The National Center for Manufacturing Sciences (NCMS) has a long-standing interest in the MIC, as the technology solutions featured have potential to evolve into projects through NCMS's Commercial Technologies for Maintenance Activities (CTMA) Program. NCMS is pleased to support the MIC by providing \$50,000 of in-kind support to both the overall MIC winner and the People's Choice winner.

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 best technology into the hands of our warfighters.

Several MIC finalists and overall Award Winners have gone on to complete successful CTMA Projects:

## 2019 Finalist – Atmospheric Plasma Coating Removal

Atmospheric Plasma Solution's (APS's) PlasmaBlast® system improves small-scale coating removal operations required for shipbuilding and naval maintenance.

The judges at the competition immediately saw the benefits of APS's coating removal technology. This resulted in a successful CTMA Project "Validation of Efficiency and Effectiveness of Atmospheric Plasma Coating Removal," an evaluation and study initiative that is taking place at Norfolk Naval Shipyard.

Glenn Astolfi, President of Atmospheric Plasma Solutions, said, "Being a member of NCMS and working closely with the CTMA program has been invaluable. At NCMS events, we were able to demonstrate the system to hundreds of maintainers, who brought it to their command's attention and showed that it fills a very important need. The CTMA Program gave us access and visibility we otherwise may not have had."

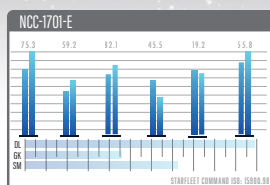
## 2016 Overall Winner – LASLAT Inspection System

Through a 2017-2018 partnership between Thermal Wave Imaging (TWI) and the Air Force, the LASLAT system—an NDI technology that uses thermography to inspect large areas of composite aircraft—was successfully demonstrated to have the capabilities the DOD requires. A key advantage of the LASLAT system is its portability: technicians can move the system directly to the aircraft instead of taking it to another location.

**“Being a member of NCMS and working closely with the CTMA program has been invaluable. At NCMS events, we were able to demonstrate the system to hundreds of maintainers, who brought it to their command’s attention and showed that it fills a very important need.”**



*Glenn Astolfi, President of Atmospheric Plasma Solutions*



Interested in learning more  
about CTMA Program?  
**VISIT US IN BOOTH #847**

Automated inspection routines eliminate manual positioning, providing repeatable inspections. The system can cover an inspection area of 17 feet by 15 feet at the rate of 7 ft<sup>2</sup> per minute, operating at up to 12 feet. This technology uses a novel thermal projector to excite an inspection zone on the aircraft surface thermally. The CTMA project demonstrated LASLAT on the Northrop Grumman RQ-4 Global Hawk, a remotely piloted surveillance aircraft. Before this technology existed, it took roughly 10-14 hours to scan one blade. With LASLAT, it takes 3-4 hours. This 70% reduction of inspection times for the NAVAIR FRC-E V-22 prop rotor blade saves an average of 625 labor hours annually.

### 2012 Overall Winner – Intermittent Fault Detection System

Intermittent faults—which the DOD defines as a “momentary discontinuity, a malfunction of a device or system that occurs at irregular intervals”—are a huge problem in the DOD because modern weapons systems contain complex electronics, which often move into extremely harsh environments. Detecting faulty electronic systems quickly can save service members’ lives.

Yet intermittent faults are notoriously difficult to identify due to nano-second fault durations and the many thousands of circuit paths in complex electronics. Intermittent faults typically result in no fault found (NFF), due to conventional test equipment’s inability to detect them, costing the DOD \$3 billion annually.

Universal Synaptics collaborated on a CTMA Project to solve this problem by implementing the Intermittent Fault Detection and Isolation System (IFDIS) at Fleet Readiness Center Southwest, Hill Air Force Base, and Ogden Air Logistics Complex (OO-ALC). The project paid for itself in less than one year. A subsequent CTMA project, completed in 2019, expanded the project’s success to the Naval Surface Warfare Center, Crane Division.

The CTMA Program is a streamlined and agile non-FAR based contracting vehicle to demonstrate, evaluate, and validate innovative technology. Over the past 20 years, the CTMA Program has helped to transition innovative commercial technologies to support DOD maintenance and sustainment.

# CONGRATULATIONS TO OUR 2020 MAINTENANCE INNOVATION CHALLENGE WINNER!

*In 2020, one innovation won both the Overall Technology Award, selected by senior DoD logisticians, and the Peoples' Choice Award, determined by audience vote.*

## 2020: AUGMENTED REALITY REMOTE MAINTENANCE SUPPORT SERVICE (ARRMSS)

Aristides Staikos, US Navy NAWCAD Lakehurst

Augmented Reality Remote Maintenance Support Service (ARRMSS) is an enabling technology for the AR for Maintainers Vision.

ARRMSS provides the on-demand ability for a fleet maintainer to communicate directly with a remote Subject Matter Expert (SME) as though they were co-located in a maintenance space

Video and audio transmissions combined with spatial mapping data to allow users on both ends of a network to troubleshoot problems and step through particularly challenging repair tasks/engineering investigations collaboratively, regardless of geographic location.



ARRMSS is an in-house designed 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

- Internet standards-based Audio/Video/Data Transmission Protocols
- Remote Expert and User Hologram Placement
- Novel algorithm developed to minimize bandwidth usage
- Network Adaptability
- Session Recording
- PDF and text document sharing
- 3D Model Sharing
- Photo Sharing/Editing



# 2022 MAINTENANCE INNOVATION CHALLENGE

## Overview:

The annual DoD Maintenance Innovation Challenge (MIC) provides an opportunity to highlight the innovative spirit and world-class capabilities resident in our sustainment community. This year the MIC received 92 submissions from which the Joint Technology Exchange Group principals selected six finalists based on criteria including technical maturity, feasibility, and cross-Service applications.

## Moderator:

Steve McKee, Director, Enterprise Maintenance Technologies, Office of the Deputy Assistant Secretary of Defense for Materiel Readiness

## Finalists:

### **Cold Spray Pop Up Production Cell**

Submitted by Jeff Campbell, NUWC Keyport, NAVSEA 05T/VRC Metal Systems  
Presented by Jeff Campbell, NAVSEA Cold Spray Project Manager  
Brett Anderson, NAVSEA 05T  
Kiley Plooster, VRC

### **E-Drill: A New Way to Remove Aircraft Fasteners**

Submitted and Presented by Jared Wright, Naval Air Systems Command/  
Jim Becker, Perfect Point EDM

### **Fiber Optic Fusion Splice Repair**

Submitted and Presented by Brett Jordan, Air Force Research Laboratory  
Technical Sergeant William Kesler, Air Force Sustainment Center

### **Letterkenny Army Depot (LEAD) Innovative Cold Spray Repairs**

Submitted by Sam Evans, The Pennsylvania State University Applied Research Lab  
Presented by Ashley Filling, LEAD  
Sam Evans, PSU Applied Research Lab

### **Metal Components from Hybrid Additive Manufacturing**

Submitted and Presented by Slade Gardner, Ph.D, Big Metal Additive

### **Witness Integrity Sensor Platform (WISP)**

Submitted and Presented by Seth S. Kessler, Ph.D., Metis Design Corporation

## COLD SPRAY POP UP PRODUCTION CELL

**JEFF CAMPBELL**

NUWC KEYPORT/NAVSEA 05T

jeffrey.d.campbell.civ@us.navy.mil

+1.360.900.8715

**Description:** Pop Up Production Cells provide an ability to implement technologies quickly in an agile manner to provide immediate effect. The implementation of Cold Spray Pop up Cells allows for the rapid repair of naval asset parts with a reduced turnaround time of weeks vs.

years. These cells offer an agility to renew and mature the technology with an average implementation from funding to open of 90 days. Implementation is modular vs. singular and incorporates organic ties with industrial bases, industry, and academia.

**Background:** Cold Spray is being used to perform dimensional repairs on a number of components used in Navy, DoD, DoE, and US industrial base components. The technology is commercially available, and systems can be designed for specific applications as well as several Cold Spray powders being commercially available. Cold Spray is being implemented in the public shipyards, submarine repair facilities, NAVAIR repair centers, Naval Warfare Centers, Marine depots and by the Army and Air Force. Significant development effort is focused on developing structural repairs,

additive manufacturing, and fabrication of new components.

**Problem/Opportunity:** The development and implementation of cold spray pop up cells expedites new technologies and addresses the following issues:


- Identification of space for implementation of new technology
- Training and certification of operators
- Long lead times for construction and installation
- Disposal of equipment of at end-of-life
- Non-uniform implementation
- Isolation from innovations in the industrial base and academia
- Long lead times for repair
- Access to the latest state of art technology in a rapidly evolving field

To rapidly capitalize on this emerging technology and quickly provide repairs to our military assets, Pop-up Cells have been developed to conduct repairs near the point of use. The average time from funding to

operation of these cells is 90 days. That's 90 days to install a repair technology that can provide fast and reliable dimensional repairs on a number of components used in Navy, DoD, DoE, and US industrial base.

**Performance:** Pop-up Cells expedite the Navy's maintenance and repair processes and is currently in use, being fielded to perform repairs much faster than the Navy's previous method, helping resolve maintenance backlogs, improved ship's conditions and on time delivery. Additionally, the pop-up cell concept is defining a new best practice for rapid transition of other technology-based solutions to benefit the Navy and the organic and defense industrial base. The cell concept will continue to expand with additional cells in other locations for cold spray other emerging technologies.

**Next Steps/Benefits:** There is one operational Pop-up Cell in use in Chesapeake, VA with the second funded Pop-up Cell currently being developed in San Diego, CA. A third is being planned dependent on additional funding.

<p align="center"><b>PROBLEM STATEMENT</b></p> <p>Implementation of new technology can take several years and requires significant investment in facilities and personnel.</p> <p>The development and implementation of cold spray pop up cells addresses the following specific issues:</p> <ul style="list-style-type: none"> <li>• Identification of space for implementation of new technology</li> <li>• Training and certification of operators</li> <li>• Long lead times for construction and installation</li> <li>• Disposal of equipment of at end-of-life</li> <li>• Non-uniform implementation</li> <li>• Isolation from innovations in the industrial base and academia</li> <li>• Long lead times for repair</li> <li>• Access to the latest state of art technology in a rapidly evolving field</li> <li>• Drive RTOC with future acquisitions and logistical footprints with the CM model</li> </ul>	<p align="center"><b>BENEFITS</b></p> <p>Pop up Production Cells provide an ability to implement technologies quickly in an agile manner to provide immediate affect. Technology transition time is reduced to weeks vs. years and offers speed and agility to renew and mature. Implementation is modular vs. singular, and incorporates organic ties with industrial bases, industry and academia.</p> <p>Cold Spray Pop up Cells have been developed to conduct repairs near the point of use. The average time from funding to operation of these cells is 90 days.</p> <p><b>Big Wins:</b></p> <ul style="list-style-type: none"> <li>• Repaired 3- elevation shafts, saving \$30K each that were previously unrepairable</li> <li>• Used a preexisting Qualified Spray Procedure to repair 2- large valve discs, \$70K savings each. 1st one completed in 4 days, second one 7th day</li> </ul>
<p align="center"><b>TECHNOLOGY SOLUTION</b></p> <p>Cold-spray cells expedite the Navy's maintenance and repair processes and is currently in use, being fielded to perform repairs much faster than the Navy's previous method, enabling access to resolve maintenance backlogs, improved ship's conditions and on time delivery.</p> <p>The pop-up cell concept is defining a new best practice for rapid transition of other technology based solutions to benefit the Navy and the organic and defense industrial base. The cell concept will continue to expand with additional cells in other locations for cold spray other emerging technologies.</p>	

## E-DRILL: A NEW WAY TO REMOVE AIRCRAFT FASTENERS

**JARED WRIGHT**

NAVAIR  
 jared.c.wright7.civ@us.navy.mil  
 +.1317.697.2019


The removal of “permanently” installed titanium fasteners may be the most difficult, labor intensive, and error prone part of depot level aircraft maintenance. In the current process, which has been industry standard for decades, a highly skilled artisan must drill out the fastener head manually. This process takes several minutes, generates scores of hazardous shavings, and exacts a substantial toll both in terms of maintenance induced damage, as well as severe ergonomic risk to the artisan. It is not uncommon for major portions of an aircraft to be damaged beyond repair due to damage caused by manual drilling. Additionally, artisans are at great risk for needing shoulder surgery due to the strain of manual drilling.

Now there is a better way. Perfect Point EDM, a small business from Huntington Beach, California has invented a new way to remove aircraft fasteners: the E-Drill. E-Drill uses a semi-automated, plunge cut Electrical Discharge Machining (EDM) tool to remove a fastener in seconds. Artisans use provided tooling to properly align E-Drill’s copper electrode, pull the trigger,

and E-Drill completes the drilling process. E-Drill has a different cut profile for each fastener type, cutting down to where the head of the fastener meets the pin, leaving a thin (~0.015 inch) ligament of fastener material remaining. A provided Single Shot Air Punch tool is then used to sever the ligament. The removed fastener is in two pieces: head and pin. No shavings.

E-Drill uses vacuum assisted alignment jigs to assist artisans in properly aligning the electrode. These ergonomically designed jigs enable E-drill to access >95% of aircraft fasteners, including upside down, curved, or vertical sections. Artisans only need to provide enough force to compress two O-rings, which prevents the EDM di-electric/coolant fluid (water) from leaking. This drastically reduces the amount of physical strength required to remove a fastener, dramatically reducing the strain on the artisan. Proficiency with the tool takes hours, far less than traditional drilling. Studies show at least a 75% reduction in aircraft damage, and a 20x reduction in time to remove a fastener.

NAVAIR has been working toward implementation of E-Drill for the past 3 years, collaborating with Perfect Point, the Air Force, and other industry partners to solve technical problems, improve the product, and build the base of technical data necessary for regulatory approvals. On August 18, 2022, NAVAIR issued an official Authorization Letter, clearing E-drill for use on an initial set of general use cases. This represents the first broad approval (beyond individual point-solution applications) of E-drill for any major element within the DoD. This initial authorization, while limited in scope, was intended to speed the deployment of E-drill into the hands of artisans. NAVAIR continues to work toward increased approvals and use cases as more data and technology solutions become available.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>The removal of “permanently” installed aircraft fasteners, by manual drilling, is often the most difficult, time consuming, and dangerous aspect of depot level aircraft maintenance. Damage from this process, to both aircraft and artisan, is common, and a major cost driver.</p>	<p style="text-align: center;"><b>BENEFITS</b></p> <p>Studies have shown:</p> <ul style="list-style-type: none"> <li>• 20x reduction in drilling cycle time</li> <li>• 75% reduction in maintenance induced damage</li> <li>• 30x reduction in consumable costs (no drill bits)</li> <li>• Supplied tooling can access ~95% of fasteners</li> <li>• Elimination of FOD: no drill shavings</li> <li>• Closed loop system: no HAZ waste</li> <li>• Less heat put into the part</li> <li>• Alleviates ergonomic strain to artisan</li> <li>• Reduced training time</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>▪ E-Drill is a semi-automated, plunge-cut Electrical Discharge Machining tool that uses electrical energy to machine away fastener head material</li> <li>▪ Alignment tooling enables fast cycle time, high accuracy, and reduction in maintenance induced damage</li> <li>▪ Designed with the artisan in mind: elimination of ergonomic strain</li> <li>▪ Only requires 110V electric + shop air</li> <li>▪ Recent NAVAIR official use authorization</li> </ul> <p><small>NAVAIR Public Release 2022-618              DISTRIBUTION A. Approved for public release: distribution unlimited.</small></p>	<p style="text-align: center;"><b>Graphic or Image</b></p> 

## FIBER OPTIC FUSION SPLICE REPAIR

**BRETT JORDAN**

Air Force Research Laboratory  
 brett.jordan@us.af.mil  
 +1.937.470.6997

Fiber optic cables are used extensively in modern military aircraft for moving large amounts of information between systems. Unlike copper wiring, there is no approved procedure for repairing fiber optic (FO) cables onboard aircraft (“in situ”). Current practice is complete, end-to-end replacement of damaged FO cables on aircraft. The procedure is intrusive, time consuming, and negatively affects aircraft readiness.

The Aircraft Battle Damage Repair (ABDR) office desired a practical FO repair system suitable for field repairs that meets the following characteristics:

- Permanent
- Reliable
- Low loss
- Minimum increase in tooling

The Air Force Research Laboratory’s Electrical and Electronic Materials Evaluation Team and ABDR worked together with Aurora Optics, Inc. to adapt a commercial, fiber fusion-type of repair technique to work with military-type fiber cables. The starting

point was a Boeing approved kit for use in commercial Boeing aircraft.

The kit modifications and the fiber cable type changes required the fusion splices be tested for performance and durability. A series of tests based on AS6506 Fusion Splice for Aerospace Fiber Optic Cables were developed with assistance from the Joint Aviation Fiber Optic Working Group (JAvFOWG). The AS6506-based tests would verify the splices meet necessary mechanical and environmental withstand requirements. The testing plan was approved by the ABDR office.

The key criterion for success was splice insertion demonstrated 0.5 dB or less of loss as compared to the pre-test fiber cable. All environmental and mechanical tests were successful with losses never exceeding 0.23 dB for any test. Modifications to the kit became necessary after initial samples failed tensile tests. These modifications were successful, requiring only minor changes to the kit process and material list.



The splice technique was also tested on a training aircraft at Hill AFB. The link to

that testing can be found here: [hill.af.mil/News/Article-Display/Article/1961786/fusion-splice-repair-passes-field-tests/](http://hill.af.mil/News/Article-Display/Article/1961786/fusion-splice-repair-passes-field-tests/)

A total of eight fusion splice repairs were made, and they all met the minimal signal loss requirements when measured. Two splices were made on an F-35A Lightning II, and one was made on an F-22 Raptor.

Signal loss is measured in decibels and the test splices averaged less than .02 dB where .5 dB is the maximum allowed. At .02 dB, a single run of cable could feasibly be spliced 25 times and still meet performance standards.

The field test demonstrated that a trained maintainer with the proper equipment can perform an acceptable fusion splice repair on an aircraft in roughly 20 minutes once the damaged section is isolated and made accessible. The current practice of replacing a damaged fiber optic cable can take hours and sometimes days.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Unlike copper wiring, there is no approved procedure for repairing fiber optic (FO) cables onboard aircraft (“in situ”).</li> <li>• Current practice is complete, end-to-end replacement of damaged FO cables on aircraft.</li> <li>• The procedure is intrusive, time consuming, and negatively affects aircraft readiness.</li> </ul>	<p style="text-align: center;"><b>BENEFITS</b></p> <p style="text-align: center;">Fiber Optic Fusion Splice Repair tooling allows:</p> <ul style="list-style-type: none"> <li>• Permanent repairs to broken fiber cables</li> <li>• Reliable splices</li> <li>• Low loss splices</li> <li>• Minimum increase in tooling for maintainers</li> <li>• Increased readiness of 5<sup>th</sup> generation aircraft to deter near peer adversaries</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>▪ The starting point was a Boeing approved fusion splicing kit for use in commercial Boeing aircraft.</li> <li>▪ Fusion splicing is the least-loss method of repairing fiber optic cables; non-fusion techniques typically have greater losses and might not meet loss goals.</li> <li>▪ The Air Force Research Laboratory’s Electrical and Electronic Materials Evaluation Team and ABDR worked together with Aurora Optics, Inc. to adapt this commercial, fiber fusion-type of repair technique to work with military-type fiber cables.</li> </ul>	<div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> <p>Commercial version of the fiber fusion splice repair kit. Military version is visually identical</p> </div> </div> <div style="display: flex; align-items: center; margin-top: 10px;">  <div style="margin-left: 10px;"> <p>Fiber fusion splice repair underway on training F-35</p> </div> </div>

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## LETTERKENNY ARMY DEPOT (LEAD) INNOVATIVE COLD SPRAY REPAIRS

**SAM EVANS**

Pennsylvania State University Applied Research Lab  
 sse11@arl.psu.edu  
 +1.814.863.5961

**Introduction:** Letterkenny Army Depot (LEAD) maintains and repairs land-based vehicles and missile systems. Engineers at LEAD constantly evaluate new and emerging technologies to increase their capabilities and reduce repair cost and time. Several years ago, LEAD identified Cold Spray (CS) as an enabling technology and began to identify critical applications. Early applications focused on restoring corrosion damage on aluminum components. LEAD worked closely with the Applied Research Lab at Penn State University (ARL/PSU) to develop and validate CS repairs on several aluminum components. The repairs were performed at ARL/PSU. The success of this effort led to the installation of a CS system at LEAD in 2015, with certification complete in 2021. LEAD artisans grew their skills and familiarity with the technology on noncomplex corrosion repairs. The investment and effort to bring CS online at LEAD showed its true value in recent repairs to the High Mobility Artillery Rocket System (HIMARS) and Patriot Missile System.

**Problem:** HIMARS and Patriot systems had significant corrosion in critical locations.

There was no approved repair process for the HIMARS. Cost to replace the cab was \$750,000 with 18 months lead time. Repair was possible for the Patriot, but it would add 14 weeks lead time. Both HIMARS and Patriot availability was critical due to current geopolitical situation (e.g., Ukraine).

**Technology Description:** Cold Spray is a solid-state process that allows for the rapid deposition of various metals at temperatures below their melting points.

**Current Development Status:** Research to develop and deploy CS technology in industrial settings has been ongoing for several decades. The use of this technology is relatively new to DoD depots and maintenance facilities due to the necessary funding, safety approvals, training, and deployment challenges. LEAD is one of the first depots/maintenance facilities to implement stationary CS technology. This capability made it possible to perform CS repairs on large vehicles in the field without removing the component. Development of these repairs requires consultation with researchers with experience in the use of

unique applications of CS and the ability to certify the repair. LEAD worked closely with ARL/PSU to build their CS capability and to certify their artisans. ARL/PSU quickly teamed with LEAD to develop and certify the HIMARS repair.

**Test Data Supporting Performance**

**Claims:** ARL/PSU has successfully developed and transitioned a number of CS applications to the Navy and Army.

**Next Steps/Potential Benefits:** Cold Spray technology has been implemented in many DoD industrial operations, but largely in isolation. The technology's benefits and capabilities are now proven. Services should initiate a consolidated effort to collaborate across all industrial operations in order to rapidly advance the capabilities this technology offers.

**PROBLEM STATEMENT**

- Traditional repairs on weapon systems and assemblies are not possible due to excessive heat causing damage to layered materials or electronic components/wiring in close proximity
- High Mobility Artillery Rocket System (HIMARS) corrosion repair of 46100 armor with composite layer (Dyneema)
- Patriot 6061 aluminum repair in proximity to wiring



**BENEFITS**

- **HIMARS (x3):** Repair: \$1200 vs. Cab Replacement: \$750K, 18 months lead time. Total savings: \$2.25M
- **Patriot:** Repair = Replacement cost. Saved 14 weeks lead time.
- Innovative mobile application of Cold Spray on systems continues to reduce costs and lead times
- Demonstrates value of depot modernization efforts

**TECHNOLOGY SOLUTION**

- Letterkenny Army Depot (LEAD) recognizing the geopolitical criticality of both weapon systems expanded the envelope of its fledgling Cold Spray capability to complete these repairs.
- Collaborated with Cold Spray research and development team at The Pennsylvania State University Applied Research Lab for assistance with mobile equipment and certification
- LEAD continues to grow Cold Spray capability to enable unique repairs on system to reduce cost and project delays due to parts lead times

**On-System Cold Spray Repairs**



**Patriot repair** – wiring in proximity of repair



**HIMARS repair** – composite armor

## METAL COMPONENTS FROM HYBRID ADDITIVE MANUFACTURING

### SLADE GARDNER

Big Metal Additive  
 slade@bigmetaladditive.com  
 +1.303.371.0515

Supply and availability of metal castings, forgings and even large billet have become a critical issue for maintenance and sustainment in all industrial sectors and branches of the DoD. Repair and maintenance schedules suffer even more for demanding pressure rated components especially larger than 15 inches in diameter. Critical components such as valves, fittings, manifolds, inlets, and vessels can sideline heavy equipment and facility operations when replacements are not quickly available.

Hybrid additive manufacturing (AM) has been validated to TRL 7 (Technology Readiness Level) for pressure components on Navy Unmanned Underwater Vehicles (UUV). This manufacturing technology combines large scale metal AM with 5 axis CNC machining to produce dimensionally tolerant, finish machined products that are ready to use without additional post processing. Metal components are produced quickly using industrial scale AM. Machining can occur at intermediate periods of the production, so interior surfaces that may not be accessible later, can be machined before the part is completed. Finish machining of exterior surfaces can occur as a final step using


the same machine, reducing schedule by continuously using the same fixtures, clamps, and positioning. A wide variety of metal alloys are compatible with hybrid AM to meet a broad range of applications.

Full sized 21-inch diameter aluminum pressure vessels were tested to hydrostatic design loads up to 700 psi and performed above 2,300 psi before failure. These 21-inch diameter vessels have a 95% improvement in lead time and a 63% improvement in cost over traditionally manufactured options.

A customer urgently needed a custom geometry 9-inch diameter pressure component for a UUV ocean test. Hybrid AM was used to produce the component in one week to meet article acceptance testing, integration with the UUV, basin testing and more than 50 UUV missions during ocean trials.

When experts from the oil and gas industry saw this case study, they engaged for first article demonstration and acceptance of 30-inch diameter valves critical to production operations. Valves will be made from low carbon steel and

stainless steel. Future components made from duplex steel and Inconel are planned for the next phase of acceptance.

<p><b>PROBLEM STATEMENT</b></p> <p>Supply and availability problems plague maintenance</p> <ul style="list-style-type: none"> <li>metal castings - forgings - large billet</li> </ul> <p>Repair and maintenance schedules suffer</p> <ul style="list-style-type: none"> <li>All industrial sectors</li> <li>All branches of the DoD</li> </ul> <p>Problems worse for demanding pressure rated components</p> <ul style="list-style-type: none"> <li>Especially larger than 15 inches in diameter</li> </ul> <p>Critical components can sideline heavy equipment and facility operations when replacements are not quickly available</p>	<p><b>BENEFITS</b></p> <p>Large metal pressure rated components delivered quickly</p> <ul style="list-style-type: none"> <li>95% improvement in lead time</li> <li>63% improvement in cost</li> <li>21-inch UUV pressure vessels proof tested to 700 psi</li> <li>Max performance above 2,300 psi before failure</li> </ul> <p>Customer need: UUV pressure component for ocean test</p> <ul style="list-style-type: none"> <li>Hybrid AM produced the component in one week</li> <li>More than 50 UUV missions during ocean trials</li> </ul> <p>Oil and gas industry saw this case study</p> <ul style="list-style-type: none"> <li>Now: first article demonstration and acceptance</li> <li>30-inch valves critical to production operations</li> <li>Low carbon steel and stainless steel</li> <li>Future components: duplex steel and Inconel</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>Hybrid additive manufacturing (AM) validated to TRL 7</p> <ul style="list-style-type: none"> <li>Navy UUV pressure components</li> </ul> <p>Hybrid AM combines metal AM + 5 axis CNC machining</p> <ul style="list-style-type: none"> <li>dimensionally tolerant, finish machined products</li> <li>ready to use without additional post processing</li> </ul> <p>Machining can occur at intermediate periods of production interior surfaces can be machined before part is completed</p> <p>Finish machining exterior surfaces as a final step</p> <ul style="list-style-type: none"> <li>using the same machine, reducing schedule</li> <li>using same fixtures, clamps and positioning</li> </ul> <p>Wide variety of metal alloys are compatible with hybrid AM to meet a broad range of applications</p>	

## WITNESS INTEGRITY SENSOR PLATFORM (WISP)

**SETH S. KESSLER, PH.D.**

Metis Design Corporation  
 skessler@metisdesign.com  
 +1.617.661.5616





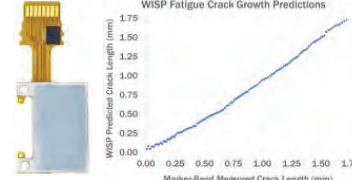
The Witness Integrity Sensor Platform (WISP) was developed as a practical means to accumulate sensor data to facilitate condition-based maintenance (CBM). Having previously experienced the pains of sensor system integration with defense & aerospace assets, the WISP distributed architecture aims to minimize, and in some cases altogether eliminate, the need for cables and connectors. The standalone version (WISP Solo) joins a single sensor with a small (10 cm<sup>2</sup>) lightweight (10 g) hardware package and is completely passive with no batteries or wires required. When the WISP Reader (13 cm<sup>2</sup>, 25 g) is magnetically coupled with the WISP Solo, power is inductively transferred to facilitate data collection, which is then transferred to the WISP Reader over Bluetooth Low Energy (BLE). The WISP Reader itself is powered over USB supplied by a phone, tablet or laptop, and data streams are supported for Windows, iOS, and Android. The networked version supports up to 64 WISP Edges (10 cm<sup>2</sup>, 8 g) along a 4-wire daisy-chained cable, each of which can be mated with different sensor types. At the front of the up-to-30m long bus, the WISP Base (10 cm<sup>2</sup>, 10 g)

provides power and data services for the entire network through the same inductive/ BLE WISP Reader wireless coupling as the WISP Solo. All WISP hardware has passed environmental airworthiness testing as defined by MIL-STD-810 and DO-160, and the BLE connection has been endorsed by cybersecurity experts at both the USAF and Navy.

WISP accepts any commercial-off-the-shelf (COTS) analog or digital (SPI, I2C) sensor that conforms to the defined electrical and physical interface documentation. Additionally, a suite of carbon nanotube (CNT) based advanced sensors have been developed to leverage the unique benefits of WISP, including those that measure fatigue cracks, the corrosivity and the erosivity of an environment. The most mature of these sensors is the fatigue crack gauge, which uses a thin-film resistive network of polymer nanocomposite (PNC) to track cracks as they grow under the gauge. The gauges are bonded down using aerospace-grade cyanoacrylate adhesive, and cracks permanently physically alter the PNC on a nanoscale, regardless of crack

closure, allowing for accurate crack length measurements during or after loading. These gauges also contain built-in compensation for environmental conditions and strain. Through more than 100 fatigue tests we have established a probability of detection a90/95 value of 0.33 mm following MIL-HDBK-1823, and WISP hardware utilizing this crack gauge has been field-tested by the Navy on a submarine and destroyer, and by the USAF on a fighter jet. Aside from defense applications, testing is currently being planned for customers in commercial aviation and the energy (oil/gas/wind) industries.

WISP has been a collaboration between Metis Design Corp., Analog Devices Inc., and the Massachusetts Institute of Technology (MIT), with funding provided through USAF and Navy SBIR efforts.

<p align="center"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Inspections are typically conducted manually by highly specialized experts on a fixed pre-scheduled interval</li> <li>• Manual inspection often requires tear-down at a depot location, taking an asset out of service</li> <li>• Present approach has proven to be safe, but also very conservative, time-consuming &amp; expensive</li> <li>• Fixed-interval inspections are susceptible to prolonged service disruptions due to unanticipated damage</li> <li>• Manually collected data is not optimized for fleet-wide trending or logistics planning</li> </ul>	<p align="center"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• <b>NEAR TERM BENEFITS</b> <ul style="list-style-type: none"> <li>• Improved asset availability</li> <li>• Improved maintenance logistics</li> <li>• Reduction in maintenance cost</li> <li>• Reduction in inspection costs</li> <li>• Service life extension</li> </ul> </li> <li>• <b>LONG TERM BENEFITS</b> <ul style="list-style-type: none"> <li>• Reduction in structural weight w/lower safety factors</li> <li>• Improved performance w/real-time monitoring structural limits</li> <li>• Better post-damage performance w/avionics feedback</li> </ul> </li> </ul>
<p align="center"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• WISP is as a practical means for accumulating sensor data to facilitate condition-based maintenance (CBM)</li> <li>• Solo version is inductively powered, requires no cables or connectors to collect data from a single sensor</li> <li>• Networked Edge/Base version daisy-chains up to 64 sensors on a 4-wire bus, inductively powered from up to 30 m away.</li> <li>• Distributed architecture reduces system mass, compatible with COTS analog &amp; digital sensors, new CNT sensors too</li> <li>• Advanced CNT crack gauge has demonstrated an a90/95 of 0.33 mm through probably of detection evaluation</li> <li>• Have also developed CNT gauges for corrosion &amp; erosion</li> <li>• WISP has passed environmental airworthiness standards</li> <li>• Technology is being validated today by USAF &amp; Navy through field testing on a submarine, destroyer &amp; fighter jet.</li> <li>• Ultimate goal is to be able to use CBM to guide inspection and maintenance actions, as well as inform maintainers and suppliers to streamline logistics.</li> </ul>	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;"> <p><b>WISP Solo</b></p>  </div> <div style="text-align: center;"> <p><b>WISP Edge</b></p>  </div> <div style="text-align: center;"> <p><b>WISP Base</b></p>  </div> </div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <p><b>WISP Reader</b></p>  </div> <div style="text-align: center;">  </div> </div>

## ADDITIVE MANUFACTURING PROCESS FLOW

DAVID COATES

Altair Engineering, Inc.  
 dac@altair.com  
 +1.248.321.4550

Spare parts availability across all DOD agencies are plagued with numerous problems; diminishing mfg. resources, long production lead times, high tooling and reverse engineering costs for low quantities spent on old-outdated designs that do not benefit the warfighter. Providing solutions which optimizes weight and perf. and can help improve system reliability, maintainability and supportability helping weapon system readiness and availability to execute missions. AM at the point of need reduces the logistics footprint in theater and allows repairs of systems requiring parts to be completed faster.


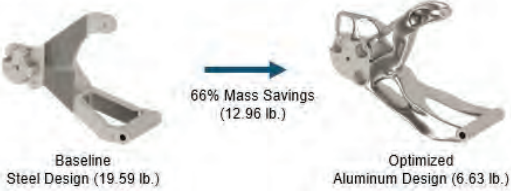
Altair proposes a solution that couples proven design optimization technologies with the benefits of AM executed in a model-based workflow. This approach will drastically improve efficiency of the current spare part process and update the old-outdated part designs. This approach will not only solve the noted process problems but maximize the benefits to the war fighter with simulation driven designs that fully exploit the capabilities of AM, optimizes weight, improves performance

and reliability, maintainability, and supportability, and reduces the logistical footprint and its associated time and costs.

Over the last year, Altair has demonstrated this approach redesigning six ground vehicle components defining mass savings of 26% to 83% while securing part performance. Similar success has been experienced in automotive and aerospace applications. To execute this successful workflow more efficiently and with limited data (lack of component loads), Altair has developed a model-based approach. A POC of this approach was executed with GVSC with a beta being delivered at the end of October 2021. These components have received the same engineering discipline as their baseline versions resulting in a reduction of mass and as good or better performance. In some instances, the cost to additively manufacture the part is lower than traditional manufacturing techniques. These components are now in the print and test phases where results will be compared to simulations and the technology and process will be refined in filling any gaps.

Potential benefits of the approach is to not only improve the overall efficiency of the spare part ordering process but deliver updated state of the art part designs to support the warfighter. Other benefits include improved system reliability, maintainability and supportability, reduction of logistics footprint, and quicker repairs to improve system availability.

Next steps are to gather additional DOD interest and collect any unique agency requirements. This will maximize the benefits of the tool across all DOD agencies. Once all requirements are understood the team will re-focus on development and refinement of the model-based process management software tool and help to transition the process and tools across the DOD Organic Industrial Base and Defense OEMs.

<p><b>PROBLEM STATEMENT</b></p> <p>Spare parts availability across all DOD agencies are plagued with numerous problems; diminishing manufacturing resources, long production lead times, high tooling and reverse engineering costs for low quantities spent on old-outdated designs that do not benefit the warfighter. Providing solutions which optimizes weight and performance and can help improve system reliability, maintainability and supportability helps weapon system readiness and availability to execute missions. Additive manufacturing at point of need reduces the logistics footprint in theater and allows repairs of systems requiring parts to be completed faster.</p>	<p><b>BENEFITS</b></p> <p>The potential benefit of the approach is to not only improve the overall efficiency of the spare part ordering process but deliver updated state of the art part designs and manufacturing processes to support the warfighter. Other benefits include improved system reliability, maintainability and supportability, reduction of logistics footprint, and quicker repairs to improve system availability.</p> 
<p><b>TECHNOLOGY SOLUTION</b></p> <p>Altair proposes a solution that couples proven design optimization technologies and methods coupled with the benefits of additive manufacturing executed in a model-based work-flow. This approach will drastically improve efficiency of the current spare part process and update the old-outdated part designs. This approach will not only solve the noted process problems but maximize the benefits to the warfighter with simulation driven designs that fully exploit the capabilities of additive manufacturing, lowers weight, improves reliability, maintainability, and supportability, and reduces the logistical footprint and its associated time and costs.</p>	<p><b>GRAPHIC</b></p> 

## MELD METAL 3D PRINTED PARTS

### WES DOWNS

MELD Manufacturing  
 wes.downs@meldmanufacturing.com  
 +1.619.433.9002

The MELD technology solves lead time challenges facing maintenance, lifecycle, new construction, and repair for each branch of the DOD and the respective industries that support their needs.

MELD is a solid-state metal additive manufacturing process that enables parts to be printed in a rapid, repeatable, and reliable manner at a competitive cost.

MELD technology does this by providing the capability to manufacture legacy parts that no longer exist, parts that aren't accessible in the field, or parts that continually fail or wear out during operation. MELD technology is able to produce these parts at rapid pace, reducing 6-12+ month lead times to a matter of days, while meeting SPEC requirements.

The MELD process is capable of printing large metal parts at scales not yet seen in the metal additive space. The key enabler of this scalability is that, unlike traditional additive processes, MELD is not restricted to small powder beds or costly vacuum systems. The MELD process is an open-atmosphere process and is not sensitive to the operating

environment or material surface condition, making it ideal for real-world manufacturing.

This technology allows parts to be made in a way that has never been done before, achieving sizes that have not been thought possible, and printing/making new materials that could not exist before this process.


The timeframe of transitioning the technology for use by the DOD is within the next 1-2 years. There is an ongoing NAVSEA SBIR to be completed in FY22 focusing on printing parts to install onboard NAVY ships under repair. The ARMY is receiving two printers that will be completed by the end of FY22 and will commence printing immediately afterwards. The technology of the materials they are interested in (Aluminum and Titanium) are at a TRL 8-9. Additional materials that have been demonstrated but not yet validated against SPEC have a lower TRL.

Each branch of the DOD is conducting their own validation efforts of the technology to utilize it as they see fit within their branches.

The technology has been through rigorous testing throughout the years and validated by 3rd party sources at every step. Recently the ARMY Research Lab (ARL) tested and validated that the Ti 6-4 printed using the MELD technology exceeds both ASTM and AMS SPEC for Ti 6-4 forgings. The Air Force is in the process of qualifying the MELD Al7075 to forging SPEC by the end of CY21. The NAVY has an NSRP RA focusing on printing in AH36 steel in FY22.

The ARMY has recently awarded MELD the contract to build the world's largest metal 3D printer (Build Volume: 12ft x 20ft x 30ft) to print monolithic hulls for the underside of tanks.

There are ongoing projects with each branch of the DOD to use the technology within their respective areas, collaboration between branches, and active discussions with OEM vendors/suppliers to understand their needs and how they can utilize the technology to sustain existing equipment and critical components.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>There are lead times in excess of 12 months to acquire parts for maintenance, lifecycle sustainment, new construction, and repair for each branch of the DOD and the respective industries that support their needs.</p>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Reducing lead times from 6-12+ months down to days/weeks.</li> <li>• Manufacture in almost any metallic material, including making new materials that can't exist without this process.</li> <li>• Manufacture at the scale of several meters.</li> <li>• Can achieve repeatable results with forged equivalent properties.</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Make high quality near net shape parts at a high production rate.</li> <li>• Repair even unweldable metals – from casting defects to equipment in the field.</li> <li>• Protect parts with wear resistant coatings that will not delaminate.</li> <li>• Open up primary manufacturing options by adding features after.</li> <li>• Join same or dissimilar materials.</li> </ul>	

## TRACEABILITY & SERIALIZATION FOR ADDITIVE MANUFACTURERS

**TOM HARGETT**

TIP Technologies  
 tom.hargett@tiptech.com  
 +1.410.733.3480

Additive manufacturers need to ensure complete traceability throughout the product lifecycle to yield high quality products. With the TIPQA Quality Management Solution, managers can gain complete visibility into the production of every part, sub-assembly, and final assembly to help identify quality issues before they become a problem.

Product genealogy tracks information such as raw materials, equipment usage, inspection results, dates, quantities, lot and serial numbers, including supplier products. The information collected through the product genealogy process is used to measure quality output at each manufacturing stage against the intended product specifications.

Tracking product genealogy within TIPQA increases confidence that comprehensive records will be electronically maintained for audits. Quality records include associated as-built/as-maintained configuration records and nonconformance dispositioning. A digital thread of historical production data is maintained within the system.

Traceable configuration allows users to view a data file of each assembly in a graphical

format that can save days, or even weeks' worth of information gathering.


- Configuration Management / Device History Record
- As-Built serial number relationships
- Nonconformances at any level in configuration
- Open Nonconformances before moved to stock to support build-at-risk
- Device History Record brings quality history together for upper-level item
- Prevents processing with missing operations & serial numbers
- Parts can be identified as Serial or Lot Controlled, or both
- Graphical presentation of build structure with Nonconformances highlighted

TIPQA facilitates compliance to DoD requirements for Counterfeit Parts Avoidance, Mitigation, and Disposition, as well as Diminishing Manufacturing Sources and Material Shortages (DMSMS) sources and material shortages. Parts produced using additive techniques for the aerospace

and defense industry must be qualified with Federal Aviation Administration (FAA) on an individual basis. With full visibility into sub-tier suppliers, TIPQA can ensure parts meet this standard and provide objective evidence that supports industry compliance.

Regardless of the method, manufacture, or source, (Work Order, Receiver), TIPQA can trace the genealogy of the Part Number and Traceable element combinations such as Serial Number, Lot, Date, Heat Code throughout the build process, including the raw material that is melted to print a 3D part. As-built Genealogy can be reviewed in a report prior to shipment and provided to the end client. TIPQA Temperature Controlled Materials validates the quality of powders used in the additive manufacturing process, manages cure times, and maintains control over temperature sensitive materials.

It is vitally important for manufacturers to maintain component level traceability and product lifecycle records. TIP Technologies can help organizations reach this sophisticated level of quality by tracking the quality of all parts to ensure the highest industry standards.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Operational excellence is at risk with disparate systems or lack of quality / manufacturing data integration.</li> <li>• Additive manufacturers need a reliable system to manage the introduction of emerging products.</li> <li>• Lack of genealogy on supplier subassemblies and final assemblies result in issues with compliance or counterfeit parts.</li> <li>• Failed audits or issues with industry compliance increase the cost of quality.</li> </ul>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Enforcement of requirements (Serial Number, Lot Code, UID, etc.)</li> <li>• Ensure all issues are resolved before product release</li> <li>• All inspections completed</li> <li>• All Nonconformances / issues resolved</li> <li>• All deviations approved</li> <li>• Ability to rapidly identify suspect material for recalls</li> <li>• Open non-conformances are highlighted in red, while the non-conformances with an accepted disposition are highlighted in green</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Complete Product Lifecycle Genealogy / Configuration</li> <li>• As-Built / As-Maintained/ As-Returned data</li> <li>• Design for Manufacturability (DFMA)</li> <li>• Design for Maintenance, Repair, and Overhaul (DMRO)</li> <li>• Temperature Controlled Materials module validates quality of powders used in the additive manufacturing process</li> <li>• Holds suppliers accountable for quality standards</li> </ul>	<p style="text-align: center;"><b>GRAPHIC OR IMAGE</b>                  Configuration Management –                  An exploded view of a simple BOM</p> 

## SOFTWARE DEVELOPMENT

**JAMES HASS**

ATTI

jlhass06@outlook.com

+1.757.561.3799

While General Pawlikowski served as the Commander of the Air Force Materiel Command, she stated, “But the traditional Pentagon systems engineering process is not set up to produce new and updated software with speed”.

Mr. William Roper while serving as the Assistant Secretary of the Air Force, Technology said “One of his most imperative duties in his job is to get the Air Force to a point where it can do agile software development.”

And General John Hayten, as Vice Chairman of Joint Chiefs of Staff, said about software development: “And as of now, the process is a nightmare across the board”.

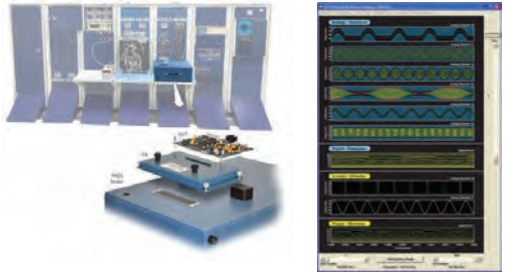
Advanced Testing Technologies, Inc. (ATTI) took the challenge. Using their own research and development funds, they created a software development tool that provides that agile software development. The Parallel Automated Development System (PADS) can be used to develop software in a fraction of time and funds.

The PADS hardware is a small, carry-on suitcase size, software development station that can be driven with a laptop computer. An additional benefit is that the PADS software development station can also be used to test and repair the unit the software was developed to test. The interface test connector (ITA) can be connected directly to the test station and unit under test. This eliminates the need for extremely expensive test equipment normally needed after software development. This is a game changer in software development. The parallel testing is faster and more accurate than legacy test procedures allowing reduced testing and repair times.

The PADS is a commercial-off-the-shelf (COTS) tool and be ordered from the GSA catalog. This can be the first step in reducing development time, reduce testing time and reducing repair time for all services.

ATTI has demonstrated the PADS to several senior leaders in the DoD and received positive feedback.

Recommendation: Fund a proof-of-concept test to ensure the PADS can meet DoD requirements. Pick a backlogged requirement and watch the PADS fill the need.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Several senior DoD leaders have addressed the critical problem of software development time and money             <ul style="list-style-type: none"> <li>• General Pawlikowski, past Commander of Air Force Materiel Command</li> <li>• Mr. Roper, past Assistant Secretary of the Air Force, Technology and Logistics</li> <li>• General John Hyten, past Vice Chairman of Joint Chiefs of Staff</li> </ul> </li> <li>• Limited number of developers.</li> <li>• Limited funds for development.</li> <li>• Priorities creating long back-log numbers</li> </ul>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Small-portable tool already in existence for immediate use</li> <li>• Significant reduction in software development time and cost.</li> <li>• As an added benefit, the development system also functions as a test set, providing test and repair capability for the items using the developed software, eliminating a requirement for other expensive test equipment, estimated to be in the millions of dollars.</li> <li>• \$300K for the PADS is a great value</li> <li>• Can start to reduce back-log requirements across all services.</li> <li>• Small footprint and easily deployable</li> <li>• PADS can be integrated into other ATS to expand their capabilities.</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Advanced Testing Technology, Inc. (ATTI) used their own research and development funds to create a software development tool that can cut software development cost and time significantly.</li> <li>• This technology is called the Parallel Automated Development System (PADS)</li> <li>• No research and development cost – already developed</li> <li>• This is a commercial-off-the-shelf (COTS) item that can be purchase through the GSA catalog.</li> <li>• ATTI will train potential users how to develop software using this tool.</li> </ul>	<p style="text-align: center;"><b>Graphic</b></p> 

# ADDITIVE MANUFACTURING

## BUILD, REPAIR & ENHANCE METAL COMPONENTS ON-DEMAND

MELANIE A LANG

FormAlloy Technologies, Inc.  
melanie.lang@formalloy.com  
+1.619.377.9101

Build, Enhance Performance, and Repair metal parts on-demand with FormAlloy's metal additive manufacturing (AM) technology with digital build certification capability, DEDSmart™. FormAlloy's metal AM technology offers a versatile, field-deployable metal deposition process that enables its users to handle several different applications including building replacement parts, enhancing existing components for improved corrosion and wear resistance, and repairing high-value components. With FormAlloy's high deposition efficiency and in-process monitoring, high quality parts are manufactured by machine tool operators up to 100X faster than traditional manufacturing methods and repaired at a fraction of the cost. Advanced coatings can be applied to extend the life of equipment and add vehicle protection.

FormAlloy technology utilizes the widest range of metals within additive manufacturing, and custom alloys can be created quickly to produce unique properties for demanding applications. Feedstock materials are commercially available or may be created on-site from bar stock, further reducing supply chain complexity.

FormAlloy systems utilize a simple interface and run-on G-code, a standard used by many machine tools, so that soldiers are easily trained, and skills are transferable to other manufacturing operations. FormAlloy systems run autonomously, without the need for user input, so that parts may be made and repaired efficiently and repeatably. The autonomous operation of the systems rely on an advanced suite of in-situ monitoring and control to ensure parts are of the same quality and perform equally.

In addition to autonomous operations, FormAlloy systems are equipped with their own DEDSmart™ software suite, enabling data logging and build recording. DEDSmart™ data logs capture all parameter and machine data for the build, ensuring each part has a built-in document with the full build history. FormAlloy data can be exported, and a build summary report is automatically generated which includes a unique report number, machine information, such as serial number, feedstock information, and time-stamped build parameter data. This data file can be customized and used to support digital build certification, ensuring users have full access

to how a part was built and can be expected to perform.

FormAlloy on-demand metal AM technology can solve pain points within the DoD maintenance and sustainment communities by offering a deployable, affordable, trainable, and maintainable system to produce high-quality, repeatable metal components now.

<p><b>PROBLEM STATEMENT</b></p> <p>Need/Problem: Technology capable of</p> <ol style="list-style-type: none"> <li>1. Performing full-quality metallic <b>component repairs</b> <ul style="list-style-type: none"> <li>• Return parts back to service in hours to days instead of weeks to months</li> </ul> </li> <li>2. Producing <b>replacement parts on-demand</b> <ul style="list-style-type: none"> <li>• High value, complex geometries, large freeform fabricated structures, and functionally graded materials (FGMs)</li> </ul> </li> <li>3. Applying <b>corrosion resistant coatings</b> <ul style="list-style-type: none"> <li>• Corrosion damage to military assets costs the DoD Billions</li> </ul> </li> </ol>	<p><b>BENEFITS</b></p> <p>Potential Uses/Impact:</p> <ol style="list-style-type: none"> <li>1. Additive Manufacturing <b>Improved components for enhanced lethality</b></li> <li>2. Lightweight and advanced materials development <b>Increased vehicle protection and transportability</b></li> <li>3. Advancing coating for improved corrosion resistance <b>Extended life</b></li> <li>4. Advanced joining development <b>Advanced repair processes</b></li> </ol> <div style="background-color: #1a3d54; color: white; padding: 5px;"> <p><b>High TRL: 7+</b></p> <ul style="list-style-type: none"> <li>▶ Fast build rates (15 lb/hr)</li> <li>▶ Scalable</li> <li>▶ Multi-Material Capable</li> <li>▶ Open Source Materials</li> <li>▶ Waste Reduction</li> <li>▶ Field Deployable</li> </ul> </div>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Metal Additive Manufacturing to <b>BUILD, ENHANCE, &amp; REPAIR</b> On-demand</li> <li>• <b>BUILD</b> fully-dense components on-demand</li> <li>• <b>ENHANCE</b> existing components with multiple materials to improve strength/corrosion/wear</li> <li>• <b>REPAIR</b> damaged components and return to service quickly and cost effectively</li> <li>• Widest range of alloy processing - steels, nickel super alloys, copper, titanium, cobalt alloys and exotics</li> <li>• Machine programming in G-code is transferable skill to/from CNC machine tools</li> <li>• <b>VERIFY</b> with full build control and data logging for digital build certification with DEDSmart™</li> </ul>	<p>The diagram illustrates the FormAlloy process flow. It starts with a machine tool labeled 'VERIFY'. An arrow points to a 'BUILD' stage, which shows a laser deposition process creating a part. Another arrow points to an 'ENHANCE &amp; REPAIR' stage, which shows a laser coating process on a part. The final output is a finished metal component.</p>



## RAPID COMPLEX METAL PARTS USING ADDITIVE AND CASTING MANUFACTURING

SIMON MILLER

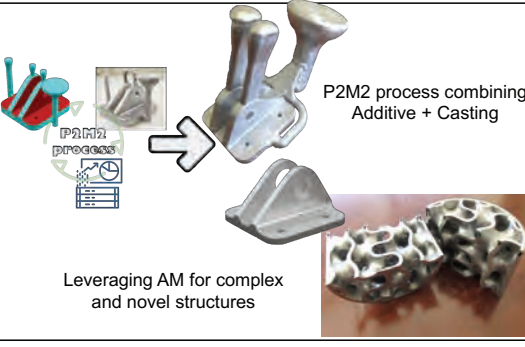
Penn State ARL  
 swm154@arl.psu.edu  
 +1.814.863.5399

Deployed systems need replacement of metal parts to sustain operations and maintain operational availability. In expeditionary settings, access to the supply chain is not guaranteed and there is often limited infrastructure. The Navy & USMC continuously explore means to produce replacement parts forward; however, both traditional manufacturing methods and new ones such as metal additive manufacturing, have proven difficult to field and are quite costly. Deployed USMC units are now fielding rapid repair sites that are equipped with polymer-based 3D printing capabilities. The printers in terms of piece-part size, volume, weight, and (critically) material choices limit these mobile manufacturing facilities. This limits the armed forces to small repairs and tooling using small plastic parts.

iMAST/ARL continues to develop the ability to print plastic parts and use those parts to make patterns and molds in which parts are then metal cast. Using this Print Plastic to Make Metal (P2M2) approach, the services can create needed metal parts using well-known, approved materials, with well-characterized material properties that can be larger than direct-metal 3D printed

parts, at orders of magnitude lower cost. Our tools and techniques provide design and manufacturing training to consider the entire process from technical data definition, intermediary file format creation, design for X considerations, polymer printing, pattern and mold design, casting, and post-processing in a holistic package that educates and enables others to leverage additive and traditional manufacturing. Multi-part patterns have been created that exceed 12"x12"x12" in volume.

The next steps are to refine the process documentation, operating procedures, create training material, and perform demonstrations at events such as REPTX. The major benefits are the combination of design freedom via material extrusion additive made at point-of-need, with casting that provides (approved) well-known and accepted processes, material properties, and workflow. This process ultimately reduces the lead time and cost to build necessary parts by orders of magnitude (compared to contemporary metal additive) for necessary metal parts in forward locations.

<p><b>PROBLEM STATEMENT</b></p> <p>Deployed systems require replacement of metal parts to sustain operations and maintain operational availability. In expeditionary settings, ready access to the supply chain is not guaranteed and infrastructure is limited. The Navy &amp; USMC are continuously exploring means to produce replacement parts forward, however, both traditional manufacturing methods and new ones such as metal additive manufacturing, have proven difficult to field and are quite costly. Deployed USMC units are now fielding rapid repair sites that are equipped with polymer-based 3D printing capabilities. These mobile manufacturing facilities are limited by the printers in terms of piece-part size, volume, weight, and (critically) material choices. This limits the armed forces to small repairs and tooling using plastic parts.</p>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Process for rapid part production of parts in forward locations to improve Operational Availability (Ao) of fielded vehicles by reducing delays due to supply chain</li> <li>• Combine additive manufacturing for complex geometry made at point-of-need with casting that provides well-known and accepted processes, material properties, and workflow</li> <li>• Reduce lead time and cost to build metal part (temporary, replacement, novel, fixtures, tools, etc.)</li> <li>• Use easily accessible tools and processes to make on-demand metal parts with cast material properties</li> <li>• Provide training and educational material for end-users</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>The solution that iMAST/ARL has been developing is the demonstrated ability to print plastic parts and use those parts to make patterns and molds in which metal parts are then metal cast. Using this Print Plastic to Make Metal (P2M2) approach, the services can create needed metal parts using well-known, approved materials, with well-characterized material properties that can be larger in size than direct-metal 3D printed parts, at orders of magnitude lower cost. Our tools and techniques provide design and manufacturing training to consider the entire process from technical data definition, intermediary file format creation, design for X considerations, polymer printing, pattern and mold design, casting, and post-processing in a holistic package that educates and enables others to leverage additive and traditional manufacturing.</p>	 <p>P2M2 process combining Additive + Casting</p> <p>Leveraging AM for complex and novel structures</p>

# ADDITIVE MANUFACTURING

## ADDITIVE MANUFACTURING AND REPAIR OF ARMAMENT PARTS

HOWARD SIZEK

USAF

howard.sizek@us.af.mil

+1.937.713.5616

The Armament Sustainment Division (ASD) (AFLCMC/EBW), Robins AFB, supports many systems across the Air Force that are experiencing diminishing source of supply issues resulting in long lead times and excessive costs ultimately reducing aircraft availability and mission readiness. To combat these issues, the ASD enlisted the help of the Rapid Sustainment Office (AFLCMC/RO)/Advanced Manufacturing Program Office (AMPO).

The RSO's mission is to increase mission readiness and capabilities by scaling innovative solutions to advance and modernize Department of Air Force sustainment operations. The AMPO is utilizing Additive Manufacturing (AM), Cold Spray Repairs and other advanced manufacturing technologies like reverse engineering tools to support the ASD.

The ASD has converted significant amounts of legacy data into 3D Model-Based Technical Data Packages (MTDP). The MTDP, a machine-readable part definition, supports traditional and advanced manufacturing, enables digital engineering analysis, supports the "Digital Twin,"


and streamlines quality control. Reverse engineering tools were utilized to develop and verify technical data.

The initial focus was to solve current and pending supply chain shortfalls, especially those impacting readiness, and evaluate low demand, long lead time items. In a collaboration between EXPANSIA, University of Dayton Research Institute, ASD, and AMPO, the MTDPs and databases were mined to identify parts suitable for the current AM capabilities. To date, approximately 600 ASD parts have been identified as candidate parts for AM.

The AM parts were designed to be interchangeable with traditionally manufactured components. The AM process enables production of complex geometries and part consolidation that are difficult to achieve with traditional methods. The AM parts can be modified to address known failure modes. AM and AM assisted methods are often less costly for limited run parts and those requiring expensive tooling. Cold Spray Repair enables deposition of powdered metal for dimensional restoration. For several parts the process restored

bearing and other non-structural surfaces with no impact to the substrate; repairing components that were previously replaced.

To date, 41 Technical Data Packages (TDP) and part sets have been submitted to ASD for approval; 63 additional parts are under development. Many components are scheduled for live fire testing in the Fall of 2022 and several components are fully approved. The development of TDPs for AM ultimately creates an alternative manufacturing source, reduces gaps in the current supply chain, and creates competition amongst existing sources. Approved AM metal and polymer parts have average production times of 60 and 30 days respectively. Current Air Force supply chain lead times for some of these components exceed 400 days. The lead time for delivery of AM armament parts was reduced by one year.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"><li>▪ Diminishing manufacturing sources (DMS) with large number of investment cast armament parts creating long lead times and excessive cost, resulting in reduced aircraft availability and mission readiness<ul style="list-style-type: none"><li>▪ 382 Parts identified with lead time over 9 months</li><li>▪ 248 Parts identified with lead time over 12 months</li><li>▪ 88 Parts identified with lead time over 18 months</li></ul></li><li>▪ Weld repair processes difficult to execute on complex geometries and large areas needing restoration</li></ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"><li>▪ Alternate sources of supply</li><li>▪ AM process can allow for improved geometry, reducing stress concentrations, greater durability, and improving part reliability</li><li>▪ AM process can consolidate complex assemblies</li><li>▪ Cold Spray can repair parts previously replaced</li><li>▪ Reduced Lead Time<ul style="list-style-type: none"><li>▪ Metal AM parts produced in an average of 60 Days</li><li>▪ Polymer AM parts produced in an average of 30 Days</li><li>▪ Armament part lead time is reduced by <u>one year</u></li></ul></li></ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"><li>▪ Data mining of digital engineering model-based technical data packages and procurement systems to select parts</li><li>▪ Reverse engineering techniques to complete and validate technical data packages</li><li>▪ Additive Manufacturing (AM)<ul style="list-style-type: none"><li>▪ Direct Metal Laser Melting (DMLM) – Metal Powder</li><li>▪ Fused Deposition Modeling (FDM) – Thermoplastics</li></ul></li><li>▪ Cold Spray (CS) Repair<ul style="list-style-type: none"><li>▪ Solid-state deposition of powdered metal for dimensional restoration</li></ul></li></ul>	<p><b>Metal AM Part</b></p> <p><b>Cold Spray Repair</b></p>  <p>The image contains three distinct parts. At the top left is a 3D model of a complex metal part. Below it is a photograph of a similar metal part with a blue spray applied to a curved surface. To the right is another photograph of a metal part with a blue spray applied to a different curved surface. At the bottom left is a close-up photograph of a substrate with a label 'CS Repair' and 'Substrate' pointing to a repaired area.</p>

## DISTRIBUTED QUALIFICATION FOR ADDITIVE MANUFACTURED PARTS

MIKE VASQUEZ

3Degrees  
 mike@3degreescompany.com  
 +1.651.503.9085

The challenge of maintaining a fleet of aging aircraft is immense. According to Air Force Lt General Warren Berry, “an internal review showed 80% of all demand for aircraft parts is satisfied by a repair instead of a replacement...of those part repairs, 92% can only be performed by a single supplier.

The DoD has already identified one solution to fixing this problem: the use of Additive Manufacturing (also known as 3D Printing) as an alternate manufacturing pathway.

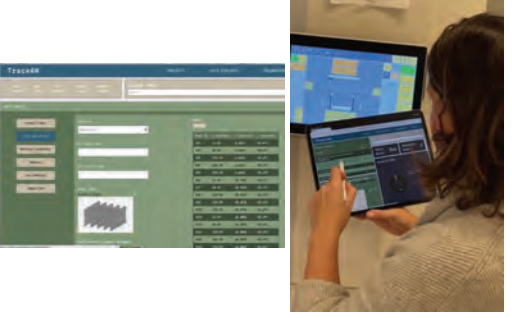
In order to realize the benefits of this technology, technical data packages and manufacturing operations need to be validated and qualified. This is essential to ensure the manufacturing information is transferred and implemented correctly, and that all steps along the product life cycle are documented and traceable. Failure to properly qualify parts has a high price: potential malfunction of key equipment, damage to government property, and loss of life.

3Degrees’ TraceAM system allows users to track all their critical information, organizes it for multi-purpose use, and most importantly

enables users to share a streamlined data set with internal and external partners. What makes TraceAM unique is that not only can the system collect the information in a central database, but the information can also be consistently structured and exported to additional systems for further analysis and use, differentiating it from any other software solutions on the market.

3Degrees has also developed a testing as a service model to provide surveillance on Additive Manufacturing systems that can translated close to the point of manufacture.

The successful implementation of the TraceAM software would accelerate DAF capabilities to generate accurate, timely, and consistent data packages for existing and future components that could be 3D Printed.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>The challenge of maintaining a fleet of aging aircraft is immense. According to Air Force Lt General Warren Berry, “an internal review showed 80% of all demand for aircraft parts is satisfied by a repair instead of a replacement...of those part repairs, 92% can only be performed by a single supplier.</p> <p>The DoD has already identified one solution to fixing this problem: the use of Additive Manufacturing (also known as 3D Printing) as an alternate manufacturing pathway.</p> <p>In order to realize the benefits of this technology, technical data packages and manufacturing operations need to be validated and qualified. This is essential to ensure the manufacturing information is transferred and implemented correctly, and that all steps along the product life cycle are documented and traceable. <b>Failure to properly qualify parts has a high price: potential malfunction of key equipment, damage to government property, and loss of life.</b></p>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>Centralizing the collection and storage of this data using TraceAM improves data reliability and frees up engineer’s time for higher impact activities. Through our discussions and customer discovery interviews, <i>we can estimate that labor cost savings alone from using the TraceAM system at a typical production center averaging two builds per week would be \$25,000 on an annual basis per engineer.</i></li> <li>Accelerating qualification of AM will increase the capabilities of the DoD allows the organization to control its own destiny – printing quality parts on demand, quickly, where they are needed and at any scale</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <p>3Degrees’ TraceAM system allows users to track all their critical information, organizes it for multi-purpose use, and most importantly enables users to share a streamlined data set with internal and external partners. What makes TraceAM unique is that not only can the system collect the information in a central database, the information can be consistently structured and exported to additional systems for further analysis and use, differentiating it from any other software solutions on the market.</p> <p>3Degrees has also developed a testing as a service model to provide surveillance on Additive Manufacturing systems that can translated close to the point of manufacture.</p>	

# ADDITIVE MANUFACTURING

## ADVANCED MANUFACTURING DIGITAL HUB

SEAN WADE

PTC

sewade@ptc.com

+1.850.202.6098

**Problem Statement:** The goal of this project is to foster innovation, reduce cost, and create a more rapid and agile supply chain for parts affected by long lead times, or DMSMS. This will directly increase aircraft and ground system operational readiness, as it has for our other DoD and industry customers.

The solution mitigates disruption to the supply chain through deploy with the capability to meet requests for critical parts creation, supporting and printing parts faster, and with greater precision while at sea. The DoD needs an ability to reduce the tyranny of distance for supply chains particularly in contested environments. Our Additive manufacturing solution, built on existing secure cloud enclave, will enable a forward advanced manufacturing hub that will improve readiness and expedite battle damage repairs when at sea with the following functions.

**Technology Description:** Fully Integrated Connected Digital Thread

- Strategic Enterprise System for Product Data – Windchill PLM is considered a

strategic enterprise domain application providing digital continuity for product data (Computer Aided Design (CAD), bills of material (BOM), Requirements, Test, Simulation, etc.)

- Platform (Digital Thread Layer) – ThingWorx, Kepware, and Vuforia. These PTC technologies provide integration/contextualization/visualization creating the Digital Thread across other strategic enterprise systems such as MES, ERP, MRO, connected data/device cloud, and into the supply chain (multi-system orchestration). Connecting factory machines leveraging Kepware, PLM, and Windchill is the backbone for this Digital Thread.
- Experience and Interaction – ThingWorx Navigate. As intuitive as an average smartphone app, ThingWorx Navigate enables organizations to dramatically increase productivity and improve collaboration by radically simplifying data access.

been deployed in proven operational environments and are thus TRL level 9 and MRL level 10 on day one.



**Test/ Simulation Data Supporting Performance Claims:** USMC Digital Engineering for Additive Manufacturing Repository: The US Marine Corps is utilizing PTC's PLM and 3D CAD platforms for an engineering grade digital repository to provide a single source of truth and digital connection between product data and parts information.

**Next Steps/Potential Benefits:** This capability offers tremendous capability to the DoD providing a digital thread marketplace for advanced manufacturing which allows members to search and print critical parts on demand.

**Bottom Line:** PTC OFFERS USE OF EXISTING, DEPLOYED FEDRAMP ENVIRONMENTS FOR TESTING, WHICH CAN RAPIDLY SCALE FOR TESTING AND PRODUCTION AT LOW COST.

### Current Development Status of the

**Technology:** The team offers Commercial off-the-Shelf (COTS) products that have

<p><b>PROBLEM STATEMENT</b></p> <p>Foster innovation, reduce cost, and create a more rapid and agile supply chain for parts affected by long lead times, or DMSMS. This will directly increase aircraft and ground system operational readiness, as it has for our other DoD and industry customers. The solution mitigates disruption to the supply chain through deploy with the capability to meet requests for critical parts creation, supporting and printing parts faster, and with greater precision while at deployed or at sea. The DoD needs an ability to reduce the tyranny of distance for supply chains particularly in contested environments. Our Additive manufacturing solution, built on existing secure cloud enclave, will enable a forward advanced manufacturing hub that will improve readiness and expedite battle damage repairs when at sea with the following functions</p>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• On demand repository for advancement manufacturing parts</li> <li>• React quickly to urgent operational needs in the field</li> <li>• Enable field combatant commanders to collaborate with Program Offices to make timely decisions</li> <li>• Develop organic engineering capabilities that can be forward deployed</li> <li>• High readiness at an affordable cost</li> <li>• Understand aircraft configuration baseline</li> <li>• Modern repository for programs with open data services to:</li> <li>• Support and enhance existing systems</li> <li>• Support the Force</li> <li>• Secure Digital Information</li> <li>• Authorize critical repairs safely and expeditiously</li> <li>• Retain authority and configuration control</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>Fully Integrated Connected Digital Thread</p> <ul style="list-style-type: none"> <li>• Strategic Enterprise System for Product Data – Windchill PLM is considered a strategic enterprise domain application providing digital continuity for product data</li> <li>• Platform (Digital Thread Layer) – ThingWorx, Kepware, and Vuforia. These PTC technologies provide integration/contextualization/visualization creating the Digital Thread across other strategic enterprise systems such as MES, ERP, MRO, connected data/device cloud, and into the supply chain (multi-system orchestration).</li> <li>• Experience and Interaction – ThingWorx Navigate. As intuitive as an average smartphone app, ThingWorx Navigate enables organizations to dramatically increase productivity and improve collaboration by simplifying data access.</li> </ul>	<p><b>AM Digital Hub</b></p>  <ul style="list-style-type: none"> <li>• Intelligent Capacity Management</li> <li>• Integration with Demand (MRO) and Deliver (Supply) Integration with Supply Chain Planning and DMSMS</li> <li>• Global Production Visibility</li> <li>• Timely Engineering Dispositions</li> <li>• OSSAE Risk Management</li> <li>• Configuration Management &amp; Enterprise Source of Truth Integrated with Program PLM</li> <li>• AR/VR Bill of Process &amp; Training</li> <li>• Integrated Material Sourcing</li> <li>• Automated Production Status</li> <li>• Automated IoT/IQI</li> <li>• Global Quality Visibility</li> <li>• Deployable Solution Stack</li> <li>• Equipment Health Management</li> </ul> <p></p>

## UHP SHAFT WATER BLASTER ROBOTIC SHROUD

**ROBERT BELL**

Portsmouth Naval Shipyard  
 robert.e.bell7.civ@us.navy.mil  
 +1.207.994.0472

The shafts which Portsmouth Naval Shipyard (PNS) overhauls are massive and must meet the highest SUBSAFE standards before being reinstalled shipboard. A submarine maintenance requirement includes removing a protective Glass Reinforced Plastic (GRP) covering from the shaft which is used to preserve the steel from the undersea environment. Ultra-High Pressure (UHP) water blasting is used in this process, reducing the need for abrasive blast, thus extending the shaft's lifecycle. Mechanics used to wield a 45-pound jetlance to remove the coating, sometimes for hours on end.

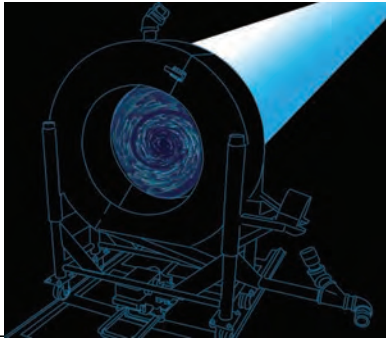
Embracing the NSS-SY goal of completing work ON TIME, EVERY TIME, a new process has been developed to increase the safety of the mechanic while simultaneously decreasing production time. A robotic UHP water blast shroud concept emerged during a Community of Practice event where PNS took the lead in getting the jetlance out of the mechanic's hands and removing them from hazard exposure.

PNS sought Office of Naval Research funding through the Institute for Manufacturing and Sustainment

Technologies hosted by Pennsylvania State University's Applied Research Laboratory (ARL). Personnel from ARL designed a robotic crawler which runs on a track the length of the shaft. The robot was designed to be capable of moving the metal shroud used to control the debris and excess water coming off the shaft during the overhaul process. The ARL equipment has adjustable speed and direction and multiple safety features such as a sensor to monitor the shaft as it rotates on a drive and idler. If the shaft stops turning, the flow of water is interrupted.

PNS personnel from several areas collaborated to design a shroud. The shroud surrounds a portion of the shaft and aims an internal UHP water jetlance a couple of inches away from the surface, while containing debris to mitigate clean up. The hydro demolition equipment obliterates all GRP materials from the surface. The shroud robotically moves along a track straddling the ARL bug crawler track and has a clamshell opening, telescopic legs to aid with placement and a coupling to connect an industrial wet vacuum recovery system hose to process the water and fiberglass hazmat.

ARL personnel provided equipment training and research and development oversight to the PNS mechanics as they worked on the initial shaft. The resulting first-time quality was impressive and reduced excess rework. Although some hand lance work will always be needed near the shaft ends, this equipment enabled a resource reduction from six to four personnel and reduced shifts from four to two. Together with savings from not enclosing the shaft entirely with Herculite and from reduced clean up time this resulted in saving nearly \$10,000 of taxpayer money and two days of critical path float in the schedule.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>A submarine maintenance requirement includes removing a protective Glass Reinforced Plastic (GRP) covering from the shaft which is used to preserve the steel from the undersea environment.</p> <p>Mechanics used to wield a 45-pound Jetlance for several hours to remove the coating by Ultra High Pressure (UHP) water blasting. This very labor intensive process risked close proximity to the UHP water hazard and fiberglass hazmat. Personnel were required to wear full body Tyvek coverings and double hearing protection as Personal Protective Equipment (PPE).</p>	<p style="text-align: center;"><b>BENEFITS</b></p> <p>Reduction of resources by 67% from six to four personnel and reduced shifts from four to two improved Operational Availability. Together with savings from not enclosing the shaft entirely with Herculite and from reduced clean-up time, this initiative resulted in saving nearly \$10,000 and two days in the Critical Path. Useable across any shipyard or shaft maintenance facility. Next step is to mount the system on an extended flatbed trailer for portability.</p> <p>Removes Jetlance out of mechanic's hands and removes them from hazards. Embraces the Naval Sustainment System – Shipyards goal of safely completing work on time, every time.</p>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <p>Pennsylvania State University's Applied Research Laboratory (ARL) designed a Robotic Crawler which runs on a track the length of the shaft and is capable of moving a metal Shroud designed and fabricated by Portsmouth Naval Shipyard. The clamshell opening Shroud with telescopic legs surrounds a portion of the shaft and is affixed with an internal UHP blaster for hydro-demolition removal of GRP. The system contains and removes the debris and excess water coming off the shaft with an industrial wet vacuum, has adjustable speed and direction, and a safety sensor to interrupt the water flow if the shaft stops turning as it rotates on a drive and idler.</p>	

# AUTONOMOUS LOGISTICS

## SARCOS SAPIEN 6M ROBOTIC ARM

TOMMY BROWN

Sarcos  
t.brown@sarcos.com  
+1.619.944.6953

Sarcos Technology and Robotics Corporation (NASDAQ: STRC and STRCW) and its wholly-owned subsidiaries, Sarcos Defense and RE2, are revolutionizing the workforce of the future across the private and public sectors through an advanced line of industrial robotic systems that augment human performance by combining human intelligence, instinct, and judgment with the strength, endurance, and precision of machines to enhance employee safety and productivity, enable remote operations and reduce operational costs. As a global leader in energetically autonomous, highly mobile, and dexterous robots, Sarcos delivers a compelling return on investment for a range of industries, including automotive, aviation, manufacturing, oil and gas, power generation, construction, logistics and materials handling, defense, public safety, infrastructure inspection, solar, medical, and subsea sectors.

The Sarcos Sapien Robotic Systems are one – or two-armed robots that mount on various surfaces, mobile and lift platforms, making them ideal for helping DoD sustainment teams tackle new build, maintenance, and decommission jobs in

the most extreme working conditions – whether at-height, in confined spaces, or working with heavy machinery. They can facilitate dexterous manipulation of tools and the completion of dangerous work, such as surface-prep (wet/dry blasting), welding, bolting/torquing, non-destructive testing inspections at-height, etc. The ultimate goal of introducing teleoperated and autonomous robotic technologies is to increase DoD sustainers' performance and efficiency without increasing the sustainment manpower requirement. Even more important, worker injuries, accidents, and long-term musculoskeletal stress are reduced. The combined benefits of augmenting the workforce, increasing worker safety, and expanding organic maintenance and repair capabilities will result in a more capable DoD sustainment capability that receives assets on-time, on-budget, and combat-ready.

The Sapien 6M intelligent manipulator offers speed, dexterity, precision, and strength in a compact, lightweight package. With six degrees of freedom, an optimized strength-to-weight ratio, embedded intelligence, and a sleek hardware design that can withstand

extreme temperatures and environmental conditions (IP66), the Sapien robotic arm can be used for a variety of complex outdoor and indoor applications. When human-in-the-loop control is required, the Sapien robotic arm can be integrated with the Imitative Controller.

### PROBLEM STATEMENT

Sarcos Robotics is revolutionizing the future of work across the private and public sectors through its advanced line of robotic products that augment, rather than replace, humans. By combining the intelligence, instinct, and judgment of humans with the strength, endurance, and precision of machines, the result is a workforce that is not only safer but significantly more productive. The Sarcos Sapien Robotic Systems are one - or two-armed robots that mount on various surfaces, mobile and lift platforms, making them ideal for helping DoD sustainment teams tackle new build, maintenance, and decommission jobs in the most extreme working conditions - whether at-height, in confined spaces, or working with heavy machinery. They can facilitate dexterous manipulation of tools and the completion of dangerous work/tasks, such as surface-prep (wet/dry blasting), welding, bolting/torquing, NDT inspections at-height, etc. The ultimate goal of introducing teleoperated and autonomous robotic technologies is to increase DoD sustainers' performance and efficiency without increasing the sustainment manpower requirement. Worker injuries, accidents, and long-term musculoskeletal stress are reduced.

### BENEFITS

- Optimized strength-to-weight ratio; powered with low-voltage DC
- Embedded computing and intelligence means no external control box required, minimizing footprint
- Low profile and hardened mechanical design is resilient to shock and vibration, indoors and outdoors
- Available with torque sensing and control at each joint
- Integrated power and communications for fast communication and easy integration with 3rd party tools and sensors (EtherCAT and Ethernet pass-through available)
- Rugged outer shell is tolerant to harsh environmental conditions, such as precipitation, condensation, and salt spray
- Capable of performing autonomous manipulation using Sarcos autonomy platforms

### TECHNOLOGY SOLUTION

The [Sapien 6M](#) intelligent manipulator offers speed, dexterity, precision, and strength in a compact, lightweight package. With six degrees of freedom, an optimized strength-to-weight ratio, embedded intelligence, and a sleek hardware design that can withstand extreme temperatures and environmental conditions (IP66), the Sapien robotic arm can be used for a variety of complex outdoor and indoor applications. It is compatible with Sarcos autonomy platforms, enabling autonomous mobile manipulation in structured environments, such as in a factory with controlled lighting, and in unstructured environments like outdoor construction sites. When human-in-the-loop control is required, the Sapien robotic arm can be integrated with the Imitative Controller.



- Left: Mobile Autonomous Aircraft Platform for Sustainment, dual 6M arm configuration; Right: 6M demonstrating surface preparation tasks at REPTX 22' on the Self Defense Test Ship

## CMD-IESR (COMMAND MAINTENANCE DASHBOARDS) – INTERACTIVE EQUIPMENT STATUS REPORTING

BRETT EKLUND AND DANIEL COOK

82nd ABN DIV (USA)  
 daniel.p.cook34.mil@army.mil  
 +1.913.530.8326

Predictive analysis and data-driven processes with quantifiable metrics exist in just about every fortune 500 company. Leveraging data as a resource and a tool can lead to many powerful insights about an organization as to what is working and what is not. It can help shed light on areas that may be bottlenecked or even help identify where resources could be better applied. Human capital and funding can arguably be the two most precious commodities the DoD has when it comes to executing its strategy. By having a better understanding of where and how our resources are being applied, we can potentially increase efficiencies within our processes yielding greater returns on our investment, which in our case is equipment readiness.


During the pandemic, the DoD made Microsoft Teams available as a collaboration platform. This platform now has a suite of integrated power applications available that allow the maintenance community to share maintenance data efficiently and effectively for the command to visualize the status of their fleets. Through one of these applications, Power BI, large sets of data can quickly be transformed into

easy-to-understand and visual interactable dashboards. These dashboards can then be auto-updated with a click of a button through a combination of Power Automate and the Army's data-rich analytics platform Vantage (a foundry-based platform). Utilizing this process, maintenance data can be updated within minutes and be finely tailored at any echelon. Maintenance managers at different echelons can use the same dataset and customize their views so commands at any level are able to visualize their fleets knowing exactly how they are impacting the organization they belong to. This process empowers commanders to be more engaged, have the right information at the right time, enabling them to make better data-driven decisions leading to an increased overall readiness posture.

Beginning in July of this year, a collaboration between HQDA G-46, 82nd Airborne Division, and the Nevada Army National Guard ensued to standardize this process for the maintenance community. The goal of this partnership is to streamline this process and bring it to the rest of the Enterprise. The standardization includes enhancing regular equipment readiness reports

like the Equipment Situation and Status Reports (ESR) for automated consumption. The automated process has already been implemented by numerous components of the 82nd Airborne Division and Nevada Army National Guard, which has already led to a reduction in the time required for preparation and publication of these reports by more than 65%. These automated publications include, but are not limited to:

- Division Pacer Reports
- Brigade Signal / Commanders Maintenance Dashboard
- Long Lead Time Part Predictive Analysis
- Fleet Forecasting
- DLA/Depot Critical Part Touchpoints
- Work Order to Purchase Order Crosswalk
- Recoverables

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>Predictive analysis and data-driven processes with quantifiable metrics exist in just about every fortune 500 company. Leveraging data as a resource and a tool can lead to many powerful insights about an organization as to what is working and what is not. It can help shed light on areas that may be bottlenecked or even help identify where resources could be better applied. Human capital and funding can arguably be the two most precious commodities the DoD has when it comes to executing its strategy. By having a better understanding of where and how our resources are being applied, we can potentially increase efficiencies within our processes yielding greater returns on our investment, which in our case is equipment readiness.</p>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Vastly reduced time spent on pulling and compiling reports; from hours to minutes.</li> <li>• Interactive visualized equipment readiness posture</li> <li>• Identify areas of improvement or efficiencies with ease via quantifiable metrics</li> <li>• Keeps commands in the "know" enabling them to make better data-driven decisions</li> <li>• Better oversight on resource management</li> <li>• Uses data to advance the National Defense Strategy</li> <li>• Cross COMPO and cross service accessibility</li> <li>• Aligns with the DoDs 7 data strategy goals aka "VAULTIS"</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>▪ Provides on the go insight for a multitude of maintenance related reports and issues. Commands at all levels can have real-time, or near real-time data wherever they are and/or whenever they want it. Rather than relying on static briefing report templates, answers to questions can be addressed on the spot by interacting with the visual dashboards. What gets measured gets managed, and what gets managed gets actioned. But what gives you interactive and visual dashboards, gives you a whole lot more insight on what is working and what isn't!</li> </ul>	<p style="text-align: center;"><b>EXAMPLE DASHBOARDS</b></p> 

# AUTONOMOUS LOGISTICS

## A.D.A.M.M. – THE NEXT REVOLUTION IN MAINTENANCE INFORMATION SYSTEMS

DANIEL FOURNIER

USAF

daniel.fournier@us.af.mil

+1.623.856.4489

Created by an end-user with feedback from over 100 technicians, the Administrative Data Analysis & Maintenance Matrix program, A.D.A.M.M. for short, is a relational database and Graphic User Interface (GUI) that enables high-resolution Tactical & Strategic decision capabilities from enhanced analysis across multiple dimensions of data points.

The F-35 Enterprise has proven its prowess as an advanced fighter jet, possibly the best the world has ever seen. Yet, its support equipment maintainers are equipped with a less than intuitive non-interlinked maintenance information system. The same degree of advancement seen in the aircraft should be reflective in its support systems. However, that is not the case. Maintainers, specifically support equipment maintainers, are faced with exporting Workload Reports from the Autonomic Logistics Information System (ALIS) to assess, and address the manner in which it prioritizes their ever-increasing workload. The ALIS maintenance information system lacks the necessary interrelated tools to sort, display, and present data for production decisions and analysis.

Data, when presented, or rather, represented correctly, enables us to make informed decisions that move us toward our goals. Too often, elements of data are overlooked; not because we choose to, but because we are unaware of its relation to other sources of information and how connecting the dots can lead to greater perspectives and deeper analysis of our decisions.

The inability to easily view, review, assess, and summarize an equipment fleet has forced users to view fumble with messy Excel spreadsheets that do not translate into a wholistic representation of all assets.

Before the production of the Administrative Data Analysis and Maintenance Matrix (A.D.A.M.M.) program, technicians would download what is called a Workload Report; a line-by-line spreadsheet of every discrepancy for each piece of support equipment. Currently, the Aerospace Ground Equipment team at Luke AFB maintains and tracks over 500 individual pieces of support equipment and on average is carrying over 1,100 active discrepancies from month to month. The high number of active discrepancies can be sourced to the

time-consuming process (weekly and often daily) of downloading the Workload Report and having to cull the entire list to determine priority work.

Leveraging the power of related data, the A.D.A.M.M. program enables its users to view its assets in a categorical sense. In other words, ADAMM presents information on each type of equipment with health status summaries, part acquisition information, and reporting information that reduces scrubbing and analysis time by nearly 100%.

A solution such as A.D.A.M.M. has proven itself to be a resource of unavoidable value. Its future is antifrangible.

### PROBLEM STATEMENT

The F-35 Enterprise has proven its prowess as an advanced fighter jet, possibly the best the world has ever seen. Yet, its support equipment maintainers are equipped with a less than intuitive non-interlinked maintenance information system. The same degree of advancement seen in the aircraft should be reflective in its support systems. However, that is not the case. Maintainers, specifically support equipment maintainers, are faced with exporting Work Load Reports from ALIS to assess and address the manner in which it prioritizes their ever-increasing workload. The ALIS maintenance information system lacks the necessary interrelated tools to sort, display, and present data for production decisions and analysis.

Data, when presented, or rather, represented correctly, enables us to make informed decisions that move us toward our goals. Too often, elements of data are overlooked; not because we choose to, but because we are unaware of its relation to other sources of information and how connecting the dots can lead to greater perspectives and deeper analysis of our decisions.

### BENEFITS

- Categorical data representation;
- Summary of Master Critical Equipment listing percentages & All Equipment Status stats;
- Rapid one-click email of MEL status to respective recipients;
- Interlinked with live Supply Liaison Requisition document for accurate report of parts;
- In-depth Work-In-Progress (WIP) task listings for Mx & Inspections
- Rapid Last 5 Movement data retrieval for SPUDS reporting;
- Individualized Reports for Technician work;
- ADAMM's future is Antifrangible;

Each element of ADAMM presents a function that is more intuitively presented to the user over ALIS' architecture. The entirety of A.D.A.M.M.'s existence is predicated on Theory of Constraint concepts. Its time saving functions have saved hundreds of hours thus far with many more as its functionality increases.

### TECHNOLOGY SOLUTION

Leveraging the power of related data, the A.D.A.M.M. program enables its users to view its assets in a categorical sense. In other words, A.D.A.M.M. presents information on each type of equipment with health status summaries, part acquisition information, and reporting information that reduces scrubbing and analysis time by nearly 100%. Real world test findings shows a reduction in data scrub time from 3 hours for a single task down to less than 10 seconds.





## CLOSED LOOP MOBILE APPLICATIONS (CLMA)

JASON HACKERSON


IR Technologies  
jason@ir-tech.com  
+1.571.221.1898

**Problem:** Many military maintenance facilities where maintenance, repair, and construction work is conducted lack a toolset common for private industry facilities. This tool is applications on mobile tablets (smartphones) to assist in conducting calculations, data capture, and automating manual processes. The primary drivers that restrict the usage of these devices are the camera and the ability for the device to access networks which raises vulnerabilities to insider threats. In some facilities, workers cannot enter the physical domain without having their personal devices' cameras taped over. This inhibits maintainer and their manager ability to take advantage of real time to near real time reporting of process actions and parts inventory and tool accountability. With the lack of these types of tools, military maintainers retain manual methods of operating fraught with handwriting and calculation errors and bulky and fragile paper ensuring that our military's complex industrial maintenance and repair facilities remain in inefficient paper-based environments slowing down overall repair cycle times.

**Approach:** IR Technologies proposes Closed Loop Mobile Applications. CLMAs foster the concept of treating smartphone sized tablets as tools for maintainers. Although the approach can support a Bring Your Own Device (BYOD) environment, we know that the military already procures and uses purpose-built devices that use RFID and Barcode scanning to support operations. Our approach provides applications that use these or similar devices where camera use is controlled, and network access is limited to approved physical ports by providing a means of data distribution that does not require a wireless network. CLMAs use specially designed Visual Codes to transmit and receive data. CLMA's provide the ability to record inspections and maintenance actions as well as provide the ability to support users' complex calculations. In a Closed Loop environment, workers check their tablets/devices in and out, like other tools at the beginning and end of shifts or workdays. Since these devices are network limited (either through physical switches or operating system passcodes) and physically controlled, the threat of

unauthorized pictures or data leaking from the devices is greatly reduced.

**Benefits:** The benefits of having digital tools are manifold. Data entry errors from handwriting and manual calculation are greatly reduced. Under the Closed Loop construct, data is only humanly handled once. Users have assurances that complex calculations are completed accurately and due to the unique method of data transfer, information is exchanged rapidly and correctly. Calculations can be doublechecked by another user on a separate device on the spot. Paperwork and process requirements decrease, and reporting speeds increase. This culminates in improved safety along with reduced maintenance and repair cycle times.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>Many military maintenance facilities where maintenance, repair, and construction work is conducted lack a toolset common in private industry facilities. This tool is applications on mobile tablets (smartphones) to assist in conducting calculations, data capture, and automating manual processes. The primary drivers that restrict the usage of these devices are the camera and the ability for the device to access networks which raises vulnerabilities to insider threats.</p> <p>These restrictions inhibit maintainer and manager ability to take advantage of real time to near real time reporting of process actions and parts inventory and tool accountability. With the lack of these types of tools, military maintainers retain manual and handwritten methods of operating ensuring that our military's complex industrial maintenance and repair facilities remain in inefficient paper environments slowing down overall repair cycle times.</p>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>Use inexpensive Android devices</li> <li>Portability captures data at the site of inspection/diagnosis/repair</li> <li>Simplifies complex calculations</li> <li>Cuts paper and manual data entry and associated handwriting errors.</li> <li>Focused on military requirements for data and secure transfer of data</li> <li>Updates based on standard processes to update Android/Mobile Applications</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <p>Our approach provides applications that use COTS devices where camera use is controlled, and network access limited to approved physical ports by providing a means of data distribution that does not require a network. CLMAs use specially designed Visual Codes to transmit and receive data. CLMA's provide the ability to record inspections and maintenance actions as well as provide the ability to support users' complex calculations. In a Closed Loop environment, workers check their tablets/devices in and out, in a manner similar to other tools at the beginning and end of shifts or workdays.</p> <ul style="list-style-type: none"> <li>Based on COTS Android systems with Physical and Logical controls for camera and network</li> <li>Secure transfer from mobile devices to enterprise systems without direct connection</li> <li>Easy to use UI designed for on site operations</li> </ul> <p>Unrestricted</p>	<p style="text-align: center;"><b>Example CLMA: Worklog</b></p> 

# AUTONOMOUS LOGISTICS

## SMALL TOOL INVENTORY & LOCATION TRACKING SYSTEM (STILTS)

GREG HUTSON

Andromeda Systems Incorporated  
 gregory.hutson@androsysinc.com  
 +1.757.775.3553

In dynamic DoD maintenance environments, exceptional tool control still alludes even the most disciplined units. Damaged equipment, aircraft returned from flight, ramp freezes, and countless maintenance man-hours searching for lost tools are all symptoms of inadequate tool control. While “smart” toolboxes have offered some progress, they are expensive, generally can’t be used outdoors, and don’t provide accountability once the tool is out of the box. What if a “Web of Accountability” could track tools within a hangar or designated flight line area?

Through precision integration of Real-time Location System (RTLS) technologies at the macro and micro levels, Andromeda Systems Incorporated (ASI) has created a Web of Accountability with the “Small Tool Inventory & Location Tracking System” (STILTS). Every tool is tracked from the toolbox to the point of maintenance and back. The RFID “lock” and Web of Accountability contain the story of a tool’s journey within ASI’s software, so maintainers are not left trying to recreate the day’s events to find a lost tool. “Who last had contact with the tool?”, and most importantly, “Where

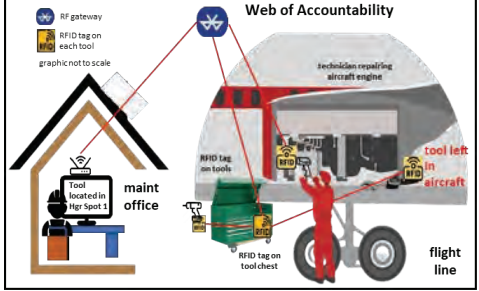
is it currently?”, are questions that will be readily answered with STILTS. Used more proactively, the real-time accountability of tools also helps leaders assess maintenance discipline throughout the day by allowing them to quickly evaluate adherence to tool control policies at a point in time. The rapid validation of tool control discipline, especially during shift changes, makes STILTS an invaluable management tool.

STILTS integrates existing technology, so the system is very stable and robust. Due to the rapid evolution of RFID technology, the open architecture within STILTS has allowed for easy adoption of even smaller, more powerful tags and antennas as well as the inclusion of other sensors. The components used in STILTS range from Technology Readiness Level (TRL) 7 to TRL 9 and the integration and accompanying software are currently assessed at TRL 6 to TRL 9. The current system has been tested in a laboratory setting (software tested/ used in field operations) and is ready to be tuned, tested, and further perfected in a dynamic maintenance setting. It is estimated that that it will take less than 90 days of

prototyping in an operational environment for the integration and software to reach full maturity for scaling purposes.

Following the challenge, ASI will work with potential customers to prototype the capability in a dynamic maintenance environment, preferably an aviation maintenance organization. Once proven for fielding, ASI will provide scaling options to meet customer requirements.

Improper tool control is one of the biggest detractors in DoD aviation maintenance and directly impacts readiness and zaps resources. ASI aims to help the DoD enhance tool control and put maintenance hours where they need to be...producing combat power.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>- In dynamic and fast-paced DoD maintenance environments, exceptional tool control still alludes even the most disciplined units</li> <li>- Damaged equipment, aircraft returned from flight, ramp freezes, and countless maintenance man-hours searching for lost tools are all symptoms of inadequate tool control</li> <li>- While “smart” toolboxes have offered some progress, they are expensive, can’t be used outdoors, and don’t provide accountability once the tool is out of the box</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>- Prevents Foreign Object Damage (FOD) due to lost tools</li> <li>- Increases warfighting readiness at the point of performance</li> <li>- Recaptures thousands of wasted man-hours spent searching for tools to DoD maintenance units across organizational, intermediate, and depot levels</li> <li>- Provides tool accountability outside the toolbox</li> <li>- Solutions can be applied to indoor or outdoor areas (i.e., hangar and flight line) and in deployed locations</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>- What if a “Web of Accountability” could track tools within a hangar or designated flight line area?</li> <li>- Each tool &amp; maintenance asset is tagged with inventory tracking technology to include RTLS (real time locating systems) beacons, UHF passive RFID tags, machine vision identifiers, and operational sensors all cohesively integrated into one backbone</li> <li>- All tools are tracked from the toolbox or tool room to the point of maintenance and back. The RFID “lock” and Web of Accountability contain the story of a tool’s journey within ASI’s OptiAM software suite</li> </ul>	 <p>Web of Accountability</p> <p>RF gateway</p> <p>RFID tag on each tool</p> <p>graphic not to scale</p> <p>maint office</p> <p>tool located in Hgr Spot 1</p> <p>technician repairing aircraft engine</p> <p>RFID tag on tools</p> <p>RFID tag on tool chest</p> <p>flight line</p> <p>tool left in aircraft</p> <p>Lost Tool Found @ Hgr Spot 1</p>

## LEVEL 5 AUTOMATED TOOL CONTROL (ATC)

ANDREW LOBO

Snap-on

Andrew.R.Lobo@snapon.com

+1.262.656.4702

Snap-on's Level5 ATC (Automatic Tool Control) significantly eases the burden of administering a tool and equipment control program by automatically recording the removal and replacement of tools and equipment from a toolbox or locker. Additionally, the availability and readiness of each tool or asset under management can be tracked and reported upon.

Utilizing innovative optical technology at its core, all transactions in an array of boxes and lockers can be summarized in reports automatically generated from the L5 Connect software. Snap-on Level5 ATC systems are installed in thousands of locations globally and across many industries, including defense, energy, civil and commercial aviation, state and local government and manufacturing. It is proven and has been upgraded with features added and expanded since its first installation in 2010. It is secure, with software developed within a NIST/RMF framework.

Thank you for considering Snap-on Level 5 ATC for the Maintenance Innovation Challenge.

### PROBLEM STATEMENT

Tools and equipment are required for nearly every maintenance task in virtually every corner of the DoD. If tools and equipment are not available at the time of the maintenance task, or are not accounted for following a maintenance task, missions are hindered. Sorties face the risk of foreign object damage (FOD), and the safety of our soldiers, sailors, airmen and marines can be compromised. Every year in DoD, there are dozens, possibly hundreds of FOD incidents. For example, Boeing estimates that FOD costs the aviation and defense industries \$4B annually. While the DoD has instructions in place to manage these risks, the task of managing a tool control program often fall upon skilled GIs or contractors, whose work could be used to support the mission, rather than the industrial hygiene – hundreds of thousands of manhours.

### BENEFITS

- Will help to comply with applicable tool control and FOD mitigation instructions and regulations for the military and defense contractors
- Moves the tool control point (often a tool crib) to the work being done – eliminating transportation waste and waiting
- Virtually eliminates lost tools and equipment
- Monitors calibration dates and validity dates for serialized measurement tools like calipers and torque wrenches
- Reduces manhours it takes to administer a control program
- Toolbox works at the speed of work – doesn't slow down the technician and works like a regular foam silhouetted box
- Tool and equipment loads are completely customizable
- Can manage very dense tool loads inside boxes, reducing the square footage it takes to manage a control program

### TECHNOLOGY SOLUTION

Level 5 ATC by Snap-on automates the process of checking in and checking out tools and equipment from a toolbox or a locker. The toolbox uses optical technology to read the contents of each drawer and creates a photographic record of each drawer's opening and closing. The lockers utilize passive RFID for tools and equipment which don't fit neatly in a toolbox. Each transaction in and out of a box or locker is traced to the individual who opened the box or locker. All the transactions in an array of boxes and lockers can be summarized in reports generated from the L5 Connect software. Tool loads in every box are placed in silhouetted foam and the tool and equipment loads in every box are fully configurable. While Snap-on tools are encouraged for the tool load, other brands can be easily managed as well.



# AUTONOMOUS LOGISTICS

## TOBYHANNA ARMY DEPOT COMMUNICATIONS SECURITY FORWARD REPAIR ACTIVITY VAN

**JAMES RILEY**

**CECOM ILSC**

james.d.riley52.civ@army.mil

+1.915.861.6158

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.

The Tobyhanna Army Depot (TYAD) COMSEC Forward Repair Activity (FRA) Van enhances the U.S Army Communications Security (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), which permits the Warfighter to have functioning equipment immediately instead of waiting for assets to arrive through standard supply channels. Additionally, the COMSEC FRA Van technicians can receive and repair COMSEC items promptly.

Since 2005, the TYAD COMSEC FRA Vans have DX'd or repaired over 23,000 COMSEC items in the operational theaters of Germany, Korea, Kuwait, and Afghanistan. The TYAD COMSEC FRA Vans ensure minimal downtime occurs during supply and maintenance actions allowing units to continue their mission and not risk enemy forces accessing sensitive communications.

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.

The mobile repair center contains a specialized depot data center for COMSEC supported by two qualified COMSEC electronic technicians, and has approved storage for cryptographic devices and classified support equipment, power, heating, cooling, and Local Area Network. Additionally, it has electrostatic repair and test benches capability.

The van is capable of deployment worldwide and has been deployed in desert, mountain, and temperate environments.

### 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



## DIGITAL TWINS FROM PAPER

ALEX SHAW

RedShred, LLC  
ashaw@redshred.com  
+1.513.910.3722

Legacy records and disconnected operations create an enormous workload that can slow down or even halt digital transformation initiatives. Teams need to ensure that historical data is available to accurately observe and forecast trends. Organizations may not want to invest the significant resources needed to manually convert their legacy data without a known return on investment.




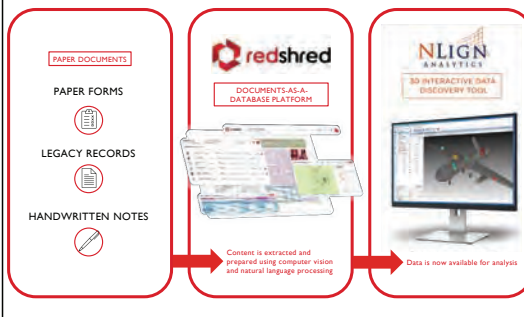
Together, RedShred and NLog Analytics can solve this challenge by combining RedShred's documents-as-a-database platform with NLog's suite of digital engineering tools. RedShred allows 2D PDF data to be quickly ingested into NLog's spatial database and fortify it as the single source of authoritative truth for digital engineering analysis. Both products are derived from SBIR-funded technology and are eligible for sole source procurement.

Both NLog and RedShred provide state-of-the-art solutions to their specific domains and combined, would provide a new capability that does not yet exist. In 2017, prior to the A-10 Aircraft Structural Integrity Program's adoption of NLog's software, only

17% of the inspection records were of good quality. After adoption in 2019, that number increased to 95% (Hazen Sedgwick, Defining and Developing the Digital Groundwork to Realize Tangible Tactical Advantages). NLog software was estimated to save \$325,000 - \$700,000 annually in the F/A-18 composite repair program (New Engineering Software Targets Composite Repair Process, FRCSW Almanac). Northrop Grumman estimated in 2016 that deployment of NLog Analytics' software would save 23% of inspector/quality assurance labor hours (John Crawford et. al., "Digital Thread for Material Review Board").

NLog is currently deployed and is at a Technology Readiness Level (TRL) of 9. RedShred is currently at a TRL of 6 but is scheduled to be at a TRL of 8 within the next six months. NLog currently has deployments at all Air Force ALCs, several Air Force field locations, NAVAIR fleet readiness centers, and at NAVSEA Surface Warfare Center Carderock. RedShred is currently working with the USAF Rapid Sustainment Office to automate the digitization of tech data for use in flightline modernization initiatives.

This project will build an integration between RedShred and NLog Analytics for a specific form relevant to an existing customer. This effort will take two months and will be deemed successful (and ready to scale) when the integration automatically digitizes documents to within the same standards that would be expected of a human performed conversion.

<p><b>PROBLEM STATEMENT</b></p> <p>Legacy records and disconnected operations can create an enormous digitization workload. Proven digital engineering tools need to ensure that all data is available to be able to accurately observe and forecast trends. Additionally, older programs need new solutions since manual data entry creates a massive barrier to entry.</p> 	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>Legacy programs can use the <b>latest digital engineering tools</b> and <b>access all their historical data without a prohibitively priced manual conversion effort.</b></li> <li>New paper records can be easily ingested without needing to devote personnel for data entry.</li> <li>Resolves a recurring challenge in <b>building a digital authoritative source of truth for existing platforms</b> - how to leverage existing paper or unstructured data</li> <li>More quickly deliver the benefits of NLog to legacy platforms such as:             <ul style="list-style-type: none"> <li>Improvements in data quality</li> <li>Accelerated maintenance processes</li> <li>Additional reuse of dispositions</li> </ul> </li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p>  <ul style="list-style-type: none"> <li>Our combined solution is to build an ingestion pipeline using <b>RedShred's</b> platform to <b>automatically create NLog records</b> from paper-based documents.</li> <li>RedShred provides database-like access to documents using computer vision and natural language processing to understand and decompose documents.</li> <li>NLog provides a 3D digital twin of aircraft to store maintenance records in a spatial database that is proven to accelerate analysis and is trusted across the Department of Defense.</li> <li><b>RedShred and NLog Analytics are both derived from SBIR funded projects and are eligible for sole-source acquisition</b></li> </ul> 	

# AUTONOMOUS LOGISTICS

## INTEGRATING 3D VIZ AND SMART FACTORY CAPABILITIES TO OPTIMIZE REFITS

VINCENT STAMPER

NAVSEA, Trident Refit Facility Bangor (TRFB)  
vincent.c.stamper1@navy.mil  
+1.360.340.27818

**Problem:** Trident Refits provides rapid incremental maintenance to maximize operational availability of Trident submarines supporting the strategic deterrence mission. As the Navy transitions to Columbia class, it is essential to optimize maintenance, by maximizing insight from Ohio to drive efficiency through the Columbia lifecycle.

**Description:** Integrate ‘smart factory’ capabilities developed for industry, with Navy’s existing 3D visualization and collaboration capabilities, to improve cycle time and reduce constraints at Trident Refit Facility Bangor (TRFB). Combining these capabilities will enable: Autonomous monitoring of the maintenance, self-adaption to learn from new conditions, and dynamic identification of improvement opportunities. Specifically, TRFB will install additional sensors to monitor progress across the refit process against planned activities in the 3D visualization. This data will be integrated into a single model to enable deployment of optimization algorithms. The “training” of these algorithms will be accelerated by leveraging industry models. These models will in turn be used, for regional maintenance centers, and scale for

larger maintenance efforts such as fleet availabilities at public shipyards.

**Development:** TRFB has partnered with NAVSEA, NAVFAC, NCMS, and Synergy360 to scan and deploy 3D visualizations in NAVFAC’s SPIDERS 3D tool. SPIDERS3D is approved for use on the Navy Marine Corp Intranet meeting DOD cybersecurity standards, and is migrating to a Navy Azure Cloud, which will enable rapid scalability. TRF will integrate this tool with Smart Factory solutions developed by Deloitte that have demonstrated results.

**Supporting:** The SPIDERS 3D tool has already reduced planning and decision-making time for the Naval Enterprise. For smart factory solutions, Deloitte used the approach proposed by TRFB to help Spirit Aerospace deploy a cloud-based production control application that synchronized shop floor with smart devices and predictive machine learning analytics. This solution led to a 15-20% work-in-process (WIP) reduction, 5-10% throughput increase, and 10-20% labor cost reduction, all within Spirit’s WW2 era facility.

**Next Steps:** Pilot first 100 hours in the drydock work start plan, using asset tracking sensors (RFID, LIDAR, heat sensors, etc.) feeding streaming sensor data, historic data, and updated 3D scans into one integrated physical/digital data model. This will provide remote job sites monitoring. Analyze results, during subsequent dry-docking refits (~four/year), and aggregate with historical data. Develop descriptive and predictive analytics (regression, machine learning, AI) to identify bottlenecks, critical path dependencies, and other key production metrics.

**Benefits:** Accelerate refit schedules by at least one day per cycle, with target of one week reduction. Apply lessons learned from Ohio to reduce maintenance costs for Columbia program, test optimization approaches, and integrate with fleet maintenance to realize comparable schedule acceleration.

<p><b>PROBLEM STATEMENT</b></p> <p>Trident Refits provides rapid incremental maintenance to maximize operational availability of Trident submarines supporting the strategic deterrence mission. As the Navy transitions to Columbia class, it is essential that the Navy optimizes maintenance, by maximizing insight from Ohio to drive efficiency through the lifecycle of Columbia program. As part of overall Shipyard optimization and condition-based maintenance efforts, Navy seeks to incorporate 4th industrial revolution (4IR) ‘smart factory’ capabilities developed for the manufacturing industry to improve ship availabilities and overall readiness.</p>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Enables 3D visualization and reporting for each step of the refit process</li> <li>• Improves refit cycle time by identifying bottlenecks</li> <li>• Allows new process changes to be implemented in one cycle, then autonomously monitored and assessed for impact on a future refit cycle</li> <li>• Drives down manpower needs for TRF maintenance by reducing clipboard time and increasing wrench time</li> <li>• Lowers cost savings due to shorter cycle time with fewer resources</li> <li>• Improves readiness by decreasing time in port</li> <li>• Provides reusable models to accelerate algorithm training for similar condition-based maintenance optimization efforts at shipyards, logistics centers, or depots</li> </ul>				
<p><b>TECHNOLOGY SOLUTION</b></p> <p>By combining smart factory with Navy’s ashore 3D modeling and visualization capabilities, will enable:</p> <ol style="list-style-type: none"> <li>1. Autonomous monitoring of the maintenance cycle</li> <li>2. Self-adaption to learn from new conditions</li> <li>3. Dynamic identification of improvement opportunities.</li> </ol> <p>Specifically, TRF Bangor will install additional sensors to monitor progress across the refit process against planned activities in the 3D model. This data will be integrated into a single model to enable data mining and deployment of optimization algorithms. The “training” of these algorithms will be accelerated by leveraging existing models from industry. These models will in turn be used, for regional maintenance centers, and scaled up for larger maintenance efforts such as fleet availabilities at public shipyards.</p>	<p><b>Manufacturing companies embracing Smart Factory approaches have seen...</b></p> <table border="0"> <tr> <td style="vertical-align: top;"> <p><b>20%</b> Improved Asset Efficiency</p> <ul style="list-style-type: none"> <li>⬆ Optimized capacity</li> <li>⬆ Asset utilization</li> <li>⬆ Changeover time</li> <li>⬆ Downtime</li> </ul> </td> <td style="vertical-align: top;"> <p><b>30%</b> Improved Product Quality</p> <ul style="list-style-type: none"> <li>⬇ Scrap rates</li> <li>⬆ Fill rate</li> <li>⬆ Yield</li> <li>⬇ Lead times</li> </ul> </td> </tr> <tr> <td style="vertical-align: top;"> <p><b>30%</b> Reduced Costs</p> <ul style="list-style-type: none"> <li>⬇ Labor costs</li> <li>⬇ Sourcing Costs</li> <li>⬇ Inventory Levels</li> <li>⬇ Maintenance Costs</li> </ul> </td> <td style="vertical-align: top;"> <p><b>10%</b> Improved Safety/Sustainability</p> <ul style="list-style-type: none"> <li>⬇ Safety Incidents</li> <li>⬆ Worker Satisfaction</li> <li>⬆ Sustainable Practices</li> <li>⬇ Environmental Impact</li> </ul> </td> </tr> </table> <p><a href="https://www2.deloitte.com/us/en/pages/consulting/solutions/the-smart-factory.html">https://www2.deloitte.com/us/en/pages/consulting/solutions/the-smart-factory.html</a></p>	<p><b>20%</b> Improved Asset Efficiency</p> <ul style="list-style-type: none"> <li>⬆ Optimized capacity</li> <li>⬆ Asset utilization</li> <li>⬆ Changeover time</li> <li>⬆ Downtime</li> </ul>	<p><b>30%</b> Improved Product Quality</p> <ul style="list-style-type: none"> <li>⬇ Scrap rates</li> <li>⬆ Fill rate</li> <li>⬆ Yield</li> <li>⬇ Lead times</li> </ul>	<p><b>30%</b> Reduced Costs</p> <ul style="list-style-type: none"> <li>⬇ Labor costs</li> <li>⬇ Sourcing Costs</li> <li>⬇ Inventory Levels</li> <li>⬇ Maintenance Costs</li> </ul>	<p><b>10%</b> Improved Safety/Sustainability</p> <ul style="list-style-type: none"> <li>⬇ Safety Incidents</li> <li>⬆ Worker Satisfaction</li> <li>⬆ Sustainable Practices</li> <li>⬇ Environmental Impact</li> </ul>
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## NEXT GENERATION DEPOT MODERNIZATION

**ABIGAIL DENBURG**

The Boeing Company  
 abigail.denburg@boeing.com  
 +1.70. 203.8675

Depots play an essential role in fleet readiness. According to a recent Government Accountability Office report, the US needs to take action to improve depot efficiency and reduce cost. Depot operations are typically slowed by unplanned work, which drives additional engineering analysis and requirement for parts not kitted or readily available.

Boeing's digital analytics applied to a digital twin medical record of the aircraft (a/c) can vastly improve depot operations by identifying those additional needs and leveraging the data continuously throughout the depot visit.


Boeing has shifted the way we do depot work to transform the customer experience. In pre-induction, our configuration manager tool aggregates multiple sources of a/c history, condition, and configuration for one common view to improve awareness of needs in planning. All non-conformance reports (NCRs) are visualized and interrogated against a hierarchical model of the platform. Predictive analytics provide insight on the incoming condition, enabling early material acquisition and prep of

engineering resources needed to resolve the anticipated condition, thus reducing throughput risk. At induction, autonomous a/c inspection is used to identify cracks and external corrosion to increase speed and accuracy. By roll-in, a/c are well positioned for successful throughput because parts are pre-positioned based on predicted needs. The data is interrogated by floor supervision to shape the best outcomes given the unique a/c condition. During maintenance (mx) and mod, a learning system of past mx data is used to enable artisans to be as effective as possible. That set of actions is fed into a workflow optimizer to add speed and decrease labor costs. The process then prioritizes a/c based on workable jobs, NCRs, and parts. Artisans are able to use AR/VR reach-back technology to help accelerate the engineering communication process. Upon return to the customer, all of the activity and configuration changes are updated in the customer's source system to ensure the fleet has the latest information to continuously learn.

Our mid-to-high TRL tools are implemented across F/A-18, F-15 EPAWSS and C-17.

At Cecil Field, we avoided post-induction scope creep that would have resulted in 43% increased work. Our analytics pilot at McGuire AFB has yielded a 12% reduction in unscheduled mx while saving 1,192 mx man hours, and 1,494 NMC hours.

Boeing can support DoD plans to upgrade the industrial base in multiple innovative ways. Boeing is focused on partnerships to enable organic capability while leveraging our expertise, processes, and tools. Next generation depot modernization offers access to a suite of capabilities that optimize scheduling and mx, bringing savings that could fund future mods. We can help DoD depots be more efficient, affordable, and predictable while working to improve the demand signal. We are not just enhancing readiness but also using data to plan for a contested environment.

<p><b>PROBLEM STATEMENT</b></p> <p>Depots play an essential role in sustaining readiness by completing maintenance on time and returning refurbished equipment to the warfighter. According to recent Government Accountability Office (GAO) reports, the U.S. Services need to take actions to improve the conditions of their depots because they impact maintenance timeliness and efficiency. The declining performance over the last ten years at most depots reduced the availability of weapons systems for training and operations. As we look to looming threats across our various Combatant Commands, it is imperative that depot not hamper our readiness for the future fight.</p>	<p><b>BENEFITS</b></p> <p>Seamlessly integrated, scalable and secure</p> <ul style="list-style-type: none"> <li>• Reduce unplanned work</li> <li>• Maximize supply chain efficiency</li> <li>• Inform maintainers</li> <li>• Manage process flow</li> <li>• Lower O&amp;S costs following depot</li> <li>• Increase force readiness by minimizing time in depot</li> <li>• Offering predictability to leadership</li> <li>• Prepare fleet for contested environment sustainment</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p><i>A suite of digital capabilities to enable more efficient depot</i></p> <p>Pre induction:</p> <ul style="list-style-type: none"> <li>• Configuration Manager: aggregates aircraft history, condition and configuration data to improve depot/mod planning</li> <li>• Damage/Corrosion Mapper: collects damage reports that can then be actioned using compliant maintenance processes</li> <li>• By Tail Predictions: enables advanced planning, reduces throughput risk, and offers a heat map with data of predictions</li> </ul> <p>Induction:</p> <ul style="list-style-type: none"> <li>• Autonomous Aircraft Inspection: identifies cracks, increases speed of inspection, and is extremely mobile and adaptable</li> </ul> <p>Roll in, Maintenance and Roll out</p> <ul style="list-style-type: none"> <li>• Optimizer: sequences work flow and decreases labor and costs</li> </ul> <p>Delivery and Fleet</p> <ul style="list-style-type: none"> <li>• Dispatch: prioritizes which aircraft to induct and how to deliver back to fleet to maximize readiness</li> </ul>	

## STARLINK-POWERED 5TH-GEN AIRCRAFT

CASSANDRA HERMAN

748 Aircraft Maintenance Squadron (USAF)  
 cassandra.herman@us.af.mil  
 + 44 163852 6226

F-35 operations are dependent on a connection to the Autonomic Logistics Information System (ALIS) for mission planning, supply chain management, and maintenance. To access ALIS, an internet connection is required to the ALIS server, the Standard Operating Unit (SOU). To access ALIS from a deployed location, you must either deploy the SOU or utilize a Dynamic Multipoint Virtual Private Network (DM-VPN) over a secure connection to “tunnel back” to the SOU. However, both require a high-bandwidth internet connection. Many countries do not have the bandwidth infrastructure to obtain a connection reliable enough to transmit F-35 flight data to the SOU. Additionally, portable Wi-Fi pucks manufactured in certain countries are not suitable for F-35 operations.

Starlink coverage provides greater bandwidth than military SATCOM or a commercial ISP. Starlink internet transfer speeds meet the F-35 SOU requirements. The 48th Fighter Wing at RAF Lakenheath is using Starlink for F-35 deployments as Starlink coverage is broadening globally.

One of the greatest benefits of Starlink is that it provides more agility due to portability. When the 495th Fighter Squadron was tasked to deploy with a 48-hour notice, the unit was required to scale the equipment footprint down due to minimal available airlift. Therefore, SOU deployment was not feasible. To tunnel back to the home-based server, high bandwidth is necessary for stable data synchronization, especially in a deployed environment. Starlink enabled a secure tunnel-back connection with a DM-VPN for the duration of the movement.


Another benefit of using Starlink for deployed F-35 operations is the ability to connect to a deployed SOU. The 495th Fighter Squadron deployed the SOU to Greece in July 2022. However, Combat Communication capability was unavailable. The use of Starlink powered and connected the SOU to sustain flying operations for two weeks and transmit flight data for 84 sorties.

Using Starlink, whether the SOU is deployed or at home station, requires minimal setup. The small size and easy setup enables more agile movements

and reduces the manpower and logistics footprint. Combat Communication Squadrons are in high demand and are limited by available personnel and equipment to perform the mission.

If using Starlink for tunnel-back, the unit can use a faster and more stable process than burning DVDs and transferring data between sites. Using a direct connection to the home base server reduces F-35 maintenance and flight data synchronization time from 8 hours to 36 minutes. On the 495th Fighter Squadron’s short-notice deployment, it took 20 minutes to pull data from the Portable Memory Device (PMD) and zip the files plus 16 minutes to transfer. Maintainers were also able to access ALIS via DM-VPN on personal NIPR laptops.

The Joint Strike Fighter is utilized by three services and multiple partner nations. This process can enable the agility, connectivity, and lethality of all F-35 users.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Sustained F-35 operations require an ALIS connection to support mission planning and maintenance</li> <li>• ALIS connection is achieved through an internet connection to the Standard Operating Unit (SOU)</li> <li>• High bandwidth is vital for F-35 communication, operations and SOU tunnel-back capabilities</li> <li>• Many countries don’t have the bandwidth infrastructure to gain reliable internet access</li> <li>• Portable Wi-Fi pucks have potential for compromised parts</li> <li>• Combat Communication Squadrons are in high demand, have long lead times, and are limited by number of personnel to perform their mission</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Provides deployment connection options:                         <ul style="list-style-type: none"> <li>• Connect deployed SOU without Combat Communication support</li> <li>• Tunnel-back to home base SOU via Starlink</li> </ul> </li> <li>• Allows for a stable and faster process via a direct connection to home base ALIS server vs. older process of burning DVDs and transferring data between sites</li> <li>• Reduces F-35 MX/flight data sync time from the 8 hours to 36 minutes                         <ul style="list-style-type: none"> <li>• A recent test took 20 mins to pull data from the PMDs/zip the files, followed by 16 mins to transfer the information to the server</li> </ul> </li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• ALIS can be accessed off-station via a Dynamic Multipoint Virtual Private Network (DM-VPN) to the home-based SOU over a Starlink internet connection</li> <li>• Starlink:                         <ul style="list-style-type: none"> <li>• Provides quick and reliable connection to either connect deployed SOU or tunnel back to home base network</li> <li>• Not reliant on local country ISP/infrastructure</li> <li>• Small size allows easy transport and is accessible for Agile Combat Employment (ACE)                                 <ul style="list-style-type: none"> <li>• &gt;1 hour set up time</li> </ul> </li> <li>• Internet transfer speed meets server requirements</li> </ul> </li> </ul>	



## DIGITAL TWIN FOR MRO OPTIMIZATION

GREG HUTSON

Andromeda Systems Incorporated  
 gregory.hutson@androsysinc.com  
 +1.757.775.3553

Examining repair processes within MRO&U operations is a tedious and exhausting chore that can include everyone from senior commanders to line technicians. These stakeholders work diligently to recreate a factory floor in their conference room discussions to address constraints. These processes are documented, mapped, recorded, or photographed on dry erase boards and brought back out, when necessary, as part of the DoD's continuous improvement environment. While minor tweaks can occur to ongoing operations, there is often great difficulty in developing "what if" scenarios should there be a change to workload demand and/or resources.

Not unlike the assets they maintain, repair, overhaul, or upgrade, production lines can also be modeled as digital twins within 2-dimensional (2D) or 3-dimensional (3D) configurations. Andromeda Systems Incorporated (ASI) has uniquely combined technologies to do this. The technology includes an enterprise model that synergizes advanced computing capabilities, operations research techniques, and modeling and simulation (M&S) tools to optimize resourcing strategies and business practices as well

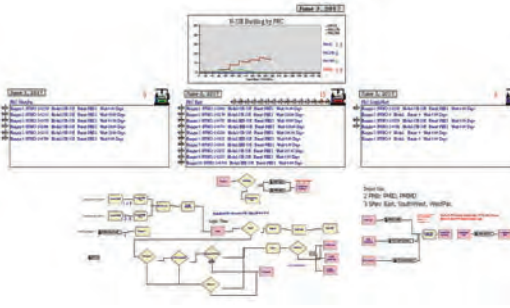
as maximize throughput and availability. A key enabler of the MRO&U digital twin is ASI's state-of-the-art Process Capture Methodology (PCM). The PCM ensures that all resources as well as any production idiosyncrasies are effectively harnessed for proper modeling.

ASI's research indicates that most DoD MRO&U lines can benefit significantly from a 2D digital twin model. The technology readiness level (TRL) for this capability is at a TRL 9 and has been operationally employed to provide an unprecedented view of resource utilization. In multiple simulations covering a decade-long period, resource utilization/readiness scenarios increased over 20% on average over the baseline planning for the H-1 upgrade program. In cases where greater fidelity is required, i.e., heavy industrial manufacturing, a 3-dimensional model might prove to be more advantageous. In this instance, models are currently in development. While the 3D software is at a TRL 9, the application in a production setting is currently at TRL 6.

The MRO&U digital twin is a decision support and analysis tool that provides a

holistic view of how all the sites can manage their current maintenance and production workloads. Key metrics are collected including throughput, Turnaround Time (TaT), resource utilization/availability, and backlog. Future workloads can be evaluated, and scenarios can be analyzed to determine their impact. Benefits to all the services throughout the DoD include:

- Reallocating of resources (personnel, machinery, tools) to fill gaps in some locations and relieve excesses in other locations
- Prioritization of components/assets to meet the warfighter's needs
- Evaluating the ability to meet an increase in demand (surge) across the various sites
- Prioritization of Continuous Process Improvement efforts to reduce TAT and increase

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>- Accurate assessments of capabilities and capacities within a single DoD repair location can prove elusive, especially across product lines. Add in multiple repair levels (i.e., organizational, intermediate, and depot) as well as other locations and a credible analysis of capabilities and capacities becomes almost insurmountable</li> <li>- While great gains have been made within the DoD repair organizations to initially identify production constraints, it is often a noniterative and very time-consuming process</li> </ul>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>- Digitization of maintenance, repair, overhaul, and upgrade processes across multiple activities and locations allows leaders to optimize activities and understand limitations of capabilities and capacity</li> <li>- Quickly quantifies and supports objective enterprise-wide resourcing decisions</li> <li>- Modeling and simulation attributes of repair digital twin allow system of record to be rapidly manipulated to support extensive "what if" scenarios for decision makers</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>- ASI has developed an asymmetric advantage with its unique Process Capture Methodology (PCM) to create a digital twin of repair lines (e.g., component overhaul, asset modification, inspections)</li> <li>- PCM is used to accurately assess resources (personnel (available hours/skill sets), support equipment, etc.) in repair lines at respective locations</li> <li>- Resources are then modeled and programmed with appropriate attributes in either 2D or 3D environment (depending on required specificity) to create a digital twin simulation that can be easily employed</li> </ul>	 <p>The screenshot displays a software interface for a digital twin simulation. At the top, there is a line graph titled '10:08 Predicting to PCM' showing a rising trend. Below the graph are several data tables with columns for various parameters. At the bottom, a complex flowchart or process map is visible, illustrating the relationships between different components and resources within the simulation.</p>

## AURORA INTELLIGENT SCHEDULING FOR INCREASED MAINTENANCE THROUGHPUT

ROBERT RICHARDS, PH.D.

Stottler Henke Associates, Inc. (SHAI)  
Richards@StottlerHenke.com  
+1.650.931.2715

Stottler Henke has studied human expert schedulers making scheduling decisions in critical applications for 25+ years and has implemented these decision-making processes in the world's most intelligent scheduling software, Aurora. Aurora has been applied to a wide variety of domains, demonstrating its generality, and Aurora has always been shown to generate more optimal schedules in every domain where a comparison has been performed. Most of these comparisons were made by the clients themselves in order to pick the tool that performed best. In the case of Boeing, after they performed a worldwide search for applicable scheduling tools, Aurora beat all competitors, including Boeing's own internally developed software, which had been specifically optimized for aircraft manufacturing scheduling. The use of Aurora for scheduling has typically meant that 10% to 25%+ more tasks can be accomplished with the same resources in the same amount of time (or the same tasks accomplished in 10% to 25%+ less time) compared to other scheduling methods.

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

Boeing selected Aurora initially for the final assembly scheduling of the Dreamliner 787 aircraft due to its superior resource-constrained scheduling and is now used on both the commercial and defense side of their business. Boeing was kind enough to provide a subset of real data that Stottler Henke is permitted to share. Even though this subset is much simpler than the actual project, it still reveals the significant difference between the scheduling results. The results of scheduling this Boeing resource-loaded file with different software are as follows:

Primavera P6 115 days

Aurora 102 days

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

Aurora is best leveraged when integrated with other enterprise applications. So, the next step is to integrate Aurora with other DoD data sources for seamless data flow, so that the DoD can receive all the benefits of Aurora, including but not limited to the following: 1) Multiple-pass intelligent resource-constrained scheduling; 2) Large multi-project support; support for 100,000+ tasks per project; 3) Mixed-mode scheduling -- providing both ASAP and ALAP scheduling; 4) Schedule rationale -- Aurora provides an explanation for each task on why it was scheduled where it was scheduled; 5) Support for more types of constraints than other software.

**PROBLEM STATEMENT**

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

**BENEFITS**

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

**TECHNOLOGY SOLUTION**

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

Designed for Customization  
Complex Constraint Support  
Forward & Backward Scheduling  
Schedule Rationale  
Increased throughput

## NAVY REPAIR TECHNOLOGY EXERCISE (REPTX) 2022

SUSAN SIMMS

NUWC KEYPORT/NAVSEA 05T  
 susan.l.simms.civ@us.navy.mil  
 +1.360.340.5971

From August 22 to September 2, 2022, NAVSEA 05T sponsored the first ever 2022 Repair Technology Exercise (REPTX) event, hosted by NSWC Port Hueneme and conducted aboard the ex-US Paul F. Foster, DD 964, the Self Defense Test Ship (SDTS). During this event, participants were able to apply multiple cutting-edge technologies in real-world scenarios on a working naval asset, engaging with fleet personnel for immediate impact and input. This REPTX team brought a unique technology transfer and engagement opportunity to 68 organizations that included academia, government, and industry partners.

The result of this extraordinary event was the rapid identification of several technologies that are ready for immediate transfer to the fleet to support forward-deployed maintenance and repair.

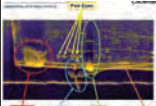
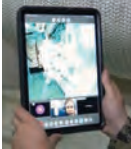


Technologies include the use of robotics, both pier side and at sea, in air and below water drone systems, additive manufacturing, 3D scanning, laser and plasma ablation, cold spray repair, and many, many more. Feedback received from industry participants was overwhelmingly

positive, specifically citing the ability to field their technology in a live environment. This engagement allowed for real time adjustments to technologies in order to better meet the needs of the Navy. Collaboration between participants was crucial to the success of REPTX. As stated by an industry participant: “unique to REPTX, was the spirit of cooperation among the companies attending the event. Participants actively sought out each other’s capabilities, where complimentary, and incorporated them into a variety of scenarios. Many partnerships were forged, and the teamwork and camaraderie among the participants, encouraged by the leadership of NAVSEA and NCMS, were evident throughout the event. Spontaneous cooperation among companies, some even competitors, is not something I have ever witnessed at the scale I saw at REPTX.”

While not all technologies are ready for immediate implementation and tech transfer, the testing phase of many of these technologies allows for further development. Several technologies were identified as ready to be fielded and the transfer of those technologies is underway, utilizing

pre-staged funding to support a host of technologies such as the utilization of remote connectivity that provided a mechanism for inexperienced personnel to solve problems with confidence and effectiveness. This damage control scenario that was viewed “live” in Washington DC, Pennsylvania, and Mississippi simultaneously with enough fidelity for comments from all participants.

REPTX was a groundbreaking event that is being viewed by other DoD components as a benchmark of how we can improve the pace of technology transfer. The REPTX event planned and executed in just six months, included five days pier side and three days underway to allow for the fielding of over 68 technologies using over 35 Battle Damage Assessment and Repair (BDA/R) scenarios that were developed in cooperation with the fleet.

<p><b>Objective:</b> REPTX addresses identified fleet inspired expeditionary maintenance problems through technology-based solutions</p> <p><b>Approach/Solution:</b></p> <ul style="list-style-type: none"> <li>Allowed partner stakeholders to evaluate current state and potential effectiveness of technology-based solutions</li> <li>Real-world scenarios provided teams the chance to field, adjust, learn, and repeat technologies both pier side, underway and in forward locations.</li> <li>Provides an experiential learning environment across the organic and defense industrial base to understand how to respond to the unexpected in untraditional locales.</li> </ul> <p><b>Benefit:</b></p> <ul style="list-style-type: none"> <li>Rapid assessment and fielding of technology-based solutions at the speed of the need.</li> <li>Define technology gap areas to target future investment.</li> </ul>	<p><b>Technologies:</b></p> <ul style="list-style-type: none"> <li>68 unique industry/academia/gov partners working towards common goals and creating unique solutions to address Navy needs.</li> <li>Demonstrations in 4 key areas:             <ol style="list-style-type: none"> <li>Visualization</li> <li>Command and Control Aids (C2)</li> <li>Forward Manufacturing</li> <li>Expeditionary Maintenance</li> </ol> </li> </ul> <p><b>Execution:</b></p> <ul style="list-style-type: none"> <li>2-week test period executed in Aug-Sept in-port and underway with fleet maintainers as testers onboard the ex-US Paul F. Foster, DD 964, Self Defense Test Ship.</li> <li>Current engagement up to CNO levels to prioritize investments.</li> <li>Investment protocols pre-staged to ensure rapid investment and implementation.</li> <li>Performed iterative repairs to restore operational capability.</li> </ul>
<p><b>Impact to the fleet:</b> Assessment of the operational relevance and impact technology-based solutions offer for inspection, maintenance, and repairs including:</p> <ul style="list-style-type: none"> <li>Unmanned aerial ground, and subsurface vehicles</li> <li>Forward and expeditionary manufacturing at point of need</li> <li>In-situ repair capabilities such as cold spray, robotics, plasma</li> <li>Rapid visualization, modeling and reporting</li> </ul> <p><b>Impact to industry:</b></p> <ul style="list-style-type: none"> <li>Ready to field, real-world learning, vector for aligning technology to Navy use cases.</li> </ul> <p><b>Wins to technology transfer:</b></p> <ul style="list-style-type: none"> <li>UAV and UUV drones, advanced manufacturing equipment, remote connectivity equipment and software, magnets, Fastorq™ tools, cable pullers, digital planning and maintenance aid, robotic platforms demonstrated at REPTX currently on contract for further fielding exercises to define equipment needs and standardize training.</li> </ul>	<div style="display: flex; flex-wrap: wrap;"> <div style="width: 50%;">  <p>Sonar Scan from an autonomous UUV clearly and quickly identifies hull conditions</p> </div> <div style="width: 50%;">  <p>SurgeMain sailors utilized technology to remotely communicate with vendors to develop specifications to build a part</p> </div> <div style="width: 50%;">  <p>Nearly all robotic bases became platforms to automate other technology solutions</p> </div> <div style="width: 50%;">  <p>SurgeMain sailor used plasma technology to remove corrosion</p> </div> </div>

## NOVEL SUPPLY CHAIN PROCESS FOR MEDICAL DEVICE REPAIR PARTS

CHRIS YERGER

Fort Defiance Industries, LLC  
 cyerger@fortdefianceind.com  
 +1.865.406.6348

For field deployed medical devices, the Defense Health Agency (DHA) does not have an agile, effective, efficient, and affordable process for procuring repair parts in support of combat readiness. This is a significant issue for all service branches as it places our warfighters at tremendous risk of not being able to receive effective combat casualty care due to critical medical devices being out of service. DLA's medical device Electronic CATalogue (ECAT) is affordable (3.2% cost recovery fee), but the system is not flexible or comprehensive enough for the dynamic nature of the repair parts supply chain. Unfortunately, logisticians must make time-consuming phone calls to difficult-to-reach medical device original equipment manufacturers (OEMs), (often foreign owned), wait on quotes, and purchase with Government Purchase Cards (GPCs). With each service buying repair parts in various ways, tremendous opportunity is lost for cost reduction, data management, and reliability improvements.

Fort Defiance Industries (FDI) proposes to configure our award-winning cloud-based Enterprise Resource Planning system

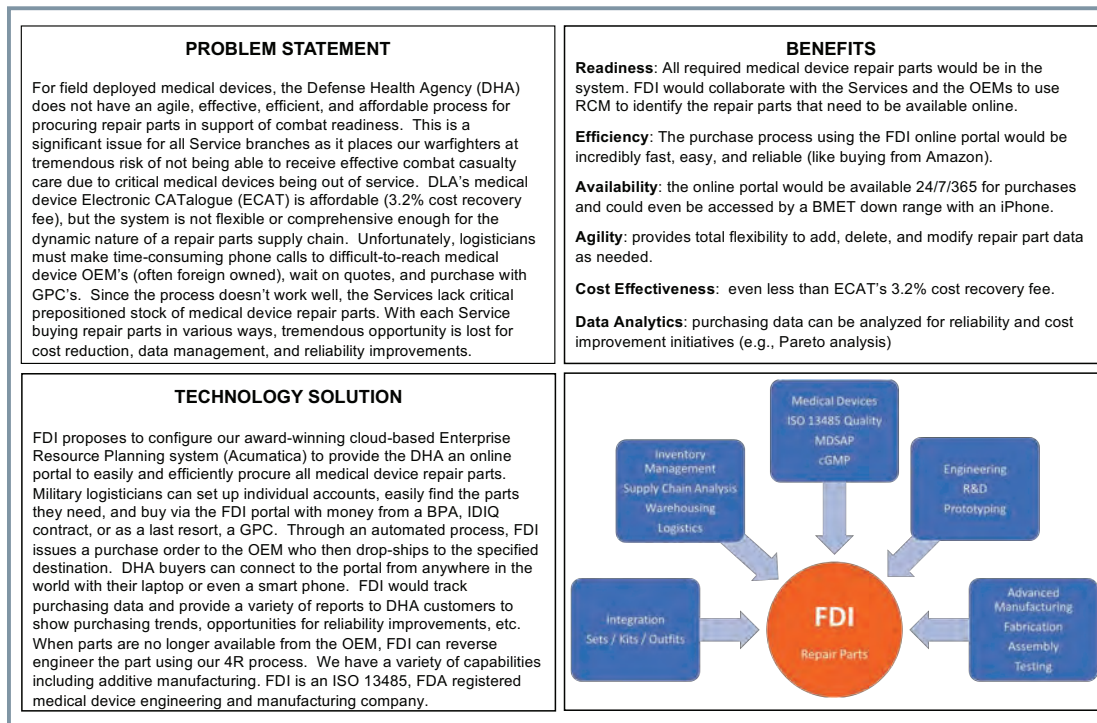
(Acumatica) to provide the DHA an online portal to easily and efficiently procure all medical device repair parts. Military logisticians can set up individual accounts, easily find the parts they need, and buy via the FDI portal with money attached to a blanket purchase agreement (BPA), Indefinite Delivery Indefinite Quantity (IDIQ) contract, or as a last resort, a GPC. Through an automated process, FDI issues a purchase order to the OEM who then drop-ships to the specified destination. DHA buyers can connect to the portal from anywhere in the world with their laptop or even a smart phone. FDI would track purchasing data and provide a variety of reports to DHA customers to show purchasing trends, opportunities for reliability improvements, etc. When parts are no longer available from the OEM, FDI can reverse engineer the part using our 4R process. We have a variety of capabilities including additive manufacturing.

The benefits include:

- Readiness: Any medical device repair part would be on the system. FDI would collaborate with service and the OEMs to

identify every repair part that need to be made available online.

- Efficiency: The purchase process using the FDI online store would be incredibly fast and easy (like buying something from Amazon).
- Availability: the online portal would be available 24/7/365 for purchases and could even be used by a BMET down range with an iPhone.
- Agility: provides total flexibility to add, delete, and modify repair part data as needed.
- Cost Effectiveness: less than ECAT's 3.2% cost recovery fee.
- Data Analytics: purchase history reports. Purchase data can be analyzed for reliability improvement initiatives (e.g., Pareto analysis)



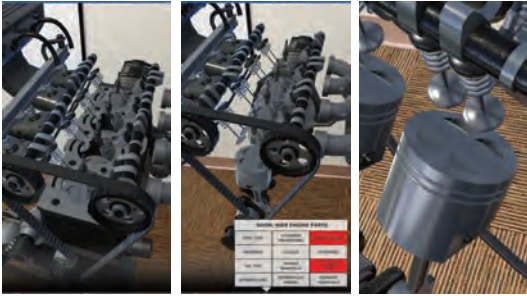
# AUGMENTED, VIRTUAL, AND MIXED REALITY (AR/VR/MR) FOR IMPROVED SHIP REPAIR

**JEAN-PIERRE BOLAT, CDR, USN (RET)**

ARSOME Technology, LLC  
 jp@arsome.com  
 +1.203.747.5697

ARSOME develops mixed reality “virtual model” Learning Management Systems (LMS) with continuously more challenging modules presenting learners high resolution 3D-models that will meet the needs advanced 21st century learning and visualization for shipboard or shore technical manuals, maintenance procedures, construction, repair, and various other applications. We envision to support a set of multidiscipline learning modalities by combining Augmented Reality and Virtual Reality to enhance and greatly improve training for casualty or maintenance scenarios. With Augmented and Virtual reality modules, maintainers can better prepare for planned or emergent repair situations. Augmented and Virtual Reality modules can be used in a pre-repair experience, then tested and evaluated through the digital/augmented scenario prior to on-site repairs, maintenance, or casualty evolutions. Further, the data captured from the tracking of performance will inform both the instructor and learners of areas where improvement is required.

In recent discussions with Ship Repair Facility (SRF) personnel, ARSOME is working to develop an opportunity for improved preparation for ship repair evolutions. If SRF personnel are provided with advanced 3D imagery and details of casualty systems prior to a ship’s return to port, they can better identify and more definitively capture the full scope of the required repairs. Additionally, with 3D augmented overlays and exploded views, SRF experts can better identify unique or underreported parts required for the repairs. Furthermore, with the Augmented Reality version of a damaged part overlaid with the Augmented CAD of the original part, further damage can be identified to enhance original shipboard assessment. Additionally, with advanced Augmented Reality or Virtual Reality depiction of the damaged part, SRF maintainers can train and rehearse the repair evolution days or weeks prior to the ship returning to port for the repair. Finally, compartment access issues and logistics requirements can be rehearsed well in advance.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>As ships pull into port for repairs, SRF maintainers can be surprised by the level of needed repairs that may have been underreported.</li> <li>Although reporting procedures are detailed, minute parts, pieces, supplies, or procedures can be missed.</li> <li>Challenges arise with 'just in time' repair requirements, with either a lack of parts, a lack of expertise, or lack of training.</li> </ul>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>Improved efficiency and training prior to a maintenance evolution.</li> <li>SRF crews are better prepared for all maintenance evolutions prior to ship return to port.</li> <li>Improved Readiness of combat systems.</li> <li>Specific training and expertise acquisition can be done well in advance of complex maintenance or repair evolutions.</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <p>ARSOME’s AR/VR/MR solutions can be tailored to the requirements, needs, and pain points of Navy maintenance, repair, construction, and casualty preparation. Leveraging industry standard equipment, local networks, and/or handheld localized devices, ARSOME’s AR/VR/MR development environment is local to the end user’s secure environment. 3D models are internally developed from captured images that are inputted into the environment.</p>	

## GOAL-DRIVEN CONDITION-BASED PREDICTIVE MAINTENANCE

CHRISTOPHER L BOWMAN

Data Fusion & Neural Networks, Inc.  
 cbowman@df-nn.com  
 +1.303.469.9828

**Problem:** To achieve Condition-Based Maintenance (CBM), both known and unknown abnormal conditions requiring maintenance, need to be detected, characterized, and trusted.

**Technology:** Off-line, we train neural networks (NNs) to learn the correlated behaviors in the historical system State of Health (SOH) and other relevant data. We cluster these and give default names to similar abnormality detections. We track these automated named detections to determine abnormal events with sufficient persistence and anomalous behavior of interest.

We automatically train categorization NNs for each different event to distinguish each abnormal signature class. We train a trust NN on the historical signatures from each abnormal detection class. We allow the user to create an ontology with his new names for all the abnormal event classes as desired. We find the historical correlations of the historical abnormal events to the overlapping system repair data using Structural Topic Model for textual repair descriptions to integrate with numerical repair logs. We provide visualizations that

enable the user to confirm high confidence correlations of abnormal SOH events and/or operator debriefs with recommended repairs based on historical discovered patterns or known models. The neural architectures are automatically adapted while training to be the smallest possible to meet user performance requirements for training.

We apply the NNs to operational online SOH data to detect all the abnormal signatures over time and provide the abnormality signatures to all the categorization NNs. For each declared historical category the corresponding trust NN is run to score how similar the SOH online test signature is to all the SOH signatures that the categorization NN was validated on. If the trust is too low these categorizations will be eliminated. The valid abnormal event categorizations approved by the user will trigger repairs/responses as defined from off-line CBM recommendations. The new abnormality detection signatures will be automatically named and flagged for later operator resolution. The system evolves by following operator goals as to when to retrain, what to retrain on, what to test on, and when to promote on-line.

**Status & Testing:** The GCPM CBM system described above has been tested on years of C-130 DFDR, Engine Trend, Pilot Debrief, and REMIS repair data from Robins AFB. DF&NN has Certification to Field for Abnormal Catalog Update detection at National Space Defense Center (NSDC) and have installed software at 3rd Space Experimentation Squadron and 3 SOPS at Schriever AFB. We sold licenses to Aerospace Corporation.

**Benefits:**

1. Affordable & reliable tailoring of the NNs solution and robustness
2. Finds the unknown unknowns in big data
3. Provides a trust score for operational categorizations
4. User does not need to label the classes
5. Reduced maintenance costs
6. Increased system availability
7. Improved performance as system evolves

Looking for new applications.

<p align="center"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Unknown anomalies in word recognition rate machines are not being detected and characterized since only Deep Multi-Start Residual Training neural networks have been proven to find these.</li> <li>• Unknown abnormal power behavior using ARL Autonomous Real-time Electric-/Magnetic-field Integrated Sensor (ARTEMIS) are not currently detected.</li> </ul>	<p align="center"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Unknown abnormal precursor detection/characterization enables reduced cost Condition-Based Maintenance in an evolving automatically retrained system to meet goals.</li> <li>• The GCPM anomalies provide inputs to QSI's TEAMS® models that capture system-agnostic functional failure cause and effect dependency relationships.</li> <li>• ROI is about tenfold in slightly more than 2 years due prevention of CNC machine breakdowns and reduced material wastage</li> </ul>
<p align="center"><b>PROCESS/TECHNOLOGY SOLUTION</b></p> <p>The goal is to develop intelligent system tools that learn normal patterns of life from energy consumption auditing of both cyber and manufacturing devices in manufacturing systems and use a hybrid machine-learning (ML) and a digital-twin (DT) approach to learn and correlate changed patterns from physical and cyber threats to Computer Numerical Control (CNC) machines. This work is being done for AFSC Energy Consumption Abnormality Detection SBIR Phase II.</p>	

# MISSION-DRIVEN MAINTENANCE & LOGISTICS OPTIMIZATION USING MACHINE LEARNING

KEN DRODDY

Tagup Inc  
kdroddy@tagup.io  
+1.205.566.3795

Current US Marine Corps (USMC) logistics information systems do not possess predictive modeling and simulation tools required for strategic mission-critical Marine Air-Ground Task Force planning efforts. While the USMC incorporates data-driven techniques to evaluate maintenance efficiency, equipment performance, and unit readiness, there are no tools available to forecast operational readiness and future sustainment needs.

Through combining existing operating and maintenance data with novel machine learning methods, we have developed mission-driven material mobilization and scenario planning technology. This technology can predict asset availability, fleet readiness posture, and unit sustainment needs (including maintenance efforts, spare parts, and associated costs). It enables the following core capabilities that maximize readiness while minimizing costs:

- Predictive Maintenance: Consolidated data records for each asset, coupled with new machine learning methods, provide recommendations for

maintenance, including expected spare parts requirements.

- Asset Lifecycle Planning: Maintainers can easily access an asset's operating history to verify and justify asset selections for depot maintenance and overhaul.
- Block Building & Parts Fulfillment: Supply officers can model and simulate spare parts requirements and sustainment costs based on actual operational demands and deployment scenarios.
- Readiness Forecasting: Commanders can forecast unit readiness to determine which assets are most likely to be available in the future and provide materiel cost estimates for sustaining readiness levels.
- Mobilization Planning: Equipment can be rank ordered by failure probability to select the most operationally reliable assets for deployment.

The technology was developed alongside the warfighter through SBIR Phase I & II projects and is currently at a technical readiness level of 6. Development was focused on the LAV

and MTRV asset classes and included four distinct phases:

- Definition of technical requirements via 60+ user workshops
- Design and prototyping of capabilities that serve three functional groups (command, maintenance, supply)
- Training and validation of over 1,000 machine learning models with the best performing models producing financial forecasts within 1% error
- Deployment of the technology in a FedRAMP compliant AWS GovCloud environment

Tagup is working with the USMC to transition the technology to a Phase III effort. Next steps include thoroughly testing the technology in operational use and expanding to additional asset classes.

<p><b>WHO</b> SYSCOM: NAVAIR / MARCOR</p> <p><b>TRANSITION TARGET:</b> EXPECTED: PEO EIS PMW-230 Global Combat Support System-Marine Corps</p> <p><b>DOD TPOC:</b> Dr. Michael Guest, 403-381-8936</p> <p><b>TRANSITION OPPORTUNITIES:</b> MARCOR Ground Equipment, DON legacy equipment, Army Ground Equipment (GCSS managed), DOD Asset Managers.</p> <p><b>NOTES:</b> Tagup machine learning capabilities were developed on the LAV using GCSS-MC maintenance records, and successfully scaled to the MTRV platforms. The predictive modeling capabilities are applicable to any asset platform with similar O&amp;M data records</p>		<p><b>WHAT</b> <b>OPERATIONAL NEED AND IMPROVEMENT:</b> To improve MAGTF scenario planning capabilities, machine learning (ML)-based readiness and sustainment analytics augment the warfighter by identifying best available assets, evaluating historical unit/asset performance, and forecasting upcoming sustainment needs. The application of machine learning (ML) can drastically improve mobilization planning capabilities by taking advantage of historical O&amp;M data readily available in GCSS.</p> <p><b>SPECIFICATIONS REQUIRED:</b> This ML technology is prototyped on AWS GovCloud and deployable to any authorized cloud environment (e.g., MCBOS, McCEITS). A containerized architecture allows deployment via a robust continuous integration/continuous delivery (CI/CD) pipeline that can flexibly integrate with existing ERP systems.</p> <p><b>TECHNOLOGY DEVELOPED:</b> New machine learning methods rapidly improve mobilization planning capabilities of commanders, maintainers, and supply personnel through unified data and intuitive dashboards. Prototyped alongside the warfighter, tools use ML-based analytics to present accurate forecasting of fleet readiness, asset availability, and unit sustainment needs.</p> <p>Capabilities include:</p> <ul style="list-style-type: none"> <li>- Data cleaning and restructuring sourced from multiple available systems, and rapidly scalable</li> <li>- Comprehensive summary of any asset's O&amp;M history</li> <li>- Readiness forecasts out to 30 days, aggregated by unit or TAMCN</li> <li>- Mobilization planner to optimize EDL specification and Class IX block building</li> <li>- Depot-level operational logistics planner linking materiel posture to tactical unit activity</li> </ul> <p><b>WARFIGHTER VALUE:</b> Lightweight, intuitive dashboards unify the mobilization process for Commanders, Maintainers, and Suppliers to evaluate best-available criteria on assets and sustainment needs using real-world operational data. Models are built to maximize mission success while minimizing operating cost via reduced customer wait time and logistics response time with an improved readiness posture.</p>																					
<p><b>WHEN</b></p> <table border="1"> <thead> <tr> <th>Milestone</th> <th>Measure of Success</th> <th>Ending TRL</th> <th>Date</th> </tr> </thead> <tbody> <tr> <td>SBIR Phase II Prototype Complete</td> <td>Successful deployment of prototype using historical data to MAGTF workgroups, including onboarding and feedback</td> <td>6</td> <td>Nov 2021</td> </tr> <tr> <td>Phase III Integration and Test</td> <td>Integration with live data sources (e.g. MDR, McBoss), and interoperability and secure API architecture development. Prototype validation with streaming data.</td> <td>7</td> <td>Oct 2022</td> </tr> <tr> <td>Phase III: Field Deployment and Scaling</td> <td>Additional TAMCN data ingestion. Integration with new data sources (e.g. telemetry, manufacturer data, and other logistics information systems)</td> <td>8</td> <td>Dec 2022</td> </tr> <tr> <td>Phase III: Fleet Deployment</td> <td>Full Deployment. Software built and operated across TAMCNs to demonstrate performance in the actual operational environment</td> <td></td> <td>Dec 2023</td> </tr> </tbody> </table>		Milestone	Measure of Success	Ending TRL	Date	SBIR Phase II Prototype Complete	Successful deployment of prototype using historical data to MAGTF workgroups, including onboarding and feedback	6	Nov 2021	Phase III Integration and Test	Integration with live data sources (e.g. MDR, McBoss), and interoperability and secure API architecture development. Prototype validation with streaming data.	7	Oct 2022	Phase III: Field Deployment and Scaling	Additional TAMCN data ingestion. Integration with new data sources (e.g. telemetry, manufacturer data, and other logistics information systems)	8	Dec 2022	Phase III: Fleet Deployment	Full Deployment. Software built and operated across TAMCNs to demonstrate performance in the actual operational environment		Dec 2023	<p><b>HOW</b> <b>Projected Business Model:</b> Tagup offers licensed custom integration into enterprise software applications. System interfaces use a REST API, providing direct access to the data pipeline and analytics engine, including all data and forecasts. The analytics may be expanded to additional asset classes and data sources. Professional services are offered to support implementation, training, and sustainment.</p> <p><b>Company Objective:</b> Tagup seeks to provide industry-leading machine learning algorithm development and custom applications, both as a Prime and to support joint-service warfighter mission readiness.</p> <p><b>Potential Commercial Applications:</b> Tagup provides industrial equipment owners and operators intuitive forecasting and planning tools to minimize operating costs without compromising safety, reliability, and efficiency. Current software deployments in general industry are with electric utilities, power generators, oilfield operators. All industry applications use AI to predict critical events, identify unusual operations, and optimize control decisions. Core product applications include procurement and inventory optimization for improved asset management.</p>	
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## AI ASSISTED DATA ENTRY FOR AIRCRAFT MAINTAINERS

**JAMES HILL**

Aging Aircraft Solutions  
 james.hill@agingaircraft.us  
 +1.478.225.4044

Aircraft maintenance data entry is inefficient, & time consuming for maintainers, resulting in inaccurate or incomplete maintenance data. Analysis has shown that as much as 30% of Air Force maintenance data has inaccurate work unit codes.

Inaccurate or incomplete maintenance data results in degraded ability to run actionable analytics and reports to keep aircraft fully mission capable in the field.

Sustainment, lifecycle management and engineering functions performed by Air Force Lifecycle Management Center (AFLCMC) require accurate and standardized information to be effective.


The solution is an artificial intelligence assisted data entry technology that helps maintainers quickly and accurately find the best work unit code, action taken and how mal codes during data entry.

The solution leverages natural language processing to understand what he maintainers are working on and interpret discrepancy narratives, include

understanding acronyms shorthand and slang not found in the technical data.

Benefits:

- Reduces time spent by maintainers on data entry; increases time spent performing maintenance
- Increases first time quality / data accuracy
- Upskills inexperienced maintainers
- Reduces re-work/corrections caused by errors in data – supervisor and maintainer time savings
- Reduces need and cost of data cleansing prior to analysis
- Increases analytical accuracy and quality of decisions
- Increases the ability of field units to understand what maintenance and non-mission-capable drivers are
- Increases ability of the sustainment enterprise to keep aircraft sustained and mission capable

<p><b>PROBLEM STATEMENT</b></p> <p>Aircraft maintenance data entry is inefficient, &amp; time consuming for maintainers, resulting in inaccurate or incomplete maintenance data. Analysis has show that as much as 30% of Air Force maintenance data has inaccurate work unit codes.</p> <p>Inaccurate or incomplete maintenance data results in degraded ability to run actionable analytics and reports to keep aircraft fully mission capable in the field.</p> <p>Sustainment, lifecycle management and engineering functions performed by Air Force Lifecycle Management Center (AFLCMC) require accurate and standardized information to be effective.</p>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Reduces time spent by maintainers on data entry; increases time spent performing maintenance</li> <li>• Increases first time quality / data accuracy</li> <li>• Upskills inexperienced maintainers</li> <li>• Reduces re-work/corrections caused by errors in data – supervisor and maintainer time savings</li> <li>• Reduces need and cost of data cleansing prior to analysis</li> <li>• Increases analytical accuracy and quality of decisions</li> <li>• Increases the ability of field units to understand what maintenance and non-mission-capable drivers are</li> <li>• Increases ability of the sustainment enterprise to keep aircraft sustained and mission capable</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>The solution is an artificial intelligence assisted data entry technology that helps maintainers quickly and accurately find the best work unit code, action taken and how mal codes during data entry.</p> <p>The solution leverages natural language processing to understand what he maintainers are working on and interpret discrepancy narratives, include understanding acronyms shorthand and slang not found in the technical data.</p> <p>Unrestricted</p>	<p><b>AI Assisted Data Entry for Maintainers</b></p>  <p>Switch Aircraft</p> <p>AI Assisted Search</p> <p>Search Results Ranked by Relevance</p> <p>WUC, Action Taken, How Mal Code tabs</p> <p>WUC, Action Taken, How Mal Code tabs</p>



# CBM+ AS A CATALYST TO PROCESS IMPROVEMENT

**BRENT MOON**

3d Marine Logistics Group (3d MLG), USMC//BoozAllenHamilton  
 brent.moon@usmc.mil  
 +1.804.279.4251

**Problem:** 3d Marine Logistics Group (3d MLG) has a two-part problem for ground motor transportation (MT) assets. On the average, these assets spend 60 days in shop for corrective maintenance (CM). Additionally, the preventative maintenance (PM) requirements of the fleet is \$1M and 15K man-hours.

**Description:** In 2018 we knew CBM+ was the solution to our maintenance problem. However, we were not clear how to proceed within the 3 facets of people, process, and technology. Out of the 2019 Maintenance Symposium we realized our epiphany moment when the keynote speaker made the following 2 statements: 1) Good technology overlaid on bad, unrefined, and unimproved processes results in bad technology. 2) Relying on the addition of manpower, funds, or structure is unsustainable. These two statements shape our CBM+ solution focusing on changing our processes and empower our people thereby ensuring the effectiveness of the forthcoming enterprise CBM+ technology solution. Applying these concepts to CM, we eliminated administrative non-value-added business steps not directly contributing to

the restoration of the asset. Moreover, a system of standardization of work centers, workspace ownership, quality assurance, and minimizing physical movement has been implemented to increase efficiency. In the area of PM, a side-by-side comparison between the owner/operator monthly service checks were found to be more in-depth compared to the annual PM. Strictly enforcing the owner/operator annual monthly service checks had enabled us to remove the redundant tasks found on the annual PM resulting in a reduction of man hours. Furthering the concept, interval and time-based PM material replacements were changed to condition-based replacement resulting in a reduction of material cost. The totality of the process changes have enabled no cost, immediate positive effects in the morale of the owner/operators/mechanics and improved tactical level equipment availability.

**Current:** As of this submission, we have fully implemented CM/PM process changes in ground motor transport assets. Additionally, we codified these changes in directives, maintenance standard operating procedures, obtained a service level maintenance

process waiver, developed, and delivered training to 600+ personnel, and perform formalized CBM+ compliance inspections.

**Data:** Our initial baseline data for CM of 60 days in shop compared to the improved CBM+ process data of 19 days in shop have indicated we have reduced the days in shop by 41 days, a 60% improvement. Similarly, our initial baseline data for PM \$1M and 15K man-hours, as required by the technical manuals has improved to \$200K (80% reduction in material cost) 1K man-hours (90% reduction time effort).

**Next Steps:** Expand to Engineer equipment including both Heavy and Utilities equipment, scale up to the service level component adopting the process changes into policy, and empower individuals to think about maintenance in a condition-based context.

<p align="center"><b>PROBLEM STATEMENT</b></p> <p>Inefficient and administratively burdensome process/procedures add cost and degrade maintenance production activities.</p> <ul style="list-style-type: none"> <li>• Sub-optimal maintenance process resulting in an average of 60 days in shop</li> <li>• 15,000+ man hours in PMCS (annually)</li> <li>• \$1M+ PMCS cost (annually)</li> </ul>	<p align="center"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• CBM+ requires people, process, and technology to achieve predictive/prognostic maintenance                         <ul style="list-style-type: none"> <li>• <u>People</u> – What they do, how they do it, what is reported</li> <li>• <u>Process</u> – What is required in sequential steps to eliminate “no value added” steps.</li> <li>• <u>Technology</u> – HQMC driven for an enterprise solution</li> </ul> </li> </ul> <p>Our program focused on what an organization can influence and control (i.e., people and process). Results are immediate, scalable, and low/no cost. It can be done and done today.</p>																		
<p align="center"><b>PROCESS/TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Standardize work centers, assign workspaces, and reallocate manpower</li> <li>• Eliminate non-value-added maintenance steps and reporting</li> <li>• Eliminate redundancies between owner/operator monthly PM and annual PM done by maintenance personnel</li> <li>• Change PM material replacement from interval to condition based</li> <li>• Eliminate intrusive PM disassembly to visual checks</li> <li>• Incorporate a total quality assurance maintenance program</li> </ul>	<table border="1"> <tr> <th colspan="2">D TAMCN Annual FULL PM Cost</th> </tr> <tr> <th>Pre-CBM+</th> <th>Post-CBM+</th> </tr> <tr> <td>\$1,098,652 <small>(843 assets, cost IAW TM)</small></td> <td>\$216,141 <small>(projected for FY23)</small></td> </tr> <tr> <th colspan="2">D TAMCN Annual PM Man Hours</th> </tr> <tr> <th>Pre-CBM+</th> <th>Post-CBM+</th> </tr> <tr> <td>15,716 <small>(cost IAW TM)</small></td> <td>1063.5 <small>(projected for FY23)</small></td> </tr> <tr> <th colspan="2">D TAMCN Median Days in Shop</th> </tr> <tr> <th>Pre-CBM+</th> <th>Post-CBM+</th> </tr> <tr> <td>59.5 Days</td> <td>19.2 Days</td> </tr> </table>	D TAMCN Annual FULL PM Cost		Pre-CBM+	Post-CBM+	\$1,098,652 <small>(843 assets, cost IAW TM)</small>	\$216,141 <small>(projected for FY23)</small>	D TAMCN Annual PM Man Hours		Pre-CBM+	Post-CBM+	15,716 <small>(cost IAW TM)</small>	1063.5 <small>(projected for FY23)</small>	D TAMCN Median Days in Shop		Pre-CBM+	Post-CBM+	59.5 Days	19.2 Days
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## ZERO-CLOUD ANALYTICS PLATFORM FOR INDUSTRIAL MAINTENANCE

**FORREST SHRIVER**

Sentinel Devices LLC  
 forrest.shriver@sentineldevices.com  
 +1.956.495.6445

Our solution reduces equipment failure-related downtime in manufacturing facilities and maintenance depots by as much as 20%, by reducing the cycle time of maintenance procedures and improving awareness and readiness for equipment faults. The technology behind this solution is sponsored by the U.S. Department of Energy’s Advanced Manufacturing Office due to its promise in hard-technology applications. Maintenance technicians within these facilities spend almost 40-60% of their time exclusively on identifying and finding the root cause of equipment failure. Once equipment faults are identified they can usually be fixed very quickly, but while the problem is being identified the rest of the production line will likely be completely stopped until the issue is resolved.

Our solution to this problem is a drop-in rack-mounted module that connects to local industrial control systems within the facility. This module learns normal behavior and uses these learnings to both identify equipment failure as soon as it starts happening and interactively provide insights to maintenance technicians on what pieces of equipment are actually

at fault. Our module does this without any sort of cloud connection – all data is kept on-device, ensuring safe and secure analytics without introducing any additional cybersecurity vulnerabilities. This approach enables enhanced situational awareness within DoD facilities and equipment – the module can catch anomalies for which it has not been trained, identifying equipment failure even if it has never happened before. The technology is currently at TRL 6, with multiple feasibility studies and real-world demonstrations having taken place.

In a simulated valve fault scenario, the platform is able to immediately identify a valve fail-open and is able to pick out the signals best informing operators on which valve failed as well as supporting data indicating the valve failure. A facility technician would be able to immediately and quickly secure the necessary materials to repair the valve without having to perform non-relevant maintenance checks on other non-faulting systems. The platform reduces an hour-long maintenance procedure to roughly 10 minutes – we expect this benefit to translate directly to other faults within production facilities.

The overall benefit will be a significant reduction in the time it takes to detect and resolve equipment faults through analytics that do not require cloud connectivity, improving the effectiveness and security of the DoD logistics enterprise and ultimately improving weapons platforms availability. Next steps for this platform is securing Interim Authorization to Test (IATT) for this platform within DoD production systems, proving that we improve the operational uptime of production facilities and maintenance depots. We also have an ongoing collaboration with the Georgia Institute of Technology’s Advanced Manufacturing Pilot Facility to perform pilot studies within their testbeds.

### PROBLEM STATEMENT

Equipment failure within production manufacturing & maintenance systems causes significant downtime and delays, reducing the availability of weapons platforms by as much as 5%. As much as 40-60% of the time spent fixing these failures is just spent finding the root cause of the issue. Predictive maintenance can reduce this downtime, but existing approaches are all cloud-based, exposing undue security risks. It is also difficult and expensive to retrain production personnel with machine learning experience – something cloud-based solutions often require, as they assume the customer implements the model themselves. Finally, these solutions usually ask for a host of new sensors to be installed – vibration, temperature, etc. – which require extensive personnel time to install, especially for custom equipment.

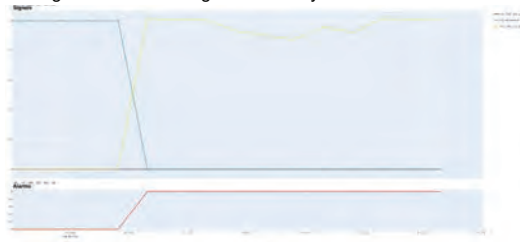
### BENEFITS

- Reduce the time maintenance personnel spend finding and fixing the root cause of equipment issues
- Reduce the time DoD production lines spend in a stopped state as they wait for equipment issues to be found and fixed (as much as 20%)
- Identify potential issues early and point them out to operators, before the equipment breaks
- Reduce the cognitive load on maintenance personnel, allowing them to more rapidly and effectively assess field conditions and status of their equipment
- Enable analytics in production without compromising cybersecurity policies, without requiring personnel retraining, and without reorganizing your entire infrastructure

### TECHNOLOGY SOLUTION

The solution is our zero-cloud monitoring and analytics solution for industrial control systems. Our ZAPIM platform is a single module that is deployed on-rack alongside existing controls hardware. Technicians only need to spend a total of 15 minutes configuring and deploying our solution, “setting and forgetting” it afterwards. When an issue is detected, the platform both alerts operators and interactively works with them to identify the root cause. Our platform does this with zero connection to the outside world – all data is kept entirely-on device, removing cybersecurity concerns. The platform is also continuously self-improving – operators can interactively update the platform in response to changing field conditions, enabling it to provide better insights relevant to on-the-ground conditions.

Platform has autonomously shown the top three signals corresponding to a failed-open valve – the technician quickly assesses likely cause and goes to fix that part of the system, saving time and reducing unnecessary maintenance checks.



# GROUNDFAULTINSIGHT™


**ERIC STRONG**

AURA Technologies, LLC  
 eststrong@aura-tech.us  
 +1.865.498.3269

Detection of ground faults and other electrical problems is typically diagnosed by manual detection (e.g., using an insulation resistance tester) and localized by manual inspection for insulation breakdown. Alternatively, other solutions may install intrusive electrical monitoring systems that may not be suitable for all equipment.

AURA has developed GroundFaultInsight™, an intelligent and portable device to non-intrusively detect and locate electrical ground faults in real time. GroundFaultInsight™ can sample electrical data (including current and voltage) at high sampling rates, and it contains AI/ML algorithms that can diagnose and prognose electrical faults.

The benefit of this solution is to rapidly and non-intrusively detect ground faults in continuously powered subsystems, allowing instantaneous detection of electrical problems. The solution augments high-precision, high-bandwidth low-voltage and current instrumentation with AI/ML algorithms to detect and locate ground faults in real-time.

<p><b>PROBLEM STATEMENT</b></p> <p>Detection of ground faults and other electrical problems is typically diagnosed by manual detection (e.g., using an insulation resistance tester) and localized by manual inspection for insulation breakdown. Alternatively, other solutions may install intrusive electrical monitoring systems that may not be suitable for all equipment.</p>	<p><b>BENEFITS</b></p> <p>The benefit of this solution is to rapidly and non-intrusively detect ground faults in continuously powered subsystems, allowing instantaneous detection of electrical problems. The solution augments high-precision, high-bandwidth low-voltage and current instrumentation with AI/ML algorithms to detect and locate ground faults in real-time.</p>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>AURA has developed GroundFaultInsight™, an intelligent and portable device to non-intrusively detect and locate electrical ground faults in real time. GroundFaultInsight can sample electrical data (including current and voltage) at high sampling rates, and it contains AI/ML algorithms that can diagnose and prognose electrical faults.</p>	 <p>Our solution has already undergone lab testing and is ready for transition to another application, as well as ruggedization.</p>

## MINI-MUX HIGH DENSITY ELECTRICAL SWITCHING

**CHRISTOPHER THOMAS TEAL**

Eclipse International  
 CTEAL@ECLYPSE.ORG  
 +1.951.317.0781

**Problem:** Advanced Automatic Wiring Test Sets (AWTS) were deployed to Joint Service maintenance activities in FY 2010 in order to accurately and rapidly test and inspect Electrical Wiring Interconnect Systems (EWIS). Success was immediately obtained at Intermediate and Depot level. O-Level maintenance activities are requesting this capability be brought forward so that it can be implemented at O-Level electrical maintenance and troubleshooting continues to be not only reactionary, but also a slow, manual, and tedious process - Expending man-hours and \$\$\$. O-Level Maintenance requires small footprint. Reduced Mission Readiness is the current outcome.

**Solution:** New electrical test capability has been miniaturized to greatly reduce footprint for Test Interface Cables used to test avionics chassis. Based on the current use of the deployed technology known as the Automatic Wire Test Set (AWTS), our team will focus on efforts to reduce its overall deployment footprint for use at O-Level. Miniaturization of aircraft testing equipment accomplished by the integration and use of solid state switching in small, distributed modules. The Test Adapter Cable

management will reduce further footprint and ensure the delivered capability retains the ability to aid in rapid fault resolution related to intermittent faults and the occurrence of Re-Test Okay (RETOK) events.

**Benefits:** Uses existing government logistically supported proven software and hardware - Joint Services tester knows as AWTS. Utilizes precise measurements that detect very hard to find electrical issues. Locates true root cause of faults. The field does not currently possess this capability. Will provide 75% or greater reduction in deployed footprint vs typical fielded testers. Test turnaround times at O-Level will be reduced resulting in increased Mission Readiness!

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<p align="center"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>Based on the current use of the deployed technology known as the Automatic Wire Test Set (AWTS), our team will focus on efforts to reduce its overall deployment footprint for use at O-Level</li> <li>Miniaturization of aircraft testing equipment accomplished by the integration and use of solid state switching in small distributed modules</li> <li>Test Adapter Cable management - reduce further footprint</li> <li>Ensure the delivered capability retains the ability to aid in rapid fault resolution related to intermittent faults and the occurrence of Re-Test Okay (RETOK) events</li> </ul>	<p align="center"><b>EXISTING</b>      <b>SOLUTION</b></p>

# AI MACHINE LEARNING AND KNOWLEDGE AUTOMATION FOR SMART MAINTENANCE

SHENG-CHUAN WU

Franz Inc.  
scw@franz.com  
+1.510.452.2000

**The problem:** As machines become more complex, so does their maintenance and the knowledge required to perform the tasks effectively. We want to fix any problems with the equipment correctly the first time with the least amount of time and money. Better yet, we want to do preventive maintenance guided by analyses of past maintenance records, so that problems do not happen. An effective maintenance program directly impacts our war fighting readiness, besides mitigating the costs and resources associated with ineffective maintenance processes. Unfortunately, most of the machine knowledge and maintenance data needed to achieve the above objectives are stored as natural language texts in either structured databases or semi-structured documents, or in the heads of experienced engineering staff. Such knowledge is difficult to search and apply and to share, let alone to automate. The tacit knowledge in the heads of experienced staff are typical knowledge silos, gone with the staff eventually.

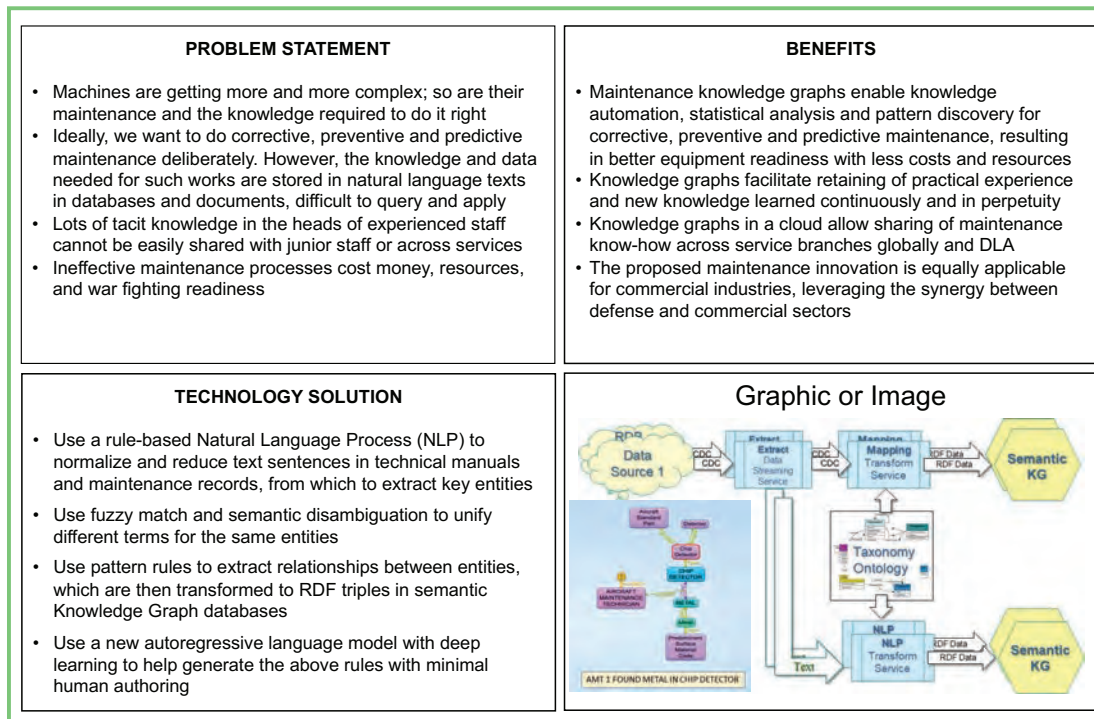
**The technology:** There has been significant progress in Natural Language Processing (NLP) and Semantic Knowledge Graph technology. A rule-based NLP system is able

to normalize and reduce text sentences, and to extract key entities based on a domain ontology with the aid of fuzzy matching and semantic disambiguation. Pattern rules are employed to extract relationships between entities, which are stored as subject-predicate-object triples in the Knowledge Graph database. A new autoregressive language model with deep learning helps generate such rules with significantly less human authoring. This NLP process can be applied to the textual descriptions in the maintenance database as well as technical manuals and notes, making the information computable beyond simple keyword search. Such maintenance knowledge enables knowledge automation, statistical analysis and pattern discovery for corrective, preventive, and predictive maintenance.

**The current development status:** The Knowledge Graph technology is in production currently. The NLP process is being tested with FAA Service Difficulty Reports of aircraft maintenance, showing great promise.

Test/simulation data supporting performance claims: The semantic Knowledge Graph database technology has been deployed at various customer sites. For example, we support mission-critical applications such as the Essilor Supply Chain Management system which handles 100,000 concurrent queries per minute during peak hours. The NLP technology has been proven effective in extracting knowledge from production call logs, greatly improving the effectiveness at support call centers.

**Next steps/potential benefits:** The proposed Smart Maintenance system can potentially be deployed to every military branch and DLA, which all need an effective maintenance program to upkeep their equipment. Such a system is also very useful for commercial industries. Franz needs additional funding and most importantly a target DoD user to help productize the technology.



## PAINT OPERATIONS OPTIMIZATION

HUNTLEY BODDEN

Marine Corps Logistics Command  
 huntley.bodden@usmc.mil  
 +1.229.639.7307

Paint & Blast operations (AKA “Coatings operations”) constitute critical pieces of the vehicle maintenance process at Marine Corps Logistics Command’s (MARCORLOGCOM) Albany Marine Depot Maintenance Command (MDMC). These operations are often complicated by issues related to highly variable preparation & paint times for parts, travel times between distant Coatings stations, paint booth downtimes, personnel scheduling challenges, & downstream prioritization of required painted parts. Delays or poor scheduling of jobs in Coatings can result in significantly increased vehicle maintenance cycle times, which in turn can compromise combat readiness.

MDMC & Georgia Tech Research Institute have partnered through the University Affiliated Research Center (UARC) to develop a toolkit of statistical analysis, computer simulation, mathematical optimization, & traditional industrial engineering (IE) techniques to improve current & future Coatings operations. The development of this unique toolkit is underway, & the following notable successes are now in place:

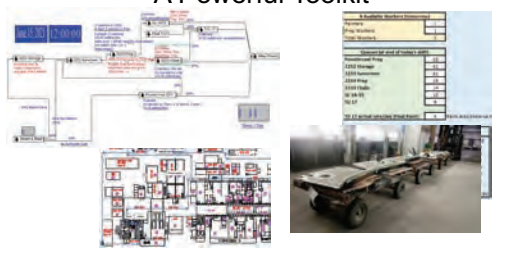
1. A tug & tow train system plan to improve movement between stations in Coatings. Traditional IE analysis reveals that the new train system has the potential to reduce part travel times by > 80% between stations & can reduce forklift wear & personnel cost significantly.
2. A computer simulation model of Coatings operations that has been used to determine maximum production capacities under certain paint booth & personnel constraints, leading to better planning & more efficient use of resources.
3. A personnel scheduling tool that responds to day-to-day production needs, allowing for efficient use of manpower & cost savings.

In addition to the near-term development that has successfully been implemented as described above, MDMC anticipates a number of mid-term achievements as well, including consolidation of the toolkit components into a one-stop-shopping synergistic tool (vice individual applications) that can link up with related inventory,

scheduling, & tools that we have developed (or are developing) in non-Coatings contexts.

MDMC is positioning itself to optimize upcoming operations for a new building devoted to Coatings that will come online in the middle of the next decade. This long-term building project will necessitate: the demolition of the existing Small Paint building, re-modeling of current blast operations buildings, new robots to accomplish paint / de-paint operations, & robot system operator training & set up of robotics systems.

The anticipated benefits of this work are tremendous: reduced vehicle cycle times; increased efficiencies in terms of labor & machines; & reduced environmental pollutants as the result of transitioning from particulate-based blasting to the use of robots. Moreover, the generic applications of the Coatings toolkit will allow for migration to other MDMC plant opportunities and could be incorporated throughout the DoD.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Paint and Blast (“Coatings”) operations constitute critical pieces of the vehicle maintenance process at MDMC</li> <li>• Operations are often complicated by:             <ul style="list-style-type: none"> <li>• Highly variable preparation and paint times for parts</li> <li>• Travel times between distant Coatings stations</li> <li>• Paint booth downtimes (planned or unplanned)</li> <li>• Personnel scheduling challenges</li> <li>• Downstream prioritization of required painted parts.</li> </ul> </li> <li>• Delays or poor scheduling of jobs in Coatings can result in:             <ul style="list-style-type: none"> <li>• Unnecessary costs</li> <li>• Significantly increased vehicle maintenance cycle times coming out of MDMC</li> <li>• Reduced combat readiness.</li> </ul> </li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Near-term: Train system in Coatings will reduce travel times by as much as 80% and will increase throughput in the steam operations by as much as 60%. System will also result in significant reduction in forklift wear. Computer simulation tool has shown that Small Paint has not hit capacity limits.</li> <li>• Mid-term: Toolkit will allow for optimal job and personnel scheduling to account for personnel and machine availability as well as downstream prioritization of required painted parts. Work will help to reduce vehicle cycle times.</li> <li>• Long-term: Fully functional toolkit will be ready for eventual new Coatings building, and will optimize part movement, machine use (including robots), personnel scheduling, and environmental concerns (e.g., by using scheduling robot use instead of particulates for blasting).</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>We will develop a toolkit of statistical analysis, computer simulation, optimization, and traditional industrial engineering techniques to improve Coatings operations at MDMC.</p> <ul style="list-style-type: none"> <li>▪ Near-term: Implement / enhance a tug and tow train system plan to improve movement between stations in Coatings.</li> <li>▪ Mid-term: Consolidate of the toolkit components into a “one-stop-shopping”, synergistic tool that can link up with related inventory, scheduling, and tools we have already developed.</li> <li>▪ Long-term: Continued improvement of and then integration of our technology with new Coatings building scheduled for the middle of the next decade.</li> </ul> <p><b>Various preliminary related projects have been completed in recent months, including a Small Paint personnel scheduler and a working train system in Coatings.</b></p>	<p><b>A Powerful Toolkit</b></p>  <p>Simulation, Scheduling, and Industrial Engineering Toolkit components</p>

## AERIAL ROBOTIC SPOT REPAIR SYSTEM FOR SURFACE PREPARATION, COATING & INSPECTION

ROBERT DAHLSTROM

Apellix  
r.dahlstrom@apellix.com  
+1.904.476.3798

Apellix specializes in precision flight control that allows uncrewed aerial vehicles (UAVs) to function as industrial tools for complete corrosion management of the built environment. Our tethered and untethered computer-controlled aircraft have flight control within +/-3cm, allowing our aircraft to perform observational inspections, contact-based inspections, pressure cleaning, and airless coating of elevated structures. Many elevated structures are difficult to access and exist in environments that expose the fabric and surfaces to salt, moisture, and factors that can reduce the effectiveness and longevity of protective coatings. The accumulation of mold, salt and other contaminants can further reduce the lifespan of the coating as well as create aesthetic issues. Also, in some instances a small defect or damage can sometimes impair a coating's protective ability and allow for accelerated localized corrosion well in advance paint failure in other areas of the structure.

The proposed Aerial Spot Repair System for Inspection, Surface Preparation, and Painting works as follows:

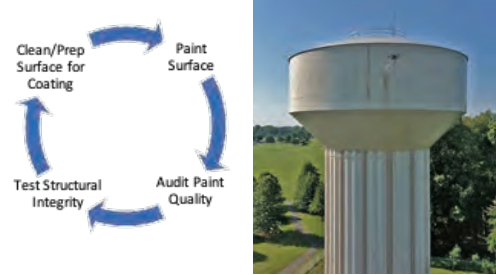
1. Identify Corrosion. We currently provide commercial services in oil & gas facilities including close visual inspection (CVI) and contact-based paint thickness (dry film thickness or DFT) and wall thickness of the underlying steel (ultrasonic UT). Our computer vision solution would quickly identify areas of interest.
2. Clean and Remove Corrosion. Our current systems can complete SSPC-SP 1 Solvent Cleaning and come close to SSPC-SP 7 / NACE No. 4 Brush-off Blast Cleaning standards.
3. Apply Coating. Apellix is operating under a joint development agreement with AkzoNobel (International Paints) to develop and commercialize our autonomous spray-painting drone for maritime and protective coatings.
4. Evaluate Job Quality – When possible, our existing systems for CVI and measuring contact-based DFT thickness will be utilized for post-job evaluations.

aerial robotic spot repair system builds upon our currently developed systems for mapping and inspection, surface preparation, and painting.

Apellix has designed and built our aerial robotic system to operate at heights of up to 150' while handling the weight of hoses, coatings, cleaning materials, components, and sprayers. This allows the system to keep reservoirs and pumps on the ground, connected to the aircraft via a tether. The aircraft operates with ground power (single phase 240vac at 50A) via tether with a battery backup, eliminating the need to land and swap batteries.

The most important working principles of our technology, and effectively the heart of our solution, is our precision flight control software. We look forward to additional questions about our current capabilities and requirements to mature the technology.

The Apellix mission is to provide industry solutions to address all phases of corrosion management and the proposed

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• 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 and exposure to the environment can cause localized corrosion and potential failures in the coatings protecting the underlying structure. These issues can also reduce the lifespan of the coating as well as create poor aesthetic. 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 potentially leading to cleaning or painting a large area not just the small area of concern.</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Cleaning, surface prep, and painting infrastructure such as storage tanks, ships, architectural structures, and their associated supporting infrastructure is costly and dangerous and sometimes requires the asset be taken out of service. <b>An aerial spot repair system for inspection, testing, cleaning, surface preparation, and painting will save millions of dollars, reduce risk to workers, and enable more sustainable operations of the assets.</b> Further, as a digital worker the system can create a fully auditable data record. 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, and safety benefits could be substantial as falls are a leading cause of workplace deaths.</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• We propose 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 close to NACE No. 4/SSPC-SP 7, then coating the repaired area with a protective coating such as Interzone 954 from International Paints or specialty coatings designed to encapsulate and stop corrosion. Components of this system are lab-scale tested TRL 7 (measurement) and pilot-scale tested TRL 8 (surface prep) with the final product using technology that has been under development for years.</li> </ul>	<p><b>GRAPHIC</b></p> 

# COATING AND CORROSION PREVENTION

## HYBRID BUILDING SYSTEM

DONALD DEPTOWICZ

Aspen Hybrid Technology Solutions  
Don@AspenHTS.com  
+1.970.532.4736

Concrete is used extensively in the approximately 550,000 DOD facilities worldwide. The DOD spends approximately \$10 billion annually on facility maintenance. Between 2015-2016 the number of DOD facilities that received a failing grade went from 7% to 18.9%. The Hybrid Building System (HBS) is an improved concrete system that can provide a more environmentally friendly concrete with the ability to tailor the properties to the specific project needs, reducing concrete, steel, and energy requirements while at the same time making significant increases in resiliency as compared to traditional concrete.

The HBS combines several existing commercial technologies into a unique process that addresses the issues with current commercial concrete. The HBS's enhanced properties result from the addition of one of today's super materials, Graphene. Numerous tests have shown that the addition of Graphene in concrete and many coatings can increase strength, electrical conductivity, improve resistance to water penetration, biological growth, and thermal conductivity. With the recent development of a high

volume, low cost, manufacturing process, Graphene is now commercially economical for large projects. In addition, the HBS formulation can be tailored to provide properties to support specific project needs.

The first step in the HBS process is to prepare the structural element (assuming that the project requires it) for encapsulation by removing the chlorides, oxides, surface corrosion, etc. using an environmentally friendly Laser Ablation (LA) system to vaporize the contaminants. By eliminating the surface contaminants, the encapsulating coating can't be attacked from the inside, eliminating one of the primary failure mechanisms of structural elements used in traditional reinforced concrete.

The second step of the HBS process is to apply a specially selected "Graphene Enhanced" coating to the structural element. The coating will keep moisture from contacting the structural element, thereby eliminating the initiation of corrosion. A U.S. Navy study concluded that in addition to improved coating adhesion, LA cleaned and painted test specimens had significantly

improved corrosion resistance as compared to non-LA test specimens.

The third step of the HBS process is to enhance the concrete with Graphene, which is combined with the coated structural element following standard commercial concrete processes.

A fourth step can be added by applying a specially selected "Graphene Enhanced" coating to the outside.

HBS provides increased strength, water resistance, and resiliency the HBS formulation can be modified further with the addition of a commercially available "Cellular Foaming Agent" that can provide a significant increase in the thermal resistance with a corresponding weight reduction. The LA, Graphene manufacturing and cellular foaming agents are all commercially available. Preliminary testing has verified improvements, optimization is now required.

### PROBLEM STATEMENT

- U.S. DOD spends roughly \$10 billion annually on their ~550,00 facilities maintenance with an additional ~\$140 billion in unfunded maintenance issues
- Concrete building products are affected by nature's elements such as carbon dioxide causing carbonation that reduce concrete pH, which over time negatively impacts the structural steel
- The Structural steel used in current concrete building systems is contaminated resulting in corrosion starting from the inside
- Corroded structural steel expands 2-3 times over non-corroded steel, creating stresses, causing cracks and rapid deterioration
- DOD facility maintenance failing grades increased from 7% to 18.9% between 2015-2016
- Traditional concrete has almost no insulating capability requiring significant costs to insulate increasing construction costs
- Concrete contributes ~8% to Global CO2 emissions

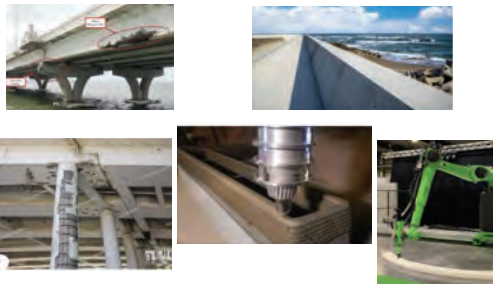
### BENEFITS

- The HBS combines several existing commercial technologies into a unique process that addresses corrosion, water penetration, thermal resistance for reduced project MRO costs
- Eliminating surface contaminants from the structural element removes one of the primary reinforced concrete failure mechanisms
- Applying a Graphene Enhanced coating to the structural element further reduces the initiation of corrosion
- Graphene enhanced concrete has shown to increase strength, water penetration, thermal and biological growth resistance, etc.
- HBS provides the ability to tailor properties to address specific project needs providing additional savings besides annual MOR costs in concrete, steel and energy required during construction
- Improving the warfighter and their families living, schooling and training facilities provides a more solid foundation for success

### TECHNOLOGY SOLUTION

- HBS is a 3 or 4 step process depending on the specific project application
- The first step is to use an environmentally friendly, DOD and FAA approved, laser ablation system to eliminate any external contaminants on the structural element
- The second step is to apply a "Graphene Enhanced" Nano-coating to the structural element to reduce corrosion initiation
- The third step is to encase the structural element in a Graphene enhanced Nano-concrete that improves concrete strength, water penetration and thermal resistance, electrical conductivity and can tailor properties to specific project needs
- The fourth (and an optional step) is to apply a Graphene enhanced Nano-coating system to the exposed surfaces of the concrete for even further reductions in annual MRO costs
- Applicable for traditional or 3D printing construction projects

### Graphic or Image





## SURFACE TREATMENT SYSTEM

DONALD DEPTOWICZ

Aspen Hybrid Technology Solutions  
 Don@AspenHTS.com  
 +1.970.532.4736

The Surface Treatment System (STS) is an evolutionary approach to providing a nearly impervious protective layer for virtually all metallic hardware in the U.S. Military inventory. Whether applying STS to gas turbine compressor airfoils to address fouling, anti-corrosion or a host of other hardware readiness related issues, STS's "once and done" process will contribute to significant savings, as well as allow more time for our war fighters to spend developing their skills, instead of conducting repetitive maintenance related activities.

STS is a unique three step system that has been specifically developed to address many of the limitations of current protective coatings. STS's three step system consists of an FAA approved Laser Ablation (LA) system to clean the hardware surface from any contamination such as oxides, chlorides, etc. that remain from the manufacturing and post manufacturing processes. Removal of the surface contaminants will eliminate any possibility of a chemical attack from the surface outward. The U.S. Navy conducted a study in 2013, and concluded, that LA can leave a surface in a "near passivated state" that testing confirmed, resulting in

a significant increase in the adhesion and reduced corrosion of the LA test samples as compared to the non-LA test samples. Since this report was issued, the U.S. Navy has approved the use of LA for the removal of corrosion, paint as well as numerous other materials from the Aluminum and Steel structures of their surface fleets.

The next step in the STS application process is to address hardware surface finish irregularities. This is particularly important due to the extremely thin "Diamond Like Carbon" (DLC) protective outer layer. The thickness of the DLC outer layer is important for a number of reasons. One reason is that the hardware undergoing the STS process is typically finished hardware. Therefore, the fit, form and function of the component can't be affected. This includes the surface finishing process, which also must not result in loss of any parent material, nor re-contamination of the cleaned surface. Since the thickness of the DLC coating is only 4 microns, and well within manufacturing tolerances, this is not an issue.


The original DLC coating has been proven to be extremely durable. During the early phase

of the Iraq war, the F18 IR targeting pods were being damaged due to sand impact. After the application of the DLC coating, this issue was eliminated. In addition, over 100,000 F-22 lens have also been successfully coated.

The DLC used in the STS process was modified to include a bond coat specifically tailored to improve adhesion to metallic surfaces.

DLC is applied using an economical, commercially available, Plasma Enhanced Chemical Vapor Deposition (PECVD) process. The same process is used to apply thin coatings to many everyday items such as doorknobs, etc. DLC has also been successfully tested in the casting industry on core tooling.

STS is currently at TRL 5.

<p><b>PROBLEM STATEMENT</b></p> <p>There is a wide range of maintenance issues that the U.S. Military addresses annually, from corrosion, gas turbine fouling, wear, etc. Addressing them typically requires multiple products and processes. Engine fouling is a significant concern for all types of gas turbines due to the harsh environments they operate in. Compressor cleaning is costly, time consuming and impacts readiness. Corrosion related maintenance costs over \$20 billion annually and impacts readiness. Hardware replacement due to wear also impacts readiness.</p> <ul style="list-style-type: none"> <li>• Compressor fouling accounts for 80% of gas turbine power losses</li> <li>• Compressor fouling causes significant MRO costs due to washing</li> <li>• Remaining Chlorides/oxides/manufacturing residue allow corrosion/pitting on all surfaces, even after coating application</li> <li>• Corrosion occurs on internal and external surfaces, even if coated</li> <li>• Traditional protective coatings are typically thick and can't be applied to threads, gears, etc. allowing corrosion and wear issues</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Increased compressor efficiency for lower fuel consumption saving costs</li> <li>• Increase hot section durability due to reduce cooling temperature</li> <li>• Reduced MRO costs due to longer intervals between water washing</li> <li>• Less power loss due to deterioration for additional cost savings</li> <li>• Significant reduction in the \$20 billion annual corrosion maintenance and hardware replacement costs due to wear</li> <li>• Significantly reduces tedious maintenance activities for the war fighter</li> <li>• Allows more time for war fighter to improve skills</li> <li>• Improves moral by significantly reducing tedious maintenance activities</li> <li>• Increases readiness of the U.S. Military</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>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 (Rpk) 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 machining surface imperfections that would penetrate the DLC coating and could result in local nucleation point for possible 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 durable, as it has been used a long time on military aircraft missile sensor domes, specifically for sandy environments. DLC was also successfully tested in the investment casting industry on high strength steel turbine core tooling.</p>	<p><b>GRAPHIC</b></p> 

## CRACKED-ARMOR LAMINATED PATCH REPAIR (CALPAR)

SHIV JOSHI

NextGen Aeronautics  
 sjoshi@nextgenaero.com  
 +1.310.626.8360

NextGen Aeronautics (NextGen) developed non-weld repair of cracking in HH/UHH steel and 5000-series Al vehicle armor components that (1) arrests further growth of the component crack(s); (2) restores and maintains ballistic performance and structural capabilities of the armor component to the maximum extent possible; and (3) is durable over the vehicle depot-level scheduled repair/maintenance, with robust performance over full range of vehicle usage, operations, and environments. The non-weld repair procedures developed by NextGen are compatible with depot and temporary tools/equipment and mechanic-technician workforce skillset allowing for accelerated implementation of composite patch armor crack repair procedures.


HH and UHH steel and 5000-series Al armors on USMC, USA, USAF, and other DoD vehicles experience significant cracking in operation. Cracking reduces ballistic and structural performance that are critical safety and readiness concerns. The current repair solution uses welding processes to fill and repair the cracks. Resulting high weld temperatures alter the metallurgy and

introduce residual stresses that lead to subsequent crack initiation and growth.

NextGen developed composite patch-repair process arrests crack growth and restores ballistic and structural performance. Lower patch curing temperatures do not alter metallurgy or introduce residual stresses. They are implemented on one-side of the armor, not requiring removal of the spall line. Composite patch-repair capabilities are demonstrated to USMC by extensive testing and analysis.

Technology is based on one used for decades to repair cracks in military and commercial aircraft. Unlike weld-repair, patch repair does not alter armor metallurgy or introduce residual stresses that can initiate new cracks in the post-repair armor and show recovery of ballistic V50 and structural properties of the armor. It can be used in most crack-repair scenarios where weld-repairs are currently performed. Repair minimally requires only two-days of training for a technician to be able to perform patch repairs.

Testing performed by NextGen demonstrated that Cracked-Armor Laminated Patch Repair (CALPAR) restore ballistic performance (V50) to uncracked levels. It recovers structural performance (stiffness, strength, fatigue) to operationally acceptable levels. Repair remains effective and durable under vehicle operational environments (temperature, humidity, salt-water). NextGen can provide CALPAR Repair Kits (CARK) for permanent repair when performed at depot-level facility using trained technicians and temporary repair when performed at field-level facility using minimally trained technicians.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• HH and UHH steel and 5000-series Al armors on USMC, USA, USAF, and other DoD vehicles experience significant cracking in operation.</li> <li>• Cracking reduces ballistic and structural performance → critical safety and readiness issue.</li> <li>• The current repair solution uses welding processes to fill and repair the cracks.</li> <li>• High weld temperatures alter the metallurgy and introduce residual stresses that lead to subsequent crack initiation and growth.</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Does not alter armor metallurgy or introduce residual stresses that initiate new cracks in the welded armor.</li> <li>• Substitute for most crack-repair scenarios where weld-repairs are currently performed.</li> <li>• One sided repair on the spall lined or firewalled armor.</li> <li>• Requires only two-days of training for a technician to be able to perform patch repairs.</li> <li>• Permanent and temporary repair solutions</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Composite patch-repair process that arrests crack growth and restores ballistic and structural performance.</li> <li>• Lower process temperatures that do not alter metallurgy or introduce residual stresses.</li> <li>• Can be implemented on one-side of the armor → removal of the spall liner not needed.</li> <li>• Composite patch-repair process demonstrated by extensive testing and analysis.</li> </ul>	<p>Composite Patch Repair Performed on JLTV Door Frame</p> 



## APPLYING NANOCOMPOSITES TO ENHANCE FLEET FLIGHT CAPABILITIES

BRIAN LINDGREN

HII

brian.lindgren@hii-tds.com

+1.843.465.3481

### Problem Statement

Aircraft carrier flight decks face two problems: 1) They cannot withstand MV-22 or F-35B vertical take-off and landings because the heat weakens the surface, which limits flight deck operations; 2) The decks are covered with a coarse “non-skid” product to provide traction, but this breaks down during aircraft arresting hook landings, and from leakage of oil, fuel, and hydraulic fluids.

### Description of the Technology

Carbon Dots (CDs) are non-toxic and ecologically safe. The diamond-like carbon quantum dots variety have high external surface areas that allow for immense heat dissipation. When combined to make carbonized polymer dots, the composite can be applied as a surface sealant/coating, giving pavement/concrete certain diamond-like characteristics. The composite can be applied with electrostatic sprayers or high-volume, low-pressure compression systems. This approach enables immense heat dissipation from flight-capable ship decks and can mitigate shipboard fires caused by chemical hazards on deck or below.

### The Current Development Status

With its nontraditional partner, Wagner Star Industries, HII tested a new production method yielding a near 1:1 carbon-to-CDs conversion ratio, which is significantly higher than other conventional processes currently in the CD market. The carbon conversion process is currently at technology readiness level (TRL) 4; it is repeatable and scalable.

### Test/Simulation Data Supporting Performance Claims

Repeated tests captured on video show that when an amplified laser is pulsed at carbon dot powder and wafers, the exposed temperature fluctuates and dissipates rapidly. This outcome is similarly seen in carbon black from tires (a source of CDs) that avoid electrostatic charging and help conduct heat away from hot spots, like in the tread and belt areas. This reduces thermal damage to the tire and extends its lifespan. Likewise, carbonized polymer dot coating/sealants prototypes indicate fire-proofing qualities. For concrete/pavement repairs, prototypes were pliable upon application, then over time strengthened and hardened, demonstrating how CDs strengthen while exposed to extreme heat.

### Next Steps/Potential Benefits

Vertical thrusters can reach 10,000° F causing damage to the deck. The CD composite can allow 75% of the V-22 or F-35 takeoffs to be vertical (typically 100% of launches are horizontal), while mitigating heat damage; and simultaneously permitting horizontal launches. The technical applications can be extended throughout ship infrastructure, while also having a cross-application use for firefighting from chemical or non-chemical hazards. Additionally, spray applications can safely smother fires if damaged planes land, saving lives / manpower, while skid-resistant properties can further prevent damage to the deck.

#### PROBLEM STATEMENT

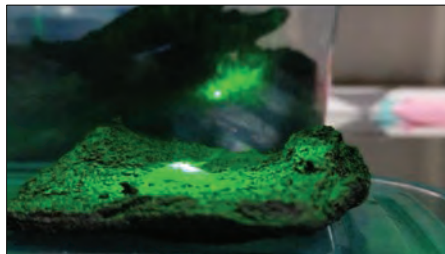
Aircraft carrier flight decks face two problems: 1) Vertical thrusters can reach 10,000° F, thereby limiting the number of MV-22 or F-35B vertical take-off and landings because the heat weakens the surface; 2) The decks are covered with a coarse “non-skid” product to provide traction, but this breaks down during aircraft arresting hook landings, and from leakage of oil, fuel, and hydraulic fluids.

#### BENEFITS

Applying CD composite to the flight deck can feasibly enable 75% of V-22 or F-35 takeoffs to be vertical, while mitigating heat damage; and simultaneously permitting horizontal launches. The technical applications can be extended throughout ship infrastructure, while also having a cross-application use for firefighting from chemical or non-chemical hazards. Spray application can safely smother a fire if a damaged plane lands, resulting in life-saving measures and manpower.

#### TECHNOLOGY SOLUTION

The *diamond-like carbon quantum dots* variety have high external surface areas that allow for immense heat dissipation. When combined with carbonized polymer dots, the composite can be applied as a surface sealant/coating, giving the pavement/concrete diamond like qualities. This approach enables immense heat dissipation from flight capable ship decks and can mitigate shipboard fires caused by chemical hazards on deck or below.



Heat dissipation image shows that a laser being pulsed on a powder-coated Carbon Dots wafer does not ignite.

## NON-EXPLOSIVE LITHIUM REPLACEMENT BATTERIES

BRIAN LINDGREN

HII

brian.lindgren@hii-tds.com

+1.843.465.3481

### Problem Statement

Lithium and conventional batteries are ubiquitous but pose significant hazards due to their highly explosive/corrosive nature and carcinogenic qualities. Unfortunately, few technically equivalent, low-cost, safe, mass-producible, and ecologically responsible alternatives exist. Furthermore, lithium and other rare earth elements that comprise these batteries is largely controlled by adversarial countries.

### Description of the Technology

Carbon Dots (CDs) are nanoscale, crystalline structures of elemental carbon (i.e., de-sulfurized coal) produced by transforming common carbon to adopt unique superconductivity and supercapacitor properties. Mixing CDs with peroxide and a composite liquid formed from byproducts gathered while purifying coal, produces a low-cost, safe battery that functions by converting photons into electrons. Thus, CD batteries are biodegradable, non-toxic, and biologically and ecologically safe.

### The Current Development Status of the Technology

With its nontraditional partner, Wagner Star Industries, HII tested a new production method yielding a near 1:1 carbon-to-CDs conversion ratio, which is significantly higher than other conventional processes currently in the CD market. Early results show possibility of significant scaling, following streamlined production. The carbon conversion process, CDs, and batteries are technology readiness level (TRL) 3, with three prototypes ready for independent third-party verification, which can validate its performance compared to lithium batteries.

### Test/Simulation Data Supporting Performance Claims

By beaming a 1-watt laser beam onto the composite mixture, we observed the CDs converting the beam into stored energy while not igniting, as a fuel source would. Instead, the CD battery sourced its electric power from one or more electrochemical sources, mainly converting radiation photons to electricity.

We have three prototypes: 1) The 1:5 CDs-to-composite liquid ratio shows robust rechargeable qualities. 2) The 1:10 CDs-to-composite liquid is less rechargeable but decomposes entirely within 24 hours. Notably, CDs will decompose when exposed to water, whereas lithium batteries will explode. 3) The third prototype employs a proprietary composite liquid of fluoride ions for increased durability, numbers of cycles, and photoluminescence to indicate active charging.

### Next Steps/Potential Benefits

CD batteries cost half that of lithium and current conventional batteries and can be made domestically from lightweight carbon and water composite. Other potential benefits for this technology include forming nanodiamond batteries with CD filaments for industrial and automotive applications and self-rechargeable batteries for electronics (e.g., cell phones, laptops, radios). CDs can also feasibly replace highly volatile hydrazine in satellites in space. The next step is to verify testing and field applications.

#### PROBLEM STATEMENT

Lithium and conventional based batteries pose significant environmental and personal hazards due to their high explosive and corrosive nature and carcinogenic qualities. Producing a non-explosive battery using carbon dots does not pose these same hazards. Domestically, we lag in the excavation of lithium and other rare earth elements that comprise these batteries because the market is largely controlled by adversarial countries.

#### BENEFITS

The cost of CD batteries is half that of lithium and current conventional batteries and can be made domestically from lightweight carbon and water composite. CD filaments can be used to make nanodiamond batteries which can power industrial batteries (automotive), and as self-rechargeable batteries for electronics such as cell phones, laptops, and radios. Additionally, it may be plausible to build functional satellites based on the concept of self-rechargeable batteries.

#### TECHNOLOGY SOLUTION

Production method yielding a near 1:1 carbon-to-Carbon Dots (CDs) conversion ratio, which is significantly higher than other conventional processes currently in the CD market. Mixing CDs with peroxide and a composite liquid formed from byproducts gathered while purifying coal, produces a low-cost, safe battery that functions by converting photons into electrons. Samples of encased CDs in a composite liquid indicate battery energy storage/conversion. Early results show these batteries are biodegradable and can use byproducts from coal purification to enable scaling, following streamlined production. Thereby making CD batteries biodegradable, non-toxic, and biologically and ecologically safe.



Mixing Carbon Dots with peroxide and a composite liquid formed from byproducts gathered while purifying coal, produces a low-cost, safe battery that functions by converting photons into electrons.

## COCOON IMPROVED THERMAL ACOUSTIC BLANKET (ITAB)

PETER LORD

Cocoon, Inc.  
 plord@cocoon-inc.com  
 +1.603.964.9421

### Problem Statement:

The Cargo Helicopter Program Management Office identified deficiencies in the Chinook legacy blanket system that negatively impact readiness, and maintenance costs and man-hours. Identified deficiencies included:

- Moisture trapped between blankets and airframe leads to mold and corrosion, and requires frequent inspections and cleaning.
- Absorption of fluids, oils, lubricants - contaminates the blankets and adds weight.
- Absorption of hydrocarbon contaminants increases potential fire hazards.
- Chronic attachment failures require stringing 550 cord across blankets, limiting access to the airframe and adding maintenance time.
- Quilted design decreases durability while also making field repair difficult.

### Description of Technology:

Cocoon developed a 5-layer textile featuring nonwoven material at the center, microporous membranes above and below, completed with facing and backing materials. The 5 layers are laminated together into a single material.

The ITAB had to deliver a series of features that would seem to be mutually exclusive. For example, it had to be highly air-permeable but also oleophobic and hydrophobic, laminated while retaining air-permeability, and lightweight but meet or exceed the acoustic and thermal performance of the much heavier legacy blanket.

Producing a blanket featuring so many competing properties was a significant challenge.

### Product Features:

- Lightweight (140+ lbs. lighter than legacy blanket after use)
- Air-Permeable
- Mold/Mildew Resistant
- Thermally Efficient (12% improvement over legacy blanket)
- Acoustically Absorbent (40% improvement over legacy blanket)
- Hydrophobic & Waterproof
- Oleophobic
- Inherently Anti-Static (approved for use with ordnance)

- Sand/Dust Proof (filters to 0.5 microns)
- Fire-Resistant

### Current Development Status:

The ITAB is at TRL 9. It received Air-Worthiness Certification, is in the CH-47 IETM, and has been installed on +/- 80 CH-47s.

### Testing/Simulation Data:

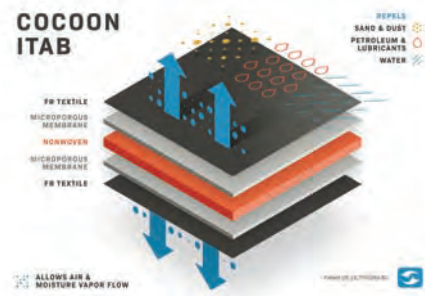
The ITAB underwent significant testing, which included the following:

- ASTM D737 (Air Permeability)
- ASTM E96 BW (Water Vapor Transmission)
- MIL-STD-810G (Vibration, Fungus, Fluid Contamination, Humidity, etc.)
- ISO 811 (Hydrostatic Pressure Test)
- AATCC 118 (Oil Repellency)
- ASTM D3776 (Fabric Weight Wet & Dry)
- FAR 25.853 (Smoke Density, Flame Resistance)
- BSS 7239 (Combustion Toxicity)
- ASTM C518 (Thermal Transmission)
- ASTM E2611 (Sound Transmission Loss)
- ASTM D4966 (Martindale Abrasion)
- ASTM D5035 (Tensile Strength)
- ASTM D2261 (Tongue Tear)
- ASHRAE 52.2 (Filtration)
- FED STD 191A TM 5931 (Electrostatic Discharge)

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- FED STD 191A TM 5931 (Electrostatic Discharge)

### Next Steps/Potential Benefits:

Development is underway for the C-130 Hercules, which also suffers from airframe corrosion. The technology is applicable to any military cargo aircraft employing similar blanket systems. Cocoon also continues to improve the ITAB system.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>The Cargo Helicopter Program Management Office, identified the following deficiencies in the Chinook legacy Thermal Acoustic Blanket:</p> <ol style="list-style-type: none"> <li>It traps moisture against the airframe, causing mold, mildew, and corrosion, impacting readiness, maintenance man-hours and safety.</li> <li>It's heavy out of the box, and gains additional weight as it absorbs fluids.</li> <li>It absorbs hydrocarbon contaminants, increasing potential fire hazards.</li> <li>It suffers chronic attachment failures, resulting in the use of 550 cord which impedes access and adds time to inspections and maintenance.</li> <li>The perforations in its quilted design allow fluids to enter the blanket, adding weight and contaminants.</li> <li>Its quilted design decreases durability (one pulled thread can cause a chain-reaction) and makes field repair difficult.</li> </ol> <p><i>(Outline letters correspond across all three text boxes.)</i></p>	<p style="text-align: center;"><b>BENEFITS</b></p> <ol style="list-style-type: none"> <li>The ITAB passes testing for microbial growth and ongoing flight tests have shown a dramatic reduction in both mold and corrosion on the airframe.</li> <li>The ITAB is 140+ pounds lighter than the legacy blanket after use, increasing the mission capability of the CH-47.</li> <li>The materials themselves are flame resistant and resist contaminants. The ITAB passes all required testing regarding flame, smoke, and toxicity.</li> <li>By eliminating the need for 550 cord, access panels remain accessible and inspections are quicker and easier. Installation, maintenance, and removal are also quicker and easier.</li> <li>Lamination versus quilting eliminates absorption of fluids, preventing contamination and weight-gain.</li> <li>The ITAB requires less repair and is far more easily repaired in the field when necessary.</li> </ol>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <p>Over multiple years, different combinations of textiles were tested, and then prototypes were both lab and field tested.</p> <ol style="list-style-type: none"> <li>Microporous membrane technology allows the ITAB to be highly air-permeable, preventing moisture from building up on the blanket and against the airframe.</li> <li>Advanced materials technology is lighter from the start, and because the ITAB is oleophobic, hydrophobic, and laminated, it doesn't absorb liquids that add weight over time.</li> <li>All layers of ITAB are oleophobic so hydrocarbons are not absorbed.</li> <li>Lightweight materials that remain light eliminate the need for 550 cord.</li> <li>Because the ITAB is laminated rather than quilted there are no perforations to allow moisture and fluids into the blanket.</li> <li>Being laminated means the ITAB is less susceptible to pulls and tears and can be easily repaired in the field with iron-on patches.</li> </ol>	 <p style="text-align: center;"><b>COCOON ITAB</b></p> <p>70 TEXTILE MICROPOROUS MEMBRANE NONWOVEN MICROPOROUS MEMBRANE 70 TEXTILE</p> <p>REPELS SAND &amp; DUST, PETROLEUM &amp; LUBRICANTS, WATER</p> <p>ALLOW AIR &amp; MOISTURE VAPOR FLOW</p>

## DESCALERS WITH ZERO CORROSION THAT ALSO PASSIVATE

**BEN OHLMEYER**

**Envirofluid**  
 ben.ohlmeyer@envirofluid.com  
 +1.202.869.8240

Defense equipment cooling and sewage systems has issue with corrosion, worker health, high labor costs and significant asset damage (especially Navy). Envirofluid (Australian defence Manufacturer of the Year 2022) designed the descalers specifically for the submarine fleet. The product is currently in product both in Australia and the United States. Extensive test data is available showing zero damage to all metal surfaces, no elastomer damage and 100% efficacy with full concentrations over 6 full days. Full radiation contamination results achieved also.

Envirofluid have also innovated complete flush systems and the rate of cycle docking activities has reduced significantly due to improved flush results. Systems are also passivated with the envirofluid chemistry each time. Next steps would involve US testing and validation before incorporation across the fleet and other Defence equipment.

System efficiencies will be significantly improved because equipment flushing can now be conducted in situ without having to remove items. maintenance costs savings

will be substantial and due no not having to dismantle and reassemble plus zero corrosion of assets will mean less asset replacement. Envirofluids scale removers are not hazardous and can be typically disposed to sewer after flushes are complete because they are manufactured from 100% biobased renewable plant sources.

Product is ready for the US market with manufacturing happening in Tennessee.

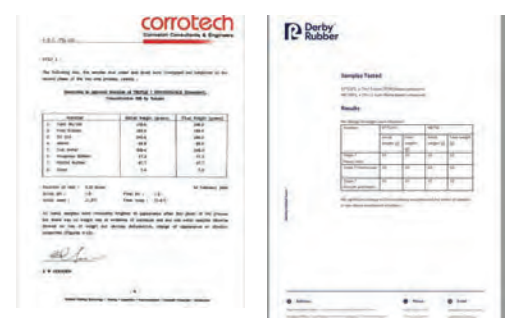
Envirofluid descalers was developed for submarines and no other descaling chemistry in the world offers zero corrosion, safety, and ease of disposal. The product is mature and is being used around the world. Applications include any areas where scale may develop in water supplies, water cooling / heating systems, radiators, cooling towers, and all marine applications.

Flushing and descaling already exists as an action within DoD, however the adaption of the innovative chemistry will transform maintenance procedures by reducing prep and clean-up activities, eliminate dangerous goods and eliminate asset damage. Adaptation will involve refinement

of work instructions and the associated operator training.

Envirofluid has written comments from NATO in Europe that we are keen to materialize (edited extract copied below)

“Thank you for your insightful presentation, which I will take on board from central support to operations of codification system. I do observe numerus approaches to hazmat materiel in the nations, so the challenge we face was how to find a common grounds, and while we move to new environment of more flexible data exchange, these will be revisited. I see that your approach is an effective one, and same pattern could be undertaken in other countries, among 60 plus countries.” - Codification Support Section Chief, NATO Support and Procurement Agency | General and Cooperative Services Programme LB | L-8302 Capellen, G.D. Luxembourg

<p><b>PROBLEM STATEMENT</b></p> <p>Scale and calcium growth issues abound throughout Defense creating the need for costly sustainment activities that often result in added asset damage and increased maintenance expenditure. Standard descalers are corrosive.</p> <p>Additionally, the servicing of onboard equipment requires costly disassembly and refit procedures (especially submarines). Dangerous goods (corrosive acids) also involve complex management and reporting programs as traditional cleaning substances used are composed of Hydrochloric, Sulphamic and Phosphoric Acids which are toxic and require extensive personal protective equipment when transporting, storing and handling.</p>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Reduce the annual cost to the DOD of corrosion, asset damage, rubber deformation as a result of acidic chemical attacks</li> <li>• Extend the service life and performance of systems, pipework and associated equipment and other damage to sensitive equipment</li> <li>• Enable in situ cleaning operations reducing downtime and manhour requirements</li> <li>• Protect personnel from dealing w/toxic health issues and acid burns</li> <li>• Able to operate within sensitive radar system cooling</li> <li>• Product has radiation reduction properties</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>New technology has finally produced a worksafe limescale removal system that doesn't rely on highly corrosive chemicals to dissolve away deposits.</p> <p>Triple7 descalers will not erode or corrode metal surfaces or damage rubbers or elastomers. They are safe to use on pumps and pipework in situ, saving enormous time, effort and money by not having to remove equipment from cooling towers, ship systems, heat exchangers or other water-operated machinery.</p> <p>100% biobased acids from renewable plant-based sources protect assets, people and the environment.</p>	

## AUTOMATED ULTRASONIC BEARING CLEANING LINE

MIKE POCHKOWSKI

DAES Group  
 mike.pochkowski@daesgroup.com  
 +1.512.994.5706

Bearings are fielded inside many DoD aviation systems and their care and maintenance is critical to mission capability. Operating Automated Ultrasonic Bearing Cleaning Line (AUBCL) systems within the DoD depots will improve mission readiness utilizing repeatable part processing reducing and, in many cases, eliminating rework. Additionally, flight safety will be maximized because these depot maintenance systems will help find component deficiencies (cracks and corrosion) efficiently and with higher fidelity than artisans who possess varying experience and training.


The first dedicated Ultrasonic Bearing Cleaning Line is designed to process bearing components, regardless of design or size, through a 5 stage fully automated washing, cleaning and drying process that allows the bearing components to be accurately inspected to Engine OEM and/or customer requirements.

The FinnSonic “Tempo” process is fully automatic from the loading to unloading; smart process control that allows a selection of process parameters, full process traceability including automatic chemistry

analysis and auto adjustment control based on usage.

The system is Manufacturing 4.0 ready.

Finally, reduced operating costs, ergonomic as well as optimized health and safety designs result in a reduction in the number of artisans required per line allowing the depot to repurpose those labor skills to areas and tasks requiring a higher degree of engineering oversight. With seven (7) Tempo™ Automated Ultrasonic Cleaning Lines in operation at major engine OEMs and engine overhaul facilities globally this proven capability presents a risk mitigated automation process solution the DoD can readily implement today within the depots.

PROBLEM STATEMENT	BENEFITS
<p><b>Commercial Experience</b></p> <ul style="list-style-type: none"> <li>• Bearing cleaning and refurbishment greatly reduces supply chain risk.</li> <li>• The potential savings from bearing rework varies from 53-82% of the new bearing depending on cost, size and complexity of the bearing.</li> <li>• Automation results in up to 80% cycle time reduction and eliminates rework.</li> <li>• Life of the reworked bearing ranges from 87-99% of the new bearing.</li> <li>• 90% of used bearings can be recovered and reused during engine MRO.</li> <li>• FAA encourages this practice for all Commercial Engine Overhaul activity.</li> </ul> <p><b>Current DoD Issue</b></p> <ul style="list-style-type: none"> <li>• Bearings are often the limiting factor in the supply chain during MRO process.</li> <li>• Current DoD bearing cleaning processes are primarily manual.</li> <li>• Many DoD repair facilities acquire new bearings during MRO adding costs.</li> <li>• Cleaning the Bearings can be a challenge.</li> <li>• Safety issues can result from improperly cleaned bearings.</li> </ul>	<ul style="list-style-type: none"> <li>• Environmentally friendly aqueous cleaning solution that uses innovative ultrasonic transducers optimally positioned to maximize efficiency.</li> <li>• Robust and commercially proven system that facilitates a first-class component inspection result and ensures correct component disposition</li> <li>• In excess of 90% of the used bearings will be fit for further service..</li> <li>• Increased first time cleaning yields by 24%.</li> <li>• Safe and effective application of industry/OEM accepted standards.</li> <li>• Improved asset management, reduced asset cycle time, 300% reduction in cleaning time, with associate lower costs.</li> <li>• Improved asset readiness at the lowest cycle time, with resultant cost benefits. 19% improvement in Return to Service Yields (RTS)</li> <li>• Repair has a significantly lower carbon footprint than replace with a new component... regardless of reparability</li> <li>• Ergonomically friendly – eliminates worker injury</li> <li>• Faster, Safer and Cheaper with proven technology</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• The first dedicated Ultrasonic Bearing Cleaning Line is designed to process bearing components, regardless of design or size, through a 5 stage fully automated washing, cleaning and drying process that allows the components to be accurately inspected to Engine OEM requirements.</li> <li>• The FinnSonic “Tempo” process is fully automatic from the loading to unloading; smart process control that allows a selection of process parameters, full process traceability including automatic chemistry analysis and auto adjustment.</li> <li>• The system is Manufacturing 4.0 ready.</li> <li>• There are 7 FinnSonic systems in operation with major Engine OEM’s and Engine overhaul global facilities.</li> </ul>	

# COATING AND CORROSION PREVENTION

## FULLY AUTOMATED THERMAL SPRAY PROCESS

MIKE POCHKOWSKI

DAES Group

mike.pochkowski@daesgroup.com

+1.512.994.5706

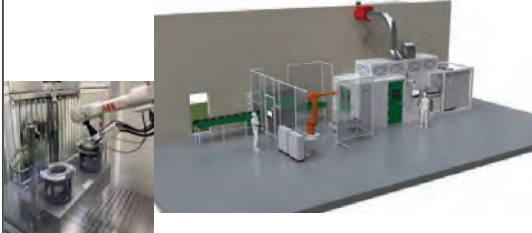
U.S. Department of Defense has had to decommission countless high-value military platforms due to corrosion damage. Without adequate repair technologies available, maintenance members faced enormous costs and downtime whenever they tried to fix and replace corroded parts. The thermal spray process addresses the corrosion issue by enhancing the properties of metal surfaces, providing superior wear resistance, corrosion resistance, and tribological performance.

Via robotic automation and superior flame/powder management The Coating Machine Model IITM offers high first pass yield and excellent throughput. repeatability. The machine is a very complete – plug and play and well suited an asset for coating applications where parts need to be sprayed in medium to large batches.

Benefits:

- Less operator involvement while quality is checked and safe guarded using new and available technologies

- Continuous operation results is increased production rates in comparison to conventional spray system. Up to 500% has been achieved with high volume components.
- Due to continuous running and the use of integrated flame sensor technology increased quality and reduction in rejects
- Operators are 75% less exposed to toxic fumes, dust and noise
- Small footprint
- Thermal Spray system is pre-installed and tested at manufactures site, making installation quick and easy. Installation times at site are reduced by 30-40%
- Using remote and VR technology, service can be provided in a far more efficient manner. 75% of onsite visits are eliminated reducing service costs considerable

PROBLEM STATEMENT	BENEFITS
<ul style="list-style-type: none"> <li>• Thermal Spray Operation is in many cases a semi automated operation.</li> <li>• Operators work in a noisy and dusty environment.</li> <li>• Coating quality results are many times subjected to operators' level of expertise.</li> <li>• Many variables, some not or difficult measurable, contribute to the process being subject to inconsistent quality results.</li> <li>• Difficult, in the event of a process or human error, to detect that error.</li> <li>• Ergonomically, or Health &amp; Safety wise the environment is not conducive for high performance activities.</li> <li>• If not automated the process can be very labor intensive and repetitive, and inaccurate</li> </ul>	<ul style="list-style-type: none"> <li>• Less operator involvement while quality is checked and safe guarded using new and available technologies</li> <li>• Continuous operation results is increased production rates in comparison to conventional spray system. Up to 500% has been achieved with high volume components.</li> <li>• Due to continuous running and the use of integrated flame sensor technology increased quality and reduction in rejects</li> <li>• Operators are 75% less exposed to toxic fumes, dust and noise</li> <li>• Small footprint</li> <li>• Thermal Spray system is pre-installed and tested at manufactures site, making installation quick and easy. Installation times at site are reduced by 30-40%</li> <li>• Using remote and VR technology, service can be provided in a far more efficient manner. 75% of onsite visits are eliminated reducing service costs considerable</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>▪ Using fully digital system so all components work in a net-work and data can be extracted for quality checks and process controls</li> <li>▪ Use of automatic in-feed and out-feed to increase production and less operator involvement</li> <li>▪ Use of flame analyses equipment to assure the flame with powder is always running within the given parameter range</li> <li>▪ Use of automated coating thickness measurement equipment to make sure applied coating thickness is always within spec.</li> <li>▪ In-line laser ablation to replace the grit blasting process is being implemented</li> </ul>	



## FULLY AUTOMATED GREEN PARTS CLEANING AND SURFACE TREATMENT PROCESS

MIKE POCHKOWSKI

DAES Group  
 mike.pochkowski@daesgroup.com  
 +1.512.994.5706

The Factory of the Future – Fully Automated Surface Treatment Cleaning Line (FAST-CL™) combines strict regulatory compliance with safe and smart process control and automation for aircraft component processing. System automation minimizes human risk factors, adds rigorous traceability, and significantly speeds up processing time thus reducing the overall end to end depot cycle time contributing to improved materiel readiness. Innovative ventilation and wastewater treatment processes isolate process chemistries significantly minimizing health challenges to personnel and structural damage to facilities.

FAST-CL™ launched operations within the Ogden ALC in Q3 2021 cleaning a substantial mix of APU parts for several different airframes. Measurable, significant reduction in energy consumption, chemical usage, backlog reduction, and enhanced first pass yield have been realized since system startup.

Using a FASTCL™ automated parts cleaning system improves mission readiness via utilization of automated smart process control greatly reducing artisan involvement and handling risks. Reduced cycle times mean more components and systems will be available to the warfighter as needed. Parts processed by these systems result in maximized flight safety. Finally, reduced operating costs and valuable human resources can be repurposed to more strategic roles.

### PROBLEM STATEMENT

- Data indicated that industrial activity accounts for two thirds of the pollution that causes climate change
- World Health Organization stated 9 out of 10 people breath air that exceeds pollution standards, causing 4.2 million deaths annually.
- The Surface Treatment activities are a prime source of pollution due to hazardous chemical usage, toxic exhaust and wastewater residue.
- Component Cleaning processes are usually the “sore thumbs” within the facility that are environmental, technology and investment challenges.
- Cleaning processes are in the critical path for nearly all components undergoing MRO and the cleaning shops are often “bottlenecks”.
- Generally, the cleaning operations have the highest staff turnover and the highest absentee rates.
- **Effective cleaning processes are critical for expedient cycle times and for the overall integrity of the maintenance process.**

### BENEFITS

- The automated, smart process greatly reduces, or eliminates, human involvement and handling risk.
- Manufacturing 4.0 ready – full digital traceability
- Significantly reduces labor costs by 50+%, energy costs by up to 55%, chemical utilization by up to 30% & wastewater by 50%; all key elements in creating a sustainable operation.
- Reduced cycle time means more components and systems are available to warfighters when needed.
- Valuable human resources can be repurposed to more desirable roles.
- **Safer, Greener, Cheaper, Quicker resulting in an efficient and cleaner work environment**

### TECHNOLOGY SOLUTION

- Surface Treatment can be clean, safe and an environmentally friendly process with the innovative use of technology.
- The “Galvatek Future Factory” Surface Treatment operations combine strict regulatory compliance with safe & smart process control and automation.
- Embracing Chemical and EH&S concerns with the demands of process efficiency, ecological, sustainable and safe production can be achieved.
- The innovative ventilation process effectively extracts vapors from chemical tanks; eliminating the possibility of them emitted dangerous vapors into the air and causing health challenges and structural damage.
- An ultra-efficient recycling Wastewater Treatment Process manages wastewater to strict local, state and federal regulations.
- Automation minimizes human risk factors and significantly speeds-up processing time – reducing overall end to end MRO cycle time.



# COATING AND CORROSION PREVENTION

## THE FULLY AUTOMATED 14 AXES SHOT-PEENING SYSTEM

MIKE POCHKOWSKI

DAES Group

mike.pochkowski@daesgroup.com

+1.512.994.5706

Military applications require metal parts and components with exact, even finishes, and improved compression and fatigue strength. The parts must meet the most demanding specifications and tolerances and perform well under extreme and challenging conditions. Due to their geometric complexity the most difficult parts to peen for optimum fatigue strength are aero engine fan blades and turbine discs.

Implementing 14-axis robotic technology with two robots, an automated nozzle / lance exchange, process control of shot size and shape, plus closed loop shot flow and air pressure systems the Fully Automated 14 Axes Shot-peening system has unmatched performance. Cycle times are reduced up to 45%, setup times are shortened by 60%, and measurement and control of key parameters leads to guaranteed process repeatability. First pass yields are measurably higher over manual methods and artisan fatigue and exposure to injury are non-existent with this robotic methodology.

### PROBLEM STATEMENT

- Complex parts such as aero engine fan or turbine discs are challenging to peen
- High variety of components to be peened
- Many different shape nozzles are needed to access complex geometries
- Multiple shot sizes required to complete whole process
- Shot size- and shape are key
- Changing setups are time consuming
- FAA/ EASA and the aerospace industry demands 100% repeatability

### BENEFITS

- Completes cycle without any human intervention
- Minimum time needed to change setup. Setup time reduced by 60%
- Reduction of cycle time by up to 45%
- Limiting manual work
- Measurement and control of key parameters leads to guaranteed process repeatability
- Process data stored for traceability
- 100% repeatability and traceability
- High performance ergonomics

### TECHNOLOGY SOLUTION

- Two 6 axes robots
- Auto nozzle/ lance exchange
- Continuous control of shot size
- Continuous control of shot shape
- Fully automatic closed-loop shot flow system
- Fully automatic closed-loop air pressure system
- Off-line programming (OLP) with built-in collision detection



## FULLY AUTOMATED IBR & BLISK REPAIR PROCESS

MIKE POCHKOWSKI

DAES Group  
 mike.pochkowski@daesgroup.com  
 +1.512.994.5706

IBRs and Blisks are often the limiting factor in the supply chain during the MRO process – small defects in the component require replacement – leading to excessively long MRO cycle times as well as leading to non-availability of critical system and components needed by the warfighter. Current DoD IBR and Blisk processes are primarily manual, time-consuming, subject to human-induced variations in quality of airfoil performance. Many DoD repair depots opt for only acquiring new IBR and Blisk during MRO, which adds significant cycle time and cost to the process.


The manual IBR and Blisk inspection processes often result in variable decisions on go/no-go for repairs, avoidable scrappage and/or incorrect work-scope application can be delivered with IBR and Blisk repair automation. Additionally, safety issues can result from improperly manually repaired and inspected IBR and Blisk components, results in weld metallurgy, airfoil leading edge final profile and cord width can be less than perfect. Performance loss and safety critical failures have resulted from improperly repaired components.

The Fully Automated IBR and Blisk Repair Process uses automated non-contact scanning of IBR and Blisk components to compare the SCAN STL to the original CAD model and characterize damage / wear. Then the TTL Adaptive Machining technology scan data updates the CAD model, to create a serialized CAD model CAM process for repair scheme cut back. A clean, Liburdi welding process is then employed to add minimum material onto each airfoil repair in line with updated repair scheme geometry. All data creation and movement are automated with industry 4.0 compliant architecture.

The Fully Automated IBR and Blisk Repair Process employs robust and commercially proven automation system used on many airfoil P/N's. Additionally, the system will allow the DoD to realize:

- More than 80% of the airfoil damage 'repairable' IBR and Blisk will be fit for further service.
- Inspection standardization with yield increase + 25%

- Improved IBR and Blisk asset management, reduced asset supply cycle time, 200% reduction in process time, with associated lower costs.
- Quality up, risk down, supply chain security.
- A significantly lower carbon footprint than replace with a new component... regardless of reparability
- Ergonomically friendly – eliminates worker costly repetitive injury from complex blending operations

<p><b>PROBLEM STATEMENT</b></p> <p><i>Current DoD Issue</i></p> <ul style="list-style-type: none"> <li>• IBR &amp; Blisk are often the limiting factor in the supply chain during the MRO process - small defects in the component require replacement – leading to excessively long MRO cycle times - leading to non-availability of components.</li> <li>• Current DoD IBR &amp; Blisk processes are primarily manual, time-consuming, subject to human-induced variations in quality of airfoil performance.</li> <li>• Many DoD repair facilities opt for only acquiring new IBR &amp; Blisk during MRO; which adds significant cycle time and cost to the process.</li> <li>• Currently many IBR &amp; Blisk inspection processes are manual; resulting in variable decisions on go/no-go for repairs, avoidable scrappage and/or incorrect work-scope application can be delivered with IBR &amp; Blisk repair automation . Resource optimization, shorter lead times and cost avoidance.</li> <li>• Safety issues can result from improperly manually repaired and inspected IBR &amp; Blisk components, results on weld metallurgy, airfoil leading edge final profile and cord width can be less than perfect. Performance loss and safety critical failures have resulted from improperly repaired components.</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Robust and commercially proven automation system used on many simple airfoil MRO P/N's</li> <li>• In excess of 80% of the airfoil damage 'repairable' IBR &amp; Blisk will be fit for further service.</li> <li>• Inspection standardization with yield increase + 25%</li> <li>• Automated, Safe and effective application of industry/OEM MRO process accepted standards.</li> <li>• Improved IBR &amp; Blisk asset management, reduced asset supply cycle time, 200% reduction in process time, with associated lower costs.</li> <li>• Quality up, risk down, supply secure.</li> <li>• Repair has a significantly lower carbon footprint than replacement.</li> <li>• Ergonomically friendly – eliminates worker costly repetitive injury from complex blending operations</li> <li>• Faster, Safer and Cheaper with proven technology</li> <li>• Technology transfer – re-application of approved processes to a more complex, higher payback IBR &amp; Blisk part family, critical to the DoD.</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Automated Non-Contact scanning of IBR &amp; Blisk components to compare the SCAN STL to the original CAD model and characterize damage / wear.</li> <li>• TTL Adaptive Machining technology Scan data update of CAD model, to create a serialized CAD model CAM process for repair scheme Cut Back.</li> <li>• Clean, Liburdi Welding process to add minimum material onto each airfoil repair inline with updated repair scheme geometry.</li> <li>• Non-Contact scan, Automated Scan Data - CAD, Serialized NX CAD/CAM for TTL 'Adaptive Machining' Blending, post process, simulate = Closed Loop. Toolroom Technology Limited – (Based in the UK 35 Years experience in Gas Turbine Repair Automation working with DAES Group)</li> <li>• Inspect, feedback any process improvement to improve quality of blend and reduce final finishing of airfoil.</li> <li>• Automated loading and unloading of the Scan-box, Machine tool cut-back, Welding system and Machine tool Adaptive Machining Final blending.</li> <li>• All data creation and movement automated with industry 4.0 compliant architecture.</li> </ul>	

## CORROSION HAS FOUND ITS KRYPTONITE

DANIEL REID

ToughGuard High Performance Coatings, LLC  
danreid@toughguard.com  
+1.503.784.1791

The annual financial cost of corrosion to the US DOD is somewhere in the \$25 billion range. Corrosion not only takes its toll on the US DOD in terms of dollars, but corrosion also takes its toll on having critical military assets out of service for extended periods of time. Instead of having critically important assets deployed where needed, they sit in dry docks or paint and repair stations around the globe. Sustainment of the US DOD assets is more critical than ever with the reduction of military budgets coupled with growing tensions around the world with adversarial nations.

The protection and sustainment of existing (as well as new) assets is needed now more than ever.

The problem is that there has not been any new, revolutionary technologies or products to really protect US DOD assets from corrosion, abrasion, chemical and UV attacks on paint. Existing paint companies keep producing and supplying the same old paint technologies from the same old playbook from yester-year. For decades now, there really has not been any new, innovative paint technology introduced into

the marketplace. That's because the same chemistry knowledge base has nothing new to offer other than minor changes that allow these companies to create "new" products with a new name that in reality, these new products are basically the same old product but with just a different marketing campaign that allows those companies to do what they are expected to do by their stockholders and that is to sell paint and sell a lot of it. Why introduce new technologies when the customers keep purchasing the old or revised technologies?

ToughGuard High Performance Coatings manufactures a true innovative product that is a game changer in the paint coatings industry. The ToughGuard NHP Xtreme clear coat paint system is the answer not only for corrosion mitigation, but our revolutionary technology/chemistry provides unheard of protection against chemical, abrasion, and UV degradation. Our technology took over 10 years to develop and over 4600 iterations of the product before it was taken to market. Our NHP Xtreme coating has been tested, vetted, and approved by some of the most recognizable US and global companies.

Our technology outperforms all other paint coating systems on the market. We have extensive tests conducted by reputable 3rd party laboratories as well as real world, in the field use and tests. NHP has been in the market around the world and is winning over customer's admiration and trust. Our ToughGuard NHP was tested by the USAF corrosion group in 2020 at The U of Dayton Research Institute & performed exceedingly well. The USAF was so impressed with the results, they are looking to conduct more testing on our NHP product. They just need some funds for more testing.

If the DOD wants to solve the ongoing and severe issues & costs of corrosion & paint degradation due to chemical, abrasion, and UV attacks, then NHP Xtreme is their answer to this problem!

### PROBLEM STATEMENT

Paint degradation caused by corrosion costs the US DOD in the neighborhood of \$25 billion per year and this cost is only going to get more expensive in the years to come due to the increases of material costs and labor costs. There is also the real problem associated with corrosion and that is the cost of having critical military assets not deployed or in ready to be deployed status due to the fact of having these assets in dry-docks or other paint and repair stations.

Paint degradation in terms of abrasion, chemical and UV attacks also has annual costs and assets not deployed or ready for deployment. For instance – helicopter rotor blades are constantly being re-painted due to paints being chipped off due to sand and other debris degrading the paint. Again, the out of service issue is a real problem in this critical area.

### BENEFITS

- Reduce the annual cost to the DOD of corrosion, abrasion, chemical & UV attacks on paint systems
- Keep critical military assets deployed or ready to deploy status
- Extend the service life and performance of current paint systems by at least 10 years
- Reduction of re-paint costs in terms of dollars and out of service costs
- Reduction of existing paint volumes due to the innovation of ToughGuard NHP Xtreme to protect far greater and extend performance with less paint coatings
- Sustainment of fewer and fewer assets due to budget reductions
- Protect service personnel from dealing w/toxic health issues

### TECHNOLOGY SOLUTION

The solution is our ToughGuard NHP Xtreme clear-coat paint system. ([www.toughguardnhp.com](http://www.toughguardnhp.com)). Our clear-coat paint system works with other paint systems such as PPG or Sherwin Williams products to make them last longer and perform to a far greater extent than they are capable of performing on their own. All current paint systems are built off of single linear polymer molecules. The backbone of the ToughGuard NHP Xtreme product is a ground-breaking, innovative, proprietary formulated 3D polymer molecule. This 3D aspect of our formulation creates a crosslink density that is stronger than any other paint coating system on the market. In working with existing paint systems our technology and chemistry chemically and mechanically bonds with these other paint systems to create an almost impenetrable coating.

Before NHP Xtreme



After NHP Xtreme



## AUTONOMOUSLY TRIGGERED LUBRICATION & SELF-REPAIR

JON SCHUPP

InfraTrac  
jschupp@infratrac.com  
+1.301.693.9979

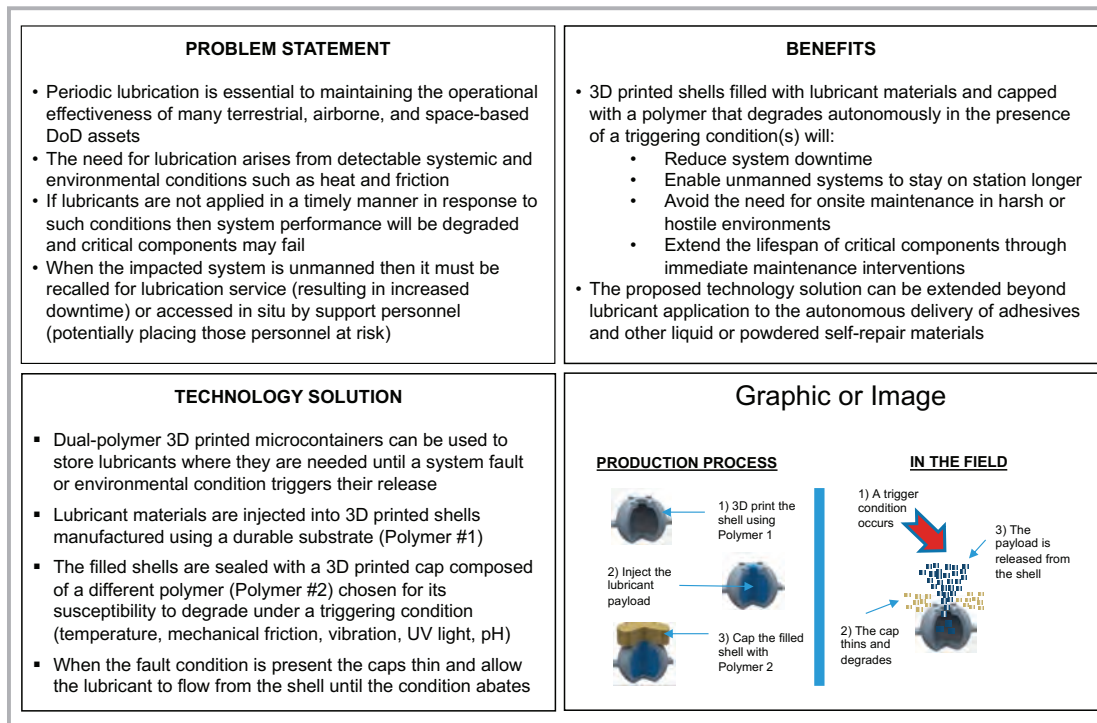
Unmanned systems and difficult-to-access fixed assets experience fault conditions requiring application of lubricant materials. Readiness is lowered and cycle times increased by the need to recall an unmanned platform for servicing. Likewise, there are potential risks to personnel involved in accessing remote fixed assets to perform lubrication services. The ability to autonomously apply lubricants (or adhesive materials for self-repair) in response to fault conditions without human intervention and while the asset remains on station will avoid downtime and eliminate risks to personnel.

The technology solution places lubricant materials where they will be needed until their release is triggered by the presence of a fault condition. Lubricants (or adhesives or other self-repair materials) are stored in 3D printed microcontainers and affixed to the system component potentially requiring maintenance. These storage shells are constructed of a durable polymer (Polymer #1). After lubricant is injected into the storage shells each is sealed with a second, less durable polymer (Polymer #2). The polymer used to cap the shells is selected for its sensitivity to one or more

expected fault conditions (e.g., excess heat, friction, vibration, or acidity). Polymer #2 is printed atop the shells with a graduated depth leaving some shells thinly capped while others are covered more thickly. If a fault condition arises its presence acts to erode the fault-sensitive caps until the payload is released, starting with the shells that are most thinly capped. When the fault condition is resolved through application of the released payload, erosion of the Polymer #2 caps ceases with the thicker caps remaining intact and available to release additional lubricants in response to a recurrence of the fault condition. The self-lubrication/repair process is triggered autonomously without any action required by maintenance personnel.

InfraTrac's experiments, including a pending patent and two refereed publications, show feasibility in leak-free encapsulation, in polymer containers with cap-trigger mechanisms and microfluidic-fill liquid cores. Already replicated in lab conditions, the work is being extended to assess additional materials for the shells, caps, and core payloads. The effectiveness of autonomous self-lubrication/repair can be demonstrated

by applying vinegar to an asset operating in a dusty environment, such as a drone or robotic system, to simulate a corrosive fault condition. The vinegar will erode the polymer caps covering the 3d printed storage shells and allow a thin monolayer of lubricant to coat the impacted surface. Effectiveness is evaluated on the released lubricant's ability to correct the corrosive fault condition. Further research is needed to confirm the range of DoD maintenance material payloads suitable for encapsulation and to define timed release curves for Polymer #2 candidates under various operating conditions.



## COLLABORATION TO ENHANCE LASER SURFACE PREPARATION

SUSAN L SPRENTALL

SurClean Inc.  
 sjsprentall@surclean.com  
 +1.248.797.9352

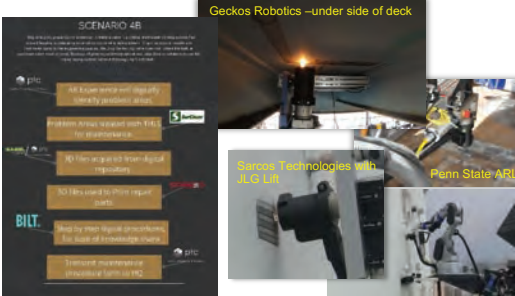
SurClean is an Optoelectronics Laser Ablation Research and Development company. It provides application development and manufactures advanced laser coating removal and surface prep machine tools. SurClean is different from its competitors. Its product is the beam delivery system integrated with COTS lasers, chillers, and other products such as robots, vision systems, or AI. We listen to prospects' problems, what is their desired result, and why they want to use laser. SurClean receives calls asking if we have this capability or that type of machine tool. We thought we were focused. SurClean participated at NAVSEA REPTX and saw first-hand why the industry needs to collaborate. SurClean had many inquiries for a self-contained system to move from location to location allowing the business owner or operator to reduce costs, prevent hazardous waste, and increase safety. Prospects wanted simple, easy-to-use but durable to withstand drops. We built the Transportable Handheld Laser Ablation System. However, at REPTX, we quickly learned the suitcase approach was too difficult to maneuver

in and out of compartments and down tight stairs. It's being repackaged to meet those requirements.

Another discovery is robotics are needed to do large or out-of-reach areas. A solution is collaborating with Geckos Robotics, Penn State ARL, or Sarcos Technologies. SurClean is in discussions on how we might provide add-on kits to the interface. Additionally, BILT offers IPAD instructions to assist the warfighter on how to step by step prepare and set up to use the equipment. SurClean intends to digitize and package with our DoD Transportable Handheld Laser System. SurClean's equipment is designed based on industry standards simply defined in Wikipedia. Laser ablation is "the process of removing material from a solid surface by irradiating it with a laser beam. At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates. At high laser flux, the material is typically converted to a plasma." To complete the application, optical devices are utilized to guide and manipulate the light to a specific spot size to effectively perform the application. Optoelectronics

"is the application of electronic devices and systems that find, detect and control light. In this context, light often includes invisible forms of radiation such as infrared, in addition to visible light. Optoelectronic devices are electrical-to-optical or optical-to-electrical transducers."

SurClean develops devices to allow for programming-specific parameters for the application, automation, and safety control for the operator, asset, and equipment. SurClean's focus needs to be expanded to include TOTAL SYSTEM SOLUTION. We must answer the question, "what is needed to complete the repair?" Innovation is constantly taking place in the laser industry, but sometimes it is simply thinking outside the box and collaborating to deliver a TOTAL Solution to complete the repair.

<p><b>PROBLEM STATEMENT</b></p> <p>REPTX opened the opportunity to innovate by simply thinking outside the box and allowing industry to experience the obstacles sailors face when making repairs.</p> <ul style="list-style-type: none"> <li>• Not one piece of equipment solves the problem</li> <li>• Sustainability requirements are not met with traditional methods for surface preparation</li> <li>• Hazmat issues interfere with doing the job</li> <li>• Manual documentation is time consuming and requires multiple human touches to track by boat let alone the area and what occurred.</li> <li>• Safety is an issue climbing to address high points.</li> <li>• Small, tight spaces are not accessible manually when the tools are larger than the area</li> <li>• <b>Knowing what to do is not known by everyone</b></li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Collaboration is the key for Innovation</li> <li>• Companies reduce overall costs when shared with other companies and provides the customer with a higher satisfaction rate for repetitive sales</li> <li>• Providing kit adaptations for automation allows DoD to purchase the TOTAL Solution from ONE Supplier but with the support of each individual company</li> <li>• Adds versatility if ship has various robotics onboard</li> <li>• Reduces cost when one tool will work for numerous applications</li> <li>• Laser ablation reduces hazmat</li> <li>• Laser ablation is safe and requires no PPE other than laser goggles to protect eyes.</li> <li>• Sensor technology protects asset</li> <li>• Programming changes for multiple applications</li> <li>• Digitizing maintenance records reduces cost improves efficiency</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>The use of advanced optoelectronics in laser ablation is improved when combined with robotic manipulation. Collaborating with different manufactures provides versatility by mixing and matching various pieces of equipment for numerous repairs while generating ideas, improvements, and stimulating communications that leads to more solutions. In SurClean's proposed solution to offer kits containing nozzles and lens for small, tight spaces or to direct the light to the backside of a pipe, will help prevent extensive corrosion and higher repair costs. Offering the various end of arm connections and programs to select the robotic manufacturer provides a cost savings for the DoD while increasing capabilities. iPad instructions for specific repairs reduces the chance of errors and equipment damage utilizing a check list. Data is captured and available for accountability as well as planning purposes. More can be accomplished when industry is focused on the TOTAL solution.</p>	<p><b>TOTAL SOLUTION</b></p> 

## SPARTABRAKE METAL SURFACE CLEANER

CLAYTON BALMES

SpartaMax Defense and Products  
office@spartamaxdefense.com  
+1.815.637.1574

SpartaBrake Metal Surface Cleaner is an advance in formulation and design to use Hi-Performance Technical Grade Oxygenated chemistry with a specific target in-job or task to be accomplished provides immediate efficiency and effectiveness to every application it created to accomplish and complete – EASY TO USE & WORKER SAFE. Normally less product is used to accomplish the very same task as compared to the 100% petroleum counterpart.

SpartaBrake Metal Parts Cleaner is original and innovated unto itself (currently) the ONLY USDA certified product (USDA # 11282) to its application and category. This product and chemical technology was BIRTHED from QPL performance qualification with a similar product, since there was not exact specification, we were allowed without restriction to create a complete Hi-Performance product and we did.

Maintenance is improved as SpartaBrake provides both: excellent cleaning performance: a safe use environment for the personal worker to not be effected by harsh chemicals – to work effective with greater personal efficiency.

REAL benefactor of implementing the SpartaBrake program is the worker/mechanic and how well he can do this job better as compared to the use of harsh chemicals.

SpartaBrake program was BIRTHED about five years ago during the test and successful development of the SpartaMax 372F BioRBC QPL MIL-PRF-372F.

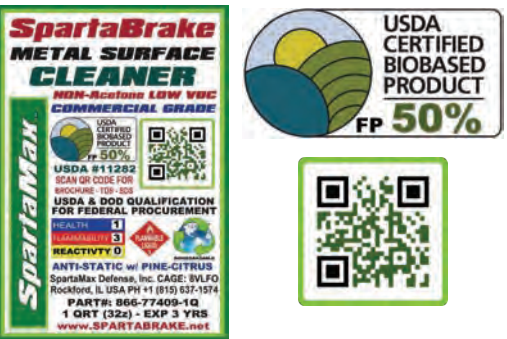
During that period of creation, a discovery (Idea) was to development a second product. SpartaBrake was then developed in use with multiple automotive & common working shop applications.

Through the STED program for promotion of BioBase Hi-Performance alternatives the Noblis Organization as of 15 OCT has made SpartaBrake w/ successful demos to multiple (12) Military or Gov groups such as but not limited to:

- Joint Base Lewis McCord
- Red River Army Depot
- FBI Quantico TEVOC
- Marine Corps Mountain Warfare Training Center

- Marine Corps Air Ground Combat Center
- Shaw AFB, Eglin AFB, Hurlburt Field AFB
- Patrick Space Force AFB
- NASA Marshall Space Flight Center
- NASA Armstrong Flight Research Center
- NASA Kennedy Space Center

These 12 mentioned have acceptance.

<p><b>PROBLEM STATEMENT</b></p> <p>Mechanics &amp; Service Members in situations within Multiple Branches of DoD, Federal &amp; Commercial shops or work facilities with the areas of Automotive, Aerospace &amp; Military vehicles etc. that require the need to clean and remove metal surfaces of Carbon, Contaminates and light oils etc. (like a brake job etc.)</p> <p><u>ALL HAVE THE SAME PROBLEM OR ISSUE.</u></p> <p>Common Brake Cleaners (if you look at the SDS) contain many different harsh petroleum chemicals: when breathed in the air or absorbed into the skin and gets into the lungs or blood stream by the worker: over time will cause multiple troubles with the Human Body, many times creating long term physical &amp; neurological etc. effects. Current formulated Common Brake Cleaners because of EPA regulations have been reduced in cleaning &amp; overall operational performance: while the cost today is higher.</p> <p>These issues as mention above have been and are solved with a technical solution that has been around for nearly ten years, and today (2022) has come forth. Multiple certifications and approvals are as mentioned below.</p>	<p><b>BENEFITS</b></p> <p>SPARTABRAKE METAL SURFACE CLEANER – USDA CERTIFIED # 11282 BENEFITS:</p> <p>SpartaBrake THE ONLY BIOBASE METAL CLEANING USDA REGISTERED PRODUCT</p> <p>No harsh petroleum chemicals, NON-Acetone – LOW VOC Commercial Product (considered as a off the shelf commercial product – NON Military Specification).</p> <p>SpartaBrake Cleaner can be used in multiple applications with easy cross reference replacement to current Petroleum Brake &amp; Metal Parts Cleaners without any reduction in cleaning performance. NO Physical issues in use (unless allergic to Pine or Citrus).</p> <p>NO OSHA- NON HARAZARD reportability. EASY TO USE with HI- PERFORMANCE.</p> <p>Universal to multiple applications and use. Can be easily sold through multiple DoD, Federal &amp; Commercial purchase platforms including but not limited to: DLA (Defense Logistics Agency), GSA, Fed-Mall and many others or MFG Direct.</p> <p>IN the end, Just about everyone that used or has experienced SpartaBrake Metal Surface cleaner says: “where have you been all my life” thank you being here now.</p>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>TODAY- NOW THERE IS AN ANSWER TO SOLVE THE PROBLEM &amp; ISSUE STATED.</p> <p>USE A SPECIFIC formulated product that does not use harsh petroleum chemicals. Product that uses Technical Grade Bio Based Renewable Resource Chemical Materials that are naturally oxygenated. Technical Grade designed to go after Carbon with a specific Detergent package to cleanse deep into surfaces &amp; most contaminants. Anti Static capability to help resist during cleaning event carbon &amp; dirt from returning. Commercial Grade Evaporation capability, when completing its job it is gone &amp; clean.</p> <p>USDA - Bio Preferred (w/ approval &amp; certification listing w/ 50% biobase content) with FP- Federal Procurement ; working the GSA requirements of FAR 52.223-2 for BioBase Purchasing with approval by STED program through the Under Secretary of Defense Energy &amp; Environment with the Program Manager NOBLIS that is SAFE TO USE.</p> <p>Product available right now w/ years of real life testing &amp; development BIRTHED from DoD Qualification testing in a similar Rifle Bore Cleaning product is called:</p> <p><u>SpartaBrake Metal Surface Cleaner - by SpartaMax Defense CAGE: 8VLFO</u></p>	 <p>The image shows the product packaging for SpartaBrake Metal Surface Cleaner. The main label features the product name in large, bold letters, along with 'NON-Acetone LOW VOC COMMERCIAL GRADE'. It also includes a QR code and a USDA Certified Biobased Product logo with 'FP 50%' (Formula 50% Biobased). Below the main label, there is a smaller label with 'SpartaMax' branding and 'USDA # 11282'. To the right of the main label is a circular logo with a sun and the text 'USDA CERTIFIED BIOBASED PRODUCT FP 50%'. Below the main label is another QR code and a small label with 'HEALTH 1', 'REACTIVITY 0', and 'ANTI-STATIC w/ PINE-CITRUS'. At the bottom, it lists 'SpartaMax Defense, Inc. CAGE: 8VLFO', 'PART#: 866-77409-1Q', '1 GRT (32oz) - EXP 3 YRS', and 'www.SPARTABRAKE.net'.</p>

## HYDROGEN FUEL GENERATOR-MORE POWER-LESS FUEL

JERRY A BROWN



ADI Technologies Inc.  
 jbrown@aditechnologies.com  
 +1.703.850.9207

**Problem:** Without fuel, an army dies on the battlefield. Refueling on the battlefield is a dangerous operation for a combat unit so reducing fuel consumption is needed. In 2008 alone, approximately 68 million gallons of fuel were supplied per month to support U.S. military operations in Iraq and Afghanistan, and in the 2014 fiscal year, DOD consumed 87.4 million barrels of fuel, and the “fully burdened” cost runs as high as \$400+ per gallon. (Note: Diesel fuel costs have increased approximately 75 to 100% in the last 3 years) Maintenance costs also continue to rise in the military and commercial market because of the laws and regulations that are designed to reduce Greenhouse Gases (GHG). The problem exists now and needs a solution now because there does not appear to be a replacement as good as diesel on the battlefield in the near future. Payloads continue to increase bringing the margins of horsepower available per vehicle down.

**Solution:** America possesses plenty of the natural resources to produce diesel. There is no shortage of petroleum so how do we improve on an excellent fuel with the minimum change to existing

equipment and engines? The Hydrogen Fuel Generator (HFG) is a TRL-9, MRL-10 mature product that has been tested and fielded on commercial trucks, boats, and generators. The HFG produces hydrogen from water by patented electrolysis device and injects it through the air intake, mixing it with the air and diesel in the combustion chamber resulting in 10-20% reduction in fuel consumption and an increase of horsepower and torque by 4-5%. Hydrogen provides a more complete burn in the combustion process which will result in lower maintenance costs. Hydrogen will burn off carbon in the cylinder reducing friction and decreasing the need for oil changes. The cleaner burn of the diesel results in a reduction of GHG (20-50%) and particulates (86-90%) resulting in less replacement of Diesel Particulate Filters (DPF). When using hydrogen, safety is paramount. The HFG is completely safe autonomically because hydrogen is produced only on demand. There is no storage of hydrogen on the vehicle. The HFG is lightweight and small, easy to install at the organizational level of maintenance, and can adapt to any diesel engine.

**Benefits:** HFG produces hydrogen on-demand directly into the engine combustion chamber by using water as its source of hydrogen fuel. It significantly reduces fuel consumption (10-20%) and increases horsepower and torque (4-5%). It is a mature product that is in production. It is adaptable and easy to install on any diesel, JP-8 engine for military or commercial vehicles, ships, locomotives, or generators. The patented electrolysis device is small and lightweight. Reduction in fuel consumption can potentially reduce casualties and the burden on the logistic supply line. The HFG reduces maintenance costs and improves reliability and durability. It is scalable to any equipment or platform that uses a diesel engine.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <ol style="list-style-type: none"> <li>Without fuel, an Army dies on the battlefield.</li> <li>Casualties among fuel resupply personnel are significant. A report calculates that a 10% reduction in fuel consumption over a five-year period could lead to a reduction of 35 fuel-related resupply casualties over the same period.</li> <li>Fuel and Maintenance costs are rising.</li> <li>Problem exist now and needs a solution now.</li> <li>Refueling of combat vehicles is a vulnerable operation.</li> <li>Studies show that diesel fuel and diesel engines will not be replaced with alternative energy in the near future.</li> <li>Payloads are increasing on existing trucks</li> <li>Need energy that reduces fuel consumption and increase horsepower now.</li> <li>Need to reduce logistics burden</li> </ol>	<p style="text-align: center;"><b>BENEFITS</b></p> <ol style="list-style-type: none"> <li>Reduces casualties and loss of vehicles by reducing the number of trucks needed to resupply.</li> <li>Reduces vulnerability of combat vehicles from long-range artillery, aviation, UAV's by refueling less on the battlefield.</li> <li>Reduces fuel consumption (10-20%)</li> <li>HFG increases horsepower and torque by 4-5%</li> <li>TRL9/MRL10 –Easily installed on any existing diesel engine.</li> <li>Completely safe because no hydrogen is stored-Produced on Demand</li> <li>HFG Reduces maintenance costs because the hydrogen increases thermal efficiencies keeping the engines cleaner thus reducing oil changes and diesel particulate filters (DPF) of trucks.</li> <li>HFG Improves reliability and durability of diesel engine.</li> <li>HFG Reduces substantially GHG (20-50%) and particulate (86-90%)</li> <li>HFG is scalable and adaptable to any diesel engine used in military or commercial trucks, rail, marine, and power generators.</li> </ol>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ol style="list-style-type: none"> <li>Hydrogen Fuel Generator (HFG) produces hydrogen on-demand directly into the engine combustion chamber by using water as its source of hydrogen fuel</li> <li>iPhi™ HFG significantly reduces fuel consumption (10-20%) and increases horsepower and torque (4-5%)</li> <li>Mature product, TRL 9/MRL 10- fully tested in the commercial market on long-haul trucks, ferry boats, and generators.</li> <li>Adaptable and easy to install to any diesel, JP-8 engine for tactical or combat vehicles or commercial trucks.</li> <li>Electrolysis device is Small and lightweight.</li> <li>Petroleum is a plentiful natural resource and the HFG improves the efficiencies and effectiveness of diesel.</li> <li>Reduces logistics burden and, improves tactical mobility now by reducing the amount of fuel used.</li> </ol>	<p style="text-align: center;"><b>HFG</b> <b>iPhi™</b></p>  <p style="text-align: center;"><b>HFG Installed</b></p> 



## MOBILE WATER PRODUCTION

JERRY A BROWN

ADI Technologies Inc.  
 jbrown@aditechnologies.com  
 +1.703.850.9207

**Problem:** Water resilience, logistics, cost and soldier safety: The closer to the point of the spear on the battlefield, the more costly water becomes; in funds, fuel, vehicle assets, and the lives of soldiers' bringing the water, and the soldiers needing water. DARPA states that the USMC suffered 10-12% of casualties in Iraq and Afghanistan to water and water-related logistic. The average cost per gallon was estimated to be \$55/ gallon on the battlefield. Water is the fuel for the soldier. Without water, the soldier dies in 3 days. In the past, we had to go to the source of water, a lake, river, and transport it to where the need is. If there is a natural disaster, usually bottled water is distributed, but this is a band-aid to the problem for hospitals, schools, manufacturing plants, etc. A severe drought in the western states will be restricting water to homes, schools, farmers, manufacturing plants, etc. Bottled water cannot solve this problem. We need a sustainable water production source that can meet emergencies and long-term water shortages.

**Solution:** Molecule Atmospheric Water Generator (MAWG) is a TRL-6 product that has been tested by the US Army Corps of

Engineers and determined that it is the only technology to have exceeded the DARPA target, tested by active-duty personnel on active bases. Two mobile (2) MAWGs will make enough water to sustain a platoon of troops on the move, indefinitely. The water is clean (< 4-8 ppm nominal). Add salt, and you have injectable saline for a mobile hospital or for combat medics. The MAWG coupled with an innovative Hydrogen Fuel Generator (HFG) called iPhITM is what makes the MAWG mobile because it uses Hydrogen to increase the propulsion system diesel engine horsepower and torque (4-5%) that feeds the energy needs of the MAWG. The HFG also reduces fuel consumption (10-20%) which can turn any military or commercial truck that uses a diesel engine potentially into an integrated mobile water platform using existing equipment for combat mobility or for natural disaster response. The MAWG used in a static situation such as a FOB or commercial hospital or school can use any power source such as alternative energy.

**Benefits:** MAWG provides long-term sustainable clean water for military and commercial use. MAWG reduces logistics burden and costs: casualties, fuel, and

transportation. MAWG brings water production mobility to combat units so that water production moves with the troops and first responders. MAWG is an excellent resource for the State National Guard and FEMA to respond to natural disasters that disrupt water production and distribution. HFG is completely safe because there is no storage of hydrogen on the vehicle. HFG reduces maintenance costs and labor because hydrogen reduces oil changes and diesel particulate filters (DPF) for commercial trucks. HFG Reduces substantially GHG (20-50%) and particulate (86-90%). HFG Improves the reliability and durability of diesel.

<p><b>PROBLEM STATEMENT</b></p> <ol style="list-style-type: none"> <li>1. Supplying Potable Water on a mobile battlefield or on an isolated Forward Operating Base (FOB) and in response to natural disasters is needed now.</li> <li>2. Water is produced in the rear and normally resupplied using trucks, trailers, and helicopters. Studies state that 10-12% of USMC personnel casualties in Iraq and Afghanistan were from transporting water to the front. Russia is experiencing this today.</li> <li>3. Water production today (reverse osmosis or bottling plants) is not mobile</li> <li>4. Need a way of producing sustainable mobile or stationary water production at the point of need on the battlefield, hospitals, ships, communities, etc.</li> <li>5. Additional power will be required from the existing vehicle propulsion system to produce mobile water production.</li> <li>6. Alternative energy sources can be used effectively for static situations, but they have many disadvantages when mobility is needed.</li> <li>7. Severe droughts in western states by providing innovative solutions which impact agriculture, manufacturing, hospitals, community drinking water, and etc.</li> </ol>	<p><b>BENEFITS</b></p> <ol style="list-style-type: none"> <li>1. MAWG provides long-term sustainable clean water for military, First Responders, and commercial use such as hospitals.</li> <li>2. MAWG reduces logistics burden and costs: casualties, fuel, and transportation.</li> <li>3. MAWG brings water production mobility to combat units and first responders; an excellent resource for FEMA and State National Guard</li> <li>4. HFG Reduces maintenance costs because the hydrogen increases thermal efficiencies keeping the engines cleaner thus reducing oil changes and diesel particulate filters (DPF) for commercial trucks.</li> <li>5. HFG Improves reliability and durability of diesel engine.</li> <li>6. HFG Reduces substantially GHG (20-50%) and particulate (86-90%)</li> <li>7. HFG decreases fuel consumption but increases horsepower/torque thus providing the needed energy to fuel the MAWG and the MAWG in return provides the hydrogen for the diesel engine.</li> <li>8. MAWG and HFG are both scalable to meet mobile and static needs.</li> </ol>
<p><b>TECHNOLOGY SOLUTION</b></p> <ol style="list-style-type: none"> <li>1. Two innovative technologies, Molecule Atmospheric Water Generator (MAWG) and Hydrogen Fuel Generator (HFG) will provide mobile water at the point of need using existing diesel propulsion systems.</li> <li>2. The MAWG is a TRL-6 level of development that has been tested by the US Army Corps of Engineers and states that it exceeds DARPA requirements.</li> <li>3. The HFG is a TRL-9, MRL-10 product that is fully tested and validated by 3<sup>rd</sup> Parties such as truck, marine, rail, and generator companies.</li> <li>4. The HFG reduces fuel consumption (10-20%), increases horsepower/torque (4-5%), reduces maintenance costs, reduces GHG, and is completely safe because the hydrogen is not stored (produced only on demand).</li> <li>5. The MAWG is ideal for use with alternative energy for static situations.</li> <li>6. The HFG provides mobility using the vehicle engine because of the extra horsepower produced by the HFG.</li> <li>5. The MAWG and HFG are scalable for mobile and static water production.</li> <li>6. The water is clean (&lt; 4-8 ppm nominal). Add salt, and you have injectable saline for mobile combat hospitals or static commercial hospitals.</li> </ol>	

## THE BLASTBAG COMPANY

PATRICK CHRISTIAN

The Blastbag Company  
patrick@theblastbag.com  
+1.925.584.4470

The Blast Bag Company products help reduce the environmental impact of facilities with hazardous chemicals and waste. By using our containment devices, you can route wastewater to the proper locations, keeping it off of the ground entirely and surrounding areas. Having no liquid touch the ground is an option, and we can help you accomplish that goal through our products along with custom design.

This would be very instrumental when cleaning the heat exchangers and lube oil coolers onboard the Navy Vessels while both at sea and when in port.

### PROBLEM STATEMENT

The current way of containing the effluents while hydroblasting or water washing the Oil Coolers and other heat exchangers on board the Naval vessels is very inefficient and costly due to the inability to contain the effluents properly thus causing additional time having to clean the surrounding areas.

### BENEFITS

- Significantly reduces clean up time.
- Reduces setup and teardown time.
- Prevents having to completely shut down the area where the cleaning is taking place.
- Provides additional protection for nearby personnel from wastewater over spray.
- Products are designed to keep effluent and process fluids from hitting the deck.
- Very cost effective.
- Can be custom made to meet your needs.
- We are DOD Approved, Cage Code 902N0.

### TECHNOLOGY SOLUTION

- The Blastbag Company manufactures containments that are designed to capture the wastewater and route it to your desired location. The Blast Bag is attached and secured around the flange of the heat exchanger and there is a drain at the bottom of the Blast Bag that has a Camlock fitting which allows for a drain hose to be attached.
- The Blast Bags were recently used at the REPTX Expo at the Naval Base Ventura County in Port Hueneme, CA. to contain the water while Terydon was demonstrating a Heat Exchanger cleaning and when Sarcos Robotics was doing VF Blasting.

### Blast Bags used at REPTX



## HUMAN AUGMENTATION FOR MAINTENANCE PROCESSES

ZACHARY COULSON

76th Aircraft Maintenance Group, U.S. Air Force  
 zachary.coulson@us.af.mil  
 +1.405.582.1369

The mission of the Oklahoma City Air Logistics Complex (OC-ALC) is to produce combat ready airpower. The 76th Aircraft Maintenance Group (AMXG) is the largest group in the Air Force, with the combined efforts of 4,400 military and civilian professionals performing heavy depot maintenance on KC-46, KC-135, B-1B, B-52, E-3, and Navy E-6 airframes. 76 AMXG is directly responsible for heavy depot maintenance of the structure and auxiliary systems of various airframes. During the course of this maintenance, mechanics are often required to perform tasks in difficult ergonomic positions for long periods of time. Despite the implementation of many ergonomic solutions to reduce the inherent risk surrounding aircraft maintenance, 76 AMXG mechanics still suffer from strain and sprain injuries. These sprains were either due to direct workload, or due to mistakes classically associated with fatigue or inattention. Industrial exoskeletons (exo) were evaluated as a possible solution. Forty-nine (49) exoskeletons were acquired for the purposes of targeted injury risk reduction. Over the course of several months, dozens


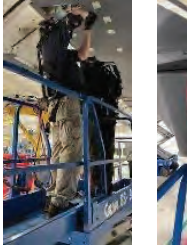

of trials were conducted on a variety of maintenance processes within 76 AMXG.

The results those trials have been overwhelmingly positive. The data reveals that within 3 weeks, exo users saw significant reduction in fatigue for targeted physiology, with as much as a 90% reduction in some cases. In four months since the trial began, not a single mechanic has been injured while using the exoskeletons. Additionally, we have witnessed efficiency gains for exo users; in some cases, we have observed tasks completed in half of the expected time. We have also witnessed multiple mechanics reporting palliative effects. More than one mechanic asked to show the exoskeletons to their doctors because it relieved so much back pain. This palliative effect has already contributed to increased mechanic retention and morale boost. We anticipate avoiding over one million dollars in 76 AMXG this year alone.

Local success has spread to other organizations, both inside and outside of the OC-ALC. Internal to OC-ALC, 76 Propulsion Maintenance Group (PMXG)

has started their own exo trials modeled after our own. We have also consulted with both Cannon AFB and Minot AFB as subject matter experts, helping to advise them on specific mission requirements. Tinker AFB is an integral member of the DOD-wide Human Augmentation Users Group. Tinker collaborates with the Navy, Army, and other ALCs, by trading critical data on best practices for exoskeleton use. We have also informed the Combat Ready Airman Program's requirements for aircraft mechanics, which will have positive ramifications for the entire Air Force upon implementation.

- 50% fatigue reduction in first 3 weeks of use
- Average task efficiency gains 10% resulting in \$512K efficiency-related annual cost savings
- OC-ALC expected to save \$1.4M injury cost avoidance for the first forty-nine (49) exoskeletons

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Aircraft structural repair operations have a tendency to result in work-related musculoskeletal disorders of our civilian and active-duty mechanics, due to fatigue and repeated movements</li> <li>• Many strain or sprain injuries caused annually by fatigue, poor ergonomics, or use of excessive force within the 76 Aircraft Maintenance Group</li> <li>• Reduced mechanic effectiveness and increased manpower constraints due to mechanic absence and permanent injury</li> <li>• Need improved processes and equipment to reduce standard ergonomic risk factors such as exerting excessive force, repeating same or similar movements, and maintaining postures that place stress on the body</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Mechanics utilizing human augmentation have maintained an injury rate of zero since program implementation</li> <li>• Reduced mechanic fatigue 50% on average</li> <li>• Enabled better quality control through improved focus</li> <li>• Increases tool stabilization during overhead processes</li> <li>• Exoskeletons increased maintenance efficiencies per user by 10% on average with anecdotal reports of up to 50%, resulting in an annual cost avoidance of \$512K</li> <li>• Injury cost avoidance over \$1.4M annually</li> <li>• Exoskeletons have exhibited palliative effects in some of the 46 users, leading to increased mechanic retention</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Industrial exoskeletons were identified as a possible way to improve mechanic ergonomics, reduce fatigue, and mitigate risks of injuries caused by stress and strain</li> <li>• Three commercial systems from technology front-runners were evaluated and the best system was selected for trials</li> <li>• B-1B Structures Repair Line was chosen for initial introduction and vetting of the technology</li> <li>• Exoskeletons passively transfer weight from user's arms and legs to the hips and core via mechanical cable technology</li> <li>• Human augmentation, via exoskeletons, reduces musculoskeletal burdens while maintaining static postures and allowing for repeated movements</li> </ul>	<p><b>Graphic</b></p> <div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>Back Exo Utilization</p> </div> <div style="text-align: center;">  <p>Mass Exo Utilization</p> </div> <div style="text-align: center;">  <p>Shoulder Exo Utilization</p> </div> </div>

## ROBOTIC CRACK SEALER FOR SUPERIOR PAVEMENT MAINTENANCE

ZAC GRABER

necoTECH  
zgrab@necotechusa.com  
+1.419.966.6918

### Problem:

Asphalt is the bedrock of our nation's transportation and logistics infrastructure. USAF bases alone contain over 2.2 billion square feet of it, while the other branches of the DoD and the rest of the federal agencies have considerably more. Preservation of these asphalt runways, roads, and parking lots is significantly more cost-effective than replacement and reconstruction. Industry studies have confirmed that for every \$1 invested in crack sealing, \$6 is saved on future repair and maintenance work. However, current crack sealing methods are done through manually operated machinery and large numbers of personnel. A typical on-base asphalt repair crew consists of 6-14 CE Squadron members or 3rd party contractors capable of repairing 2-4 miles per day.

### Technology:

The Robotic Maintenance Vehicle (RMV) is the only robotic pavement maintenance solution on the market. Complete with an:

- Integrated air blow-off system for cleaning out cracks

- Advanced vision system for volumetrically measuring and mapping the cracks
- FANUC robot with an adjustable arm to fill and squeegee the cracks

Plus, it can be altered in the future for smart pavement installation, pothole filling, etc. to become a versatile all-in-one maintenance solution!

### Current Development Status:

The RMV is currently at TRL: 8 and in July 2022 was awarded a \$750k AFWERX SBIR Phase II. We are already working with the U.S. Army and other federal agencies to expand to other branches.

### Testing:

Successfully tested and demonstrated on miles of road and multiple parking lots, commercial and private airports, and both Tyndall and Luke Air Force Bases.


Over the past 2 years RMV has received:

- 2020 USAF Base of the Future Selection
- Top 50 US Army xTechSearch-6
- 2022 FANUC Innovator of the Year Award

- USAF Flightline of the Future Challenge – Airfield Maintenance and Repair
- 2022 TechConnect Smart Cities Startup Challenge Innovation Award
- 2022 TechConnect World SBIR Innovation Award
- 2022 Defense TechConnect Innovation Award
- 2022 Army Technology Innovation Awardee – Robotic Pavement Crack Sealer

### Benefits:

- Can be used 24/7 (day and night) to minimize disruptions
- Moves up to 2x the speed of a traditional 'trained' crew
- Reduces the number of personnel required from 6-14 to 1-2
- Reduces the amount of training required – bases can be self-sufficient instead of relying on outside contractors
- Self-contained system – no other vehicles required
- Improves safety – workers not in harm's way

<p><b>PROBLEM STATEMENT</b></p> <p>Asphalt is the bedrock of our nation's transportation and logistics infrastructure, and USAF bases alone contain over 2.2 billion square feet of it. Preservation of these asphalt runways, roads, and parking lots is significantly more cost-effective than replacement and reconstruction. Industry studies have confirmed that for every \$1 invested in crack sealing, \$6 is saved on future repair and maintenance work. However, current crack sealing methods are done through manually operated machinery and large numbers of personnel. A typical on-base asphalt repair crew consists of 6-14 CE Squadron members or 3<sup>rd</sup> party contractors capable of repairing 2-4 miles per day.</p>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Can be used 24/7 (day and night) to minimize disruptions</li> <li>• Moves up to 2x the speed of a traditional 'trained' crew</li> <li>• Reduces the number of personnel required to 1-2</li> <li>• Reduces the amount of training required – bases can be self-sufficient instead of relying on outside contractors</li> <li>• Self-contained system - no other vehicles required</li> <li>• Improves safety - workers not in harm's way</li> <li>• Reductions equate to a lower total cost of maintenance operations</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>The Robotic Maintenance Vehicle (RMV) is the only robotic pavement maintenance solution on the market</p> <ul style="list-style-type: none"> <li>• Integrated air blow-off system for cleaning out cracks</li> <li>• Advanced vision system for volumetrically measuring and mapping the cracks</li> <li>• FANUC robot with an adjustable arm to fill and squeegee the cracks</li> <li>• Can be altered in the future for smart pavement installation, pothole filling, etc. to become a versatile all-in-one maintenance solution!</li> </ul>	

- Reductions equate to a lower total cost of maintenance operations

### Next Steps:

- Could have multiple R&D/ Pilot units available by the end of 2022
- Altering for a smaller footprint all-electric vehicle (EV) chassis
- Working towards autonomy option for late-2023
- Looking to scale within the DoD and seek purchases of the first vehicles and support for additional funding from the TACFI/ STRATFI program

## TECHNOLOGY, SYSTEMS, PROCESSES FOR EXTRACTING AIRCRAFT STRATEGIC METALS FOR REUSE

PATRICK HARRIS

Shannon Airline Services Inc  
 pharris@mercuryaviation.net  
 +1.(561.702.7849

**Problem:** The Gas Turbine Engine (GTE), Jet-A and Avgas (fuel) must be replaced. However, it cannot be replaced because it takes 15 to 20 years to introduce it into service, and longer. If the supply chain is disrupted, it puts engine CAMO and production at risk because material supplies – Ni-Alloys and composites are advanced technologies and Earth Metals are under Chinese control.

**Technology:** System, process and method to recover, build a stockpile, for reuse to make parts for engine overhaul.

**Status:** From 2014 to date, we have advanced the system and we need to move to the stage of extracting the materials for commercialization.

**Performance claims:** We have completed work on more than thirty commercial aircraft and about one hundred engines.

**Next steps/Potential Benefits:** We need to prove to government and industry that stockpiling Earth Metals is in the national interest.

### PROBLEM STATEMENT

**Problem:** The Gas Turbine Engine (GTE), Jet-A and Avgas (fuel) must be, replaced, but cannot be because it takes 15 to 20 years to introduce it into service, and longer. If the supply chain is disrupted, it puts engine CAMO and production at risk because material supplies - Ni-Alloys and composites are advanced technologies and Earth Metals are under Chinese control. **Technology:** System, process and method to recover, build a stockpile, for reuse to make parts for engine overhaul. **Status:** From 2014 to date, we have advanced the system and we need to move to the stage of extracting the materials for commercialization. **Performance claims.** We have completed work on more than thirty commercial aircraft and about one hundred engines. **Next steps/potential benefits.** We need to prove to government and industry that stockpiling Earth Metals is in the national interest.

### BENEFITS

- Builds in a layer of protection for the aircraft supply chain, dependent on Earth Metals for hot section parts manufacture
- Replacing the Gas turbine engine, Jet-A and Avgas has a 50-year life cycle. China controls the mining/extraction of Earth Metals. Uses exports as a Trade negotiating weapon and may use as a military tool. which can be diluted by building a stockpiles from EOL engine sources in the West, estimated at or around one million engines.
- Climate change aside, GTE and Jet-A have to be kept serviceable until a new technology can replace them, a time frame of 15 to 20 years.
- The average GTE costs \$12M. Hot section is 40% of that. Around 100,000 needed by 2050, Earth Metal parts about a third of that. – Resource Saving: ~\$160Bn over ~30 years.

### TECHNOLOGY SOLUTION

Control over strategic aerospace materials – Earth Metals, Ni-Alloys and Composites have come to the fore because (a) scarcity, (b) location – China mostly, (c ) global trade implications and (d) threat to NATO air defenses. We have focused on aircraft Earth Metals recovery from commercial aircraft for over a decade. We developed methods to identify the location of the metals, and the means to extract the parts made from Earth Metals. It requires high technology instruments, which makes the process expensive. We have developed systems, and methods of extraction that makes the work commercially practical. We need to test that proposition in real-world conditions in military and civilian environments, across a range of aircraft platforms, of which the DOD has hundreds if not thousands of suitable candidates. Lighter metals, reduce fuel burn emissions, reduces GHG emissions, reduces global temperatures.

Earth Metals are the weak link in aerospace & defense aircraft supply chain in a global crisis scenario.



## PROVIDE DOD ENVIRONMENTALLY FRIENDLY INDUSTRIAL CHEMICALS

**EDWIN KINCAID**

NewTech  
ekincaid@new-tech-co.com  
+1.405.642.8255

Military and commercial aircraft are made of metals that are highly susceptible to corrosion, exposed to extreme heat & cold temperatures, water, sand, hydraulic and other liquids. When these aircraft are in the depot for maintenance, the maintenance cleaning processes are currently labor intensive and require hazardous chemical treatments. R Squared Chemicals is a North American distributor of Bio-Gen Active (BGA) chemicals that are safe for the environmental, simplifies transportation, safe for workers to use in handling, easy to store, and have no disposal restrictions.



What makes us unique from other cleaning chemicals? The BGA chemicals were formulated in Sweden by two chemists. The chemicals developed with biodegradable amino acids derived from milk whey. Whey, a high-quality and natural by-product from cheese manufacturing, is converted into Bio Gen Active® by a carefully designed microbiological process without using any additional chemicals. The amino acids help release hydrocarbon and/or scale from their attached surfaces in an environmentally friendly manner. Current BGA chemicals examples are Combi 202 which is effective

for landing gear degreasing, descaling and de-rusting properties in one product. Our Combi products efficiently removes oil, dirt, rust and limescale in a single step. Another is Scale 130 effective on limescale and rust but mild to different surface materials such as Heat Exchangers. Optimized performance for efficient CIP (Cleaning In Place) of both oil and water borne systems. The products are also effective and gentle to skin, materials, and the environment.

We are dedicated to support our customers improving their level of safety for co-workers and at the same time reduce the environmental impact of their operations by using solutions based on the unique ingredient Bio Gen Active® – a 100% natural, health and environmentally optimized substrate based on fermented Whey.

Our proposed project is to perform the necessary certification testing to demonstrate we can meet MIL PRF 29602A, Performance Specification Cleaning Compounds, Parts Washer, and Spray Cabinet with Combi 202. American Airlines Landing Gear is the target application and then results will be shared with Hill AFB

Landing Gear office. We will also connect to the Office of the Deputy Assistant Secretary of Defense for Materiel Readiness and propose possible expansion to joint Military and Commercial applications as a DoD Autonomy Initiative for industry (Boeing and American Airlines), academia participants (HBCU Alabama A&M), USAF to advance AFSC Depots and maintenance field levels for certifying environmental cleaning solutions. In additional other applications include Heat Exchangers, Engine blades, and other critical parts. We rate our current chemicals as TRL -8 and once proven for military applications can be classified as TRL -9. It is estimated that cost reductions of our product, storage, disposal, and environment will be 50% or more.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>DoD Aircraft Maintenance includes cleaning critical parts. This results in costly pollution, worker safety concerns, costly handling, and hazardous disposal</p> <p>It is difficult and costly for industry to demonstrate their commercially proven environmentally friendly products that meet DoD requirements</p>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Support DoD Corrosion Policy and Oversight in Cost Reduction Goals and Improve Readiness</li> <li>• Effectively replaces hazardous chemicals (VOC Free)</li> <li>• Reduced wear and tear on aircraft parts</li> <li>• Reduces operations &amp; maintenance costs</li> <li>• Safe for workers and reduces health risks</li> <li>• Reduces or eliminates hazard disposal processes and cost</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <p>With Hill AFB's Landing Gear Office request will show we meet MIL PRF 29602A for using BGA Chemical Combi 202 for Landing Gear cleaning jointly with American Airlines for a commercial application meeting Boeing Specifications</p> <p>While above is being accomplished we will work with DoD Office for Corrosion Policy and Oversight on scheduling approval and funding for Heat Exchangers, Engine Blades and other Aircraft Parts with commercial team members</p>	<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p>Example of Plate showing before and after reconditioning</p> </div> <div style="text-align: center;">  <p>Heat Exchanger Plate showing before and after reconditioning</p> </div> </div>

## OIL RECLAIMING

OCTAVIO MANZANO

APFELBAUM INDUSTRIAL, INC.  
octavio@apfelbaumind.com  
+1.915.845.2009

Problem: Oil is an element indispensable for the operation of machinery, tanks, all types of military vehicles, vessels, helicopters, and airplanes. It is impossible to operate without oil, and the amounts of oil used are tremendous requiring constant resupply. This requires a perfect logistics system with tank trucks scheduled according to the hours operated. The oil changes are mandatory as preventive maintenance and the waste oil must be properly disposed, and its final disposition is going to cost additional money. Every year more than two billion gallons of oil are improperly disposed according to the Department of Energy.

The solution is our oil reclaiming Mobil equipment. ([www.apfelbaumind.com](http://www.apfelbaumind.com)). The technology has already been proved for over 15 years in different countries used mostly to reclaim transformer oil using no chemicals in the innovative process. We have basically four processes: moisture removal, dust removal, metal particles and the rest of the solids' removal, and vacuum to remove all the gases. The reclaiming process removes the rest of the contaminants as paints, and the most important Sulphur removing under the standard values. The oil is left ready to

make any type of oil just adding the additives depending on the type of oil required. Oil transformers require only antioxidant, while motor oil requires extra additives to reach the particular characteristics of the oil. This last part needs to be adapted and tested.

Benefits:

- Reduces the annual cost for mineral oil purchasing
- The logistics for oil supply can be reduced
- Oil Changes can be done on time because the reclaimed oil is made on the same site where is needed
- Final disposal for waste oil can be reduced dramatically, reducing the expenses for final disposal
- Compliance with the carbon reduction is part of the benefits
- The power transformers useful life should be extended
- The total savings could become an important additional budget consideration

### PROBLEM STATEMENT

Oil is an element indispensable for the operation of machinery, tanks, all types of military vehicles, vessels, helicopters, and airplanes. It is impossible to operate without oil, and the amounts of oil used are tremendous requiring constant resupply. This requires a perfect logistics system with tank trucks scheduled according to the hours operated. The oil changes are mandatory as preventive maintenance and the waste oil must be properly disposed, and its final disposition is going to cost additional money. Every year more than two billion gallons of oil are improperly disposed according to the Department of Energy.

### BENEFITS

- Reduce the annual cost for mineral oil purchasing, DOD can use the additional resources for other purposes
- The logistics for oil supply can be reduced obtaining additional savings
- Oil Changes can be done on time because the reclaimed oil is made on the same site where is needed
- Final disposal for waste oil can be reduced dramatically, reducing the expenses for final disposal.
- Compliance with the carbon reduction is part of the benefits
- The power transformers useful life should be extended
- The total savings could become an important additional budget consideration

### TECHNOLOGY SOLUTION

The solution is our oil reclaiming Mobil equipment. ([www.apfelbaumind.com](http://www.apfelbaumind.com)). The technology has already been proved for over 15 years in different countries used mostly to reclaim transformer oil using no chemicals in the innovative process. We have basically four processes: moisture removal, dust removal, metal particles and the rest of the solids' removal, and vacuum to remove all the gases. The reclaiming process removes the rest of the contaminants as paints, and the most important Sulphur removing under the standard values. The oil is left ready to make any type of oil just adding the additives depending on the type of oil required. Oil transformers require only antioxidant, while motor oil requires extra additives to reach the particular characteristics of the oil. This last part needs to be adapted and tested.

### Color of Oil Before and After Reclaim



## MRO CHEMICAL AND EQUIPMENT RATIONALIZATION

**BEN OHLMEYER**

Envirofluid Inc.  
ben.ohlmeyer@envirofluid.com  
+1.202.869.8240

A current problem in Defense is high inventory issues, dangerous goods management, and resultant inefficiencies. Technology involves adoption of hierarchy of control in chemical management.

Technology is currently used in Australia and has resulted in 80% reduction of inventory, elimination of dangerous goods and over 50 million dollars saving in Navy single platform. An example case study can be found at [envirofluid.com/eco-friendly-chemicals-solve-sewage-systems-issues-aboard-lhds](http://envirofluid.com/eco-friendly-chemicals-solve-sewage-systems-issues-aboard-lhds)

Steps involve inventory review, analysis, reporting, onboarding of all parties, planning and implementation. This is normally done on an individual platform basis but can also be actioned as a comprehensive review. Activity can be conducted in partnership with Unichem Inc. [unichemgroup.net](http://unichemgroup.net) depending on size of project.

Impacts of this proposed Innovation on maintenance can be significant, including but not limited to huge decreases in inventory management requirements, virtual elimination of dangerous goods,

reduction in the need of mechanical controls (i.e., ventilation, bunding, storage etc.), administrative controls (i.e., safety statements, work packs, safety audits etc.) and PPE (i.e., protective clothing, goggles, fire blankets and respirators etc.).

In spending time both eliminating and substituting chemicals of concern and multiple items of similar performance 80% of current time and expense incurred in administration, mechanical and personal protection equipment can be saved with spare resources then available for real Defense related activities. This inventory rationalization is not undertaken in full anywhere else in the world because there needs to be logistic specialists, engineering teams, safety officers, environment technicians, and other personnel that understand Defense brought together to enact a tangible result – this is what Envirofluid Inc. specialize in.

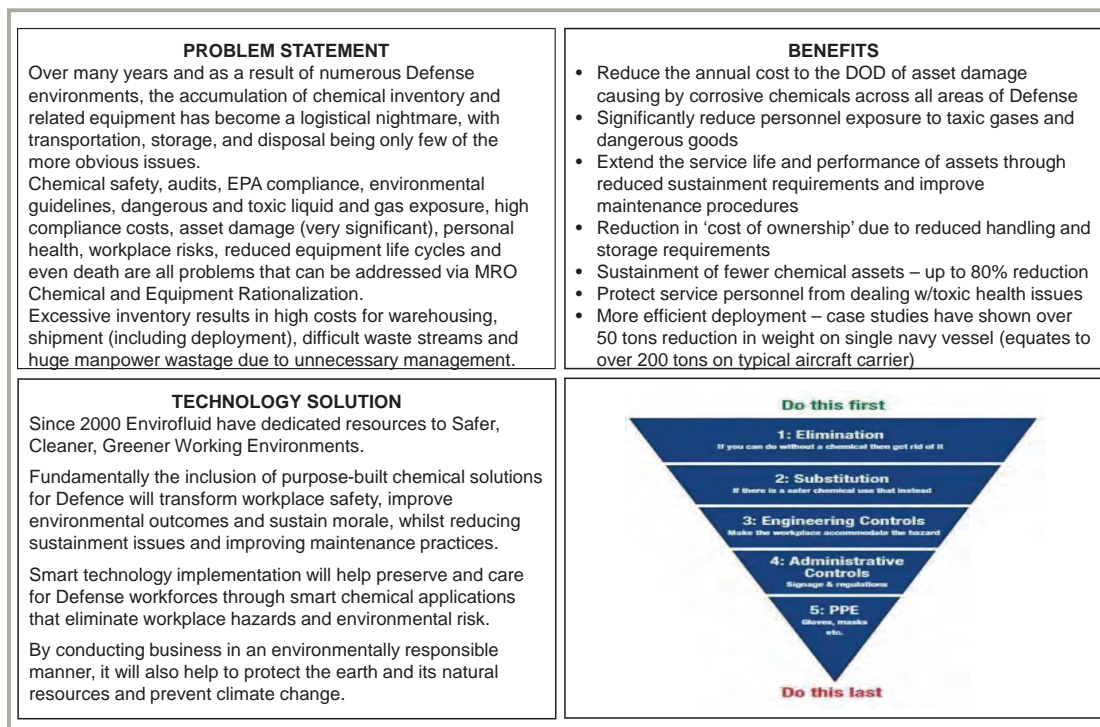
Maintenance improvements include redefined workplaces, reduced clutter, improved workflow, reduced sustainment requirements, elimination of toxic and dangerous work environments, lower carbon

footprints, significant waste reduction, lower health issues and resultant claims etc. (we can expand on each item following further interest; however, the current 3000 limit doesn't allow).

Technology is proved, current and ready for action.

The Innovation proposal is applicable across all areas of the DLA where chemicals are used.

Transition of technology is very viable for use by the DoD and full implementation will also result in a significant reduction of maintenance requirements – this includes the elimination of corrosion due to chemicals, hydrogen sulphide gas damage, damage to assets including rubbers, structural surfaces, pipework, radars, electronics etc. Overall, the greatest reward will be in personal safety by reducing exposure to toxic gases, fire, irritants, cancer causing substances and much more.





## SAFE SOLVENT INTEGRATION

**BEN OHLMEYER**

Envirofluid Inc.  
ben.ohlmeyer@envirofluid.com  
+1.202.869.8240

Maintenance solvents (and degreasers) across all sectors of Defense are typically dangerous both to human health and the environment, also carrying risks of fire, whilst being very expensive to manage.

Triple7 & Purasolve technology brings hope in providing products that work as well and better than the toxic lethal substances that they replace. Whilst the full product range is still in development, solvents that replace TCE, benzene, n-hexane etc. for purposes such as weapons cleaning, brake cleaning, parts cleaning, paint clean-up etc. are now readily available within the United States. Whilst the technology is still emerging departments such as the US Marines recently said they have nothing that works as well, like the weapons cleaner available to them currently.

Some solvents have recently gained MILPRF680 approval from SMI, however recognition and support from the US DoD and DLA would be required to help support the development of a full range.

Next steps would involve recognition, support, testing, integration, and adaption


to DoD sustainment systems. Whilst pound for pound, alternative safety solvents are more expensive, the cost of ownership is significantly less. Savings are made in lower handling costs, less storage and transport issues, reduction of typical mechanical and administrative controls in use of solvents and above all greater human safety and environmental outcomes.

In Australia the Army, Navy and Airforce have eliminated solvent waste streams from Parts Washers, saved thousands of dollars on ventilation requirements, and reduced exposure to toxic chemistries. This is also currently enjoyed by the most welcomed US Marines based in Darwin. The range being developed is unique to Envirofluid as pioneers in safe solvent development, recently recognized by global companies such as Boeing who have signed a global distribution agreement for the developing product range. Prototypes are continually emerging on user demand however integration depends on major influencers and early adopters such as NATO and the US DoD.

Recent correspondence received from NATO is copied below however as a smaller enterprise we need help to continue this innovation process.

“Thank you for your insightful presentation, which I will take on board from central support to operations of codification system. I do observe numerus approaches to hazmat materiel in the nations, so the challenge we face was how to find a common grounds, and while we move to new environment of more flexible data exchange, these will be revisited. I see that your approach is an effective one, and same pattern could be undertaken in other countries, among 60 plus countries” - Codification Support Section Chief NATO Support and Procurement Agency | General and Cooperative Services Programme LB | L-8302 Capellen, G.D. Luxembourg

Adaptability across all sectors of Defense should be relatively easy and would typically have full backing from organizations such as OSHA an EPA etc.

<p><b>PROBLEM STATEMENT</b></p> <p>Solvents and Degreasers used today were largely developed last century and have serious health and safety implications that are not dissimilar to the breadth of issues of asbestos which are struggled with globally.</p> <p>Whilst substances like MEK, Acetone, Toluene, TCE, n-hexane, chlorinated solvents etc. have been recognized as dangerous to human health and the environment, we have another global situation where it's taking 40 years+ to adopt solutions to this serious situation.</p> <p>People are dying, climate change is happening, costs of conformance are escalating, litigation cases are increasing, and we can not continue to watch 'whilst Rome burns'</p>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Reduce the annual cost to the DOD of compliance, litigation and cost of chemical / solvent ownership</li> <li>• Preserve live and health of all Americans and DoD personnel</li> <li>• Reduction of maintenance expenditure in terms of dollars and out of service costs with less asset damage</li> <li>• Reduction of existing solvents volumes due to the innovation of lower evapourant and recyclable solvents and degreasers</li> <li>• Sustainment of fewer assets due to streamlining of inventory – up to 80% reduction</li> <li>• Protect service personnel from dealing w/toxic health issues and risks such as fire and fumes</li> <li>• Safer deployment activities</li> <li>• Conformance with all OHSA and EPA legislation</li> <li>• Save billions on health expenditure and human trauma</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>The Triple7 and Purasolve technologies offer possibilities in innovation by taking renewable plant sources and fully recyclable solvents that have toxic levels down to parts per billion.</p> <p>By taking the long way around with product development starting with safety, health and the environment in mind, whilst ensuring that final products save time, effort and cost, it is possible to provide next generation chemistry for todays needs</p> <p>Low vapor pressure solvents, with high flash points, that reduce consumption by up to 50 times, and also are readily recyclable ticks so many boxes be it ESG, HSE, WHS, Climate change, cost of ownership and professional stewardship</p>	

# ENHANCED INSPECTION

## AUTOMATED VEHICLE BATTERY MANAGEMENT REPORTING SYSTEM

HUNTLEY BODDEN

Marine Corps Logistics Command  
 huntley.bodden@usmc.mil  
 +1.229.639.7307

Fleet vehicles in long-term storage at Marine Corps Logistics Command (MARCORLOGCOM) often experience issues with battery discharge. Vehicles with discharged batteries are unable to start, thus interfering with normal warehouse operations such as vehicle movement & fleet readiness. In addition, deep discharge permanently damages batteries causing unnecessary expense & labor in replacement & charging. In addition to battery diagnosis, matching battery discharge rate with a vehicle's bumper number can aid in diagnosis of a vehicle's overall electrical subsystem.

MARCORLOGCOM & Georgia Tech Research Institute have partnered through the University Affiliated Research Center (UARC) to explore ways to maintain readiness while vehicles are in storage. Our team is developing a battery monitoring system that plugs into a vehicle's NATO slave port. This port provides a direct connection to a vehicle's battery & is available on all US military vehicles across all services. Our device autonomously forms a secure Bluetooth Low Energy (BLE) mesh network & provides battery status tagged to a vehicle ID for all vehicles in a warehouse

from a single access point. A prototype of this system has been demonstrated at MARCORLOGCOM in Albany, GA. During this test, we found that greater than 50% of the 38 randomly selected vehicles from a LOGCOM warehouse had low battery voltages. These low voltages not only impact fleet readiness, but also prevent functioning vehicles from being removed from the warehouse due to down vehicles & the tight parking configuration. In addition, BLE network tests were performed & we achieved sufficient signal strength for connectivity even with armored vehicles with NATO ports located inside the closed vehicle.

We have put together a 3-phase plan for demonstrating the near-, mid-, and long-term benefits of this system. Near-term, outfit an entire warehouse (approx. 100 vehicles) with this prototype system. The RFID & battery voltage of all of the vehicles will be available from a single access point, & a daily status will be generated. Mid-term, mesh self-localize & report battery condition, RFID, & geolocation for each vehicle. This will provide near real-time tracking & status data for all equipped platforms. Finally, long-term, autonomously recharge batteries via a

ground robot providing continual service to the warehouse & remove the need for labor intensive maintenance operations.

In addition to the main goal of improved fleet readiness, large quantities of knowledge on battery & electrical systems will be logged. This will provide insight into improved maintenance schedules. Knowledge of which vehicles are not functional & where they are located will allow for the prioritization of vehicle repairs. These improvements will lead to 100% battery health while achieving labor reductions in the warehouse.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>Fleet vehicles in long-term storage often experience issues with battery discharge.             <ul style="list-style-type: none"> <li>Vehicles with discharged batteries are unable to start, thus interfering with normal warehouse operations and fleet readiness</li> <li>Deep discharge permanently damages batteries</li> <li>Detection of low-charge batteries and charging of these batteries is a labor intensive operation</li> </ul> </li> <li>Undetected deep discharge causes unnecessary expense in both battery cost and labor to replace/charge batteries</li> <li>No current record keeping is performed to match battery discharge rate with bumper number of vehicle</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>Near-term: <b>Improved fleet readiness</b> and the acquisition of knowledge on battery discharge characteristics. This will allow an improved maintenance schedule leading to longer battery storage life.</li> <li>Mid-term: Improved geolocation information on individual assets. Precise location data will also allow scheduling decisions to be made on battery maintenance. Is a single failed battery blocking the entire warehouse?</li> <li>Long-term: Improved warehouse operations leading to 100% battery health while achieving labor reductions</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>We propose a custom solution that plugs into a standard NATO port to monitor battery condition</p> <ul style="list-style-type: none"> <li>Near-term: Provides a secure Bluetooth Low Energy mesh network that provides battery status tagged to vehicle ID for all vehicles in a warehouse from a single access point.</li> <li>Mid-term: System will self-localize via the mesh to report vehicle location as well vehicle electrical system health. Can be integrated into McPIC infrastructure for vehicle reporting.</li> <li>Long-term: Integration with autonomous ground robot for autonomous recharge of systems that fall below a preset threshold.</li> </ul> <p><b>Prototype initially tested in Albany, GA in September, 2022</b></p>	<p><b>Battery State of Measured Vehicles</b></p> <p>Measured battery status of 38 randomly selected vehicles in LOGCOM warehouse. Greater than 50% had low battery.</p>

## ENHANCED INSPECTIONS LEAD TO HIGHER QUALITY

**TOM HARGETT**

TIP Technologies

tom.hargett@tiptech.com

+1. 410.733.3480

One of the cornerstones of continuous improvement is a command of the quality inspection process. Criteria based inspection plans help meet regulatory requirements and workflows, depending upon where the product is in the manufacturing lifecycle. Online visibility and real-time tracking of incoming raw materials, parts, and subassemblies are critical to successful inspections. An effective quality management solution can process all information related to inspections and deliver a unified view of inspection results to key personnel.

Leadership often lacks detailed data or electronic access to inspection criteria. Manual translation of design documents is inefficient, prone to error, and often results in inconsistent quality. An enhanced inspection process will eliminate paper documents, standardize quality, and increase efficiencies throughout the maintenance, repair, and overhaul product lifecycle. A software solution with Characteristic Management functionality further simplifies the generation of inspection criteria and puts manufacturers in a position to deliver higher quality products.


The Characteristic Management functionality available within the TIPQA Quality Management Solution uses Optical Character Recognition (OCR) technology to scan 2D images and create intelligent bubble drawings by extracting Geometric Dimensioning and Tolerancing (GD&T) data for import. The scanner detects dimensions and tolerances for each feature included in a part drawing to save countless hours and reduce the overall cost of quality. Standardized characteristics can be translated automatically into inspection criteria for In-Process, Receiving, or First Article Inspections. Balloons can be saved as an overlay to the application to allow the user to save their progress and return to the task. Deadlines can be enforced using email notifications and escalations.

TIPQA Characteristic Management keeps suppliers on the same page. Using balloons diagrams, part requirements can be standardized to ensure design specifications and industry standards are followed throughout the supply chain. Suppliers can manage inspection plans and generate standardized reports. Inspection and quality data can be integrated with manufacturing

execution systems and enterprise resource planning (ERP) systems for a complete view of the inspection process.

TIPQA automates the process of recording inspection/test results of material assigned to Work Orders in manufacturing or engineering operations. The system maintains a history of inspection results at the part number or revision level. TIPQA eliminates lost paperwork, improves accuracy by validating data against master records, and speeds the processing of inspection results.

Every inspection facilitated with a TIPQA Quality Management Solution is carried out with the goal of simplifying the manufacturing process, improving accuracy, and exceeding regulatory and compliance requirements while providing a complete audit trail. With these objectives in mind, risk to the organization will be significantly reduced and overall quality will improve.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Defense leaders lack detailed data or electronic access to inspection criteria.</li> <li>• Manual translation of design documents is inefficient, prone to error, and often results in inconsistent quality.</li> </ul>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Standardize inspection criteria throughout the supply chain</li> <li>• Maintain a digital archive of documents and inspection plans</li> <li>• Automatically extract mfg. &amp; inspection requirements from a 2D image or PDF</li> <li>• Characteristics can be linked to the part/revision combination</li> <li>• Link criteria with Form 3 of the AS9102 FAI report</li> <li>• Track industry compliance by part</li> <li>• First receipt and FAI AS9102 reporting. Create custom FAI, PPAP, or other commonly used reports</li> <li>• Ensure part quality and increased delivery times</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>▪ The TIPQA Characteristic Management functionality simplifies the generation of inspection criteria and puts manufacturers in a strong position to deliver higher quality products</li> <li>▪ Using balloons, part requirements can be standardized to ensure design specifications and industry standards are followed throughout the supply chain. Suppliers can also manage inspection plans and generate industry standard reports as needed.</li> <li>▪ Supports various types of inspections including Receipt Inspections, Source Inspections, Purchase Order Inspections, and Production Inspections</li> </ul>	<p style="text-align: center;"><b>GRAPHIC OR IMAGE</b></p> 

## PASS: PART AUTOMATED SCANNING SYSTEM FOR SMALL PART DIGITAL TWINS

MICHAEL RAPHAEL

Direct Dimensions, Inc.  
 mraphael@dirdim.com  
 +1.410.998.0880

If the manufacturing sector in the United States learned anything from COVID-19, it's that we must better control supply chains. Additive manufacturing is proving to be an effective solution for the fabrication of complex critical parts faster, locally, and especially on-demand. One challenge, however, is that you must have a 3D CAD file for the parts you want to 3D print and many legacy parts, especially replacement parts on shelves in warehouses, do not have such technical information.

Enter the Part Automated Scanning System (PASS), from Direct Dimensions. This new innovation is a high-speed 3D scanning machine. Think photocopier for physical items – such as small parts, collections of artifacts, museum objects, footwear, and much more. You simply place an item on the machine and in 2 minutes the part is automatically captured. Then in minutes you can view the scanned part in 3D online. You can roll it around, zoom in/out, understand its shape, components, even materials, and you can read text or markings since the 3D has high resolution color. Industry neutral files can then be shared or stored with others

anywhere to make decisions. PASS enables Industry 4.0 just in time manufacturing right here in the U.S.

PASS was originally developed for the DLA (Defense Logistics Agency) so they can scan 1,000's of parts directly in their warehouses to build a database of from which decisions on fabrication, such as additive manufacturing, can be made.

**System Description:** Direct Dimensions, Inc. has designed and developed PASS: Part Automated Scanning System for high-capacity automated 3D scanning of objects. PASS allows continuous 3D digitization of small objects, parts, artifacts, and collections. The semi-portable scanner system consists of a tower structure with (16) high-resolution DSLR cameras, integrated lights, a custom table and turntable, and a computer controller for operations, metadata, and review.

Objects placed on the turntable are automatically photographed nearly 400 times from different angles over in 2 minutes. The 2D images are then automatically converted into a dimensionally accurate textured 3D

mesh model using a process known as photogrammetry.

The 3D digital models and object metadata can be uploaded to a database for cataloguing and visualization interactively in 3D. The major system components are:

- Camera tower structure with (16) high-resolution DSLR cameras
- Integrated light system
- Scanning table with turntable and backdrop
- Operator workstation computer
- Data server
- High-speed processing computer

**Functional Specifications:**

- Maximum object volume: 16" x 16" x 16"
- Accuracy: <1 mm, as low as +/- 10 microns
- Capture time: approx. 2 minutes
- Post-Processing time (unattended, in background): approx. 7 minutes

- Output: OBJ mesh file + JPG texture file + flat-file metadata table
- Additional metadata fields customizable upon request

**Physical Specifications:**

- System Footprint: 9 ft x 5 ft x 8 ft

### PROBLEM STATEMENT

- *Digital Twins* are digital data for problem solving and avoidance.
- 3D scanning is about capturing objects and spaces in the real world to create 3D data for design, analysis, visualization, and manufacturing.
- With so much demand for digital-based information for supply chain management, and with so few items in the physical world in 3D digital form, 3D scanning enables engineers, designers, and manufacturers to better control supply chains for digital-based replacement parts.
- *Do you manage the supply of physical parts for maintenance?*
- *How do you get your physical parts into 3D for subsequent design, analysis, visualization, or manufacturing?*
- *In addition, what challenges do you have solving dimensional issues with parts, assemblies, structures, vehicles, gear & equipment?*

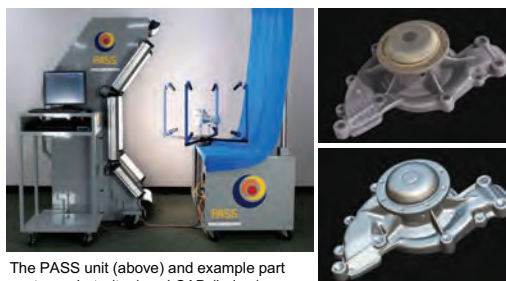
### BENEFITS

- **Library of Reference Scans:** Provides a highly versatile 3D digital model library of what a good part looks like as if holding in hands.
- **Ideal for AI/ML Analysis:** Dimensionally accurate models can be queried for suitability for AM, reverse engineering, similar part comparison, remote stock analysis, counterfeit, conformance, etc.
- **Remote Inspection:** Product evaluators can conduct dimensional testing for suspected non-conforming or counterfeit part analysis.
- **Identify Unknown Parts:** The resulting parts database can be queried against other known databases to detect similar designs, common features, part identification, manufacturing markings, etc.
- **Training and Simulation:** Having parts in digital form with color provides high quality models for training & simulation applications.

### TECHNOLOGY SOLUTION

- Direct Dimensions has over 25 years of deep domain expertise with 3D scanning across virtually all industries and applications.
- Specifically for the DLA, we developed a rapid automated 3D scanning solution for part 3D digitization with dimensional accuracy and color.
- The system consists of a tower structure with 16 high-resolution DSLR cameras, photography lights, and a custom turntable.
- Objects placed on the turntable are automatically photographed from hundreds of different angles over a span of only *two minutes*.
- The 2D photos are then automatically converted into a dimensionally accurate and textured 3D mesh model using photogrammetry.
- The system is self-contained and easily transportable and includes a custom-designed cart capable of fitting through standard doors.

### Automated 3D Imaging System for Spare Part Digital Twins



The PASS unit (above) and example part capture: photo (top) and CAD (below)

## JOINT AUTONOMOUS REPAIR VERIFICATION AND INSPECTION SYSTEM (JARVIS II)

WARUNA SENEVIRATNE

Wichita State University/NIAR  
waruna@niar.wichita.edu  
+1.316.978.5221

Due to various aspects of composite repair processes that have significant safety impacts, they must be executed with controlled environments with properly trained technicians to ensure repair integrity and reliability. An integrated robotic inspection and repair system called Joint Autonomous Repair Verification and Inspection System (JARVIS II) was developed for improving mission readiness through enhanced quality and consistency. This is a modular system that can be either field- or depot-deployable.

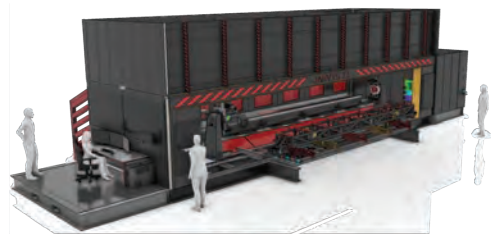
For demonstration purposes, UH-60 Black Hawk blade repair was focused, but the system can be modified to handle large composite structures. WSU/NIAR researchers engaged with Army aviation sustainment engineers and depot personnel for developing protocols for nondestructive inspections (NDI), composite repairs, and workforce training. Due to stringent load-balance requirements on rotor blades, the repairs must be carried out with minimum impact to functionality. However, current repair processes often lead to blade balancing issues and rotor

failures. According to the current rotor management program, the main rotor blades are removed for routine inspections after a pre-determined number of hours of operations. The demand for the blades as well as the stringent structural and safety requirements warrants a need for novel automated techniques to accomplish routine inspections and repairs in a timely manner so that a sufficient number of blades are available on operational readiness to support fleet during blade removal for repair and routine inspections.

JARVIS was designed for carrying out wide-area high-fidelity inspections technologies. Since the system is modular, various inspection technologies such as thermography, shearography, and ultrasonic inspection techniques are integrated. Robotic system automatically combines dozens of inspection images into a mosaic, a single digital record of all inspection data, in a fraction of the time it takes for a tap-test inspection carried out by a trained inspector. Tool path for each operation is generated by 3D scanning the surface so that variations in different blades can be

accounted for. A machine-learning algorithm is built-in to the software to interrogate digital inspection data and identify potential areas with anomalies/damages. Repair modules include milling head for damage removal and scarfing, dust collection system to maintain particle count, atmospheric plasma system for surface preparation, goniometer to quantify the surface for wettability prior to repair, and a thermal management system for heat blanket for curing composite patch.

The NDI system is also used for post-repair detailed inspections to ensure repair integrity, generating supplementary documents required for airworthiness approval, and product lifecycle management (PLM). Because all the information is captured digitally, this data can also be used for optimizing subsequent load balancing and developing a Digital Twin.

<p><b>PROBLEM STATEMENT</b></p> <p>The demand for rotor blades as well as the stringent structural and safety requirements warrants a need for novel automated techniques to accomplish routine inspections and repairs in a timely manner so that a sufficient number of blades are available on operational readiness to support fleet during blade removal for repair and routine inspections. Due to various aspects of composite repair processes that have significant safety impacts, they must be executed with controlled environments with properly trained technicians to ensure repair integrity and reliability. <b>JARVIS II is a composite inspection and repair system to improve mission readiness through integration of advanced technologies.</b></p>	<p><b>BENEFITS</b></p> <p><b>Integration of Modern Technologies and Robotics</b></p> <ul style="list-style-type: none"> <li>Automated process aided by artificial intelligence increase productivity and improve the quality &amp; consistency</li> <li>✓ Aid current sustainment by reducing Out of Reporting (OOR) and improve <i>speed to fleet</i></li> <li>✓ Digital framework for <i>Model-Based Systems Engineering</i> and <i>Digital Thread</i> to improve fleet readiness</li> <li>Because all the information is captured digitally, this data can also be used to ensure repair integrity, generating supplementary documents required for airworthiness approval, and <i>product lifecycle management (PLM)</i></li> <li>Digital data for optimizing subsequent load balancing and developing a <i>Digital Twin</i>, a virtual representation of each blade with modifications.</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>An integrated robotic inspection and repair system called <b>Joint Autonomous Repair Verification and Inspection System (JARVIS II)</b> was developed for improving mission readiness through enhanced quality and consistency. This is a modular system that can be field- or depot-deployable. Since the system is modular, various inspection technologies were integrated; repair modules include milling head for scarf repair, core removal, and patch preparation, dust collection system to maintain particle count, atmospheric plasma system for surface preparation, goniometer to quantify the surface for wettability, and a thermal management system for curing composite patch.</p>	 <p><b>JARVIS II is now operational at Corpus Christi Army Depot (CCAD)</b></p>

# ENHANCED INSPECTION

## MIXED REALITY (MR) FOR VISUAL INSPECTIONS OF COMPOSITE STRUCTURES

KONSTANTYN SHYSHKIN

Spiral Solutions Corp  
k@spiral.technology  
+1.617.915.3157

**Problem:** When defects are mis-recorded engineering disposition is delayed, visibility of the resolution status decreases, and quality suffers. Paper records reduce transparency further and make any trend analysis impossible. Knowing the exact location of the problem therefore is key in depot overhaul operations.

**Solution:** Proposed solution increases speed and accuracy of quality inspections across the maintenance lifecycle of the aircraft. Our Mixed Reality (MR) tool enables quality inspector to directly tag defects on the large structures and get them inserted in the digital twin.

**Benefits:** Spatial markers give you complete and accurate quality records, real-time digital disposition, a holistic map of every part's status.

1. **Accurate Defect Location.** Engineers see every defect mapped out in real time, through their desktop view. From here, they can create heat maps, based on aggregate data, and see a clear picture of where problems most frequently occur.

2. **Faster Defect Resolution.** Recording problems digitally in real-time accelerates engineering disposition and improves coordination between technicians on-site and engineering support. Knowing the precise location of all the defects removes ambiguity from the repair process while senior management has complete transparency of the resolution status.

3. **Seamless Communication with Engineering.** Engineers directly connect with operators via video call to provide remote assistance and feedback, if needed. Operators receive instructions directly to their headset, for regular problems. Communication becomes entirely digital, increasing efficiency and reducing errors!

Markers are persistent. When placed on a defect marker “remembers” its location, size, and distance to other objects. This provides accurate defect location to the repair crew and helps tracking status of the repairs.

Markers provide contextual instructions. Next steps in the inspection process depend on the defect location and type. Marker's spatial awareness allows providing only relevant repair instructions and prompts picking right tools.

**How it works:** We introduce Virtual Marker — a holographic cube referencing defect on the part or equipment. Created and accessed via HoloLens2 headset markers contain spatial information about the defects as well as pictures, videos, and technical parameters. Spatial marking crates virtual layer of information over the physical objects.

### Spiral Solutions

- **Problem Statement:** Aircraft mechanics suffer from delayed engineering disposition caused by the incomplete quality records.
- **Solution:** We help quality inspectors to increase accuracy of collected data by marking the defects on the digital twin of the aircraft via MR headset.
- **Description of the Technology:** Leveraging spatial awareness of the headset proposed solution <https://www.spector.vision/> allows referencing physical objects with virtual markers which automatically generates and saves their [x, y, z] coordinates. This captures marker's location, size, and distance to other objects.

### Benefits:

- Faster inspection workflow
- Fewer errors
- Hands-free issue reporting
- Better data for faster disposition
- Focused continuous improvement effort
- Data aggregation on digital twin

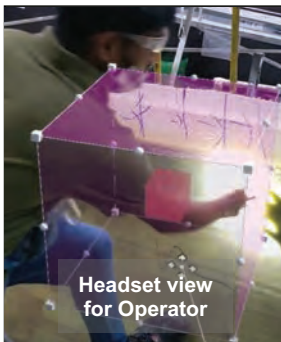
### Next steps:

- Implement the solution across all the 15 factories of the current pilot customer
- Quantify the benefits and infer ROI
- Add the AI algorithm for automated defect detection
- Integrate with UT probes to apply in NDT

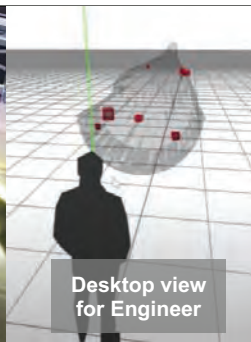
• **Current development status:** Solution is undergoing testing in the factory of the world's biggest manufacturer of wind turbines in Grand Forks, ND. TRL 7

### Why it is innovative?

- Today AR/MR is mostly offered for remote assistance or delivery of the work instructions which are the basic applications
- We engage core capability of MR – spatial awareness or continuous tracking of its own position in space. This helps to connect digital and physical spaces together



Headset view for Operator



Desktop view for Engineer

## AN FMCW RADAR BASED CABLE REMAINING USEFUL LIFE ESTIMATOR

ZHONGHAI WANG

Alex and Alice, Inc.  
zhonghai.wang@alexnalice.com  
+1.301.247.8634

Here we present a Frequency-Modulated Continuous Wave (FMCW) radar-based cable remaining useful life (RUL) estimator. It can detect and locate cable hard and soft faults, and estimate the cable RUL. The system uses the truth that a discontinued cable impedance reflects the coming RF signal. It is constructed with an FMCW radar, an impedance matching network and a lead cable, a cable degradation model, and a deep learning (DL) based data processing module.

The FMCW radar transmits a chirp down to the target cable through the impedance matching network and the lead cable, receives the reflected signal from the target cable, converts it to the base band, and collects baseband signal samples. The samples are then fed to the DL-based data processing module for cable faults detection and localization, and cable RUL estimation with the support of the cable degradation model.

The impedance matching network and the lead cable minimize the impact of transmitter (Tx) leakage and the interface reflection, and a high detection sensitivity for soft fault

sensing is obtained. Various grades cable faults are modeled in the cable degradation model for the DL model training for cable faults detection and localization, and cable RUL estimation. It's main application is for cable assembly diagnosis.

The advantages of the proposed FMCW radar-based RUL estimator include (1) high sensitivity, (2) great noise impact reduction, (3) high accuracy of fault detection and RUL estimation with the cable degradation model and DL algorithm.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>❖ Problem:             <ul style="list-style-type: none"> <li>▪ Over 1,000 aborted missions, over 140,000 Non-Mission-Capable (NMC) hours per year due to wiring incidents</li> <li>▪ Two in-flight electrical fires related to wiring failures per month</li> <li>▪ 43% Air Force aircraft mishaps or accidents relate to the wiring interconnection system</li> </ul> </li> <li>❖ Technique and current sensor             <ul style="list-style-type: none"> <li>▪ Prognostic and Predictive Maintenance (PPMx) estimates what might go wrong, and when</li> </ul> </li> <li>❖ Cable analyzers inject signal at one end and measure responses at the other end of a cable. Large, heavy, two ends sensor</li> <li>❖ Proposed sensor             <ul style="list-style-type: none"> <li>▪ A handheld, single end (inject signal and measure response at one end of a cable) sensor provides performance and efficiency</li> </ul> </li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>❖ A low SWaP handheld sensor</li> <li>❖ Detect and locate cable hard faults (open and short circuits)</li> <li>❖ Detect and locate cable soft faults (e.g., coaxial cable shield broken, twisted and parallel pair cable deform, wire corrosion, connector pin fault, insulation degradation)</li> <li>❖ Classify cable degradation level with the support of a cable degradation model</li> <li>❖ Estimate cable remaining useful life / when to repair or replace the cable</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>❖ A Frequency-Modulated Continuous Wave (FMCW) radar-based cable remaining useful life estimator</li> <li>❖ An FMCW radar – measure cable impedance change generated by faults/aging, cable insertion loss, single non-paired wire length; sample at baseband frequency with a low sampling rate</li> <li>❖ An impedance matching network and a lead cable – reduce interface reflection and push Tx-leakage away from target signal</li> <li>❖ A cable degradation model – mapping cable fault/aged condition to cable remaining useful life</li> <li>❖ A ML based data processing module – detect and locate fault, and estimate cable remaining useful life</li> </ul>	

## DEFECT CHARACTERIZATION OF NAVY SHIP STRUCTURES WITH BROAD SPECTRUM ACTIVE ULTRASONIC MODE IMAGING

DR. STEVE ZIOLA

Antech Systems, Inc.  
Steve.Ziola@antechsystems.com  
+1.303.913.0959

**Problem Statement:** Current NDT&E methods used by Naval shipyards, such as Ultrasonic Testing, to inspect ship structures for corrosion and defects are effective but are time consuming, costly, and are found lacking when confronted by interference, inaccessibility, and/or confined spaces. There are many situations where Shipyards are required to remove coatings and/or unship components all together to ensure adequate inspections can be accomplished. There is a need for a more effective and efficient method to inspect large areas of ship structures for defects without having to remove coverings or components.

**Innovation:** Antech Systems is pioneering the development of a new technology and approach for analyzing propagating waves in plate-like ship structures to identify, locate, and characterize defects, such as corrosion, voids, and disbonds. The new approach is called Ultrasonic Mode Imaging (UMI), and it represents a major step forward in signal processing and analysis in both passive and active applications because it is physics-based, uses the entire frequency spectrum, and leverages higher-level guided wave modes to provide detailed information

about the defects. It uses novel image analysis routines to overcome the effects of overlapping wave modes, dispersion, and reflections and presents more accurate results in an automated manner.

**Status:** Currently, Antech Systems is building the sensors and electronics hardware needed for the active UMI system to achieve desired monitoring ranges via a NASA SBIR project. Development work needed to prove the viability of the technology includes developing a mechanical source input device to introduce broadband guided waves into the structure, ultrasound tomography software needed to turn the UMI measurements into images of the structure to show the location of the defects, and experimental verification of our approach.

**Supporting Tests:** Antech Systems has conducted experiments with thinned areas on a 4'x8' aluminum plate which show an ability to detect about a 1% thickness reduction even under a covering with current commercially available sensors and electronics. With the new NASA hardware, we are demonstrating an ability

to quadruple the range, which will make the system cost effective and efficient for large ship structures.

**Next Steps:** The next steps are to find a sponsor willing to invest in this technology to complete the development work required and build a prototype system for field testing. We estimate the investment required is about \$500K, and it would require about a year to complete the work.

**Benefits:** The active UMI system once developed would inspect large areas of ship structures in less time than current NDT&E methods and without having to remove interferences, coatings, and coverings. Such a system has the potential to significantly reduce maintenance costs and schedules, extend the life of Navy assets, and provide the warfighter with more reliable structures, components, and systems.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"><li>• Current NDT&amp;E methods used by Naval shipyards, such as Ultrasonic Testing (UT), to inspect ship structures for corrosion and defects are effective but are time consuming, costly, and are found lacking when confronted by interference, inaccessibility, and/or confined spaces.</li><li>• There are many situations where Shipyards are required to remove coatings and/or unship components all together to ensure adequate inspections can be accomplished.</li><li>• There is a need for a more effective and efficient method to inspect large areas of ship structures for defects without having to remove coverings or components.</li></ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"><li>• The active UMI system once developed would inspect large areas of ship structures in less time than current NDT&amp;E methods and without having to remove interferences, coatings, and coverings.</li><li>• The system would provide more complete coverage of the structure and characterize the defects with more accuracy and fidelity since it leverage higher-level wave modes which contain rich information about the defective condition.</li><li>• Such a system has the potential to significantly reduce maintenance costs and schedules, extend the life of Navy assets, and provide the warfighter with more reliable structures, components, and systems.</li></ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"><li>• Develop a portable, robust, efficient, and effective active Ultrasonic Mode Imaging (UMI) system to perform NDT&amp;E of Navy ship structures for corrosion, voids, and disbonds under coatings and coverings.</li><li>• Leverage an enhanced passive monitoring system being developed under a NASA SBIR contract to boost monitoring range and automated imaging analysis software being developed by Antech Systems to better characterize defects with higher-level wave modes.</li><li>• Develop a robust mechanical input source device to excite broadband signals in the structure that propagate further.</li><li>• Develop ultrasound tomography software needed to turn the UMI measurements into images of the structure to show the location of the defects.</li></ul>	<p><b>Inspection Rays</b>      <b>Tomographic Reconstruction</b></p> <p><b>Hammer Tap</b></p>



# RELIABILITY IMPROVEMENT (HARDWARE)

## PROJECT GUSTAV | 3X COMMUNICATION CAPABILITY

RYAN AMADOR & MATTHEW CONNELLY

52nd Fighter Wing  
ryan.amador.1@us.af.mil  
+1.314.452.6187

**Backdrop:** The pandemic taught us that technology exists to create networks that facilitate smooth communication. But for the last four decades, our field maintainers have not benefited from those same technological advances. That changes with Gustav.

**Problem Statement:** Since 1981, field maintainers servicing aircraft across the fighter community have relied on sturdy analog communications with our pilots. The way we communicate is solid and reliable but there is a problem. Bandwidth is limited to only one person who in turn forwards that message audibly in a deafening environment. The situation described affects a quarter of our Air Force population and half of our Air Force fleet.

**Solution:** The Gustav Connector is an inexpensive communication reliability innovation that triples pilot-to-field-maintainer bandwidth across the joint force fighter community. On the job training as well as missions requiring radio silence will benefit from this innovation.

**Capability:** This innovation triples communication capability for field

maintainers servicing fighter aircraft. This affects both training and operations by disintermediating forward-transmission of messages from the aircraft to field maintainers. It is true that splitters and adapters are used in some combat aircraft communication solutions. A similar locally manned idea was tried in 1981 (Locally manned means that it was built in a specific place). This innovation shares some similarities to the 1981 rendition but produces a significantly improved signal quality and eliminates hissing noises. The Gustav Connector offers the user no signal degradation by using a polymer shielding and equalizing the wire gauge across the entirety of the adapter.





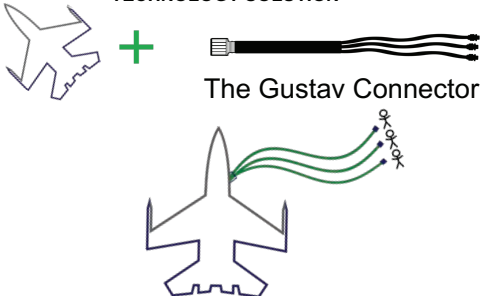

**Technical maturity:** Eighteen have been demonstrated and are in service as of August 2022, 17 are Air Force, and one is Navy. Additionally, one was used to confirm compatibility with Portuguese combat aircraft. The tech specs are ready and already accepted into Technical Order (TO) 1F-16CJ-2-23GS-00-1-WA-1 for use with Air Force F-16 aircraft. No manufacturer produces this innovation yet.

**Compatibility:** All Sister Branches and all International Partners that use US manufactured Combat Aircraft.

**Cost:** Built internally at \$200 Per Unit:

- \$340K Air Force (1.7K Aircraft)
- \$420K Joint Force (2.5K Aircraft)

**Next Step:** If chosen, our Air Force will not only trail-blaze this capability for itself, but also the joint force and 25 partner nations that use US manufactured fighter aircraft. This would be a quick win for our Air Force and the DOD writ large if used to help pilots more clearly communicate with their field maintainers.

<p><b>PROBLEM TODAY</b></p> <p>Since 1981, field maintainers servicing aircraft across the fighter community have relied on sturdy analog communications with our pilots. The way we communicate is solid and reliable but there is a problem. Bandwidth is limited to only one person who in turn forwards that message audibly in a deafening environment. The situation described affects a quarter of our Air Force population and half of our Air Force fleet.</p> 	<p><b>BENEFITS</b></p> <p> 300% Zero Communication Increase Degradation</p> <p> All Sister Services International Partners</p> <p> \$200 <b>\$340K</b> \$420K Per Unit <b>Air Force</b> Joint Force</p>
<p><b>TECHNOLOGY SOLUTION</b></p>  <p>The Gustav Connector</p>	<p><b>IMAGE OF TOMORROW?</b></p> 

# RELIABILITY IMPROVEMENT (HARDWARE)

## RAPID BONDED NUTPLATE REPLACEMENT

BRETT BOLAN

AFRL/RXSA  
brett.bolan@us.af.mil  
+1.937.656.6008

Adhesively bonded nutplates are increasing employed in the fabrication of aerospace structures with some aircraft containing tens of thousands. They find utility in assemblies where two-sided access is not possible and/or where maintenance access panels are found. In operational units, nutplates that tend to fail most often are those used to secure panels that are frequently removed & replaced for maintenance purposes. The inability of maintainers to rapidly, effectively & safely remove failed nutplates & reinstall new ones has negatively impacted aircraft mission capable rates & been a top maintenance driver for two weapons systems.

AFRL/RX's Structural Materials Evaluation Nonmetals team (including on-site contractors) worked with an Original Equipment Manufacturer (OEM), an injection molder, a major abrasive supplier, & multiple operational units to address this challenge. The AFRL/RX team developed, in-house, an innovative & novel nonmetallic reverse counterbore cutters & associated equipment (aka Adhesively Bonded Nutplate Installation and Repair (ABNIR) kit - a suite of over 40 tools), that reduce the time to prepare aircraft structure for bonding new nutplates.

In the process of developing these tools and to ensure that they were going to be put into the maintainers' toolboxes, the AFRL/RX team:





- Beta tested prototype tools with maintainers from all three Services using feedback to drive tool & procedure improvements
- Worked with a plastics injection molder in the design of molds to be able to economically produce the cutters
- Worked with tool manufacturers to produce & transition "associated" equipment into commercial off the shelf (COTS) items
- Worked with a major abrasive supplier in designing new abrasive pads for critical final prep of aircraft structure, and transitioning into a COTS item
- Developed a hands-on training course for maintainers, field-service engineers, & OEM personnel in the proper utilization of these tools
- Developed operations manual detailing the proper steps for using these tools – was foundational document for creating

Technical Orders for two weapon systems & part of an OEM's process spec in aircraft production & depot maintenance

- Trained hundreds of maintainers from the three Services
- Worked with a supplier to ensure successful transition of ABNIR Kit into a COTS item

The use of the ABNIR kit will result in a five-fold reduction in the time to remove remnant material from aircraft structure during nutplate replacement. The resultant better-prepared new bond surface provides superior bonds & mitigates premature nutplate failures thus reducing future maintenance workload. End result is increased readiness of 5th generation aircraft (and future platforms) to deter near peer adversaries.

Next step: have broader adoption of the ABNIR kit as an enterprise solution for aerospace structures that utilize bonded nutplates – could entail development of alternate sized cutters for specific platform needs.

PROBLEM STATEMENT	BENEFITS
<ul style="list-style-type: none"><li>• Fifth generation aircraft utilize bonded nutplates, upwards of 20 to 30 thousand per aircraft, to secure fasteners when there is limited or no access to the backside of the fasteners at the time of installation (e.g., for maintenance access panels and covers)</li><li>• These bonded nutplates are frequently damaged, for a variety of reasons, and need to be rapidly replaced to maintain operational tempo</li><li>• The inability of maintainers to rapidly, effectively and safely remove failed bonded nutplates and reinstall new ones at operational units has been a significant negative maintenance driver for these platforms</li></ul>	<p>Rapid Bonded Nutplate Replacement kit (aka ABNIR kit)</p> <ul style="list-style-type: none"><li>• Obtained five-fold reduction in the time to remove remnant adhesive and sealant from aircraft structure during repair</li><li>• Better-prepared surfaces with quality assurance test ensures superior bonds &amp; mitigates premature nutplate failures</li><li>• AFRL/RX procedures incorporated into Original Equipment Manufacturers' (OEMs) process specification for production as well as in several AF Maintenance Technical Manuals</li><li>• Tools and procedures being incorporated into future platforms</li><li>• Adhesive cure prototype further reduces repair to 5 hours</li><li>• Increased readiness of 5<sup>th</sup> generation and future aircraft to deter near peer threats; supports DAF Op'1 Imperatives 5 &amp; 7</li></ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"><li>• AFRL/RX developed a suite of 40+ tools (cutters, swivels, mandrels, wrenches, etc.) to enable rapid, safe, and trusted surface prep of aircraft structure for nutplate repair (aka the ABNIR* Surface Prep Kit)</li><li>• Beta tested tools with maintainers from all three Services, using feedback to drive tool &amp; procedure improvements</li><li>• Trained hundreds of field maintainers in proper operation of tools as they deployed to operational units</li><li>• Worked with plastics injection molder &amp; tool manufacturers to transition tools &amp; kits into commercially available items</li><li>• Developed training course and Distro A operational manuals</li></ul> <p>*Adhesively Bonded Nutplate Installation and Replacement</p>	 <p>ABNIR Surface Prep Kit Commercially Available</p>  <p>Maintainers being trained in the proper utilization of the ABNIR kit</p>  <p>Torlon® Adhesive Cutter removing remnant adhesive</p>  <p>Torlon Adhesive Cutter</p>

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## NON-DESTRUCTIVE ORGANIC REVERSE ENGINEERING OF PRINTED CIRCUIT BOARDS USING COMPUTED TOMOGRAPHY TECHNOLOGY

DAMON L. BROWN, P.E.

402 EMXG / MXDE, Warner Robins Air Logistics Complex, GA  
 damon.brown@us.af.mil  
 +1.478.926.3206

Avionics repair is hindered when manufacturers can no longer supply circuit card assemblies or their associated technical data packages (TDP). Reverse engineering (RE) of printed circuit boards (PCBs) is used to yield form, fit, & function replacements needed to maintain fleet readiness. The current process for reverse engineering PCBs is a destructive 'sand and scan' approach. A PCB is mechanically sanded to reveal internal circuit layers. PCB circuit layer images are obtained by optical scanning and used as a template in PCB design software over which technicians add digital traces. This process is costly in terms of effort, skill, and training needed to do the job, loss of rare physical assets, and poses environmental risks from sanding PCBs made of fiberglass and solder.

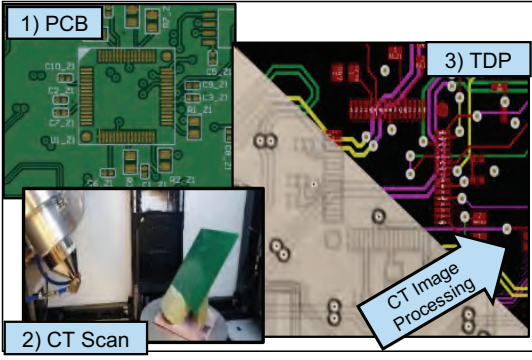
402 Electronics Maintenance Group's Reverse Engineering Avionics Redesign and Manufacturing Innovation Center has been working in partnership with Tetrahive Technologies on a SBIR project to demonstrate a technology solution using non-destructive X-Ray Tomography imaging combined with novel software

tools to yield a digitized process to facilitate semi-automated generation of TDPs for legacy electronics. Technology elements include a) XRT hardware specification & data acquisition settings for relevant environment PCBs, b) a custom imaging application with tools to semi-automatically extract TDP data, and b) ability to interface with existing PCB RE software used by various DoD agencies for further TDP editing and validation.

Test article PCB specimens representing the relevant environment of the USAF PCB assets were created and then XRT hardware and settings were determined by testing. Seven different PCB designs with features ranging from 5 mils to 20 mils were tested. The specimens ranged in size from 3"x4.5" to 9"x9", circuit layer counts from 4 to 8, and either a Pb-based HASL or OSP finish to assess the ability of the X-ray hardware. Over 20 separate scans were performed by industrial XRT service providers and the data compared for RE suitability. An XRT system recommendation and scan documents for the variety of boards tested were developed.

Phase II also developed a prototype CT imaging software that supports automatic detection of the PCB stackup and flexure. Non-destructive slices which follow the PCB flexure and are placed at the stackup locations. Correcting for board flexure has been a challenge in PCB RE as the slightest degree of flexure in PCBs makes it difficult to obtain images distinguishing individual circuit layers. The software also has functions to extract TDP data from the PCB and supports interfacing with existing PCB CAM/RE tools via exporting circuit layer raster and Gerber images.

The project is transitioning from prototype to technology demonstration, where it is being exercised on two PCBs. RE for these assets is planned to be half the cost and time of current destructive techniques. This digitized process also supplies intangible benefits such as eliminating the risk of losing rare assets during RE, reduction of 'key man' risk and enhancement of repeatability, automation, and archival functions through a digital process.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>Avionics repair is hindered when original equipment manufacturers can no longer provide circuit card assemblies or associated technical data packages (TDP). Reverse engineering (RE) of printed circuit boards (PCBs) is often required to yield form, fit, &amp; function replacements needed to maintain fleet readiness.</li> <li>Current PCB RE process is a painstaking destructive 'sand and scan' approach. A PCB is mechanically sanded to reveal internal circuit layers. Individual PCB circuit layer images are obtained by scanning and using as a backdrop in PCB RE software over which technicians recreate TDP files (i.e., trace Gerber files).</li> <li>This process is destructive and costly in terms of time, manual effort/skill, loss of rare physical assets, and poses environmental risks (sanding PCBs made of fiberglass and Pb-based solder).</li> </ul>	<p><b>BENEFITS</b></p> <p>Tangible Return On Investment considerations:</p> <ul style="list-style-type: none"> <li>- Current Phase III 'real world' project on 2 REARM PCB assets → PCB RE done at <b>half the cost in half the time</b> of current on-site destructive techniques and processes</li> </ul> <p>Intangible benefits:</p> <ul style="list-style-type: none"> <li>- Eliminates risk of losing rare electronic assets during RE</li> <li>- Reduces 'key man' risk needed to destructively de-layer PCBs</li> <li>- Digitized process enhances repeatability, automation, and archival</li> </ul> <ul style="list-style-type: none"> <li>✓ PCB RE activities can be done cheaper</li> <li>✓ PCB RE activities can be done faster</li> <li>✓ PCB RE activities can be done with less risk (key-man, non-destructive, digital processes)</li> <li>✓ DoD can have increased capacity for performing PCB RE</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>Small Business Innovation Research project/partnership between Reverse Engineering Avionics Redesign and Manufacturing and Tetrahive Technologies to find and raise the Technology Readiness Level of a non-destructive solution which can digitize and eventually automate the process.</li> <li>Technology bridges the gap between two existing technologies: X-Ray Tomography non-destructive imaging (aka XRT or CT scanning) and existing PCB CAM software tools.</li> <li>Technology elements are: XRT hardware &amp; data acquisition setups for PCBs determined via relevant environment experiments</li> <li>Custom CT imaging application with tools to automatically obtain circuit layer images and PCB TDP data (Gerber files)</li> <li>Linkage/Exports to existing PCB CAM and PCB RE software used by various Department of Defense (DoD) agencies for further TDP editing.</li> </ul>	

# RELIABILITY IMPROVEMENT (HARDWARE)

## PORTABLE SCARFING COMPOSITE STRUCTURE REPAIR SYSTEM

JESWIN CHANKARAMANGALAM

Jeswin Chankaramangalam  
Wichita State University  
+1.316.677.1794

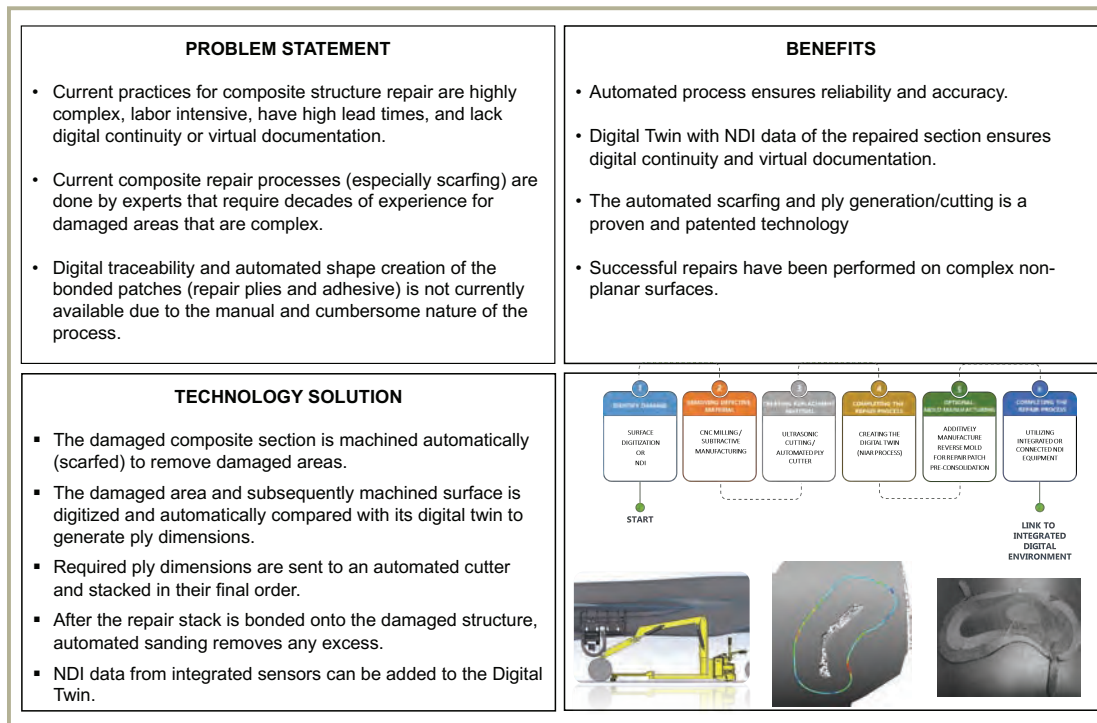
Current practices for composite structure repair are highly complex, labor intensive, have high lead times, and lack digital continuity or virtual documentation. In order to repair a composite, the damaged section must be completely machined or sanded off, which is typically done by hand making it labor intensive and inaccurate. Then to get the required repair ply profiles, a transparent medium such as Mylar is used to manually trace out the missing composite section. With the profile of the damaged section created, several iterations of individual plies are cut and assembled to find a combination that fits the damaged section. This process requires highly skilled labor and even then involves a lot of estimation and non-value add verifications. In order to vastly improve this process, the National Institute for Aviation Research (NIAR), in partnership with American GFM, proposes their patented automated composite repair and virtual documentation process.

The fundamental difference between traditional and NIAR's composite repair procedures is the use of a fully virtual and automated process. This process begins by

having a complete digital version, or Digital Twin, of the structure that will be repaired so that damage can easily be found and tracked. When damage is found, either by automated or manual NDI/inspection, it must be scanned to initiate the repair process. The area that should be removed is sent to an automated computer numerical control (CNC) mill that can attach to any surface of the structure. While the damaged area is being removed, the required plies are digitally generated then cut by a CNC ultrasonic ply cutter and stacked. The only part of the process that is currently manual is the placement of the plies and its curing setup onto the damaged section. Finally, after automated sanding of the repair patch, NDI inspection is used again to guarantee compliance and the data is added to the digital twin to ensure virtual documentation.

The process to create Digital Twins of vehicles is very mature and is being performed at NIAR for purposes far beyond composite repair. The software that takes the machined damage section scan and generates the required ply shapes is fully developed and has been demonstrated with

a few different complex surface profiles. NIAR has also fully developed an automated cobotic sander that scans the surface for parts that require sanding. This robot and accompanying software could easily be adapted to include a CNC system in order to scarf damage. In summary, NIAR and AGFM's composite repair process will vastly improve composite repair by making it more reliable, digitally traceable, and efficient.



## REACTIONLESS ENGINES WITH MACROSCOPIC THRUST

ED CHEN

Lewa Farms  
edchen0@gmail.com  
+1.808.315.5224

Reactionless drives are internal momentum thrust generators which harnesses the electromagnetic Abraham Lorentz force to generate large amounts of applicable thrust without any propellant. Until our technology was released last year, this was supposed to be an impossible feat due to violations of the conservation of momentum. Unlike other nascent electromagnetic propulsion systems our system has been prototyped and produces enough macroscopic thrust to compete with existing engines. A video of the rudimentary propulsion may be found here: [sae.org/news/video/content/13196/](http://sae.org/news/video/content/13196/).

Using just 150 watts we have measured a repeatable 8 Newtons of thrust on a 3-pound system that costs less than 100 dollars. Scaling this system is currently underway. The reliability improvement impact on ground, sea, and air transportation will be revolutionary. Without the need to carry fuel, air and space maintenance operations will open up the entire space to new possibilities as well as augment existing propulsion technologies. On the ground, an internal momentum generator will improve vehicle safety by providing the possibility of

momentum breaks, as well as allowing for frictionless propulsion in difficult terrains such as mud, ice, and snow.

The technology works by using a unique configuration of two electromagnetic solenoid coils, one active, one passive. A static electric current is fed to the passive coil to generate a standing magnetic field; pulses of current are fed into the active coil, which activates the mechanism according to the equation  $F_{rad} = \mu q^2 / (6\pi \cdot cmr^2) * 2B / (mr^2) * dB/dt$  which is derived from a previous SAE technical paper. An iron momentum carrier captures the excess net force and delivers this momentum to the system. The iron momentum carrier acts as a piston which is then reset to its original position when the pulse of electricity is off.

The system is simple, scales smoothly, and can be manufactured in different customized configurations to fit the needs of any application. All components, (e.g., solenoid coils, iron rod, power supplies) are assembled from existing manufactured parts so development and implementation can be rapid.



### Technical Advantages: Propulsion is Limited by Current Technology

- This technology generates high levels of internal momentum without the use of propellants allowing for frictionless ground propulsions, silent underwater propulsion, and propellant free atmospheric and space propulsion.
- The technology does not require propellant or friction to generate thrusts.
- No exhausts makes this engine completely emission free.
- With only a single moving part and no propellant, this engine is silent and efficient.
- All aspects of this engine can be manufactured and assembled from existing parts already abundant in the supply chain allowing for rapid implementation.

### Technical Description:

- The product is an engine which can be customized for any propulsion application
- Unique configuration of two coils harnesses the Abraham Lorentz Force
- $F_{rad} = \mu q^2 / (6\pi cmr^2) * 2B / (mr^2) * \frac{dB}{dt}$  "the Sektet equation" governs the force generated by the engine.

### Anticipated Benefits and Applications:

- **Military:** Momentum Brakes, frictionless ground propulsion, silent and exhaust free sea propulsion, and atmospheric and space propulsion will all be revolutionized by this technology.
  - Difficult operation environments such as mud, snow and ice can be navigated with this frictionless propulsion.
  - The Space Domain will be completely transformed as operating in the space environment can be done without hauling heavy fuel and propellant into space.
  - The improvement to reliability of transportation and ease of logistics will be revolutionary.
- Commercial:** The technology may be utilized on all transportation in the commercial sector as well. This technology should completely transform all aspects of transportation.

### Business Model:

- The technology can be licensed and easily customized to existing applications
- Interest in working with commercial and DoD primes to define requirements for tailored applications as well as to fully develop the technical potential of the engine.
- Interest in helping to define technology standards and solutions in this new technological space.

### Work to Date:

- To date we have developed the physical and mathematical theory underlying reactionless propulsion so that it may be fully explained under existing physical laws.
- The thrust we produced is THOUSANDS of times greater than the current state of the art in reactionless drives.
- We simulated the design on Simulink to determine variables for manipulation.
- A fully functional repeat firing engine which produces 8 newtons of thrust on 150 watts of power consumption on a 3-pound system.
- The product is currently being scaled to a 1000-watt system to attempt to generate additional thrusts.
- Different geometries of the system have also been explored

This research was developed with private funding

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# RELIABILITY IMPROVEMENT (HARDWARE)

## FRICITION REDUCING OIL ADDITIVE INCREASES ENGINE EFFICIENCY AND LONGEVITY

GREG CHRISTENSEN









Novum Nano  
 greg.christensen@novumnano.com  
 +1.605.728.4026

Billions of dollars are wasted every year due to metal loss in the industry that is caused by wear. Improving the properties of the lubricants would reduce the friction and wear of mechanical parts, which leads to extended mechanical parts lifetime, reducing the cost of maintenance, and saving fuel and energy. Internal combustion engines use significant amounts of diesel and gasoline at great cost to the owner/operator and the commercial sector, and their emissions contribute significantly to global greenhouse gas emissions. The USA DoD is the world's largest user of diesel fuel. Reducing friction and in-creasing thermal heat transfer increases internal combustion engine efficiency. Carbon nanotubes and hexagonal boron nitride have been known to reduce friction and increase thermal conductivity in many applications. The combination of these two materials in the correct concentrations and proportions was studied in detail to achieve improved performance over conventional oils, or other oil additives studied to date. The anti-wear mechanism is attributed to the aggregation of the carbon nanomaterials on the surface of the metals,

which reduces the shearing stress, thus enhancing the tribological properties.

Carbon nanotubes and hexagonal boron nitride nanosheets allow for extreme friction reduction, even when compared to high performance synthetic motor oils. Coupon testing was initially performed to refine the specific nanomaterials employed as well as the concentrations of constituents. Tests were performed by Falex corporation using an ASTM G77 Block on Ring test apparatus and revealed up to a 62% wear reduction and a 12% friction reduction compared to Mobil 1 full synthetic. A wide variety of engine tests were performed to understand the influence of the oil on a more complicated system. Engine testing showed significant improvements in fuel efficiency. Improvements up to 30% in testing engines ranging from small lightly loaded to heavily loaded diesel engines are obtained. A significant improvement in fuel efficiency was achieved in a diesel engine equipped truck. Based on this work, the typical application is expected to gain up-wards of 5 to 10% in fuel efficiency. This is dependent on the

engine type and loading, but the evidence suggests that the highest loaded engines demonstrate the most significant gain in performance. In addition, horsepower gains of up to 11% and torque increases of up to 12% were observed during testing.

Friction / Wear Testing	Gasoline Engine Testing	Diesel Generator Testing Diesel Turbo Temp Testing	Diesel Pickup and Van Testing
ASTM D2714 friction testing by Falex Corporation: - 47% reduction in the coefficient of friction compared to Mobile 1 - 62% wear reduction 	Small 4 cycle engines: - Increased run time by 7.9% Harley Davidson Motorcycles: - Increased Torque by up to 10.99% / Horsepower by up to 11.92%  Subaru Turbo – 7% better MPG	Kubota generator / light set - 5% improvement in fuel efficiency 	Mercedes Sprinter Van - 15% better MPG normal - 33% better MPG towing RAM Cummins HD - 27% better MPG towing Chevy Duramax - 25% better MPG highway  
<b>DoD / Military Component Problem</b> <ul style="list-style-type: none"> <li>The DoD uses an enormous amount of fuel and is the largest single consumer of diesel fuel in the world</li> <li>This large amount of fuel is not only expensive and detrimental to the environment but is also challenging to procure across the globe and especially in combat zones.</li> <li>Maintenance due to engine wear is a significant and related challenge</li> </ul>		<b>Warfighter Benefits</b> <ul style="list-style-type: none"> <li><b>Platforms</b> <ul style="list-style-type: none"> <li>All weapon systems and support equipment that use gasoline or diesel fuel</li> </ul> </li> <li><b>Benefits</b> <ul style="list-style-type: none"> <li>Reduce fuel costs</li> <li>Reduce logistical footprint to accomplish the mission</li> <li>Reduced battlefield exposure for resupply</li> <li>Reduce green house emissions</li> <li>Reduce engine wear resulting in less downtime and expense</li> </ul> </li> </ul>	
<b>Approach</b> <ul style="list-style-type: none"> <li>Develop a nano material based additive that increases fuel efficiency, increases torque and horsepower, while reducing engine wear</li> <li>Hydrogen bonding of carbon nanotubes and boron nitride foil has generated impressive reductions in friction and wear / improved efficiency &amp; power</li> </ul>		<b>Future / Road Ahead</b> <ul style="list-style-type: none"> <li><b>Funding</b> <ul style="list-style-type: none"> <li>Perform necessary testing for the military to adopt the oil additive leading to a MILSPEC additive or API certification for oil</li> <li>Perform additional testing on actual military vehicles and equipment followed by other applications including gear oil for vehicles including UAVs, helicopters, etc.</li> </ul> </li> </ul>	
carbon nano tubes + boron nitride foil = less friction in the engine  			

## SMART SUSCEPTOR COMPOSITE REPAIR SYSTEM

**BILL DYKSTRA**

Temper Inc.  
 billdykstra@temperinc.com  
 +1.616.648.9476

The Smart Susceptor Composite Repair System is a game changing method for repairing composite structures.

### Problem Statement

Within the aerospace and defense industry, composite repair is a major concern and is only going to become a bigger issue as composites become more prevalent across all branches of the US military. Repairs of these materials, however, have their costs.

- Incorrect repairs are not immediately obvious and can cause damage to composite structures.
- Repair quality is highly dependent on the cured joint which depends largely on the heating of the repair zone.

Considering the material advances and the capital investments into composites, it is mind boggling that the repair industry is still using the same resistance heating blanket technology developed in the 1980s. Current aircraft are being produced entirely from composites with co-bonded and co-cured joints to connect wing-skins to ribs and spars. To make a repair or cure the green material with a traditional heating blanket

results in cold spots where the material is thick, and ribs and spars draw away heat. To complete the cure, a traditional heating blanket must be turned up to raise the temperature. However, areas with less thermal load are now overheated. This is common in wing-skins with varying cross-sections or where ribs and spars act as heat sinks. These temperature variations significantly compromise the material's integrity. Therefore, it requires a very skilled and experienced technician to make quality repairs to composites without inadvertently causing greater damage.

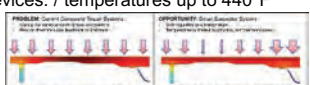



### Technology Solution

The technology solution is 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.

- Demonstrated temperature regulation within  $\pm 8$  at 350°F.
- Virtual impossibility of overheating.
- No specialized knowledge of the structure being repaired.
- Minimal training on control software and setup procedures.
- Increase productivity as constant monitoring is not required.

In addition, the technology is robust and has proven itself on the manufacturing line by processing more than 400+ rear horizontal stabilizers for Boeing's 787. Additionally, Northrop Grumman is evaluating a mobile system for integration into their production line. Included in this system are complex geometry blankets capable of running independently.

<p><b>PROBLEM STATEMENT</b></p> <p>Composite materials are becoming ever more prevalent across all branches of the US military, however, repairing composites has its problems.</p> <ul style="list-style-type: none"> <li>• Downtime due to repairs reduces combat readiness.</li> <li>• Repairs made incorrectly can create additional damage without being obviously visible.</li> <li>• Successful repairs depend on the skill of the technician.</li> <li>• Quality of the composite repairs depend on maintaining a narrow temperature band in which the resin cures. (current resistance heating is not capable requiring the skilled technician to add or remove insulation during the cure cycle)</li> <li>• Engineered features (ribs, spars, multi-thickness panels) make even heating with traditional heat blankets difficult if not impossible.</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Increased combat and asset readiness.</li> <li>• Quality repairs made with confidence.</li> <li>• Less risk of damage to costly composite structures due to operator error or sensor malfunction.</li> <li>• Highly trained technicians are not mandatory for repairs.</li> <li>• Decentralizes repair network by enabling standard warfighters to make repairs.</li> <li>• Proven operation in a production environment.</li> <li>• Does not require constant monitoring increasing technician productivity.</li> <li>• Multiple blanket systems can be synced together to facilitate large repairs.</li> <li>• Installed systems have proven robust with 400+ cycles and not a single failure.</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>The solution is a smart heating blanket capable of curing a composite without overheating or otherwise damaging the rest of the structure.</p> <ul style="list-style-type: none"> <li>• Smart susceptor heating blankets maintain a <math>\pm 8</math> °F curing temperature band without any input or software control.</li> <li>• Smart susceptor heating blankets cannot heat beyond a specified temperature regardless of inputs or power applied.</li> <li>• 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. / temperatures up to 440°F</li> </ul> 	 <p>Thermal image above showing a 16 in x 40 in blanket through the vacuum bag and breather material.</p>  <p>Image above showing blankets can be molded into almost any shape</p>  <p>Portable composite repair system</p> <p>Blankets can be produced to almost any size or shape. Temper designed and built the debulking blanket - 787 horizontal stabilizers wing skins. To date has produced over 600 wing skins</p>

# RELIABILITY IMPROVEMENT (HARDWARE)

## ADVANCED SPHERE BRAKES FOR GROUND VEHICLES

AARON LEWIS

Sphere Brake Defense LLC  
 aaronlewis@spherebrakedefense.com  
 +1.814.898.4321

Nearly all tactical ground vehicles are experiencing brake system problems. Specifically, there is significant corrosion of the drum and brake actuation mechanisms from water and debris accumulation in the inner brake drum surface and brake chambers. This problem impacts safety, performance, operational availability, maintenance time, logistics delay time and money. Furthermore, repairing and replacing brake pads require over a dozen tools, lifts, and trained personnel. This negatively impacts vehicle and personnel readiness across the fleet. Lastly, armoring and shifting mission profiles have pushed vehicles beyond their approved gross vehicle weight rating. This crushes subassemblies like brake systems preventing Warfighters to achieve the speed, mobility, and payload requirements needed on the battlefield.


New brake technology has been developed to keep Warfighters on the move, to maintain initiative and momentum in combat. The patented sphere brake uses hydraulic pressure to compress hemispherical brake pads against a spherical brake surface. Unlike disc or drum brakes, the sphere

brake generates more power with a smaller effective brake diameter. The sphere brake was designed to address the needs of the maintenance technician, the program manager, the PEO, and the Warfighter. It's holistic in the value it delivers to all stakeholders and holistic in the value it delivers in performance. It currently takes nearly a day and at least 15 tools to service brakes on ground and air vehicle platforms. The sphere brake cuts this down to minutes and you only need your HAND. This provides several days of savings back to vehicle readiness for ground commanders. We design our kits as plug and play – no hub or wheel modifications required. We've demonstrated bolt-on capability with the Stryker DVH and MTVA1P2 integrating with both CTIS and ABS subsystems. Sphere brake kits also shed up to 40 lbs. per wheel-end. This affords additional payload options for ammo, medical supplies, and fuel.

Through several concurrent defense contracts with Marine Corps Systems Command and the Rapid Capabilities and Critical Technologies Office, we've successfully certified the sphere brake

through dyno testing and performed several iterations of track testing at Aberdeen Proving Ground for both the Stryker DVH and MTVA1P2. We've passed 60 slope hill hold evaluations and several track test performance requirements.

A key ingredient to this success and the speed at which SBD iterates and scales sphere brake technology across vehicle platforms are Warfighter touchpoints. We have accumulated a trove of feedback working alongside technicians at Aberdeen; reviewing our technology with local repair facilities; performing fit ups at a Field Maintenance Shop; getting hands on with Warfighters at a Limited Military User Assessment; recent feedback from the 75th Innovation Command; and hands on demonstrations with Commanding Generals.

<p align="center"><b>PROBLEM STATEMENT</b></p> <p><b>Description of Capability:</b>                  The sphere brake kits provide unprecedented reliability, maintainability, and safety to the Warfighter that existing brakes cannot match. The collective return of investment yields thousands of dollars of savings per hour equating to millions of dollars in savings over the life of a vehicle program.</p> <p><b>Value to Warfighter:</b></p> <ul style="list-style-type: none"> <li>• Brake pads can be replaced without any tools = increased unit readiness.</li> <li>• Increased brake pad and rotor service life = increased fleet readiness.</li> <li>• Less unsprung mass at wheel-end = better stability = better mobility</li> <li>• Less rotational mass at wheel-end = better rideability = better fuel efficiency</li> </ul>	<p align="center"><b>When</b></p> <table border="1"> <thead> <tr> <th>Milestone</th> <th>Risk Level</th> <th>Measure of Success</th> <th>Ending TRL</th> <th>Date</th> </tr> </thead> <tbody> <tr> <td>FMVSS 121 Stopping Distance Track Certification on Stryker and MTV</td> <td>Med</td> <td>PASS</td> <td>7</td> <td>4Q22</td> </tr> <tr> <td>TOP 2-2-608 Mountain Brake Descent Certification on Stryker and MTV</td> <td>High</td> <td>PASS</td> <td>8</td> <td>4Q22</td> </tr> <tr> <td>ACV Production and Deployment Phase of Developmental Test at Army Training Center</td> <td>Med</td> <td>PASS</td> <td>8</td> <td>3Q23</td> </tr> <tr> <td>ACV-P Reliability Qualification Testing at the Amphibious Vehicle Test Branch</td> <td>High</td> <td>PASS</td> <td>8</td> <td>3Q22</td> </tr> <tr> <td>Army Program Transition</td> <td>Med</td> <td>LRIP</td> <td>8</td> <td>2Q23</td> </tr> </tbody> </table>	Milestone	Risk Level	Measure of Success	Ending TRL	Date	FMVSS 121 Stopping Distance Track Certification on Stryker and MTV	Med	PASS	7	4Q22	TOP 2-2-608 Mountain Brake Descent Certification on Stryker and MTV	High	PASS	8	4Q22	ACV Production and Deployment Phase of Developmental Test at Army Training Center	Med	PASS	8	3Q23	ACV-P Reliability Qualification Testing at the Amphibious Vehicle Test Branch	High	PASS	8	3Q22	Army Program Transition	Med	LRIP	8	2Q23
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<p align="center"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Bolt-on sphere brake kits deliver:                         <ul style="list-style-type: none"> <li>• No tool brake pad changes</li> <li>• Substantial weight savings</li> <li>• Affordable kits</li> </ul> </li> <li>• Sphere Brake kits have been installed on the US Army Stryker DVH and MTVA1P2 and passed numerous evaluations and requirements at Aberdeen Proving Ground (APG).</li> <li>• 5 Issued and Pending Patents</li> <li>• Dual Use - Commercial Vehicle Industry</li> </ul> <p><i>"Saves time, better system... this technology is great!" – 75<sup>th</sup> Innovation Command</i>  <i>"We installed brake pads in under 2 minutes per wheel-end without any tools." – ATEC Technician</i>  <i>"These brakes are going to change the game across the DOD." – Army CG</i></p> <p align="right">Unclassified   FOR PUBLIC RELEASE</p>	<p><b>Graphic</b></p> <p><b>Army Focus Areas:</b>                  Next Generation Combat Vehicle, Common Tactical Truck</p> <p><b>Tech Banner Statement:</b> Bolt-on Sphere Brakes reduce maintenance, while increasing readiness, range, and safety equating to \$100Ms savings across a fleet.</p> 																														



# RELIABILITY IMPROVEMENT (HARDWARE)

## FLIGHTLINE TEST INNOVATION YIELDS SIGNIFICANT SAVINGS AND SUPPORTS AGILE COMBAT EMPLOYMENT (ACE)

**JON SEMANCIK**

Marvin Test Solutions  
jon.semancik@marvintest.com  
+1.949.304.4440

**Problem:** Today's armament maintainer faces the challenge of performing O-Level (flightline) test and maintenance with legacy test sets that limit the ability to quickly and efficiently verify system readiness, diagnose failures, and return the aircraft to FMC status. Legacy test sets are typically utilized on a single aircraft, or perform only a single function for multiple aircraft, resulting in long test/repair times, and increased training/logistics challenges.

**Technology:** The MTS-3060A SmartCan™ Universal O-Level Armament Test Set incorporates more than 35 measurement channels, squib measurements, active communications interfaces, 3 ARBs, electronic loads, discrete outputs, data logging, BIT, self-test, automated calibration, cable ID, and sunlight-readable LCD display; powered by 6 AA batteries.

This COTS designated armament test set is the most cybersecure flightline test set available, leveraging innovative design and packaging techniques to replace multiple currently deployed, large-footprint, O-Level armament test sets with a single rugged, hand-held solution weighing 4 lbs. The kit

including self-test, adapters, and cables, weighs < 50 lbs.

**Status:** The MTS-3060A is a TRL 9, deployed non-developmental item available for immediate purchase and use, and is applicable to all branches of the USA, FMS Armed Forces and DLA. It has received SERD certification (SERD #75A77) and declared a fully qualified and approved solution for the F-16, effective for testing armament systems including launchers, bomb racks, pylons, fuel tanks, and gun.

**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, SERD certification, and a cybersecurity ATO further validate its capabilities.


**Next Steps/Potential Benefits:** The MTS-3060A significantly improves warfighter readiness while reducing maintenance costs. Maintenance savings are projected to be between \$7.5M – \$10M annually. When coupled with reduced training, savings are projected to approach \$12M annually. Savings are based on

scheduled maintenance activities and do not reflect additional savings realized from unscheduled activities.

F-16 armament test setup time is reduced 91% (45 to 4 minutes), test time for a MIL-STD-1760 pylon is reduced 85% (20 to 3 minutes) and reduced 89% (35 to 4 minutes) for a LAU-129. Further savings will be seen through test set consolidation, simplified logistics, and standardized training. Expanding access across the DOD supporting all armed aircraft will net similar savings.

One MTS-3060A can replace (15) armament test sets currently supporting (9) armed USAF platforms; many more for all of DOD.

The MTS-3060A enables the USAF's ACE doctrine by supporting both legacy and smart weapon test on any DOD armed aircraft, providing data for predictive maintenance, and reducing logistics and training requirements. It is the Multi-capable Airmen enabler.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>Armament maintainers currently perform O-Level (flightline) test and maintenance with legacy test sets that greatly limit the ability to quickly and efficiently verify armament system readiness and diagnose failures.</li> <li>Multiple legacy test sets are typically needed for a single aircraft, or only perform a single function on multiple aircraft, resulting in long test/repair times and increased training/logistics burden.</li> <li>Ability to adhere to DOD initiatives, including the USAF's Agile Combat Employment (ACE) doctrine, are severely impacted by current test sets.</li> <li>Returning aircraft to FMC (Full Mission Capable) status is significantly delayed due to the amalgam of currently deployed/legacy test sets.</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>Overall summary:             <ul style="list-style-type: none"> <li>Reduced costs, fastest test times, less training, test set consolidation, quicker FMC aircraft availability, rugged, handheld, cybersecure</li> </ul> </li> <li>A single, hand-held, test set conducting full functional armament test for all armed aircraft</li> <li>Maintenance savings:             <ul style="list-style-type: none"> <li>~\$8.5M annually, \$12M when coupled with reduced training</li> </ul> </li> <li>Test setup and execution savings (F-16 actual):             <ul style="list-style-type: none"> <li>Reduced 91% (setup – 45 to 4 minutes)</li> <li>Reduced 85% (execution - 20 to 3 minutes)</li> </ul> </li> <li>Test set consolidation / logistics savings (9 armed USAF aircraft):             <ul style="list-style-type: none"> <li>(1) MTS-3060A replaces (15) current armament test sets</li> </ul> </li> <li>Support for DOD initiatives:             <ul style="list-style-type: none"> <li>Enables USAF's ACE doctrine by conducting armament test for all weapons on all DOD armed aircraft; Multi-capable Airmen enabler</li> </ul> </li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>The MTS-3060A leverages innovative design and packaging techniques to replace multiple, currently deployed O-Level armament test sets with a single, rugged, hand-held COTS solution weighing just 4 lbs.</li> <li>It's pioneering design incorporates more than 35 measurement channels, squib measurements, active communications test interfaces, 3 arbitrary waveform generators, multiple electronic loads, discrete outputs, data logging, BIT, self-test, automated calibration, cable ID, and a sunlight-readable LCD display.</li> <li>Innovative power management requires only 6-standard AA batteries for up to 40 hours of operation. Innovative 4-year calibration cycle.</li> <li>USAF Cybersecurity ATO concluded that the MTS-3060A represents a Low/Very Low cyber risk</li> </ul>	<p><b>MTS-3060A SmartCan™</b> Universal O-Level Armament Test Set</p>  <p>Single case includes MTS-3060A, all cables, adapters, selftest</p>

# RELIABILITY IMPROVEMENT (HARDWARE)

## EDLORE SMART & INTERACTIVE EQUIPMENT MANUALS

JAVID VAHID

Edlore  
javid@edlore.com  
+1.949.690.2245

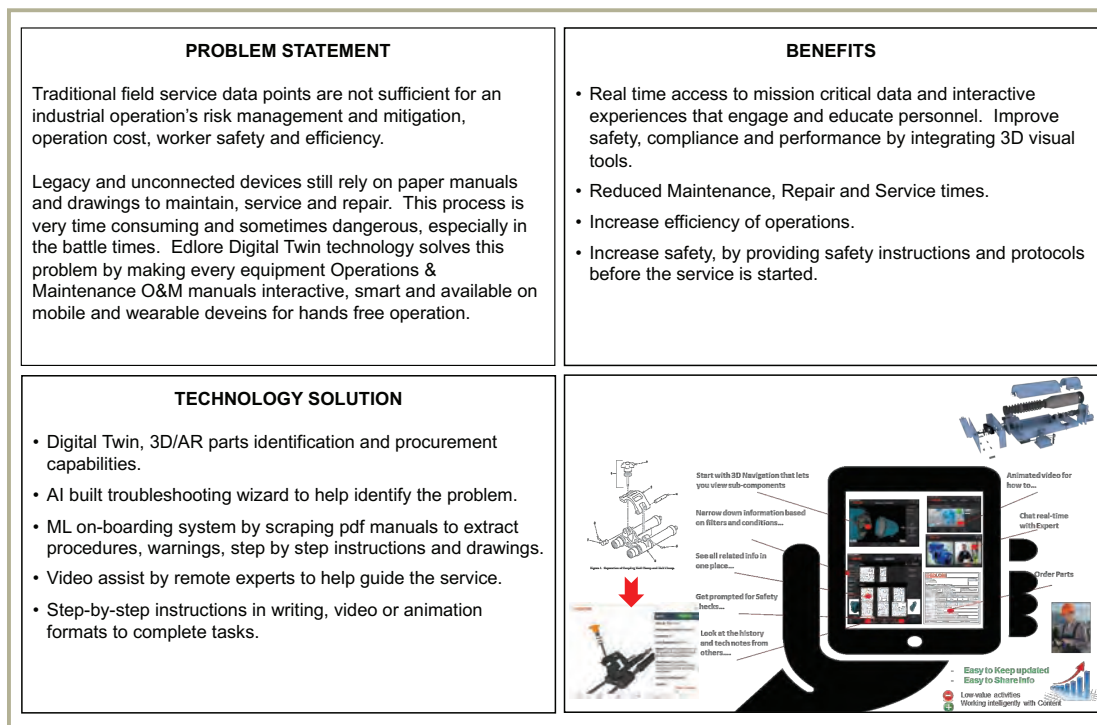
A picture speaks a thousand words, a 3D speaks a thousand pictures.

Traditional field service data points are not sufficient for an industrial operation's risk management and mitigation, operation cost, worker safety and efficiency.

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. Edlore Digital Twin technology solves this problem by making every equipment Operations & Maintenance manuals interactive, smart, and available on mobile and wearable devices for hands free operation.

Edlore platform and service converts a legacy paper, pdf manual into an interactive 3D with added parts metadata for parts identification, information, procurement, or 3D printing. Edlore modules include, cloud documentation repository, automated workorder system, artificial intelligence (AI) built troubleshooting wizard, media uploads from the field, preventative and predictive

maintenance tools and remote expert video chat. All delivered on mobile and wearable devices.



## TRANSFORMING VEHICLE REPAIR AND MAINTENANCE

**STEPHANIE BLAKE**






GTWERX Automotive Inc.  
stephanie@gtwerxauto.com  
+1.757.561.0770

The Department of Defense continues to suffer from readiness challenges. Its maintainers rely on limited numbers of hard copy technical manuals (TM) or require a desktop to access electronic TMs to support maintenance activities for the second-largest federal vehicle fleet after the U.S. Postal Service. This outdated approach to maintenance training, know-how, and vehicle servicing is inefficient, introduces errors and does not support retaining digital natives entering the force. The GTWERX Automotive augmented reality/virtual reality (AR/VR) immersive car repair app transforms vehicle maintenance and repairs by improving routine work experiences and increasing force readiness.

The GTWERX app offers several features that modernize training and guided repair. Our virtual garage utilizes 3D visualizations and high-fidelity digital models to educate the user on each step of maintenance or repair to be done, including practicing on a virtual engine. Then, using a smartphone or tablet, high-fidelity augmented reality overlays digital “how-to content” on the physical auto to peer into the engine and guide the user through the repair process.

A key difference between our app and other AR-enabled training services is our GTWERX proprietary Computer Vision software to reliably detect parts and components. This artificial intelligence (AI)-driven technology enables rapid scaling to any vehicle. We have achieved Technological Readiness Level 7 in system testing and our first commercial app for a classic Mustang is already being successfully tested at local auto shows to prepare for a public release of the GTWERX app V1.0 in late 2022.

Across the services, DOD has funded early experimentation and studies proving the value of AR/VR-enabled digital innovation for training and operations to reduce training and task time. The GTWERX app foundry can be applied to any vehicle or system and used as a standalone app or easily integrate into existing DoD enterprise platform solutions to improve maintenance effectiveness and reduce cost. GTWERX offers an affordable vehicle repair app that readily scales and will contribute to greater maintenance efficiencies to any unit across the service that is responsible for maintaining vehicles.

<p><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>➤ The Department of Defense continues to suffer from readiness challenges.</li> <li>➤ Maintainers rely on limited numbers of hard copy technical manuals or require a desktop to access electronic TMs to support maintenance activities.</li> <li>➤ This outdated process is inefficient, introduces errors and does not support retaining digital natives entering the force.</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Increases efficiency by reducing training time with our immersive virtual garage.</li> <li>• High fidelity augmented reality overlays digital “how-to content” reducing errors and repair time.</li> <li>• AI-driven computer vision enables rapid scaling and at lower costs.</li> <li>• Modern digital app improves the user experience for training and support.</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p><b>AR/VR Immersive Car Repair App</b></p> <ul style="list-style-type: none"> <li> <b>Virtual Garage:</b> 3D visualizations educate the user on each step of maintenance or repair to be done on their auto.</li> <li> <b>Guided Repair:</b> Access detailed “how-to” repair instructions with augmented reality overlays on any mobile device.</li> <li> <b>Order Parts:</b> Computer vision software identifies the specific part and accesses a list of options to compare and purchase.</li> <li> <b>Access to Repair Experts:</b> Virtually connect to experts to provide interactive guidance and troubleshooting.</li> </ul>	<p><b>GTWERX APP</b></p> 

## AUGMENTED, VIRTUAL, AND MIXED REALITY (AR/VR/MR) FOR CRASH & SALVAGE TRAINING

**JEAN-PIERRE BOLAT, CDR, USN (RET)**

ARSOME Technology, LLC  
 jp@arsome.com  
 +1.203.747.5697


ARSOME develops mixed reality “virtual model” Learning Management Systems (LMS) with continuously more challenging modules presenting learners high resolution 3D-models that will meet the needs advanced 21st century learning and visualization for shipboard or shore technical manuals, maintenance procedures, construction, repair, and various other applications. We envision to support a set of multidiscipline learning modalities by combining Augmented Reality and Virtual Reality to enhance and greatly improve training for casualty or maintenance scenarios. With Augmented and Virtual reality modules, ship or shore crash and salvage crews can better prepare for emergency casualty scenarios on multiple platforms and in multiple scenarios in a virtual or augmented reality world, thereby alleviating the need for an actual crashed aircraft. Augmented and Virtual Reality modules can be used in the training classroom, in the field, or onboard ship to provide realistic training scenarios without the need for actual crashed aircraft, improving user experience prior to casualty evolutions. Further, the data captured from

the tracking of performance will inform both the instructor and learners of areas where improvement is required.

Crash and salvage crews routinely train on only one type of aircraft and the scenarios are typically either the same or are unique to each individual instructor’s experience. With the use of Augmented and Virtual Reality, an infinite number of scenarios on multiple aircraft type can be developed and experienced in a virtual world. Such user experience will enhance training, making it more realistic. Further, it will improve readiness, leading to a greater ability to save lives and equipment.

ARSOME has developed both Augmented and Virtual Reality training scenarios to train automobile vehicle crash adjustors for a leading U.S. Insurance Company. These virtual scenarios provide for multiple types of vehicles, multiple crash scenarios, unique damage criteria, and real-life imagery in addition to the virtual models. Additionally, ARSOME’s Training Experts can appear live in the virtual world during the training evolutions as well as pre-recorded to enhance the training

experience. This type of training has decreased the time to train, reduced errors in the field, and improved learning retention, especially with the ability to train on a virtually unlimited set of car models.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <ul style="list-style-type: none"> <li>• Crash &amp; Salvage crews typically train on a single aircraft platform and only a few scenarios.</li> <li>• Availability of various aircraft type is limited.</li> <li>• Although trainers are experienced, their tools are limited to only a few aircraft type and scenarios are not as expansive as they can be.</li> </ul>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• With ARSOME’s AR &amp; VR training modules, a leading U.S. Insurance company has experienced decreased time to train, reduction in field errors, and better prepared adjustors.</li> <li>• Crash and Salvage crews will be better prepared for unique and varied scenarios on multiple aircraft types.</li> <li>• Lower costs and increased training opportunities.</li> <li>• Improved Readiness.</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <p>ARSOME’s AR/VR/MR solutions can be tailored to the requirements, needs, and pain points of training for crash and salvage operations. Leveraging industry standard equipment, local networks, and/or handheld localized devices, ARSOME’s AR/VR/MR development environment is local to the end user’s secure environment. A multitude of scenarios and aircraft type models can be developed to enhance and improve training.</p>	

## MILITARY POSITIVE REPAIR INFORMATION TEXT ANALYZER (MIL-PRITA)

**ABIGAIL DENBURG**

The Boeing Company  
 abigail.denburg@boeing.com  
 +1.703.203.8675

Efficient maintenance (mx) is a key enabler of operational readiness. Maintainer shortages have left inexperienced maintainers carrying the burden of sustaining aging fleets. Unnecessary part removals and excessive time spent troubleshooting hamper aircraft availability.

Boeing is leveraging data to enable customer outcomes and increases predictability to ultimately optimize the operational, sustainment, and training experience for our customers.

Military Positive Repair Information Text Analyzer (Mil-PRITA) is designed to bring aircraft mx into the world of automated continuous improvement. It is a platform-agnostic mx productivity tool built on historical aircraft fleet information. Mil-PRITA has a data architecture that ingests mx and repair procedures for an aircraft fleet to create a searchable knowledge base through textual analytics. Thus, when maintainers are confronted with a fault, they can see the history of successful corrective mx actions for that fault. Mil-PRITA presents the steps that actually corrected a fault in order of their

likelihood for both the squadron and the fleet.

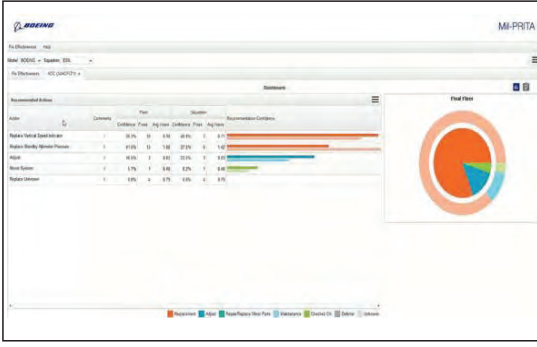
Because it relies on the textual entries, Mil-PRITA avoids the inaccuracies inherent in mx systems' code selection. History across commercial and defense customers has shown that maintainer's textual entries have a much higher accuracy rates, especially for difficult troubleshooting tasks. Mil-PRITA is intended to be used alongside technical publications and serve as an automated 'over the shoulder' 7 level maintainer, who can help guide troubleshooting and help identify the most likely fault resolution within the tech guidance. As a learning system, the more it is used, and the more mx performed on the fleet, the smarter the system becomes. The ability to age data and focus it on squadron allows for more specialized maturation of the capability to give localized advice.

PRITA's body of work includes seven patents. It has been employed across the 737, 747, 767, 777, and 787 platforms and we have leveraged that success to redesigned PRITA for our defense customers. We

developed Mil-PRITA for the F-15E and are currently completing the conversion to EX as well as a V-22 Proof of Concept. Development for CH-47 is to follow.

The commercial version has provided significant value to Boeing's airline customer in various ways, including the reduction of costly component replacements when an alternate, often cheaper, solution is available with higher historical success rate. Boeing estimates unnecessary removals due to faulty troubleshooting cost airlines \$1,500 per event. Given that PRITA was accessed over 700,000 times in 2018 by airline customers, if using the recommend actions in PRITA resulted in 1 less unnecessary removal per 100 events, the realized customer savings would be over \$10M in 2018 alone.

Mil-PRITA effectively reduces mx man hours and costs. Boeing can help DoD increase readiness and improve affordability through application of this capability.

<p style="text-align: center;"><b>PROBLEM STATEMENT</b></p> <p>The time aircraft spends in maintenance is time that is not available and ready to enable customer missions. As a result, minimizing the time aircraft is down for maintenance and expediting a safe return to service is critical. Maintainer shortages have negatively impacted aircraft readiness, with inexperienced maintainers carrying the burden of sustaining aging fleets. Unnecessary part removals and excess time spent troubleshooting result from the inability to identify the correct fix for a fault code leading to less aircraft availability.</p>	<p style="text-align: center;"><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Provides AI-driven recommended maintenance actions based off the aircraft fleet history</li> <li>• Points maintainers to the most likely resolution while following the technical data requirements</li> <li>• The system continues to improve in its accuracy over time as more fixes are recorded and validated</li> <li>• Reduces maintenance man hours to address fault codes</li> <li>• First Time Quality</li> <li>• Parts saved from unnecessary removals in maintenance process</li> <li>• The system continues to improve in its accuracy over time as more fixes are recorded and validated</li> </ul>
<p style="text-align: center;"><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>• Maintenance productivity tool built on history of maintenance for an aircraft fleet.</li> <li>• Consists of a data architecture that loads the maintenance and repair procedures for an aircraft fleet and creates a knowledge base searchable through textual analytics.</li> <li>• Advanced language processing of textual entries avoids the data inaccuracies inherent in the selection of codes in maintenance systems.</li> <li>• It is a learning system that continues to get smarter as the fleet operates.</li> <li>• The ability to age data and focus it in squadron and other environmental areas allows for more specialized maturation of operation to give localized advice, alongside the fleet knowledge.</li> </ul>	 <p>The screenshot shows the Mil-PRITA web application interface. It features a header with the Boeing logo and 'Mil-PRITA' text. Below the header is a navigation menu and a main content area. The main content area displays a table with columns for 'Name', 'Category', 'Count', 'Cumulative Count', 'Avg Count', 'Cumulative Avg', 'Avg Count', and 'Recommendation Count'. The table lists various aircraft models and their associated counts. To the right of the table is a pie chart with a legend, and below it is a 'Find Item' search box. The interface is clean and professional, with a white background and blue accents.</p>

## BOSTON ENGINEERING MIXED REALITY EXPERT GUIDANCE

**BRIAN KONONCHIK**

Boston Engineering Corporation  
bkononchik@boston-engineering.com  
+1.860.912.6943

The shipyard process for maintenance and manufacturing can cause immense amounts of “downtime” for a worker causing projects to go over budget and get behind schedule causing delays to delivery dates. A solution is required to promote efficiency through process improvement and technology integration throughout the design and manufacturing processes. Everyone from the maintenance personnel to executive leadership can and will benefit from an expert guidance solution.

By deploying on a modular, single platform solution built with an on-premises first architecture with the built-in capabilities for scaling outward to the secure cloud for a solution with hybrid accessibility one can be assured that the data is always available and highly secure. By enabling secured peer-to-peer AR video communication, secured augmented work instructions, navigational and point of interest guidance, as well as real-time data provided at the right time in the right place workers are empowered to act quickly and efficiently with the task at hand allowing overall construction to be completed on-time.

Mixed reality expert guidance solution reduces the time required to communicate with the right people, provides the right data at the right time for higher employee effectiveness reducing mean time to repair, implement, and modify all while reducing unplanned downtime. Providing a means to capture content allows one to retain expert knowledge for the retiring workforce and be able to deliver it back with visual work instructions reduces the chance of error on an install or repair.

The solution has been developed in collaboration with Portsmouth Naval Shipyard with feedback and requirements being gathered from other industry leaders. It has been successfully demonstrated to strategic stakeholders and is getting ready for Phase II which includes a production network deployment. The technology capabilities have been demonstrated in a decommissioned submarine, The Albacore.

Additionally, the development team saw a need to be able to show the solution on the road, so there is a multi-deployment demonstration which could connect via edge device, public cloud, or custom deployment.

Additional funding would allow us to improve echo cancellation on the audio as well as expand our efforts of gaining awareness and ability to positively impact as many organizations as possible.

### PROBLEM STATEMENT

This shipyard process for maintenance and manufacturing can cause immense amounts of “downtime” for a worker. A solution is required to keep the key aspects of the process but promote efficiency, allowing the end-user to get to the solution and implement it more effectively.

Key areas of improvement:

- Lost work output due to workers leaving work sites to get information or discuss work challenges
- Years of lost intrinsic knowledge leaving with a retiring workforce
- Out-of-date paper-based worker instructions or work packages

### BENEFITS

A mixed reality expert guidance solution reduces the time required to communicate with the right people, provides the right data at the right time for higher employee effectiveness, and with visual work instructions reduces the chance of error on an install or repair.

Key benefit areas:

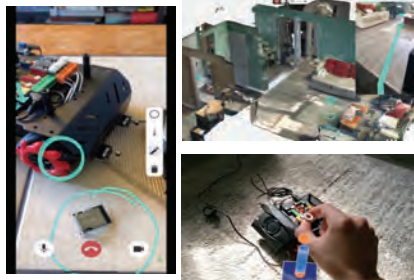
- Retain expert knowledge of retiring workforce
- Reduce the mean time to repair, implement, and modify
- Reduce worker unplanned downtime
- Increased operation efficiency

### TECHNOLOGY SOLUTION

A modular, hybrid solution allowing for an inclusive one stop shop for workforce efficiency tools. A common core platform allows flexibility to expand to other use cases as they arise. Empower the workforce to act quickly and efficiently with the task at hand allowing overall construction to be completed on-budget and on-time.

Key Features:

- Secured peer-to-peer video communications with augmented reality capabilities.
- Secure augmented work instructions
- Right time, right place, right scenario user specific data



## VIRTUAL REALITY PAINT TRAINING SIMULATOR

LEIGHTON TODD LAVENDER

USAF

leighton.lavender@us.af.mil

+1.478.222.8086

Robins Air Force Base (RAFB) Aircraft Maintenance Group (AMXG) encounters an annual \$5M in paint deficiency rework on the C-17 alone. RAFB required a training program that would ensure consistent, accurate and effective painting for the aircraft maintained onsite. Current DoD painter training has been mostly PowerPoint-driven with virtually no hands-on practice. Existing solutions did not have the following requirements: user-friendliness, multiple users operating in the same environment, simulate large/small aircraft, and accurately train painting/safety operations with currently utilized by the AF equipment/hardware.

The Virtual Reality Paint Trainer (VRPT) was developed under a Small Business Innovation Research (SBIR) contract with leveraged knowledge from subject matter experts, trainers, and paint personnel. We engaged with end-users and experienced painters and used iterative development processes to ensure the trajectory of development adhered to user-friendliness and technical accuracy.

The VRPT allows painters to train in a virtual environment that mimics the actual

work environment, thereby reducing a significant amount of rework, man hours, flow-days, and material consumption during maintenance of these assets.

The VRPT teaches paint personnel in accordance with DoD Tech Order requirements. The solution simulates appropriate paint settings, paint gun adjustments (fan pattern, PSI, etc.), and free movement throughout the virtual hangar. The user can select various paint guns and products (polycoat, primer, etc.) with their own configurable properties (viscosity, spray type, etc.). The user also interacts with realistic virtual paint panels, materials, aircraft, and fully controllable support systems (grounding points, fluid/air pressure sources/manifolds, stands and scaffolding, etc.) and safety equipment (breathing systems, fall-restraint systems, PPE).

The VRPT combines a uniquely designed core physics engine and commercial-of-the-shelf (COTS) hardware. The VRPT displays real-time paint spray performance indicators and patterns/deficiencies (wrinkling, sagging, etc.) and records for later assessment all user movement to include speed, proximity,

trigger position, stroke duration, paint depth, angle of the paint gun, and active transfer efficiency. This system is a technological leap forward for training painters across the AF and DoD.

The VRPT is TRL 9: Mission Proven and is deployed at the RAFB Virtual Reality Center of Excellence (VRCOE). During a recent 1-hour training session, well-experienced painters increased their material Transfer Efficiency by around 52%. This data translates to reduced rework and proves that this COTS product provides innovative training that can save RAFB and the DoD millions of dollars every year.

The VRPT is scalable across the DoD for any facilities that paint aircraft or aircraft parts and can be customized to meet coating requirements for Low Observable vehicles, land vehicles, space vehicles and ships. It has also been marketed to various agencies like the Naval Air Warfare Center Training Systems Division, Hill AFB, and Tinker AFB.

<p><b>PROBLEM STATEMENT</b></p> <p>The Air Force Maintenance Group's required a training program that would ensure consistently accurate and effective painting for the air platforms</p> <p>The solution needed the following acute requirements:</p> <ul style="list-style-type: none"> <li>User-friendliness</li> <li>Multiple users operating in the same environment</li> <li>Render and simulate large and small aircraft</li> <li>Accurately train painting and safety operations in DoD Tech Manuals and OSHA standards</li> <li>Simulate and train on equipment/hardware currently utilized by the Air Force</li> </ul>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>The VRPT allows personnel to train in a safe, chemical and risk-free environment             <ul style="list-style-type: none"> <li>Prevents material waste and ensures an effective baseline of skill that increases throughput of aircraft and parts.</li> </ul> </li> <li>Users are taught to DoD/OSHA standards</li> <li>Supports learning retention of required tools, systems, techniques, and muscle-memory to paint correctly</li> <li>Mitigate knowledge/skill loss due to the 20% yearly turnover of personnel             <ul style="list-style-type: none"> <li>Consistently trains to DoD standards</li> </ul> </li> <li>Potential yearly savings of nearly \$5M in rework costs on C-17 alone. Saving across DoD would be \$50-70M/yr</li> <li>Customizable/Scalable across all DoD</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <ul style="list-style-type: none"> <li>Realistic, full-scale simulation: C-5 Galaxy and Global Hawk aircraft, RAFB Paint Hangar, peripherals</li> <li>Functional/Configurable paint guns, carts, support systems (stands, scaffolding, etc.)</li> <li>Real-time paint spray performance indicators             <ul style="list-style-type: none"> <li>Speed, proximity, trigger position, stroke duration, paint depth, angle of the paint gun, and active transfer efficiency</li> <li>Paint deficiencies (wrinkling, sagging, etc.)</li> </ul> </li> <li>Individual and team-based training, with/without instructor</li> <li>Learning Management System facilitates instruction of coursework and records all user activity and metrics to support grading and training improvements             <ul style="list-style-type: none"> <li>Training Exercises, Tutorials</li> </ul> </li> <li>Utilizes COTS hardware/products</li> </ul>	

## ACTION TRAINER ARTIFICIAL INTELLIGENCE

ARY NUSSBAUM

SimiGon Inc  
 aryn@simigon.com  
 +1.407.232.4023

SimiGon is creating and adapting neural networks to enhance and accelerate maintainer training. SimiGon is in the process of developing and training many artificial intelligence (AI) neural network synthetic experts (SE) for aircrew operations and procedures. Training will continuously be performed on the models to adapt them for other domains.

The SEs, after ingesting the simulation data, provide an output of correct decisions so that the aircraft will successfully perform any given procedure. The decision data is used by the Next Generation Virtual Instructor (NxVI) to instruct students adeptly, even when the students are not performing well.

Algorithms for maintainer training will include a wide range of job guides, from flight line tasks to advanced avionics maintenance, supporting Level 3 through Level 7 technicians. The algorithms may be run simultaneously.

SimiGon’s proposed solution provides automated, robust, detailed, and constantly improving instruction and data logging for students, greatly reducing burden on

instructors in training, enhancing student progress, and providing instructors better insight about student proficiency and weaknesses in debrief.

SimiGon’s ATAI library and NxVI plugin increase quality and quantity of instruction through the reduced burden on instructors and improved training method through constantly improved feedback and virtual instruction on student performance.

<p><b>PROBLEM STATEMENT</b></p> <p>Training world-class maintainers is critical for national security - fleet readiness and aircrew safety depends on this. Yet, there are many constraints today in training maintainers.</p> <p>Instructors are overloaded with tasks leaving less time for one-on-one training; simulation or game based training in “Free play” mode without instructor engagement does not deliver effective training; a significant effort is required to create engaging courseware; siloed simulation or gaming platforms don’t talk to each other limiting reusability; there is limited availability of Virtual Instructors (intelligent tutors).</p> <p>SimiGon Inc. proposes solving these problems with it’s Action Trainer Artificial Intelligence (ATAI).</p>	<p><b>BENEFITS</b></p> <ul style="list-style-type: none"> <li>• Limited demands on instructors</li> <li>• “Free play” is enhanced by AI</li> <li>• AI-generated, interactive, engaging Courseware</li> <li>• Agnostic, reusable, cross-platform ATAI</li> <li>• Next-Gen VI</li> <li>• Framework for accessing and training AI procedure experts</li> <li>• Deep Q learning collection of reusable, pre-trained and trainable AI for action and decision-based procedures</li> <li>• Technician troubleshooting / fault diagnostics</li> <li>• Teach efficiency and decision making</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>The next step in accelerating training for maintainers is in the development and deployment of a neural network artificial intelligence (AI) library, Action Trainer Artificial Intelligence (ATAI), and next generation Virtual Instructor (NxVI).</p> <p>Developed to support multiple domains and adapted specifically for aviation maintenance training needs, ATAI provides the AI library for automated adaptation of the NxVI agents. This proposed solution is an open architecture, cross platform library and plugin available for all simulation and game engines.</p> <p>The resulting plugin will significantly reduce the time required to create troubleshooting training and courseware while accelerating efficiency and throughput.</p>	<p><b>HIGH LEVEL ARCHITECTURE</b></p> <p><b>NxVI DESCRIPTION</b></p>






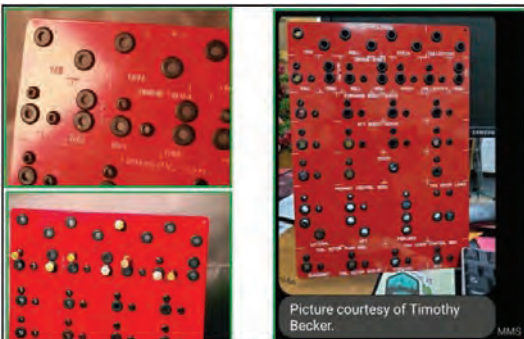
## LEAN MAINTENANCE THROUGH PROCESS AUTOMATION

CHANNING WRIGHT

Skyplates  
wright@skyplates.com  
+1.678.938.7236

50% of maintenance is spent utilizing screws and fasteners to maintenance and repair weapon systems. The Skyplate automates the sustainment process through lean six sigma initiatives. Integration reduces maintenance cost, mitigates foreign object and debris related incidents, and provides a solution to the challenges of meeting Mission Capability Goals.

The Skyplate creates a lean six sigma workflow that allows a repeatable and reproducible maintenance process and accelerates the maintenance process. A streamlined maintenance process boost productivity, minimizes weapon system downtime, maintains scheduling, and controls cost.

<p><b>PROBLEM STATEMENT</b></p> <p>Unsecured and unsorted screws, nuts, bolts, washers, etc. in aviation hangers and flightlines pose thousands of daily unnecessary but preventable risks. Misplacement of these items often results in millions of materiel repair dollars, thousands of manhours in preventable maintenance and rework, and a failure to meet mission readiness requirements for deployments and training.</p> <ul style="list-style-type: none"> <li>• iPhone: 100 screws</li> <li>• Car or Truck: 4k+ screws</li> <li>• UH-60/F-35: <b>1.5M+ screws</b></li> </ul>  <p>Lost screw that migrated into the aircraft powertrain found during an inspection</p>	<p><b>BENEFITS</b></p> <p><b>Improved</b></p> <ul style="list-style-type: none"> <li>• Increased readiness</li> <li>• Organization &amp; control of mission critical maintenance items</li> <li>• Identical schematics on Skyplate and equipment increases technician proficiency</li> <li>• Supply chain optimization through Skyplate Kits</li> </ul> <p><b>Decreased</b></p> <ul style="list-style-type: none"> <li>• Foreign Object &amp; Debris (FOD) incidents caused by misplacement of hardware (screws, nuts, bolts, etc.)</li> <li>• Location of miniature items required for maintenance &amp; repair</li> <li>• Average maintenance cost &amp; repair times</li> </ul>
<p><b>TECHNOLOGY SOLUTION</b></p> <p>Implement the patented Skyplates Process Tool to simplify and streamline maintenance processes across weapon systems</p> <div style="display: flex; justify-content: space-around;"> <div> <p><b>Maintenance Incident</b></p>  <p>Look these pictures for you a change weeks ago but found the screw there and then someone discovered the screw because they hadn't they hadn't taken responsibility of all the hardware that were at the floor before they removed it</p> </div> <div> <p><b>FOD Incident</b></p>  <p>A pre-flight inspection revealed a lost screw bag on the aircraft (Blackhawk). The screws would have destroyed the engine, at a total lost over \$2M.</p> </div> </div>	 <p>Picture courtesy of Timothy Becker.</p>

# DEPARTMENT OF DEFENSE MAINTENANCE SYMPOSIUM

**12.18.23** DECEMBER 18-21, 2023  
SAN DIEGO, CA

## MAINTENANCE INNOVATION CHALLENGE

### CALL FOR INNOVATIONS

**The Deputy Assistant Secretary of Defense for Materiel Readiness is challenging you to submit your maintenance related innovations.**

**Revolutionary or Evolutionary; showcase your discoveries to the maintenance community at the 2023 Department of Defense Maintenance Symposium and shape the future of the industry.**

This is your opportunity to demonstrate how to keep maintenance ahead of the curve in: inspections and testing, repair methods, business processes, predictive analytics, training, and more.

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

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

All submissions that meet the minimum criteria listed above 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 2023 DoD Maintenance Symposium.

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 2023 Maintenance Innovation Challenge please contact Heather Smith of SAE International at [heather.smith@sae.org](mailto:heather.smith@sae.org).**



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



