MAINTENANCE INNOVATION CHALLENGE 2017

MONDAY, DEC. 4TH

1:00 – 2:30 PM

P1768551

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

LOGISTICS AND
MATERIEL READINESS

October 17, 2017

MEMORANDUM FOR 2017 DOD MAINTENANCE SYPOSIUM PARTICIPANTS

Under the guidance of Secretary Mattis, the Department of Defense (DoD) is committed to providing lethal and ready weapon systems to our warfighters. As the primary provider of warfighter materiel readiness, DoD's maintenance enterprise must continuously seek out and rapidly adopt new and innovative sustainment technologies and processes. In keeping with the theme of the 2017 DoD Maintenance Symposium "Maintaining the Joint Force Competitive Advantage through Innovative, Agile and Adaptive Capabilities", we issued the 2017 Maintenance Innovation Challenge (MIC). The MIC aims to elevate and expand the call for maintenance innovation beyond solely novel technology; to include unique partnerships, resourcing strategies and business practices or processes that promise to make maintenance more capable, effective, agile and affordable. We are pleased to announce that 77 excellent submittals were received from DoD, industry and academia.

With assistance from the DoD Joint Technology Exchange Group, the 77 submittals were thoroughly reviewed and six finalists were selected. Senior maintenance and sustainment leaders from the Maintenance Executive Steering Committee, the Joint Group on Depot Maintenance, and the Industrial Base Commanders group selected this year's MIC winner.

The MIC finalists will be presenting their maintenance innovations during the Maintenance Innovation Challenge breakout on December 4, 2017 from 1300-1430 in the Calvin L. Rampton Salt Palace Convention Center, Salt Lake City, Utah, Room #150. I encourage your participation in this event to engage with some of the most forward-thinking individuals in our maintenance community. The MIC winner will be announced and formally recognized during the Maintenance Symposium's plenary session on the morning of December 5, 2017. Additionally, I encourage you to please interact with these maintenance innovators throughout the Maintenance Symposium in their dedicated exhibition hall space.

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

Kenneth D. Watson
Deputy Assistant Secretary of Defense
for Maintenance Policy and Programs

JOINT TECHNOLOGY EXCHANGE GROUP (JTEG)

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

JTEG Mission:

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

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

The JTEG conducts virtual monthly technology forums that feature a different maintenance topic each month. The topics generally fall into one of three areas: 1) technology focus areas which feature a specific maintenance capability such as non-destructive inspection (NDI), additive repair, or intermittent fault detection; 2) maintenance processes such as improved business processes, training, or safety; and 3) organizational perspectives which describe maintenance capabilities and initiatives at specific DoD maintenance activities such as maintenance depots or research centers. These forums provide opportunities for the DoD maintenance community to exchange information and share ideas. Industry and DoD personnel can use the JTEG website, **jteg.ncms.org**, to view and share information on new technology, processes, and equipment developments that have proven or potential applications involving depot maintenance. Visitors are welcome to review new and exciting technology projects posted on the website, or submit project ideas of their own. In addition, all JTEG technology forums are posted on the website.

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Cross Pollinating Sustainment Technology

Commercial Technologies for Maintenance Activities (CTMA)

CTMA is a partnership between the National Center for Manufacturing Sciences (NCMS) and the Department of Defense (DoD).

The CTMA Program has a proven way of quickly organizing initiatives that meet the needs of the government sponsor and secure the most effective technologies at best cost. NCMS continually looks for technologies, innovative methods and designs that, if paired with complementary COTS technologies, oftentimes allow a more rapid transition satisfying a maintenance or sustainment need.

Cooperative Agreement (CA) Streamlines Technology Transfer

The CTMA Program offers a *unique* contracting vehicle for industry, academia, and the DoD sustainment community to work in collaboration to find, develop, and invent new and innovative technologies that enhance readiness at best cost.

For 20 years, CTMA has found solutions to DoD maintenance needs.

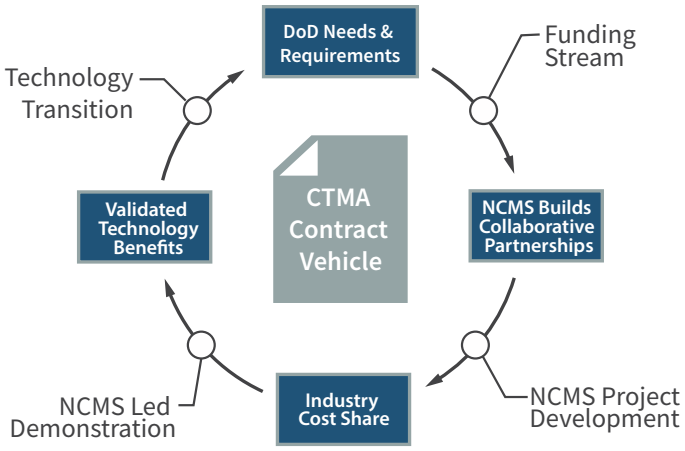
> "Universal Synaptics Corporation has been a member of NCMS for the last eight years. Our experience has been nothing short of phenomenal! Everyone we've interacted with are the best of the best. Their business model positions them as a leader in technology transitions, technology awareness, and technology use. They are advocates for where our capabilities could be used within the government. I honestly don't think we'd be doing what we're doing today without CTMA."
>
> *Ken Anderson, Universal Synaptics*

CTMA is dedicated to providing agile and streamlined collaboration to rapidly innovate how DoD sustains warfighter readiness.

COME SEE WHAT THE WORKER BEES ARE DOING AT BOOTH *#P319*

NATIONAL CENTER FOR MANUFACTURING SCIENCES

How CTMA Works:



- NCMS holds an unparalleled (non-FAR based) contracting vehicle to demonstrate commercial technologies prior to DoD acquisition.
- DoD maintenance activities have needs and requirements, which are potentially solved by innovations created by industry.
- Through a network of industry partners, academia, and outreach activities, NCMS brings the needed technology directly to the military.
- NCMS uses the CTMA CA to quickly develop project teams connecting DoD with industry developers, integrators, and end-users.
- NCMS provides industry an opportunity to understand government facilities and operations.
- Each project includes a cost share from industry so all parties have investment in a positive outcome.
- NCMS facilitates technology showcases to expose the DoD to industries with existing technologies.
- Program managers leverage their expertise to facilitate innovative technologies transfer.

Streamlined Process

The CTMA Program has a unique ability to cut through “red tape” and launch a new project within 45 days of receiving approval to proceed with a project or initiative.

For more information contact:
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www.ncms.org/ctma

About NCMS:

The National Center for Manufacturing Sciences, the largest cross industry collaborative Research & Development consortium in North America, is dedicated to driving innovation in commercial, defense, robotics and environmentally sustainable manufacturing. NCMS’ vast experience in the formation and management of complex, multi-partner collaborative R&D programs, is backed by corporate members representing virtually every manufacturing sector.
For more information on NCMS, visit www.ncms.org

CONGRATULATIONS TO OUR 2016 MAINTENANCE INNOVATION CHALLENGE WINNERS!

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

TECHNOLOGY AWARD:

"Automated Large Standoff, Large Area Thermography Inspection System"

Clint Salter, DoN NAVAIR ISSC Cherry Point/Steven M. Shepard and Maria Beemer, Thermal Wave Imaging, Inc.

This Thermal Wave Imaging is an accurate, rapid, and automated large area inspection system. Using advancement in excitation modes, physics based signal processing, and improved data analysis tools; the project produced a technique that can inspect a surface from a large standoff, while maintaining the same sensitivity and detection capability of conventional flash thermography.

TWI demonstrated a novel non-destructive inspection (NDI) capability, which uses thermography to rapidly inspect large areas of composite aircraft from a stand off of 10-15 feet. This technology, currently being deployed within NAVAIR, will bring considerable time and cost savings to the DoD's maintenance operations.

We appreciated the opportunity to showcase this new approach to a formidable problem.

Maria Beemer

PEOPLE'S CHOICE AWARD:

"Expeditionary Fluid Analysis Capability"

MGySgt Lance Baughman, HQMC, I&L, LPC-1

Spectro-Scientific provided a commercial-off-the-shelf solution that allowed the Marine Corps to use current industry standards to analyze a weapons systems fluid "health" within minutes of sampling, and use these analytics as a basis for decision-making at an organizational level, thereby saving the Marine Corps millions of dollars on changing oil and filters.

This technology will realize savings in both fiscal and human capitol resources and is a good forecasting tool for the maintenance community. With this technology what used to be a two-week turnaround for analysis now takes 10 minutes.

I was surprised and happy to win this award, which is impressive considering the stiff competition. I'm happy to bring awareness to this innovative product.

MGySgt Lance Baughman

2017 MAINTENANCE INNOVATION CHALLENGE

Overview:

The Deputy Assistant Secretary of Defense for Maintenance challenged individuals to submit their maintenance related innovations. An evaluation board comprised of maintenance subject matter experts selected six candidates to participate in the challenge during the 2017 DOD Maintenance Symposium.

Moderator:

Gregory J. Kilchenstein, Director, Enterprise Maintenance Technology ODASD (Maintenance Policy & Programs)

Finalists:

Enhanced HUMS for Fixed-Wing Aircraft
Presented by Seth Kessler, Ph.D., Metis Design Corporation, and Peter Carini, UTC Aerospace Systems

Additive Manufacturing for Masking 76 PMXG Thermal Spray
Presented by Michael Lucis, USAF 76 PMXG, Tinker AFB

Small Unmanned Aerial System (sUAS)
Presented by Timothy Morris and David Freeman, U.S. Air Force, 412th Test Wing, 412th Maintenance Group

DRIFT Composite Heat Damage Evaluation of V-22 Wing
Presented by Justin Massey and Andrea Boxell, NAVAIR

Solid State Additive Repairs for Maintenance Applications
Presented by Dr. Jennifer Wolk, Office of Naval Research

Expeditionary Hydraulic Fluid Analysis
Presented by Robert Yurko, Spectro Scientific and Mathew Boenker, AMRDEC

ENHANCED HUMS FOR FIXED-WING AIRCRAFT

DR. SETH KESSLER
PETE CARINI

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

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

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

PROBLEM STATEMENT

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

BENEFITS

NEAR TERM BENEFITS

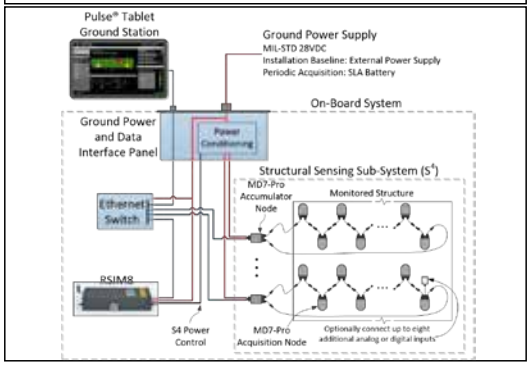
- Reduction in maintenance cost
- Reduction in inspection costs
- Improved asset availability
- Improved maintenance logistics
- Service life extension

LONG TERM BENEFITS

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

TECHNOLOGY SOLUTION

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



ADDITIVE MANUFACTURING FOR MASKING 76 PMXG THERMAL SPRAY

MICHAEL LUCIS

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

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

PROBLEM STATEMENT

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

BENEFITS

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

TECHNOLOGY SOLUTION

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

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

SMALL UNMANNED AERIAL SYSTEM (SUAS) MAINTENANCE INSPECTION CAPABILITY

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

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

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

Inspections of aircraft upper surfaces that normally can take up to 2-hours were done in 30 minutes with a quadcopter; in the case of the C-17 a sUAS would spare maintainers using a lift to inspect its tail. Maintainers at Edwards AFB were able to use the sUAS' video to sign off their preflight external inspection -an Air Force first. This testing opens the aperture on flying a sUAS near the airfield, which has been frowned upon in the past. These initial missions are establishing baselines for how operations can be conducted safely at Edwards and other USAF installations.

With proper development, this technology presents potential for multiple uses. In addition, to real time monitoring of inspections; capabilities exist to record the inspection as well as tracking aircraft condition over time. Further development of automatic flight patterns, self-contained lighting, and improved camera capability would only enhance the capability of the platform.

PROBLEM STATEMENT

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

BENEFITS

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

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

TECHNOLOGY SOLUTION

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

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

DRIFT COMPOSITE HEAT DAMAGE EVALUATION OF V-22 WING

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Over the last 35 years, the Department of Defense has been flying aircraft that include flight critical components constructed of advanced composite materials. These materials reduce the weight of the aircraft, while maintaining superior strength characteristics and corrosion resistance when compared to previously utilize metallic materials; however, the composites used on DoD aircraft are less tolerant to extreme temperature than traditional metallic materials.

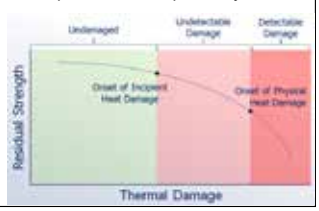
Issue: While physical damage due to extreme temperature such as charring and delamination can be detected using conventional non-destructive inspection techniques, chemical damage—often called incipient heat damage—may remain undetected. The uncertainty of undetected incipient heat damage in the composite after a high temperature event can lead to scrapped parts or scrapped aircraft, which may have otherwise been repairable.

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

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

PROBLEM STATEMENT

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



BENEFITS

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

TECHNOLOGY SOLUTION

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

Evaluation of Wing Skin

SOLID STATE ADDITIVE REPAIRS FOR MAINTENANCE APPLICATIONS

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

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

- Powder processing for steel alloys of interest
  - Steel alloys have been challenging for deposition, but are commonly used materials for structural and dimensional repairs
  - Compatibility of base materials for steel cold spray powders for a wider application space could allow for a range of properties and application techniques
  - Powder processing before deposition has been shown to enhance elongation in aluminum alloys
  - May provide an alternative to welding for thin sections prone to distortion
- Higher temperature deposition for increased adhesion
  - Higher temperatures may be needed for particle deformation in steels and other high temperature materials
  - This may require modification of existing COTS technologies and new nozzle designs
- Coupled deposition technologies (i.e. laser assisted, friction stir welding, etc.)
  - Cold spray may be used to deposit materials and subsequently processed for consolidation or end use.
  - Laser assisted technology may be able to broaden the processing space for deposition

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

PROBLEM STATEMENT

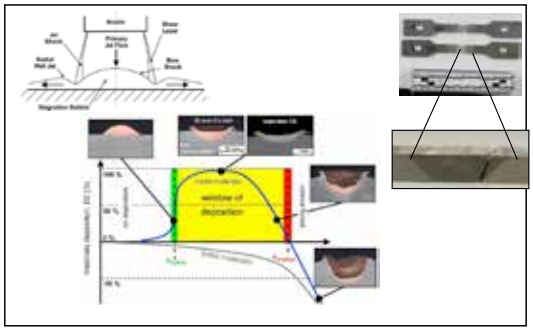
- Operational readiness is a priority across DoD platforms
- Structural repair of existing parts with additive technologies can reduce long-lead time items and current deficiencies with other repair techniques.
- New technologies, such as cold spray, are becoming available for structural repair, but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

BENEFITS

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

TECHNOLOGY SOLUTION

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



EXPEDITIONARY HYDRAULIC FLUID ANALYSIS

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

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

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

PROBLEM STATEMENT

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

BENEFITS

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

TECHNOLOGY SOLUTION

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

Field Lab 58M

ADDITIVE MANUFACTURING (AM) REPAIR FOR NAVAIR

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To steward the taxpayers' resources, the Department of Defense (DoD) must develop cost effective means of maintaining her existing assets to the extent possible. Laser-based additive manufacturing (AM) processes have been developed to address a repair need that could not be satisfied via traditional arc-based weld repairs. Specifically, the repair returns out-of-production components on the engines of AV-8B Harriers back into service.

Maintaining the aging fleet brings challenges that can only be met through modern AM technologies. Diminishing stockpiles of critical engine components can force assets to remain grounded in "hot standby" for years awaiting delivery of out-of-production replacements. Arc-based repairs can be attempted, but often result in distortion that takes the component out of tolerance. Laser-based AM weld repairs have been shown to produce significantly less distortion than conventional arc-based repairs, thereby enabling the cost-effective repair of components with tight dimensional tolerances.

As an example, the AV-8B is a single engine aircraft requiring periodic inspections to ensure its readiness. Certain critical engine components experience fretting wear during flight that are carefully monitored to avoid component (and/or system) failure. When wear limits are exceeded, these aircraft cannot be safely returned to service. To repair regions of fretting wear on the titanium F402 engine low-pressure compressor (LPC) 2nd stage rear seal ring, three weld build-up repairs about half the thickness of a dime are needed. Attempts to repair these components via arc-based processes induced too much distortion in the 20" diameter part. A repair that significantly reduces distortion was thus required.

The innovation here lies in the process. Laser-based welds are known to require less heat input and typically result in reduced distortion compared to arc-based procedures. Working in collaboration with our partners at Fleet Readiness Center – East (FRC East), the Applied Research Lab (ARL) at Penn State University developed a qualification test plan and process parameters to realize the required repairs while minimizing resulting component distortion. Qualification of both powder-fed and wire-fed directed energy deposition (DED) laser-based procedures is now possible.

ARL Penn State is currently working with FRC East to qualify repairs on nickel-based alloys for various thin-walled air seals within the T64 engines on their CH-53E and MH-53E helicopters. As the number of qualified laser-based AM repairs grows, NAVAIR will have increased confidence in employing these time- and cost-effective processes to address numerous other maintenance challenges, thus ensuring our fleet stands ready to complete its mission.

PROBLEM STATEMENT

- Limited replacement reserves & long-lead procurement/manufacturing cycles can jeopardize asset readiness
- Arc-based weld repairs to thin-walled parts induce excessive distortions that exceed permissible tolerances

BENEFITS

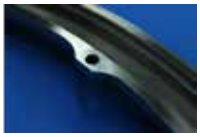
- Provide depot with qualified repair for quick implementation
- Provide NAVAIR with a low heat input / low distortion laser-based repair methodology that may be applied to other components

TECHNOLOGY SOLUTION

- Laser-based powder-fed and wire-fed directed energy deposition (DED) processes have been developed to repair thin-walled tight-tolerance components that previously required replacement
- A qualification test plan (QTP) was developed, approved, and used to produce acceptable weld repairs for titanium parts on the F402 engine
- A similar qualification process is now being pursued to repair distortion-sensitive nickel-based components on the T64 engine

AV-8B Harrier

CH-53E



MODERNIZATION OF FIELD LEVEL MANUFACTURING

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In the past, our Fabrication flight's mission was providing for the day-to-day structural maintenance of aircraft and ground equipment. As the E-3 fleet aged and resources were stretched, we filled the expanding void between warfighter needs and depot capabilities. Simultaneously, shrinking supply chains led to an increased requirement to manufacture replacement parts on station. As the mission expanded, our pool of skilled fabricators shrank during force drawdowns. We lost experienced craftsmen which ultimately comprised a 35% decrease in capability. To stay on mission, we were forced to 24 hr operations, 7 days a week for 18 months.

With no end in sight, flight and squadron leaders teamed up to modernize operations. We landed on three technologies to initiate change. First, we lobbied group and wing leaders to acquire a water-jet machining center, which was standard equipment for fighter and heavy aircraft maintenance but, due to a high cost of investment, had not been brought to AWACS maintenance. Looking beyond typical field maintenance equipment, we invested in Additive Manufacturing (AM), aka 3D printing and fielded the first industrial grade printer in an operational AF unit. Finally, recognizing that many parts had no blueprints on file, we acquired a laser arm scanner to generate reverse engineering capabilities.

Since acquisition, we have mastered the Fortus printer and OMAX Water-jet and eased fulfillment of the mission. We have ended 12 hour shifts we able to aid OC-ALC on multiple occasions. First, we designed unique tools to automate ECS duct bracket manufacture, cutting creation time to 90 minutes from 8 hours per asset. When procurable, these parts cost $4,000 each. With our new capabilities, we cut this to $70, saving $542,000 in the 1st year. Next, we developed, received approval for, and flew the 1st 3D-printed replacement part in AF history. We became the sole manufacturer of E-3 seat end caps nixing a projected $80K contract and producing them on demand in under 10 minutes. Since then, we have created 31 unique tools and engineer-approved replacement parts for E-3s, B-52s, and KC-135s. To date, these efforts saved 4,200 man-hours annually, 2 years procurement time for the E-3 mission, and 540 depot flow days for KC-135 maintenance. We also recently developed printed honeycomb cores in hopes of cutting flight control repair timelines and were approved Phase 1 testing as part of America Makes Maturation of AM for Low-cost Sustainment initiative.

We have advocated AF-wide implementation by hosting 30+ distinguished visitor tours. We have briefed Canadian RAF wing commanders, senator's delegations, ACC's Command Chief, 27th SOMXG/CC, AFIT professors, as well as AF Research Lab & Life Cycle Management experts. We hosted a webinar for ACC/A4 and were highlighted in media outlets and the LOA conference. As the sole field unit invited, we briefed leaders from every MAJCOM and Depot at the AF's 1st AM Cross-talk. We focused efforts on warfighters and helped finalize the AF AM Strategic Implementation Plan.

PROBLEM STATEMENT

- **Increased Field Maintenance Need** - Expanding structural maintenance and manufacturing requirements within field level maintenance units due to aging fleets & increased mission set (552d supports 4 AEFs & 49+ exercises/TDYs/yr)
- **Asset Availability** – Many supply chains have withered due to OEMs no longer existing and aircraft service life extensions leading to failure of assets never intended to require replacement
- **Lack of Skilled Craftsmen** – Force drawdowns siphoned precious skills from the Active Duty fabrication force. High difficulty & rare skills are typically trained on the job. Cannot be recovered. Perfect time to modernize!

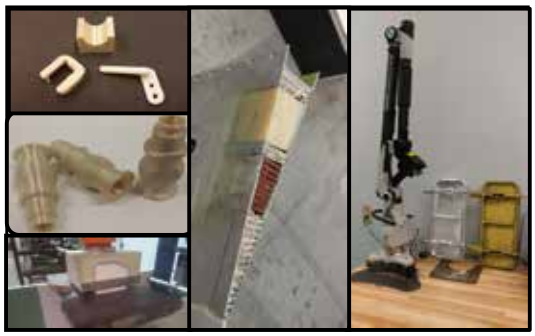
BENEFITS

- **Parts on Demand!** No requirement for warehousing assets
- **Work From Home!** Previously there wasn't time to make molds and other tools. With "No Look" manufacturing technicians can print, go home for the day, and come into a nearly complete tool or aircraft part
- **100% Repeatable Manufacturing!** With molds on hand, craftsmen can get a perfect bend every time, reducing duplication of effort. Broken molds are easily reprinted.
- **Time Savings!**
  - *540 Depot Flow Days*
  - *6.9K Man hours*
  - *6 Month Supply/contracting lead time*

Money Savings!
$2.4M parts/tools

TECHNOLOGY SOLUTION

- **Stratasys Fortus 400MC** – production grade 3D-printer utilizing Ultem 9085, the only FAA approved printable plastic
- **Omax Waterjet machining center** – Now Standard fighter/heavy aircraft mx fabrication equipment never before integrated with E-3 Maintenance. Allows rapid fabrication of 2D aircraft parts such as panels and other sheet metal parts prior to forming
- **Romer Laser Arm Scanner** – Provides rapid reverse engineering capabilities and part comparison/validation for assets that have no blueprints on file



REVERSE ENGINEERING WEAPON SYSTEM COMPONENTS

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Sustainment of aging aircraft presents unique challenges due to the lack of complete technical data, aging legacy tooling, and the need to rapidly respond to unanticipated repairs to a wide variety of aircraft and exchangeable end items. To meet the needs of the Oklahoma City Air Logistics Complex (OC-ALC) depot customers, engineering must be responsive and leverage technology to expedite the return of aircraft and their components to service as quickly as possible. The 76th Commodities Maintenance Group (CMXG) has leveraged 3D laser scanning, additive manufacturing, and castable materials to create solutions for depot maintenance problems where traditional manufacturing is either not possible or too slow. CMXG has had great success augmenting contract and organic manufacturing by enhancing and creating technical data packages for maintaining equipment, prototyping aircraft parts, and manufacturing end-use tooling including dies, jigs, and fixtures created by direct printing or resin casting into printed molds. Specific innovative solutions include using fused deposition modeling to print weld fixtures containing internal flow cavities for argon cooling out of high temperature Ultem based polymer material to resist melting. Fixtures like this reduce costs over traditional machining but more importantly allow greatly reduced turn-around times, typically 3-6 months faster, including delivering components currently unable to be sourced. CMXG has also helped aircraft maintenance reduce flow daytime and costs by modeling cracked structural members and making prototype (bathtub shaped) fittings using a binder jet printer. These rapidly created fit check models allow for easy modification to optimize prototyping results and greatly reduced time spent machining with an overall average timesavings of 3 weeks per custom repair fitting. For stock-listed part replacement, CMXG uses laser scanning of samples to verify the correct interpretation of technical data. Prior to manufacturing the part, a 3D printed test fit part is used to verify the interpretation of technical data fits properly when installed onto the next higher-level assembly. This verification of the part and technical data provides an average cost avoidance of $700,000 per year of material costs and 720 flow days of rework. Printing or resin casting of sheet metal form blocks has also proven to be an extremely cost and time effective route to support organic manufacturing. CMXG has shown that fully dense printed Acrylonitrile Butadiene Styrene (ABS), PolyLactic Acid (PLA), and Acrylic-Styrene-Acrylonitrile (ASA) polymer form blocks can withstand 10,000 psi from rubber and fluid cell presses with an average cost savings of $2500 for small to medium form blocks and elimination of nearly two months in lead-time. Printing molds and casting form blocks from ceramic filled epoxy has also been demonstrated as a major cost and time saving technique with $3500 average cost savings per block and similar production time to printing. To date, utilization of these techniques for die block manufacture have cost avoidances totaling more than $125,000 and a combined total reduction of 1500 flow days. CMXG is leveraging modern technology to deliver cost effective engineering solutions to the war fighter.

PROBLEM STATEMENT

- Sustainment of aging aircraft presents unique challenges due to the lack of complete technical data, aging legacy tooling, and the need to rapidly respond to unanticipated repairs by manufacturing solutions for a wide variety of aircraft structures and exchangeable end items. The focus is on those late-to need items that lack contract support.

BENEFITS

- Rapidly prototype parts for fit checks
  - Reduces material waste by $700K (from rework) and machining time by 720 flow days annually
- Print low production run tooling on demand to offset Local Manufacturing – annually:
  - Free up machine time by 5000 hours
  - Reduce lead time by 1500 flow days
  - Reduce metal tooling cost by $125K
- Digital models to enhance tech data packages
  - Enabling non-OEM sources of supply

TECHNOLOGY SOLUTION

- Portable laser scanning and measurement to verify component or deficiency requirements.
- Digital models created that can be easily programmed for machining or converted to enhance technical data packages.
- Additive manufacturing to rapidly prototype tooling or produce test fit items.

SEMI-AUTOMATED ROCKET MOTOR INSPECTION SYSTEM

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Letterkenny Munitions Center (LEMC) produces Low Cost Reduced Range Practice Rockets (LCRRPR) to assist the U.S. Army and U.S. Marine Corps with annual training requirements. As part of that effort, LEMC performs radiographic inspection along with other inspections and certifications, which certifies the rocket motor for an additional ten years of shelf life.

Previously, once removed from the rocket, the rocket motor had to be prepped, boxed, and transported to the Non-Destructive Testing facility to be x-rayed. The x-ray process at that facility used a 6 MEV x-ray system built in 1971 and took four hours per motor to inspect using $500.00 in materials.

The Semi-Automated Rocket Motor Inspection Station (RMIS) was designed, fabricated, proven, and validated by LEMC technicians, radiographic inspection experts from other government installations, and private sector engineers to develop a new piece of equipment to reduce handling and material cost in the x-ray process.

The RMIS is a semi-automated station capable of holding and processing five rocket motors (RM) while performing the x-ray of the sixth RM. A technician can convert the x-rays into high-resolution digital images real time which are then examined by an x-ray technician for approval or failure. The RM is rotated through the vault while eighteen x-ray shots are taken along the axis of the RM. Technicians operating this station are protected by five inches of solid lead shielding.

This self-contained Rocket Motor Inspection Station is located at the download/de-mate facility and is a major change from legacy equipment found at depots and eliminating the need for RM's to be boxed and transported to other locations for processing. The 450KVA RMIS reduces the labor hours from 4 to 1 per RM and reduces the inspection cost from $500.00 to $150.00 per RM.

Rocket motors that were otherwise going to be destroyed can now be repurposed into vital training assets for the warfighter at a faster pace and cheaper cost.

PROBLEM STATEMENT

The RMIS system reduces the labor hours required and overall costs for the radiographic inspection of Multiple Launched Rocket System (MLRS) and Guided Multiple Launch Rocket System (GMLRS) Rocket Motors. These motors are reused in Low Cost Reduced Range Practice Rocket (LCRRPR) Production and Maintenance activities.

BENEFITS

- Latest Modern Technology
- Semi-Automated Process
- Production Flow Integration
- Reduction of labor hours required per RM: 4-1
- Reduction of inspection cost required per RM: $500-$150

TECHNOLOGY SOLUTION

- The RMIS system can accommodate up to five rocket motors (RM) on the inlet side while performed the digital X-ray of the sixth RM.
- The RMIS "vault" transforms 450,000 volts of electrical energy into powerful X-rays that penetrate the steel casing and propellant.
- A detector converts the X-rays into high resolution digital images for examination by the X-ray technician for instant recognition of cracks, voids, and un-bonds.
- The RMIS takes eighteen X-ray shots along the axis of the motor as it is rotated through the vault.

6 MEV X-Ray System- Legacy Facility Built 1971

450KVA X-Ray Cabinet System- Modern Facility Built 2017

ADDITIVE MANUFACTURING TRACEABILITY ASSURANCES AND DESIGN OPTIMIZATION S/W TOOLS

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Additive Manufacturing (AM) technologies are redefining both product-ability and operability space in many industries. Reliability is of utmost importance in the AM environment for metal-based low production rate materials development. As technological and regulatory advancements progress in the next decade there will be an ever-increasing demand for reliable methods to replace OEM forged metal components with AM manufactured components. By incorporating end-to-end lifecycle management into AM components, complex systems are made more reliable for both commercial and military aviation applications.

Given DoD identified technology gaps optimizing AM designs to reduce time and expense associated with periodic inspections will be difficult unless there is an end-to-end method to compare data sets between "simulated designs", "as-built" and "in-operations". Analatom's Intelligent Management Analysis System (IMAS) is a maintenance assessment tool with an "associative memory" indexing capability linking data from multiple, disparate sources. IMAS links end-to-end expertise, knowledge, and data associated with the AM technology, and allows a data about a part to be linked and searchable as far back as design concepts, through manufacturing and quality control, all the way to field maintenance and end of life.

IMAS serves both a) parts design optimization to ensure life performance, inspect-ability, condition maintenance and b) parts traceability. When designs are modified or transferred to alternate repair facilities replicating designs, the previously "as-built" linked data can be compared against original linked data sets ensuring that critical engineering details are precisely replicated. In operational environments "as-built" linked data including NDI inspection tests can be compared to "in-operations" linked data sets where degradations from "as-built" linked data sets can be determined. A 3D engineering services team has agreed to transition the associative memory index approach into their operations, and help transition to OEM integration teams or end-use customers as linked data associative indexes can be utilized to compare "as-built" design parts with "in-operations" environmentally degraded parts.

Analatom created IMAS AM prototype associative memory software that links and correlates all above listed expertise into an associative memory index that enables designers to ascertain that optimized inspection oriented designs retain their functional capabilities.

Validation involved:

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

Supporting test data were obtained by capturing images during AM process for every fused build stage. Image-based associative memory linked data "as-built" parts could distinguish between "normal" and "seeded defects" regions.

PROBLEM STATEMENT

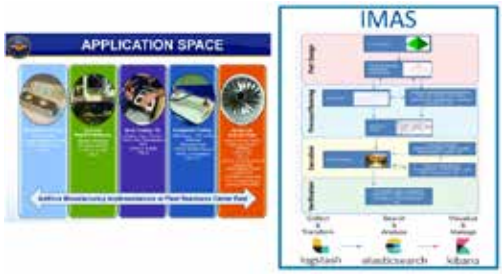
- Need for AM Driven Component Design Optimization, Process, and Configuration Management S/W Tools
- DoD Additive Manufacturing Study identified Technology Gaps in Design, Materials, Processes, Standards, Data Management.
- AM Design Optimization Tool to Ensure Component Life, Performance, Inspectability, and Maintenance Efficiency; and ensure design trades.
- AM Part Traceability and Assurance is a key requirement.
- **Standard IT data management systems aggregate data but are unable to link; provide Design Optimization Analytics; and correlate across disparate data sources.**

BENEFITS

- Solution provides AM parts traceability, configuration, process, design optimization assessments, and life performance assurances.
- AM driven component design optimization and integrated S/W tool sets lets the designer explore trades that will maximize maintenance inspect-ability to ensure life usage performance; enhance monitoring sensor placement and signal transmission; and increase maintenance effectiveness with reduced costs.
- IMAS provides traceability assurance to maintain consistency across builds, test and field prototypes and operational deployments

TECHNOLOGY SOLUTION

- Apply "big data" analytic methods that link disparate data sources to provide part traceability and assurances that allow very complex devices to be *reliably* manufactured.
- Analatom's intelligent management assessment system (IMAS) currently correlates disparate, unstructured information from multiple databases *at every stage of life*, from design specs to in-process quality control data to field maintenance data, tracking the parts in use.
- IMAS provides traceability assurance to maintain consistency across builds, prototypes, and operational AM.
- Leverage SBIR, Fathom Studios, and other efforts to provide AM Component Design Optimization Tool sets.



Linking data across domains – (IBM Watson-like associative index)

ADDITIVE MANUFACTURING FOR MASKING 76 PMXG THERMAL SPRAY

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

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

PROBLEM STATEMENT

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

BENEFITS

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

TECHNOLOGY SOLUTION

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

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

R-FAB AT PACIFIC PATHWAYS 17-3: THE EXPEDITIONARY AGILE FACTORY

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The U.S. Army / RDECOM / ARDEC expeditionary additive manufacturing system known as R-FAB (Rapid Fabrication via Additive Manufacturing on the Battlefield) was successfully demonstrated during Pacific Pathways 17-3. Pacific Pathways is a yearly exercise series conducted by U.S. Pacific Command to train for Pacific Theater mission sets. R-FAB was inserted with the 402nd Brigade Support Battalion to demonstrate point-of-need additive manufacturing. R-FAB, first and foremost, is a soldier operated system. Soldiers are trained in all aspects for the system from shelter setup, hardware initialization to CAD and scanner use and basic printer maintenance and troubleshooting. R-FAB features several 3D printers allowing soldiers access to a wide variety of polymer materials including ABS, PLA, NYLON, fiber and glass reinforcements. This range provides the capability for a myriad of temporary OEM replacements parts to be produce in the field. The onboard 3D scanner and CAD-enabled laptops allow the soldiers to create innovation parts to solve immediate field challenges. For the exercise, ARDEC provided a Field Support Representative as engineering reach back support for the innovation and scanner developed parts. R-FAB also features RAPTOR (Repository for Additively manufactured Parts for Tactical and Operational Readiness); a databased of approved files ready to be printed. ARDEC coordinates with all engineering centers within RDECOM to ensure RAPTOR has the latest and best print files for the soldier.

PROBLEM STATEMENT

- Warfighter requires the capability to produce temporary OEM-replacement parts in the field to maintain operational readiness.

BENEFITS

- Increased readiness
- Reduce supply chain requirements
- Reduce resupply or convoy missions reduces the number of Warfighters in harms way
- Enables Warfighter to Innovate to win the fight

TECHNOLOGY SOLUTION

- Rapid Fabrication via Additive Manufacturing on the Battlefield (R-FAB)
- Expeditionary additive manufacturing system
  - Polymer-based 3D printing
  - 3D scanning
  - RAPTOR Parts Library Interface

HYBRID ADDITIVE MANUFACTURING FOR DOD PART REPAIRS

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Additive manufacturing (AM) continues to grow in popularity with respect to addressing Department of Defense (DoD) needs, including production of prototypes; economically making small quantities of obsolete parts; and rapidly assessing new part fit-up to other components. However, new parts built from metal AM processes continue to be called into question due to quality concerns and lack of AM standards. This project considers only AM repairs through hybrid additive manufacturing technologies. These new hybrid AM technologies, leverage milling machines in which laser-based material deposition head(s) are installed. The laser material deposition heads build up material up to 5.5 pounds per hour onto the part(s) via lasers as the energy source along with feeders, which add powder metal to the molten section being repaired. Milling operations then remove excess material to yield a dimensionally accurate final part. In-process monitoring/ inspection are also available. All these functions are completed with a single part set-up with typical turnaround times of 1–3 hours; however, turnaround time is highly part dependent.

Hybrid AM technologies support reduced part inventories and reduced environmental impact while allowing for more than one metal to be added to a part with resulting properties approaching those of wrought materials for some alloys.

AM repair technologies will be faster to qualify than those involving full part production. The technology will allow the DoD to leverage AM, but with much less risk. The acceptance criteria for repairs need to be established, and suitable parts, materials and procedures defined to implement this technology. However, the nature of repair and the buildup of material(s) should allow for much faster qualification, even if it is on a part-by-part, or application-specific basis. The project will be executed in several key stages: select a part suitable for repair, and of an appropriate material, i.e., a non-reactive metal; perform repairs on the part(s) to determine application techniques, adhesion strength, geometric tolerance, etc.; perform testing on part(s), and appropriate material coupons; document the results; and determine a path forward for other applications. While this project is not meant to be a "qualification effort", its intended value is to quantify the benefits of AM with respect to repairing components for the DoD, leveraging hybrid technology repair procedures.

PROBLEM STATEMENT

- Maintenance of DoD platforms often requires difficult-to-source, expensive and/or long-lead-time components
- The ability to repair, rather than replace, such components offers schedule and cost benefits
- Repair processes must not degrade critical properties or features (e.g., strength and dimensions) of the components
- While additive manufacturing (AM) is being considered for many applications (including new part production), metal AM technologies still struggle with qualification, in-process monitoring and standards that are accepted and approved throughout industry/DoD
- AM repair technologies are more likely to have an immediate impact on industry and the DoD, since repair operations will be easier to qualify vs. building an entire part by AM

BENEFITS

- AM and machining all in one milling center in single setup
- Work envelope only limited by milling center workspace
- Parts to be repaired can be machined and prepped prior to AM operations, ensuring clean and consistent surfaces for material build-up
- Offers a wide range of non-reactive materials (stainless steel, nickel-based alloys, cobalt-based alloys, tool steels, bronze and more)
- In-situ controls for quality and deposition adjustments
- Will allow a wide range of DoD parts to be repaired

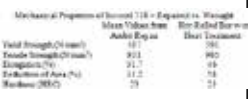

Table reference, Yamazaki 2016

TECHNOLOGY SOLUTION

- New AM repair technologies utilize a hybrid approach: combination of AM (addition) & CNC machining (subtraction) operations performed within single standard machining center
- Hybrid technologies offer:
  - Laser deposition of one or more metal(s)
  - Minimal heat input induced into the part
  - Deposition head used like other tool heads
  - In-process inspection heads available
  - Metal build rate up to 2.5 kg/hr (5.5 lb/hr)
- End product is a mechanically and dimensionally compliant component that avoids long lead times and the high cost of procuring a new component

CTC's 5-Axis Hybrid AM Milling Center Working Envelope: 120" × 40" × 30"

**Turbine Blade Repair Repair*

**Hybrid Technology Laser Deposition, and Tool Holder Storage Location*

** Photos courtesy of Hybrid Manufacturing Technologies*

DIGITAL THREAD FOR ADDITIVE MANUFACTURING

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Additive manufacturing's (AM's) roots go back nearly three decades. Its importance is derived from its ability to break existing performance trade-offs in two transformative ways. First, AM has the potential to reduce the capital required to reach minimum efficient scale for production, lowering the barriers to distributed, just-in-time manufacturing to supply repair parts across the Department of Defense (DoD). Second, the flexibility of AM facilitates an increase in the variety of products a unit of capital can produce, reducing the costs associated with product customization to meet mission-specific requirements. Yet, these AM capabilities that have the potential to transform the supply chain and product re-engineering of tomorrow have been largely confined to the research lab.

In order for the DoD to implement a scalable AM production capability, it must start by laying the groundwork for an integrated system that provides end-to-end product lifecycle management – the digital thread. The digital thread, a single seamless strand of data that stretches from the initial design to the finished part, promises to address many of the challenges hindering AM's application beyond the research lab. It seamlessly links together disparate printers, computing systems, and associated data, collecting valuable information from every stage of the product lifecycle. This increased availability of data enables repeatability, ensures quality and process control, and feeds insights downstream and upstream to drive smarter decisions.

The digital thread for additive manufacturing (DTAM) is focused on systems integration, linking existing applications and associated data to automate data transfer and translation, facilitate collaboration across organizational boundaries, and institutionalize acquired knowledge for designing, manufacturing, testing, and maintaining AM parts.

Organizations can build a digital thread off of existing PLM or ERP solutions, avoiding significant information technology (IT) replacement costs, by integrating advanced AM technology into the network of existing systems. This interconnected DTAM system is composed of both digital and physical components. Digital components include a PLM backbone, design software, quality testing software, asset performance and usage sensors, and interface applications between the PLM and the physical components of the system. Physical components include design, testing, and maintenance workstations, additive manufacturing machines, and associated control systems. In requirements gathering meetings, the Air Force, Army, and Navy have each confirmed the need for an integrated system to share AM expertise across the centers of excellence (CoEs) that are currently producing AM parts. We believe a viable implementation model for the Services would be to pilot DTAM at the CoEs and, as the Service's AM capabilities continue to mature, scale DTAM to bring advanced functionality to maintenance depots and forward operating bases.

Implementing DTAM would lead to a more efficient and effective maintenance program through improved visibility, reduced re-work, better application of existing knowledge, and increased automation. As more data is collected, additional maintenance efficiencies can be achieved through condition-based maintenance by analyzing performance and usage data linked to AM parts. With the advanced capabilities that DTAM provides, the DoD can transform the maintenance of assets by harnessing product lifecycle data intelligence across its digital enterprise.

PROBLEM STATEMENT

Defense maintenance organizations find that they have to address:

- Readiness issues due to **long lead times for replacement parts**
- **Limited availability of useable data** and insights from earlier product lifecycle stages
- **Gaps in the technical data package (TDP)** for parts in aging weapons systems
- **Silos of research and development** on new technology limiting knowledge transfer

BENEFITS

As a digital thread scales, it will increasingly provide:

- The capability to **design anywhere** and **build anywhere**
- A **singular unified interface** for end-to-end data capture, management, and analysis
- **Accessible and useable data** for rapidly reverse engineering parts and systems
- **Institutionalized knowledge** to enable repeatability and unlock insights

TECHNOLOGY SOLUTION

An integrated *Digital Thread for Additive Manufacturing* seamlessly connects applications and associated data across organizational boundaries. Digital components of this system would include a PLM backbone, design software, simulation software, quality testing software, and interface applications between the PLM and the physical components of the system. Physical components would include a design workstation, additive manufacturing machine(s), quality testing workstation, asset sensors, and control systems.

SOLID STATE ADDITIVE REPAIRS FOR MAINTENANCE APPLICATIONS

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

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

- Powder processing for steel alloys of interest
  - Steel alloys have been challenging for deposition, but are commonly used materials for structural and dimensional repairs
  - Compatibility of base materials for steel cold spray powders for a wider application space could allow for a range of properties and application techniques
  - Powder processing before deposition has been shown to enhance elongation in aluminum alloys
  - May provide an alternative to welding for thin sections prone to distortion
- Higher temperature deposition for increased adhesion
  - Higher temperatures may be needed for particle deformation in steels and other high temperature materials
  - This may require modification of existing COTS technologies and new nozzle designs
- Coupled deposition technologies (i.e. laser assisted, friction stir welding, etc.)
  - Cold spray may be used to deposit materials and subsequently processed for consolidation or end use.
  - Laser assisted technology may be able to broaden the processing space for deposition

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

PROBLEM STATEMENT

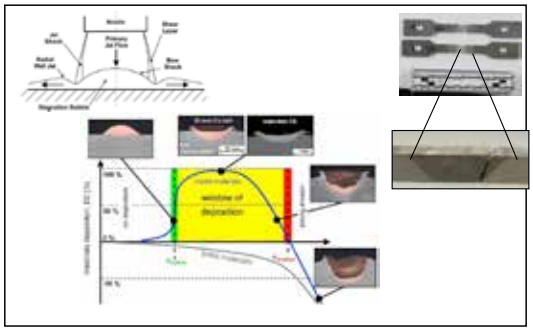
- Operational readiness is a priority across DoD platforms
- Structural repair of existing parts with additive technologies can reduce long-lead time items and current deficiencies with other repair techniques.
- New technologies, such as cold spray, are becoming available for structural repair, but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

BENEFITS

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

TECHNOLOGY SOLUTION

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



COLLABORATIVE AMMO MAINTENANCE ROBOT

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In response to the ever-increasing call to perform "more with less", most of the Army's organic industrial base has been, for decades, early-adopters of factory-floor technological advances, often incorporating robotic systems wherever feasible. The one exception has been within the depots and arsenals, which comprise the ammunition maintenance community. Here, a number of factors has slowed progress in laborsaving automation.

Historically, the biggest problem has been the hazardous nature of the shop floor environment where highly flammable propellants and other energetics are entirely incompatible with electrical servos and controllers. Another issue is that the broad variation between ammo projects does not lend itself to automation, which is geared toward stable, high volume operations. Then there is cost. The short duration of most ammo projects makes it difficult to justify the intensive upfront planning and hefty equipment investment that robotic automation requires.

In light of the above, the ammo maintenance team at Blue Grass Army Depot (BGAD) requested that Tooele Army Depot (TEAD) APE office research the following:

- The feasibility of procuring a general purpose
- XP rated robot that was easy to deploy
- Flexible enough to be used in a large variety of applications
- Sufficiently safe to operate alongside personnel with minimal guarding.

The project was assigned to Mechanical Engineer, Robert Houze. His initial focus was immediately placed on studying the potential use of Collaborative Robots – which are designed to physically interact with humans in a shared workspace. However, his market research did not uncover any that were rated for hazardous environments. However, Houze determined that paint robots, which are designed to be explosion proof and fully ATEX compliant for Category 2 and Group IIG, could be accessorized with the proper sensors to provide a "collaborative-like" capability.

Houze is presently evaluating a proposal that he believes could fulfill the expressed requirement. Once acquired, the robot's first application will be to replace personnel who are tasked with measuring the primer height of 105mm cartridges on BGAD's M1-RECAP line. Other applications will be assessed as well. If this approach to automating ammunition maintenance proves viable, then the APE office will leverage the sizable potential market of the ammunition community to convince robot manufacturers to take another look at manufacturing XP-rated robots that are inherently collaborative.

PROBLEM STATEMENT

- Cost-reducing, labor-saving automation within ammunition maintenance operations are generally hindered by:
  - Hazardous environments that are incompatible with most electrical equipment.
  - High mix, low volume operations.
  - Short duration projects which allow insufficient for recouping the upfront investment.

BENEFITS

- Increased safety
- Increased quality consistency
- Reduced Labor
- Lower Production Costs

TECHNOLOGY SOLUTION

- A general purpose Collaborative robot that is equipped to perform relatively simple tasks, and possesses the following characteristics:i
  - Rated for use in hazardous environments (i.e. XP-rated).
  - Flexible, and easy to deploy in a variety of applications.
  - Safe to operate in close proximity to personnel with little to no machine guarding.

BODY-WORN NETWORKS WITH ASSET LOCATION ID CAPABILITY

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One of the largest maintenance challenges today for the Department of Defense (DoD) is the migration of military assets to condition-based maintenance (CBM). The military is searching for a convenient, lower cost, infrastructure technology solution that accelerates the conversion from unscheduled to scheduled maintenance to cut costs and extend the life of valuable assets.

Another DoD challenge is keeping track of the location of assets, including personnel. Personnel accountability and health status, as well as asset location and condition monitoring are ongoing logistical problems for the military.

Secure Technologies, a division of Benchmark Electronics, has been working with Army R&D labs to develop a unique wireless solution that allows several devices to connect wirelessly on the body – forming a body-worn network. The devices attach various physiological sensors together to measure the health of the soldier, and then upload the data for faster analysis of the soldier's vitals.

While developing the body-worn network product, Secure Technologies discovered other features that would benefit the Army. The same chipset can be used to self-locate items in GPS-denied (or non GPS-enabled) equipment – producing lower cost and more reliable geo-location of assets.

Body-worn network technology benefits include:

- Sensor infrastructure residing on the soldier, reducing cables.
- Wireless sensor networking capability, reducing soldier's load and increasing soldier mobility & safety.
- A short-range wireless communication bubble around the soldier's body designed to operate in the presence of multiple nearby soldier body-worn networks.
- One node performing as a gateway communicating to an outside network.
- Flexible design enabling a heterogeneous mix of sensors and service requirements.
- Self-healing – any node can assume the role of 'hub' – allowing decentralized network management.

Based on these findings, the team looked at other uses for this chipset. We realized the technology in body-worn networks can also be applied to asset location ID tracking applications, such as tracking vehicle parts.

Asset location ID tracking technology benefits include:

- Tracking assets in GPS-denied (non GPS-enabled) environments.
- Sensing the health of assets for maintenance (oil changes, hours in service, etc.).
- Sending command data to devices.
- Using the device as a low power network for discrete seismic detection, low-resolution persistent video surveillance, audio monitoring, and monitoring of other available sensors.
- Easily interacting with other sensors (smart watches, cell phones, etc.) because the device is Bluetooth enabled.

By creating sensor networks for DoD rotary wings, commercial heavy equipment, trains, and ground vehicles, Secure Technologies has years of experience building sensors into vehicle maintenance applications.

Secure Technologies also offers several products that are useful in maintenance, including body-worn computers, body-worn displays, and body-worn USB hubs, as well as a variety of software products that can track and detect sensors, location and health of products.

Benchmark would be pleased to work with you to show the value and time saving nature of these products in the maintenance arena. Our goal is to create novel systems that can save time, increase efficiency, and provide better data in harsh, demanding environments.

PROBLEM STATEMENT

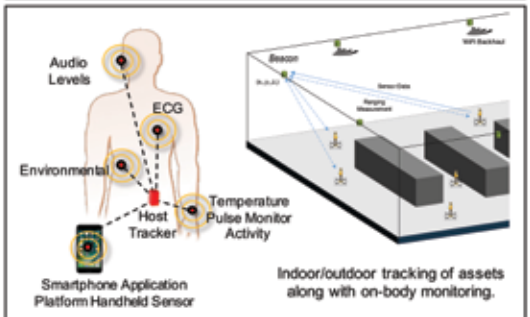
- One of the biggest DoD challenges is tracking the location and health of assets for (CBM) condition based maintenance
- Personnel accountability and health status are also important logistical challenges to track in the field
- Technology is being developed to create a body-worn wireless network that can also track and monitor assets
- We can track physiological and environmental data, as well as generated video, audio and other critical sensors

BENEFITS

- Allows for body-worn wireless networks
- Allows for location of assets in a GPS denied environment
- When combined with sensors, provides updated status on the person or other assets
- Provides on-body computing power
- Feeds data through MIMO radios, LGE or other long haul devices back to a control center
- Can handle video, seismic, audio, physiological and other sensor devices

TECHNOLOGY SOLUTION

- Body-worn networks provide:
  - A low power, LPI/LPD radio solution (works in the noise)
  - Wireless connectivity around a body or package
  - Small footprint allows the integration of COTS (commercial off-the-shelf) sensors
  - With MAC modifications, can also measure distances and location with accuracy
  - Lightweight
  - Modification of a COTS technology



USING DISCRETE EVENT SIMULATION TO REVOLUTIONIZE THE INACTIVATION, REACTOR COMPARTMENT DISPOSAL AND RECYCLE PROGRAM

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Our Command's mission is to maintain, modernize, and retire our Navy's fleet. The line of work discussed here focuses on the retiring of our fleet. That, however, does not mean that maintenance nor modernization is absent from this line of work.

The shipyard's ability to predict projected end cost and accurate completion dates of Inactivation, Reactor Compartment Disposal and Recycle (IRR) projects is complex and difficult. The resources required to complete these projects are also required for completing other maintenance, repair, and overhaul (MRO) projects within the shipyard. This creates competition for resources and leads to sub-optimal, shortsighted decision making. To further exacerbate this constraint, the workload for IRR projects is expected to ramp up from two projects per year to five projects per year in the next five years.

This is a joint endeavor with Puget Sound Naval Shipyard and Penn State University's Applied Research Lab to use Discrete Event Simulation (DES) in the IRR program.

Discrete event simulation allows us to identify constraints and validate assumptions about the planning and execution of our work. It also affords us the ability to provide insights to processes quickly and inexpensively. Using real process data, we can determine work capacity while also accounting for the complex and seemingly unpredictable behavior of systems. With this understanding, we can not only identify areas in need of process improvement, but also run "what-if" scenarios to estimate the overall effects of these improvements. While real life testing of various production scenarios can be dangerous, costly, or altogether impossible, we have the ability to mimic real life scenarios so that we may design our systems to keep our people safe and fulfill our mission.

Our discrete event simulation software gives us the ability to animate and visualize our work on a scalable basis everywhere from a single process step, to the critical chain to the project as a whole and beyond. This is not a flash in the pan solution but rather a long term planning tool we need to ensure stable and efficient demilitarization of our submarines. We owe it to our citizens to be great stewards of the taxpayers' money over the course of the submarines' lifecycle. Through this technology, we can position ourselves to ensure consistent and reliable recycling of our battle proven warships. We can also intelligently align our workforce so that they may have the requisite skills and capabilities to be successful during the execution of the actual work.

PROBLEM STATEMENT

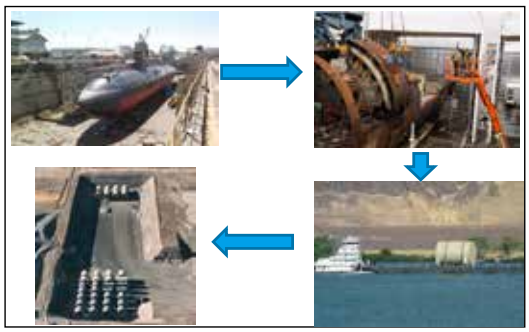
- The shipyard's ability to predict projected end cost and accurate completion of Inactivation, Reactor Compartment Disposal and Recycle (IRR) projects is complex and difficult.
- The resources required to complete these projects are also required for completing other maintenance, repair, and overhaul (MRO) projects within the shipyard. This creates competition for resources and leads to sub-optimal, short-sighted decision making.
- The workload for IRR projects is expected to ramp up from 2 projects/year to 5 projects/year.

BENEFITS

- An ability to run what-if scenarios
- Provides an ability to determine capacity
- Rapid workstructure design prototyping
- Helps identify constraints, bottlenecks
- Allows an ability to predict projected end cost and schedule completion in an ever dynamic environment

TECHNOLOGY SOLUTION

- A joint effort with Puget Sound Naval Shipyard and Penn State University's Applied Research Lab to use Discrete Event Simulation (DES) in the IRR program.
- DES affords the ability to provide insights to processes quickly and inexpensively.
- Uses real data to both model the complex and seemingly unpredictable behavior of systems and puts the power in our hands to design our future IRR program.



ENTERPRISE PRODUCT DATA MANAGEMENT (EPDM)

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Currently, product data for Army weapon systems is being managed / maintained in multiple systems and varying formats. This results in data inconsistency and redundancy, creating various engineering inefficiencies across the Research, Development and Engineering Command (RDECOM). In addition, there are varying Product Data Management (PDM) capabilities and levels of functionality across RDECOM; some locations have limited capability and are utilizing legacy solutions that do not support Army's system modernization and readiness requirements. This unified ePDM framework will promote advanced engineering tools, facilities, and analysis to strengthen the Army's organic engineering capabilities through business process and resource optimization.

The enterprise Product Data Management (ePDM) system is an innovative technology to provide a centralized repository for engineering data. The ePDM system will allow one enterprise system to contain life-cycle product/project data within a centralized location available to the (e.g., Program Managers (PMs), Lifecycle Management Commands (LCMCs), Major Subordinate Commands (MSCs), internal and external stakeholders) within the Research Development and Engineering command as well as the Army Depots. The ePDM system will allow the ability for the Department of Army to make portfolio decisions based on enterprise data that promote Army Readiness. The ePDM system is to integrate people, data, tools, processes and organizational systems. Currently, product data for Army weapon systems is being managed and maintained in multiple, disparate systems and formats. This results in data inconsistency and redundancy, creating various inefficiencies across RDECOM. In addition, there are varying capabilities and levels of functionality across RDECOM; some locations have limited Product Data Management (PDM) capability and are utilizing non-modern solutions that do not support Army's overall modernization efforts. The ePDM system will help PMs reduce time to fielding, improve quality using digital engineering data and modeling tools, foster prototyping, and track as well as predict costs and help transition technology opportunities.

The ePDM system enables the sharing of information, increasing data accessibility, usability, and collaboration, while reducing data redundancies and inconsistencies. RDECOM's ePDM enterprise environment enables standardized engineering support processes to provide Materiel Enterprise (ME) managed weapon systems, providing the essential engineering required to provide the most innovate technology to the Warfighters. This solution allows the Army to reduce the cost of sustaining legacy PDM systems in support of portfolio reduction initiatives through the Business Systems Information Technology strategy.

The ePDM system will have the advanced ability to reduce cost with a system that will have all the system accreditations and will be housed on virtual machines until moving into a cloud environment. The data rather than going through various communication tunnels will be exchange via web services. This will allow RDECOM and depots to receive the data real time and have the ability to update data real time. Having the real time and configuration-managed data will allow the ability to submit changes within the ePDM system from the required sites. Having a single system will allow for transparency with Army portfolio and process management.

PROBLEM STATEMENT

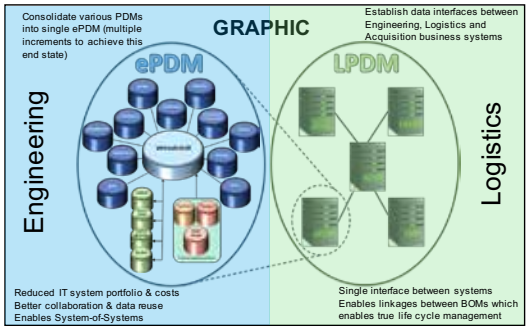
- The Research, Development, and Engineering Command (RDECOM) has various engineering systems with product and project data inconstancies, redundancy, and lack of integration. Data is obsolete at times, not updated or leveraged on new technology advancements in a timely manner.

BENEFITS

- An enterprise system that allows data access at the Depots, Program Managers and throughout RDECOM.
- Reducing cost instead of maintaining several systems in having one enterprise system.
- Collaboration though configuration managed data to promote availability, reuse and agility
- System is approved for appropriated funding and is accredited by the Army Material Command (AMC) as an ePDM system.
- Reduce data center storage by having virtual machines and cloud migration.

TECHNOLOGY SOLUTION

- The enterprise Product Data Management (ePDM) system allows for a centralized repository for engineering data that can be distributed to Army Depots, PEOs, PMs, OEMs and throughout RDECOM without having to maintain several systems and use communication tunnels. The data can be updated and maintained for all RDECOM and interfaced to the logistics community through LPDM for lifecycle product data management.



INDUSTRIAL COMPLEX INTEGRATED INFORMATION TRACKER (ICIIT)

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Production shops must answer two questions all day, every day:

1. What should I be working on right now?
2. Do I have everything I need to complete what I should be working on right now?

The Anniston Army Depot (ANAD) has developed a visual management tool that currently answers question number 1, and plans to enhance it in the future to answer question number 2 as well. The Industrial Complex Integrated Information Tracker (iCIIT), pronounced "eyesight", is a near real-time visual management solution that provides a prioritized list of what should be worked right now, and a performance visual that indicates trouble spots within the plant. ANAD has installed iCIIT in three of our high-volume processing shops, and one in-process distribution warehouse. As is common in many industrial manufacturing/remanufacturing operations, our metal cleaning and finishing operations are a throughput constraint, and time lost in those shops negatively impacts the critical path of our production projects. iCIIT is the ANAD solution, and is scalable to the Army Material Command enterprise. ANAD uses iCIIT in two modes, active and passive. The passive mode shows information on the shop floor via monitors hanging on the wall and it requires no individual to be logged on to the computer continually pushing a button to keep the data refreshed. It refreshes itself every 15 minutes with data based on when the artisans complete the work.

iCIIT reviews the work that is currently at a specific process, prioritizes that work based on an algorithm, then puts the highest priority work on the top of the screen. Artisans simply work from the top down, working the next item on the list. Once they complete the work and scan it out, it is removed from their iCIIT priority screen. The active mode shows the same information, but is adapted to work with hand-held tablets. This allows individuals that pull and stage material to walk around in the warehouse or holding lot and prioritize what needs to come into the shop next based on the priority provided by iCIIT. Since the data is updated every 15 minutes and the priority is always current, artisans and material handlers are able to work efficiently because they are working on what they should be working on right now… back to question 1 above. Before ANAD implemented iCIIT, we relied heavily on individuals to push the priority work through the processing shops, which meant we had many individuals working hard just to keep parts flowing. Now that we have implemented iCIIT, we allow the system to tell us what we need to work, freeing up individuals that previously pushed parts to focus on other tasks. iCIIT is an innovative solution to an age-old problem that plagues every production environment. It is so innovative that the Army Material Command (AMC) and the Logistics Modernization Program PMO have recognized the value that iCIIT brings to the Army and have plans to develop an enterprise version for all AMC industrial sites.

PROBLEM STATEMENT

- Production shops are continually asking themselves what should I be working on right now? To answer this question they have to continually rely on manual communication with project managers and production expeditors. This is an inefficient process that has high levels of human error and bias because project managers always want their work to be prioritized number one.

BENEFITS

- A robust, easy-to-use visual application that provides insight into a process and/or shop's performance.
- Provides a prioritized list of material to be worked using customizable algorithms, which can be increased on high priority programs with senior leadership approval.
- Displays are customizable to allow monitors to display a single or a grouping of processes and/or shops.
- Near real-time data is refreshed every 15 minutes, keeping what is displayed on iCIIT relevant to the material at the shop.
- User drill-down capabilities that provide additional data related to specific material showing on the priority screen.

TECHNOLOGY SOLUTION

- The Industrial Complex Integrated Information Tracker (iCIIT) provides near real-time visualization of work priority and production performance of a production processes or shop.
- iCIIT is capable of active and passive modes. Active mode allows iCIIT to be used on portable handheld tablets and desktop PCs, and passive mode allows iCIIT to be continually displayed on the shop floor without requiring a user to stay continually logged in.
- iCIIT is scalable to the AMC enterprise.
- Drives increased efficiency and effectiveness.

AUTOMATIC GENERATION AND PRESENTATION OF TASK-RELEVANT, ELECTRICAL MAINTENANCE DOCUMENTS

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This innovation applies digital data continuity across the electrical system (ES) product life cycle to create highly navigable and accurate data for the ES maintenance technician.

Rapid, accurate, configuration-specific, electrical system maintenance remains essential to ensure that military equipment has the highest mission availability and the lowest down time possible. Creating and using maintenance documentation remains a challenge. It is often a lengthy and error-prone process. It requires assembling data from disconnected sources and re-entering it manually or via data minimizing translation. From the technician's perspective, a book of physical documents is cumbersome to use, delays the repair, and can be outdated and confusing.

This leads to technician disorientation and the application of incorrect maintenance procedures that could result in accidents and negative impacts to platform mission availability.

Applying digital data continuity (DDC) to automate the generation and presentation of ES maintenance documentation solves these problems. DDC connects a platform's ES data model across multiple phases of its life cycle – from product definition, through design, into manufacturing, and finally on to service. It also links the ES data model to adjacent data describing the platform (e.g. mechanical & meta-data). Data describing the ES during each phase is stored, tracked and made available to enrich work undertaken in other phases.

DDC enables automated document synthesis that draws directly on the electrical system data model. This approach eliminates data re-entry and transfer errors, rapidly producing platform-specific maintenance documentation that accurately reflects all the details of the ES the first time. This documentation can be expressed in physical or virtual form using predefined, interactive formats. In addition, documentation packages can be automatically regenerated to account for changes made at any phase in the life cycle. This allows them to easily keep pace with ES variants and any type of change.

Coupled with a smart viewing environment, it also delivers maintenance technicians only the specific information relevant to the task at hand. Advanced "Click & Sprout" technology allows technicians to hone in on a single problematic point in the ES, and render all relevant connections to it. These can be dynamically explored to find the root cause of the problem and fix it rapidly. Technicians can also explore the ES meta-data in deep detail, to focus on specific systems, connectors and devices in the desired context (e.g. 2D/3D location views, connector pin-out views). In this way, DDC delivers model-based, task-specific documentation that intuitively orients and assists the maintenance technician.

This results in reduced maintenance and repair time, increased platform service availability and increased maintenance accuracy, reducing failure recurrence and maintenance induced accidents.

PROBLEM STATEMENT

- Platform mission availability negatively impacted by lengthy or inaccurate electrical system (ES) maintenance:
  - Can lead to incorrect repairs & accidents
- Technicians' challenges with ES maintenance documents:
  - Cumbersome & confusing to use.
  - Often outdated or inaccurate.
- Documents production can be lengthy and error prone:
  - Requires data from multiple disconnected resources:
    - Often requires manual data reentry, or
    - Data minimizing translation.
  - Often manually generated.

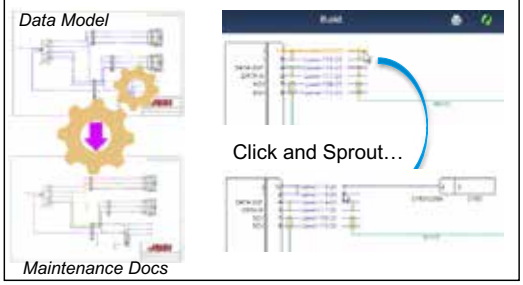
BENEFITS

- Correct-by-construction service diagrams:
  - Faithful to design & manufacturing data model.
- Effectivity-aware/tail-specific service information.
- Automatic, rapid doc preparation from existing source data:
  - Demonstrated 36% average efficiency increase.
- Intuitive, interlinked platform data, procedures, work instructions.
- Dynamic tracing signals and relevant connections around them.
- Less flow chart tracing / looking for data:
  - More inspections / fixes.
  - Demonstrated 38% average efficiency increase.
- Resulting in:
  - Rapid isolation & repair of problem areas.
  - Increased platform mission availability and uptime.

TECHNOLOGY SOLUTION

- Digital data continuity across the ES value chain:
  - Engineering to manufacturing to service.
- Programmable synthesis engine:
  - Mines/weaves data into single documentation product.
- Rule-based layout and graphics control engine:
  - Enables data reuse, repartitioning, & restyling.
- HTML5 interface:
  - Connects service diagrams, procedures, & supporting artifacts.
- User-driven view of the electrical content:
  - System/component/signal-specific presentation.
- Dynamic generation of context-specific connectivity diagrams:
  - From underlying system or harness-level connections.

Auto Generation | **Task Relevant Presentation**



NAVITAS SYSTEMS STARLIFTER LITHIUM FORKLIFT BATTERY FOR MATERIAL HANDLING PRODUCTIVITY IMPROVEMENTS

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The Department of Defense (DoD) owns and operates large fleets of Class 1 & 2 forklift trucks for material handling purposes. Many of these forklift trucks are electric and powered by very large lead acid batteries. While sufficient for low intensity warehouse applications, the 100+ year old lead acid chemistry has inherent deficiencies for high intensity multi-shift warehouses, hot temperature warehouses, and/or cold temperature warehouse applications.

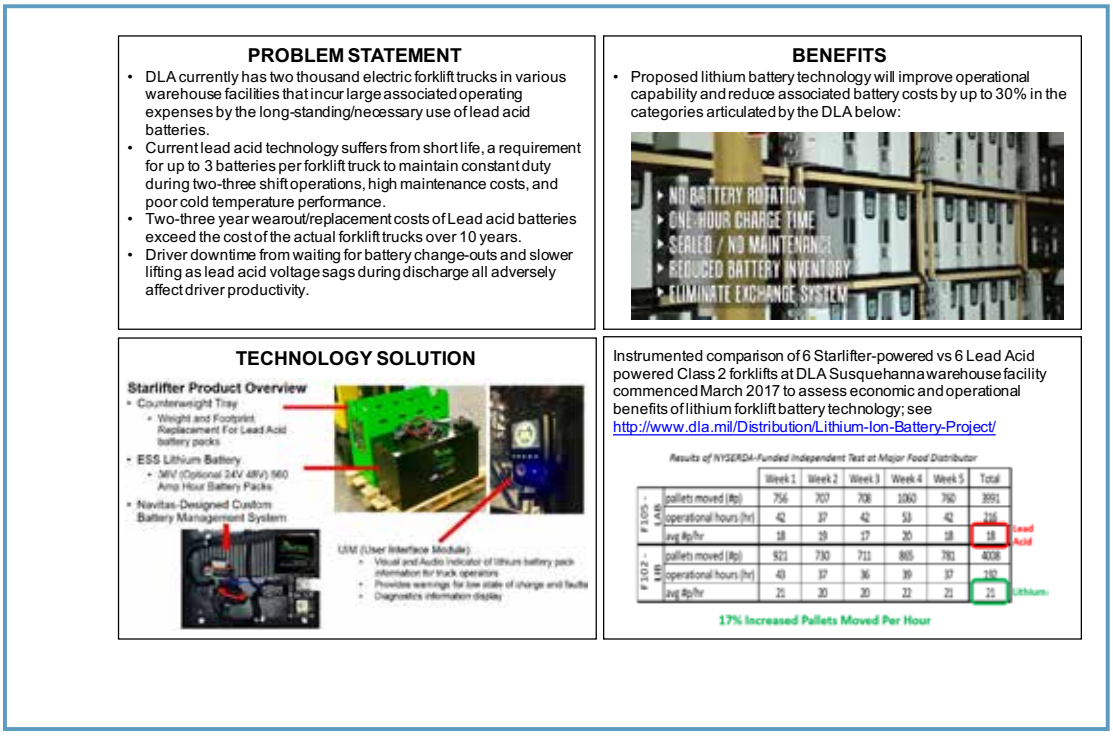
- Low cycle life requiring replacement every 3 to 5 years
- Regular maintenance required including watering and battery equalizations
- Sulfation problems when left in a partial state of charge for long periods, causing reductions in daily battery runtime and permanent damage to the battery
- Faster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

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

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

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

The next steps / potential benefits include strong applicability across the government. DLA San Joaquin is next to implement StarLifter to replace use of propane forklifts within their cold distribution warehouse; the Navy has shown strong recent interest aboard ships to replace lead acid forklifts under main decks.



MISSION-BASED FORECASTING

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Neither the Department of Defense (DoD) nor the Congressional Budget Office have been able to establish a well-defined linkage between Operations and Maintenance resource funding levels and the resulting readiness of military units. For nearly three decades, the Government Accountability Office (GAO) has attributed these inadequacies to poor demand forecasting, ineffective inventory management, and inadequate strategic planning.

To address these persisting problems, the U.S. Army established the project to Transform Army Supply Chains (TASC) in order to investigate the nature, causes, and consequences of demand uncertainty and supply variability. The TASC project developed an enterprise framework to facilitate analysis, synthesis, evaluation and design for the sustainment enterprise, then identified and tested several "catalysts for innovation" including Mission-Based Forecasting (MBF). MBF is a new concept for demand planning, which relates resource investment levels and distribution policies directly to mission performance outcomes, thereby enabling the "resources-to-readiness" linkage.

MBF fully capitalizes on Big Data opportunities: predictive analytics, innovative forecasting methods, condition-based maintenance (CBM) diagnostic and prognostic algorithms, and the Internet of Things (IoT). Analytical demonstrations and field tests indicate MBF will dramatically improve forecast accuracy, reduce both back orders and excess inventory, and eliminate costly work-around while increasing equipment readiness in military organizations. MBF has since been applied to ground systems and extended to other Military Services.

PROBLEM STATEMENT

The US Department of Defense (DoD) operates the most complex global supply chains in the world. However, effectively integrating production planning, maintenance operations, inventory systems, and distribution policies has been a strategic challenge. According to the GAO, DoD supply chain management is both wasteful and hi-risk due to poor demand forecasting, ineffective inventory management, and inadequate strategic planning.

BENEFITS

- Ability to accurately predict tactical-level demand
- Measure the actual cost of operational requirements
- Align/manage inventory to readiness-driven demand
- "Connect" CBM prognostics to forward supply chain
- Synchronize retrograde and depot repair operations
- Defend resources needed for mission Ao requirements
- Reduce tactical-level "burden" and work-arounds
- Enable "early warning" for sustainment enterprise
- Cost savings estimates on the order of tens of billions
- MBF investment ROI of several orders of magnitude
- Significantly improve tactical unit-level operational Ao

TECHNOLOGY SOLUTION

To identify potential "catalysts for innovation", the US Army established the project to Transform Army Supply Chains (TASC). Mission-Based Forecasting (MBF), a critical enabling catalyst, is a new concept for demand planning which capitalizes on big data, the Internet of Things, and predictive analytics to support military operations. MBF testing suggests order-of-magnitude reductions in forecast error, inventory savings of billions of dollars, and reduction of manpower-intensive work-arounds at the tactical level.

UTILIZING GENETIC ALGORITHMS (GA) TECHNOLOGY FOR A BRIGHTER FUTURE

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The United States Military is at a disadvantage in regards to military forces across the global spectrum, particularly when it comes to aircraft platforms. Several of the aircraft we commonly use date back to the mid-fifties (C-130, B-52, A-4), with our most versatile fighter aircraft (F-18) being introduced in 1983. The B-52 Stratofortress (introduced in 1955) is slated to remain in service until the late 2040s, which would make the aircraft over 80 years old before finally considering potential replacements. Although these aircraft are versatile and useful to the military, their continued use over immense periods leads to several different issues in maintenance and operability. In recent years, the United States Marine Corps has had to consistently cannibalize parts from decommissioned aircraft in boneyards, museums and static displays across the country in order to keep these aging aircraft in the air. Does that sound safe? To top these issues off, a recent study was released that showed the United States is on a slower trajectory towards technological aptitude than most developed countries, which could potentially set us back up to fifty years in comparison. This is not to say that the military is not trying to bring itself to the forefront of global operability, but our advances have come with their own set of problems. Just pertaining to relatively new Navy platforms, the P-8 Poseidon is prone to saltwater corrosion on its stainless-steel components, leading to the popular idea that human design flaws may have contributed to design flaws in the aircraft; on the surface side, the USS Gerald R. Ford's introduction to the fleet was set back several times as it struggled to pass the testing phase of its new Electromagnetic Aircraft Launch, Advanced Weapons Elevator, Dual Band Radar and ship defense systems.

As a solution to these problems, I suggest the utilization of genetic algorithms. This a computer program utilizing mathematical, highly parallel and adaptive search procedures based loosely on the processes of natural genetics and Darwinian survival of the fittest. It can be utilized by the Navy to make rapid prototyping of not just entire aircraft and shipboard platforms, but also each system, subsystem or component. The program can run for a few hours, a few days, or a few months before a solution is presented or a specific time termination can be applied. Studies conducted by both its inventor and third party researchers have proven that genetic algorithms are not only human comparable, but free of any human preconceptions (it also provides for advances that humans have not yet conceived). Universities and schools have utilized the program's combinatorial abilities to optimize their complex timetables for course scheduling, giving us another advantage that could be used to streamline conferences, school houses, fleet deployments or manpower distribution. NASA's Evolvable Systems Group has used genetic algorithms to design evolved antennas for satellites and believe it is unlikely that a human expert would have devised such an unconventional design with the same effective results.

PROBLEM STATEMENT

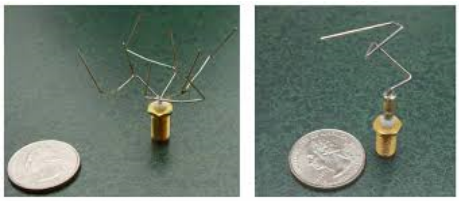
- Aging aircraft that need a modern replacement.

BENEFITS

- Lower cost
- More efficient use of modern technology
- Program can be utilized for more than aircraft design, such as individual systems, subsystems or component
- Potential for never-before-seen aircraft that should rival enemy craft
- Rapid prototyping available
- Easily customizable for mission specifications

TECHNOLOGY SOLUTION

- Utilizing a genetic algorithm, create new designs based from old specifications. Results are usually more innovative and efficient than man-made designs, yet human comparable.



The 2006 NASA ST5 spacecraft antennas. This complicated shape was found by an evolutionary computer design program to create the best radiation pattern. It is known as an evolved antenna.

ASSET VISIBILITY AND HEATH MONITORING (AVHM)

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According to QDRs, approximately 33% of all T700 engines are shipped back to CCAD for investigation and repair. Engine assets are not monitored for health conditions or environments that can degrade engines. The cost associated with sparing, shipping and handling of the T700 family of engines is a high cost driver to Army Aviation. Overall Goal is 10% reduction in the number of aviation common engines requiring depot level repair and disposition an environment monitoring during transportation and storage. Develop methods, processes and data sources to evaluate the environmental impacts to engines during exposure to transportation and storage environments. Apply this technology to other high cost driver components and subsystems.

A demonstration was conducted in order to validate the capabilities of total asset visibility and its practicality for use by Army Aviation and Missile platforms.

The goals of this demonstration are as follows:

- Demonstrate the ability to transmit data from within an Army approved container.
- Understand any lag time in sensor data from ambient conditions to container conditions.
- Demonstrate practical battery life.
- Demonstrate sensitivity of all sensors.
- Understand any lag time that may result from the use of a silicon lid.
- Demonstrate the difference in the capability to transmit inside a container between autonomous location and assisted location.
- Demonstrate Geofences and probable uses.
- Demonstrate the ability to remotely change the configuration and settings associated with the device.

The device selected for demonstration is a low cost COTS device with the ability to log and report location and environmental conditions using an array of sensors. It can be utilized while in transit or in long-term storage. The sensor package used for each device during this demonstration is as follows: Location (GPS or Cellular Triangulation), Temperature, Humidity, Light, Infrared, Pressure, Orientation, Shock, Drop, Vibration, and GPS Jamming. The sensor reports to a web based service provided by the vendor. This service allows the user to track each unit individually and control each unit's configuration independently from one another. It allows the user the ability to manage all aspects of the units remotely without the need to physically interrogate the units. Access to this system is user controlled and password protected.

PROBLEM STATEMENT

- Current State: According to QDRs, approximately 33% of all T700 engines are shipped back to CCAD for investigation and repair. Engine assets are not monitored for health conditions or environments that can degrade engines
- Impact: The cost associated with sparing, shipping and handling of the T700 family of engines is a high cost driver to Army Aviation.

BENEFITS

- Overall Goal is 10% reduction in the number of aviation common engines requiring depot level repair and disposition an environment monitoring during transportation and storage.
- Methods, processes and data sources to evaluate the environmental impacts to engines during exposure to transportation and storage environments.
- Apply this technology to other high cost driver components and subsystems

TECHNOLOGY SOLUTION

The device selected for demonstration is a low cost COTS device with the ability to log and report location and environmental conditions using an array of sensors. It can be utilized while in transit or in long term storage. The sensor package used for each device during this demonstration is as follows: Location (GPS or Cellular Triangulation), Temperature, Humidity, Light, Infrared, Pressure, Orientation, Shock, Drop, Vibration, and GPS Jamming. The sensor reports to a web based service provided by vendor.

AVIATION SYSTEM OF SYSTEMS ANALYSIS TOOLSET (SOSAT)

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The System of Systems Analysis Toolset (SoSAT) is a government owned large-scale modeling and simulation tool for analyzing integrated mission scenarios and sustainment operations. SoSAT is a stochastic and state modeling tool that allows linkages, dependencies, and shared functionality across multiple systems. This modeling tool will analyze the effectiveness of technology insertions to existing weapon systems, validation of material developer's reliability predictions and supportability plans for new or upgraded weapons systems, and provides accurate repeatable input for acquisition strategies.

SoSAT is used to create a stochastic and state model of a single AH-64D aviation battalion and a single UH-60M aviation battalion. The model is used to measure the impacts of the ITE as it replaces the T701D turbine engine currently utilized in the UH-60M and AH-64D helicopters. The baseline simulation is modeled from historical data acquired from the MTOE, RAM, OSMIS, and TAMMS-A/MCDS. The modeling and simulation tool, SoSAT 3.0 is verified and validated with Army Material Systems Analysis Activity (AMSAA) and Army Test and Evaluation Command (ATEC).

To perform this analysis, the SoSAT model includes two aviation battalions. A UH-60M battalion of 30 aircraft and an AH-64D battalion of 24 aircraft. The models include over 2000 aircraft components, scheduled maintenance, and all maintenance personnel assigned to the unit by the appropriate Modified Table of Organization and Equipment (MTOE). The simulation is iterated 30 times for each version of the model. During the simulated multi-year period, the baseline model captures over 120,000 flight hours, and almost 300,000 engine-operating hours.

Using the available data for the T701D turbine engine, a model is created which acts as the baseline model. Sensitivities to show the effects of reliability improvements, Mean Time To Repair (MTTR) improvements, modularity, Condition Based Maintenance Plus (CBM +), removal of scheduled maintenance, corrosion, and high/hot missions are created to compare against the baseline model. These sensitivities use variations of the component reliability, MTTR, and the amount of scheduled maintenance.

The SoSAT software captures the down time, failure data, and maintenance man-hours expended for each event created during the simulations. The data from each sensitivity is compared against the baseline model to show potential differences between the currently implemented T701D turbine engine and the ITE replacement.

Results of this analysis provide input into the evaluation of KPPs and KSAs for impacts to sustainment and logistics (AO, AM, AI, reliability, maintainability), the ability to conduct AoA's, APSA, and what if scenario's. SoSAT provides the capability to analysis impacts to readiness due to elimination or increase of maintenance tasks (scheduled or unscheduled), future technology upgrades, or changes to resourcing strategies (personnel or spares).

PROBLEM STATEMENT

Leverage existing government owned simulation software, System of Systems Analysis Toolset (SoSAT), to create virtual models of current and future weapon systems and to use the simulation results to conduct sensitivity analysis, trade studies, and requirements analysis for improving maintenance procedures and optimize maintenance personnel. Acquisition sustainment modeling capabilities required are:

- System Operational Performance
- System Maintainability (Am)
- System Availability (Ao)
- System Repair, Supply and Sustainment Operations
- Cost Per Flight Hour

BENEFITS

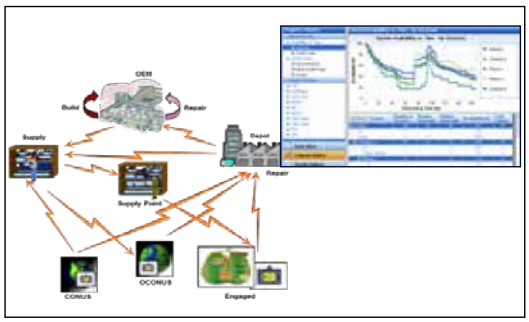
- Pre-milestone A Logistics and Sustainment modeling at a SoS level
- Ability to conduct AoAs, APSA and 'what ifs' to assist in decision making
- Identify areas of maintenance impacts, maintenance manpower, and tools/test equipment concerns in systems and system of systems
- Analysis the effects of the addition of new technologies to the sustainment parameters.

TECHNOLOGY SOLUTION

Aviation System of Systems Analysis Toolset – (SoSAT)

Large-scale M&S tool for analyzing integrated mission scenarios and sustainment operations

- Stochastic and state modeling tool
- Allows linkages, dependencies, and shared functionality across systems
- Verification, Validation and Accreditation with AMSAA and ATEC



COST WISE READINESS

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The purpose of this abstract is to provide a cost wise solution to diminishing manufacturing sources and materiel shortages. The demand for current readiness being driven by the Service Chiefs is challenging due to several factors; increased Operational Tempos, and the contraction of Department of Defense's (DoD) Modernization and Research and Development accounts. As equipment ages beyond its projected life expectancy, the requirement for parts that have seen low/no demand increases. Changes in maintenance practices from Preventative to Condition-based have disrupted the demand, frequency and forecastability of material, thus causing DoD acquisition centers (DLA) to increase the number of times they decertify National Stock Numbers. In order to meet these new demand patterns, industry has introduced innovative engineering solutions aimed at accelerating the regeneration of parts. These solutions are more costly and less timely. Procuring the right material at the right time in the correct quantities is essential to building long term sustainability. Predictive analysis allows for prudent lifetime or safety stock buys and alerts Program Managers to commence engineering solutions. CTG's Proactive Obsolescence Management program delivers sustainable production and repair, and benefits the customer by achieving the right readiness at the right cost. This program reduces sustainment, and configuration problems while slowing operating cost growth. The end result is lowered total cost of ownership by reducing costs and implementing lifecycle cost reduction initiatives.

CTG's program is a three-step process:

1. Bill of Material (BoM) Analysis
2. Course of Action (CoA) Development
3. Bill of Material Monitoring
4. First, CTG engages in Bill of Material Analysis, which categorizes the status of current material.

- *Active* – Material that is currently in production, inventories held by industry are being replenished.
- *Aging/Stable* – Replenishment production has stopped. The only material available is held in stock.Available inventory exceeds Customer demand planning.
- *Aging/Unstable* – Replenishment production has stopped, the only material available is held in stock. Available inventory has been reduced putting the customers demand planning at risk of exceeding industries supply planning.
- *Obsolete* – Material requirements cannot be met by inventory. Only costly engineering measures such as reverse engineering, 3D printing or Engineering Change Proposals can solve this readiness issue.

Second, from our analysis CTG provides our customer with CoAs to ensure operational continuity in the near and mid-term timeframe. Once CoA's are accepted and procurements are executed, PM's are notified of quantities procured and demands forecasted so they can complete engineering solutions in time to meet material consumption patterns. Finally, CTG monitors the BoM health over time ensuring that changes to inventory postures are passed to the customer.

Our presentation will provide insight into the requirements necessary to run the model, explore CoA development in detail and highlight how CoA selection can best address the customer's requirement. We will address each of the issues highlighted in this abstract, offer solutions based on ongoing collaborative efforts, which are producing tangible results.

PROBLEM STATEMENT

- The Services are having difficulty maintaining Operational Readiness due in part to the lack of material availability. Parts and material availability are a critical part of the maintenance process and are essential for mechanics and maintainers to keep their equipment in the fight.

BENEFITS

- Prudent life time or safety stock buys
- Alert program managers to commence engineering solutions
- Delivers sustainable production and repair
- Lower total cost of ownership
- Reduce sustainment and configuration problems
- Slow operating cost growth

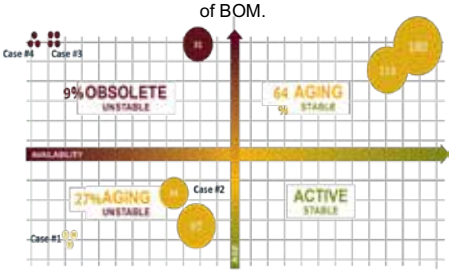
TECHNOLOGY SOLUTION

1. CTG engages in Bill of Material (BoM) Analysis which categorizes the status of current material.
   - *Active*
   - *Aging/Stable*
   - *Aging/Unstable*
   - *Obsolete*

2. From our analysis CTG provides our customer with CoAs to ensure operational continuity in the near and mid-term timeframe.

3. CTG monitors the BoM health over time ensuring that changes to inventory postures are passed to the customer.

The figure below represents the scatter gram of a 450 line item of BOM.



EXPEDITIONARY ROBOTIC INSTRUMENTED PAYLOADS

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Pearl Harbor Naval Shipyard & IMF (PHNSY&IMF) has combined STEM outreach and a culture of affordability by teaming with University of Hawaii (UH) and the U.S. Naval Academy (USNA) to design, test, and field Expeditionary Robotic Instrumented Payloads (ERIPs) that complement the Remotely Operated Underwater Vehicles (ROUVs) used in the shipyard's maintenance, salvage, and mobile repair efforts. These payloads allow for specific modular capabilities required by the shipyard dive locker at a cost less than commercial procurement of a similarly capable system while strengthening ties to universities. This teaming relationship further exposes students to PHNSY&IMF resulting in possible future collaborations and an increased pool of future candidate employees.

This project improves the PHNSY&IMF ROUV program that supports inspection, maintenance, repair, and salvage throughout the Pacific Fleet area of responsibility. Improvements resulted in increased capability, increased capacity, and reduction of resource requirements. As an offset, a decrease in capacity specific to particular capabilities was realized where equipment inventory exceeded realistic use cases based on current workload and manning profiles. No mission degradation occurred as a result of the capacity reduction. Rather, capacity was traded for improved capability across several functional areas, many of which expand the PHNSY&IMF underwater portfolio to better respond to Fleet needs using immediately forward deployable assets. Mission continuity in potentially contaminated environments was achieved with a phased risk profile of assets to minimize system degradation, financial impact, and human exposure to unsafe conditions.

The main successes of this project include:

1. Identification of replacement ROUVs for legacy vehicles that add capability and capacity
2. Launching multiple partnerships between PHNSY&IMF and academic institutions for developing ERIPs. This enables PHNSY&IMF to reproduce ERIPs, which significantly reduces costs over the life cycle of the robotic assets and allows scaling of capabilities at a fraction of the cost of commercial procurement. This savings may be spread throughout the Naval enterprise and other shipyards who are interested in our products.
3. Addition of stereoscopic 3D mapping of hull features using the UH-developed ERIP
4. Addition of modular robotic arms capable of interchangeable tools using the USNA-developed ERIP
5. Addition of capability of emergency fly-away ROUV for single-use cases (e.g., radiologically contaminated environment, battle damage that risks human presence, etc.)
6. Restoration of original ROUV inspection throughput with increased capabilities.

Total cost to PHNSY&IMF is $48,000. Total savings is estimated at $325,250 immediately with $5,793.95 saved per inspection dive. An additional $107,000 in savings is realized per use of the sacrificial dive robot. These savings omit the reduction of personnel, returning Ao to the Fleet, and other non-material factors.

PROBLEM STATEMENT

Properly outfitted remotely operated underwater vehicles have become prohibitively expensive to own, operate, and maintain for maritime inspections:

- Integrated commercial robotic systems lack necessary capabilities or are prohibitively expensive
- Proprietary interfaces prevent third-party capability expansion
- Mission-specific upgrades unable to be quickly fielded
- Proprietary payloads often unable to be physically separated from robotic host as stand alone capability

BENEFITS

- Allows for procurement of lower-cost host ROUVs
- Reduces cost of payloads by incorporating design, development, and testing into student projects
- ERIPs are manufacturable and reproducible by sponsoring organization resulting in at-cost production for future copies
- Payloads tailored & developed to meet future mission needs
- Payloads adaptable to future robotic host platforms; payloads optionally used as stand-alone or diver-carried
- Increases STEM outreach by teaming with universities

TECHNOLOGY SOLUTION

ERIPs provide mission-tailored, low-cost capabilities using an ROUV to host configurable mission-essential payloads.

- Modular robotic arm developed with U.S. Naval Academy
  - ⇒5+ degree of freedom motion that exceeds human arm
  - ⇒Modular shoulder joint allows for interface with various host robots, ship's hull, or static objects (e.g., mount on harbor bottom)
  - ⇒Modular hand joint allows for development of various graspers, cutters, and other manipulators
- Stereoscopic 3D vision developed with University of Hawaii
  - ⇒Underwater 3D point cloud mapping
  - ⇒Improves battle damage assessment and ship inspection

IFDIS ENABLES COST EFFECTIVE READINESS

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Today's defense environment requires responsive and affordable solutions to global weapon system support challenges. U.S. forces are simultaneously engaged in multiple humanitarian assistance and disaster recovery operations; rebuilding a nation in Iraq, drawing-down major combat operations in Afghanistan, fighting terrorism around the globe, and maintaining a deterrent to strategic-level threats like cyber warfare and weapons of mass destruction. However, as operations have increased, the DoD's ability to economically sustain them has become increasingly challenging. The high, sustained operations tempo over the past fifteen years in harsh environments has eroded weapon system readiness and reduced expected life span. Recapitalization of systems has been complicated by sequestration, continuing resolutions and the cancellation of weapon systems modernization programs.

No Fault Found (NFF) test results in electronic boxes, primarily driven by intermittent faults, have become a significant concern and huge maintenance and life-cycle cost driver, and an operational readiness degrader within the DoD. For many DoD weapon systems components driven to the depot for repair, less than half have the actual root cause of the problem identified and repaired. The other half test NFF. Conventional Automatic Test Equipment (ATE) was not designed to detect intermittent faults and is incapable of detecting and isolating momentary intermittent failures that cause NFF. The undetected and unrepaired intermittent faults cause many DoD weapon systems to malfunction during operation, because these faults are not detected, and hence not repaired at I-level or in the depot. Rather, the NFF systems continuously cycle between the field and depot consuming an enormous amount of resources, negatively impacting maintenance budgets, warfighter readiness and warfighter support. Currently, NFF is a $2B to $10B annual non-value added expense to the DoD.

A solution to this problem has been developed and proven under a Small Business Innovation Research (SBIR) initiative. The Intermittent Fault Detection & Isolation SystemTM (IFDISTM) was specifically designed to detect and isolate intermittent faults in electronic wiring. Its initial adaption was to detect and isolate the intermittent faults in the F-16 AN/APG-68 Radar System Modular Low Power Radio Frequency unit (MLPRF) chassis. IFDIS testing during the first few years of operation yielded unprecedented results. The operational reliability of the IFDIS tested MLPRFs has more than tripled. A cost benefit of over $200 million has already been realized with an investment of only $2.2 million (1700% ROI). Because of this tremendous success, IFDIS has been expanded to the F/A-18 Generator Convertor Unit (GCU) with similar results achieved. IFDIS is a proven solution making a positive impact on readiness today and can be utilized on any platform for any service.

PROBLEM STATEMENT

No Fault Found (NFF) test results in electronic boxes, primarily driven by intermittent faults, have become a significant concern and huge maintenance and life-cycle cost driver and an operational readiness degrader within the DoD. Conventional ATE was not designed to detect intermittent faults and is incapable of detecting and isolating momentary intermittent faults that cause NFF, leaving them unrepaired. These NFF systems continuously cycle between the field and the depot, consuming an enormous amount of resources, negatively impacting maintenance budgets, warfighter readiness and system availability. Currently, NFF is a $2B to $10B annual non-value added expense to the DoD.

BENEFITS

- Significant reduction in No Fault Found (NFF) occurrences
- Substantial reduction or elimination of MICAPs
- Enormous reduction in maintenance cost
- Increased operational availability
- Provides cost effective readiness
- Substantial reduction in repair cycle-times
- Reduction in Lost Operational Days (LOD)
- Eased work load forecasting & management
- Superior war fighter support
- Improved maintenance processes and procedures
- $2B to $10B cost benefit (assuming full DoD deployment)
- 1700% Return on Investment (ROI) already achieved by DoD

TECHNOLOGY SOLUTION

The Intermittent Fault Detection & Isolation System (IFDIS) was specifically designed and purpose built to detect and isolate intermittent faults, enabling them to be repaired. The IFDIS accomplishes this task by monitoring ALL circuit lines in an electronic box chassis ALL the time while the chassis is subjected to an operational environment. By identifying and correcting the root causes of the random, intermittent, recurrent failures, increases reliability of the diagnosed systems and subsystems. Reducing the failure rate of LRUs directly benefits the warfighter, reduces maintenance resource demands and provides cost avoidance opportunities.

Intermittent Fault Detection & Isolation System (IFDIS)

ASSET LIFE-CYCLE INFORMATION MANAGEMENT (ALCIM)

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

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

Specifically, ALCIM integrates:

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

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

This combination of the LifeMeter and ARViSS programs combined with AI machine learning "thumb print" based monitoring provides for a complete machine asset assessment reporting and decision aiding system that can be extended AF wide for critical machine asset maintenance and troubleshooting solution.

PROBLEM STATEMENT

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

BENEFITS

- The *Asset Life-Cycle Information Management* (ALCIM) project addresses the high priority technology needed to provide the Air Force Sustainment Center (AFSC) ***the ability to maintain objective assessments of Overall Equipment Effectiveness (OEE), provide prognostic status information and understand the impact of machine downtime to depot throughput.***
- Provides
- Provides key ***information about user interaction behavior for more efficient shop operations for future application refinement.***

TECHNOLOGY SOLUTION

- ALCIM integrates two successful SBIR programs for engineering analysis and decision support: 1) The **LifeMeter** condition-based machine asset maintenance program, and 2) The **ARViSS** (Analysis of Resources with Visualization and Integrated Simulation Support) information visualization and simulation program.
- ALCIM provides WR-ALC engineering with integrated "data wall-display" solution. Provides Condition-Based Maintenance (CBM) information indicating status of LifeMeter instrumented machines and alerts to out-of-tolerance operations.
- Uses embedded **machine learning AI models** to "thumbprint" normal operations that alert maintainers of "out of normal range" conditions using *multiple condition indicators*

HT-128 HANDHELD WIRING ANALYZER

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The Department of Defense (DoD) faces ongoing challenges with aircraft readiness rates across multiple platforms due largely to aging wiring and increasingly complex electronic systems. Recent activities at the Joint Services Wiring Action Group (JSWAG) in Spring 2017, highlighted the special attention being given to electronic wiring interconnect systems on aircraft and focus on training efforts to help maintainers meet operational goals.

The HT-128 Handheld Wiring Analyzer is an easy-to-use, cost-effective solution to assist avionics technicians from all branches of service and all aircraft platforms in daily aircraft troubleshooting to quickly locate faults and return aircraft to flight ready status.

This dual-function tester, with 128-point continuity analysis and TDR capability, is expandable up to 8 units (1,024 test points). Individual testers connect to each wire harness branch connector, testing for opens, shorts, mis-wires, high resistance connections, and verification of passive components. Short adapter cables eliminate the need for shorting plugs or long loop-back adapter cables.

Test results report on-screen with measured values of all tests logged in printable error reports. HT-128's can communicate wirelessly, or in-line through the UUT, depending upon the requirements of the end user. Optional TDR (currently under development) allows the user to diagnose harness failures and trace the fault to a specific location within the wire harness. Programming is simple, with minimal training using a Microsoft Excel™ template, the user is ready to test within minutes.

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

Attendees at the JSWAG Spring 2017 meeting from the MV-22, H-60, H-64, H-53, F-18, C130, and F-35 platforms expressed great interest in implementing the HT-128 to complement currently utilized test equipment on the flight line. Simulation data suggests enormous benefits to all branches of service in faster turnaround times, drastically reduced maintenance man-hours and cost savings compared to the digital multi-meters used on the flight line today. A comparison of current test methods using DMM's to the HT-128 on a 100 wire harness, testing for continuity and isolation, showed a savings of 2.40 man-hours for one test. The reduction in man-hours can be translated into increased aircraft availability as technicians accurately and expeditiously complete assigned maintenance tasks.

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

PROBLEM STATEMENT

- Declining aircraft readiness rates across multiple aircraft platforms in all branches of service largely due to aircraft wiring.
- Key contributing factors are; aging wiring, increasingly complex electronic systems, maintainer knowledge and current troubleshooting methods
- Countless hours spent specifically in troubleshooting and fault isolation of aircraft electronic wiring interconnect systems, not specific to any one platform.

BENEFITS

- Reduction in maintenance man-hours spent in troubleshooting and fault isolation
- Faster aircraft turnaround times
- Cross-service application adaptable to all aircraft platforms
- Minimal training required
- Cost effective solution compared to current automated test equipment available to all branches of military.

TECHNOLOGY SOLUTION

- Rugged, portable handheld testers
- Easy-to-use
- Cost effective
- Dual-function 128 point continuity analysis and TDR.
- Expandable up to 8 units (1,024 test points)
- Accurately tests for opens, shorts, mis-wires, high resistance connections and verification of passive components.
- Test results displayed to screen with measured values stored in printable error reports.
- Wireless or in-line communication
- Simple programming using Excel template or generated test programs using Automatic Program Generation software

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

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The Department of Defense (DoD) Maintenance Community needs being addressed include:

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

To affordably find activity patterns of interest in 'big maintenance data' we need turnkey intelligent data-driven and goal-driven systems. Data Fusion & Neural Networks (DF&NN) is proposing to develop such a CBM+ system based upon a TRL7 system it has delivered to three sites. This Goal-Driven Condition-Based Predictive (GCPM) system automatically learns normal activities in 'big' State of Health (SOH) data sets over many months and then provides abnormality detection scores in real-time for moving time windows of data of over 10K measurands. These abnormality detection's are clustered, classified, and tracked over time with the capability for the user to add the desired response for each abnormality type. As such the system detects the unexpected 'unknown-un-knowns'. Temporal pattern recognition tools are added to predict effects of detected abnormality precursor signatures based upon historical data.

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

DF&NN is proposing to adapt Data-Driven Condition-Based Predictive Maintenance (DCPM/GCPM) to detect and characterize abnormal behavior in VDATS self-test outputs. The GCPM tells DCPM when to retrain, what to retrain and test on, and when to promote to real-time operations. The Bayesian Fusion Node (BFN) web services support all levels of data fusion defined by the DF&RM Dual Node Network (DNN) technical architecture. The DF&NN Performance Assessment and Process Management (PAPM) capability computes the Probability of Detection, Probability of False Alarm, accuracies, and other Measures of Performance for the abnormalities and responses provided by these tools for each application. We propose to apply these PM tools to improve the CBM+ parameterization.

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

- DCPM affordable solution to unexpected precursor abnormality detection & characterization to extend CBM+.
- GCPM turnkey capability that automatically retrains DCPM to learn dynamic normal health behaviors.
- Identify when VDATS needs the more expensive recalibration process based on self-test data.
- Provide extensible, scalable, cross-platform and multiple user CBM+ for C-130 in PAMSS and test stations in VDATS.

PROBLEM STATEMENT

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

BENEFITS

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

TECHNOLOGY SOLUTION

- DCPM uses ANOM TRL7 data fusion and neural networks to detect unknown abnormal fault precursors for historical C-130 engine & VDATS data which DF&NN has already converted
- DCPM detects and characterizes abnormal behavior in VDATS self-test outputs
- GCPM tells DCPM when to retrain, what to retrain and test on, and when to promote to real-time operations
- Smoking Gun finds high confidence correlations with Reliability and Maintainability Information System (REMIS) data
- Bayesian Fusion Node (BFN) services support all levels of data fusion defined by the DF&RM DNN technical architecture
- Correlate abnormalities to historical REMIS data and use REMIS to determine when to retrain

NIGHTHAWK: NO FAULT FOUND REDUCTION SOFTWARE TOOLSET

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NightHawk™ ETRS is an interactive software test development, platform system that can be applied to augment standard Test Program Sets (TPSs) that will find, reduce, or eliminate No Fault Founds (NFFs) on LRUs and circuit card assemblies (CCAs) that are integrated to current weapons systems. This software has been shown to be effective on a variety of Air Force CCAs using the Air Force VDATS ATE platform. With funding from the Air Force WR-ALC, Ridgetop Group, Inc. has developed advanced anomaly detection algorithms embodied into NightHawk to detect problems not otherwise found that contribute to NFF test results.

With assistance from the Air Force WR-ALC Test Integration subcontractor at Warner Robins (ALAE), an extensive battery of tests have been conducted on complex Air Force and commercial sector CCAs.

Ridgetop tests have been applied to complex Air Force sub-assemblies such as Voltage Controlled Oscillator boards from Electronic Warfare (EW) systems that incorporate a mix of Digital, Analog and RF technologies. The NightHawk results have proven detection of difficult "Soft Faults" from degraded components that would ordinarily escape detection and would be reported as NFF.

The potential cost-avoidance enabled by NightHawk is conservatively estimated at $2 million per year per "bad actor" Circuit Card Assembly (CCA) part number in direct maintenance costs. There are additional savings from reduced indirect logistic and inventory management and increased asset availability. This is based on a very conservative estimate of 100 instances of "bad actor" CCAs, each incurring an average of two unnecessary maintenance actions at a round-trip cost of $10,000 in FY2014 dollars. The cost avoidance for just three types of bad actor ALQ-172 CCAs over the next five years is over $30 million.

More recently, Ridgetop has expanded the algorithm set and tool functionality to include electro-mechanical assemblies, such as power drive systems for actuator assemblies. Extending this technology to other aircraft and subsystems assets will further enhance cost-avoidance. This technology has leveraged Lean Depot Management System (LDMS) historical data and CCA analysis to enhance the efficiency and efficacy of the standard ATE test platform, (VDATS). Prioritized diagnostic and repair actions achieve cost-avoidance through reduced mean time to repair (MTTR) (60%), reduced frequency of NFF codes (40%), increased mean time between maintenance events (MTBE), and increased utilization efficiency of the VDATS platform. The net result is higher asset availability at reduced cost.

NFF test results on defective CCAs are a daunting problem for both the DoD and private industries with estimates indicating as high as 50% NFF on legacy aircraft electronic modules. As the average Air Force asset age is 23 years, legacy system components require testing abilities conventional TPS are not capable of providing. NightHawk is the proven enhancement that provides cost-avoidance by reducing NFF/CND occurrences. NightHawk™ is a DoD-wide application solution with many instances of future benefits that could serve rapid response platforms such as deployed UAVs.

PROBLEM STATEMENT

- *What problem or need does this technology solve?*
- Conventional test program sets (TPS) are not adequate when handling "No Fault Found" or NFF conditions. These NFFs result from aging systems subjected to harsh environments, parameter drift, and component degradation.
- With NightHawk, Ridgetop provides algorithmic methods to root out "Bad Actor" CCAs and electronic modules.
- Provides current documentation repository for test articles and TPSs.
- Is an enhanced test program set capable of detecting anomalies that contribute to intermittencies in critical systems.

BENEFITS

- Directly addresses problematic NFF and Intermittencies
- Reduction of NFF instances by up to 40% and Mean-time-to-Repair reduced by up to 60%.
- Non-intrusive tool that connects to the system under test that costs less than $90K.
- Predictable warranties are possible thereby achieving more value for NPV dollars spent. Condition Based Maintenance (CBM+) is facilitated by up to 50% cost savings.
- Potential cost avoidance enabled by NightHawk™ is conservatively estimated at $2M per year per "bad actor" CCA of direct maintenance costs using NightHawk™ on depot test systems.
- Brings powerful algorithms to solve difficult NFF problems.

TECHNOLOGY SOLUTION

- Interactive software test development platform system (test tool box) that will find, reduce, or eliminate No Fault Founds (NFFs) on LRUs, CCAs, WRAs, and components that are integrated to current weapons systems.
- Provides a unique anomaly detection algorithm library to augment current capabilities in VDATS. NightHawk roots out difficult to find NFFs.
- Consolidates and creates a storage framework for test-related data such as schematics and layouts, for rapid TPS enhancements.
- Operates on the Air Force VDATS platform with the goal of having NightHawk on every VDATS system. Software algorithms can be ported to other ATE platforms with additional funding support.

ENHANCED HUMS FOR FIXED-WING AIRCRAFT

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

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

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

PROBLEM STATEMENT

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

BENEFITS

NEAR TERM BENEFITS

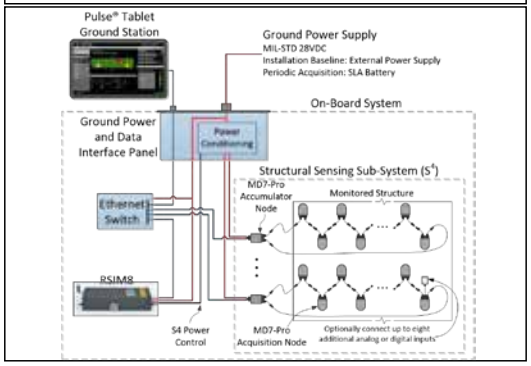
- Reduction in maintenance cost
- Reduction in inspection costs
- Improved asset availability
- Improved maintenance logistics
- Service life extension

LONG TERM BENEFITS

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

TECHNOLOGY SOLUTION

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



CBM+ DEMONSTRATION FOR P8 AIRCRAFT AUXILIARY POWER UNITS

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The P8 Auxiliary Power Unit (APU) is the military variant of Honeywell 131-9B APU, which has over 2,000 installations worldwide for Boeing 737 Aircrafts. It provides Main Engine Start (MES) functions, the first operational functional capability on any airplane. There are no other functional indications of the health of the airplane prior to the start of the main engines (MES & APU functions).

APU health is a primary contributor to aircraft availability. For example, APU "No-Start" health condition ruins the operational 'scramble' requirement for military aircraft. APUs on military aircraft have more severe and critical usage profiles than for commercial aircrafts. Smart Asset Monitoring & Management Systems (SAMMS), LLC. emphasizes the need for continuous monitoring of the operational health of the P8 APU, with evidence of need provided by RCM analysis throughout its operational life cycle. SAMMS will team with Honeywell Aerospace, who is the original equipment manufacturer (OEM) for the P8 APU. The team will apply the same hosting environment Predictive Trend Monitoring & Diagnostics (PTMD) currently used for commercial applications for the P8 APU fleet. The difference being that P8 PTMD system will be hosted on the NAVAIR selected host environment.

Condition-Based Maintenance Plus (CBM+) is a maintenance concept that has predictive usage capability. It uses system health indications to identify and predict functional failure in advance of the event so appropriate action is taken. SAMMS is applying to use the Commercial Technology for Maintenance Activities (CTMA) opportunity to demonstrate CBM+ capability on the P8 APU. The demonstration will focus on "trend analysis" using the P8 APU data.

This demonstration will apply current OEM PTMD algorithms used for equivalent commercial aircraft APUs to show that its use on the P8 will provide the same benefits as is experienced in the industry. SAMMS will demonstrate the benefits, which include avoidance of secondary damage, and extension of time-on-wing for the P8 APU, besides showing the approach can be made platform agnostic. The CTMA demonstration will show the software capability and its use for operational sustainment. We will also show how the analyses and trending can be extended to all other mechanical subsystems on the aircraft.

The OEM has deployed the technology for 12 years, and currently hosts over 5,000 Honeywell APUS. The current Mean Time to Failure for the 131-9B APU on B737 is 6500 Aircraft Hours. Data for the demonstration will be obtained from NAVAIR Propulsion and Power Systems Engineering. NAVAIR PPSE office will provide annotations for the fault events. The performance claims will be shown by the triggered alarms prior to the actual event.

The next steps will develop an engineering program that will instantiate the PTMD P8 CBM+ software deployment on the NAVAIR Propulsion and Power Engineering enterprise platform. We will parse data from the P8 fleet-wide Teledyne airborne system, using their AirFASE ground playback system and Commercial Off-The-Shelf (COTS) analytics software to create large CBM+ impact on critical P8 APU systems. No new hardware, proven COTS software and engineering efforts.

PROBLEM STATEMENT

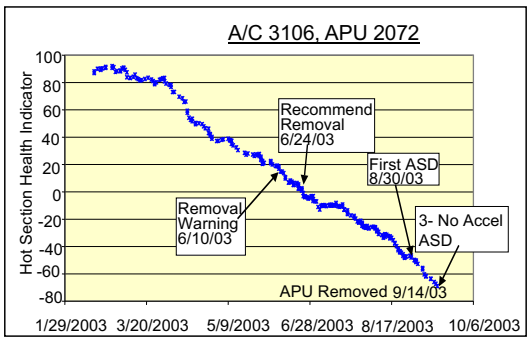
- Demonstrate current commercial web-based APU monitoring SW tool for the P8 military aircraft fleet.
- Provide CBM+ Capability for P8 APU
- Apply OEM Commercial aircraft SW for Failure Prediction and Corrective Action for the military P8 APU Operations & Sustainment
- Provide Continuous Monitoring of P8 APU Operation throughout the APU Subsystem Lifecycle.
- Host a commercial CBM capability on a military enterprise

BENEFITS

- Provide CBM+ Capability for NAVAIR P8 Fleet.
- Improve P8 Operational Availability and maintenance decisions and integrate APU into P8 lifecycle management process.
- Enable Implementation of proven technology and procedures to improve maintenance support for P8 Fleet.
- Improve fault detection, diagnostics / prognostics capability for the P8 APU.
- Can expand current COTS SW to include IETMS and support directed troubleshooting on-wing as well as extended wing time.
- Reduce secondary damage and beyond engine repair (BER) experiences with P8 APU.

TECHNOLOGY SOLUTION

- Existing Algorithms based on OEM physics-based models, Data-driven models and OEM heuristics.
- Fusion Algorithm applied to results, Trended and Displayed for each aircraft and for P8 APU Fleet.
- User Interface for Alarms and Displays modified to suit NAVAIR Propulsion and Power Engineering use.
- Data Parsed from existing P8 Teledyne airborne data collection and AirFace playback system.
- COTS APU analytic software is host web system agnostic and can be hosted on existing NAVAIR web base.



CBM+ DEMONSTRATION FOR JSF F-35 PTMS

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

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

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

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

Data for the demonstration will be obtained from the Joint Program Office (JPO). The JPO will provide annotations for the fault events. The performance claims will be shown by the triggered alarms prior to the actual event.

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

PROBLEM STATEMENT

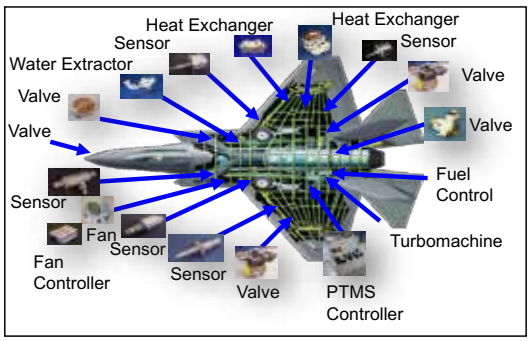
- Demonstrate current commercial web-based APU monitoring SW tool for the F-35 PTMS fleet.
- Provide CBM+ Capability for F-35 PTMS
- Apply OEM Commercial aircraft SW for Failure Prediction and Corrective Action for the military aircraft Power Thermal Management System
- Provide Continuous Monitoring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

BENEFITS

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

TECHNOLOGY SOLUTION

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



PERCĒV INDUSTRIAL INTERNET-OF-THINGS CBM SOLUTION

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Traditionally, planned maintenance (PM) has been used to maintain equipment– a process based on predefined scheduled intervals, which are typically derived from historical data. However, PM does not account for variability in the equipment or how it has been used, which leads to one of two problems: the equipment is maintained more often than needed or the equipment fails – both of which are costly.

A more modern approach is condition based monitoring (CBM) – a process that relies on gathering information from the equipment and performing maintenance only when needed. While this approach obviates the two negative outcomes associated with PM, additional upfront costs are needed to outfit the equipment with needed sensors.

Some of the important attributes of a CBM system include:

- *Configurability* – in the sense that the same core components can interface with a wide variety of transducers so that the same system can be used across all CBM applications.
- *Accessibility* – data and alerts from the CBM system should be available 24/7/365, indicating that cloud integration is a key aspect of a CBM system.
- *Actionability* – a CBM system should provide actionable information, things that personnel can act on without having to consult data analysts.
- *Ease of installation* – which favors systems that are wireless and battery-powered.

To summarize; a capable CBM system monitors key attributes of equipment to detect changes that indicate potential issues before the equipment fails. When such an issues is identified, it sends an alert to assigned personnel. These alerts should not only include the basic facts of the situation (what was detected, etc.), it should also action steps to enable the alert recipient to further diagnose and remediate the issue.

The Civionics Percēv System is an Industrial Internet-of-Things (IIoT) solution that is intended to be used for CBM applications. It combines wireless sensors, cloud-based storage, and advanced analytics to protect high-value assets and the people affected by their failure.

The Percēv System consists of three key components: Percēv Nodes, Percēv CloudGate, and Percēv Decision Workshop. Percēv Nodes are battery-powered, environmentally hardened wireless devices that interface with as many as 20 transducers and process data. Percēv CloudGate is a secure communication channel between Percēv Nodes and Civionics' cloud-based resources. Percēv Decision Workshop is a suite of cloud-based analytics packages and data visualization tools that provide clear, actionable information.

In a recent project, a Percēv System was deployed at Fiat Chrysler's Warren Stamping Plant. Specifically, two tandem-stamping lines were outfitted with Percēv Systems in early 2016. During the system's first nine months of operation, the system provided alerts that prevented two probable downtime incidents, saving FCA $0.5 million in losses—almost ten times the cost of the project. As a result of the initial success, additional Percēv systems have been deployed at the plant and more are scheduled to be deployed over the next several months.

PROBLEM STATEMENT

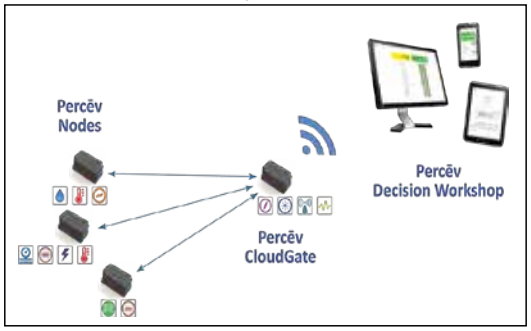
- *Problem 1:* Equipment failure leads to unplanned downtime
  - Expensive – can cost upwards of $1M per hour
  - Disruptive – can cause delivery delays of critical parts
- *Problem 2:* Process variability leads to poor part quality
  - Expensive – costs include parts, labor, and downtime
  - Disruptive – can cause in-field failures
- Root cause: Lack of visibility into machinery health
- A Condition Based Monitoring (CBM) system is needed that:
  - Provides current health status
  - Predicts the future health status
  - Sends alerts when anomalies are detected

BENEFITS

- Benefits of CBM
  - Detect potential problems before they impact production
  - Detect potential problems before they impact quality
  - Reduced facility/machinery maintenance costs
- Benefits specific to Civionics Percēv
  - Alert notifications can include corrective action information
  - Advanced statistical sampling out-of-the-box
  - User defined virtual channels
  - Access to data via exposed API

TECHNOLOGY SOLUTION

- Percēv a wireless, Industrial Internet-of-Things system
- TRL 8 – fully operational at a Fiat Chrysler stamping plant
- The Percēv solution comprises three components:
  - Percēv Nodes: mounted on the monitored equipment
    - Interface with up to 20 transducers
    - Patented edge processing capability
    - Can be battery powered (battery life up to seven years)
  - Percēv CloudGate: Secure 3G or WiFi communications
  - Percēv Decision Workshop:
    - Advanced analytics
    - Intuitive user interface



SCHEDULING ALGORITHMS FOR MAINTENANCE USING PROGNOSTIC LIFE ESTIMATES (SAMPLE)

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The United States Air Force website outlines readiness as one of the vital elements to ensure the operational effectiveness in defense strategies. Deficiency in resourcing for operations and maintenance is stated as the common culprit for poor readiness. Scheduling maintenance activities is a difficult task due to the complex relationships between maintenance operations, constraints on the maintenance tasks and resources, and uncertainties in the performance of maintenance tasks and delivery of required consumable resources. Currently, master schedulers rely on experience and foreknowledge to develop the maintenance schedule. However, unplanned maintenance events can disrupt these static schedules and cause extended downtime of critical equipment, wasted resources and unexpected costs. In addition, there is no means to assist the scheduler in dynamically re-planning that also includes the aircraft detail.

A prognostic scheduling architecture called "Scheduling Algorithms for Maintenance using Prognostic Life Estimates (SAMPLE)" is developed to address unscheduled maintenance events and provide dynamic rescheduling capability. SAMPLE incorporate prognostics to (1) determine preventative maintenance jobs for key aircraft components / systems, such that M future missions are flown successfully with minimized maintenance costs; (2) generate initial maintenance schedule options for a planning horizon of M future missions; and (3) dynamically reschedule / repair the currently executing maintenance schedule, which was previously selected by the maintenance team. SAMPLE employs prognostic-based heuristic / optimization algorithms to generate feasible maintenance schedules that satisfy resource, precedence and mission constraints. SAMPLE will be integrated into an existing flight-planning tool and demonstrated for large-scale scheduling scenarios.

Incorporating prognostic information on critical systems allows one to anticipate future failures based on the monitored condition. Thus, prognostic information can help order needed parts and resources ahead of time so that maintenance is more efficient. It also helps aircraft mission planners update their schedules. There are many operators of large fleets of vehicles and equipment that can benefit from a maintenance scheduler that utilizes prognostic data. Companies such as UPS, FedEx, taxis, truck shipment companies, etc. could benefit from this improved approach to maintenance. Computerized maintenance management software developers could also incorporate this solution into their products.

PROBLEM STATEMENT

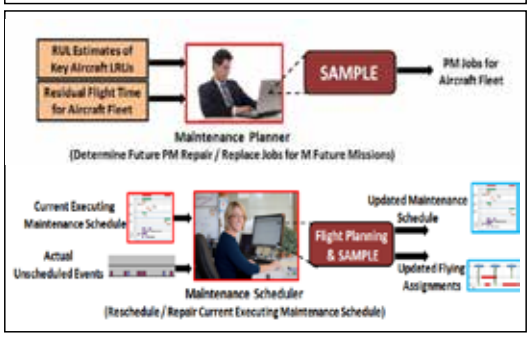
- Unanticipated and unscheduled maintenance actions in the field (organizational level)
- Current re-planning effort is a static level process without aircraft prognostics
- Currently, no means exists to assist the scheduler in dynamically re-planning on the fly that also includes the aircraft detail

BENEFITS

- Anticipating unplanned maintenance improves the performance of maintenance scheduling , increases aircraft availability and decreases maintenance cost.
- Incorporating prognostic information on critical systems allows one to anticipate future failures based on the monitored condition.
- Prognostic information can help order needed parts and resources ahead of time so that maintenance is more efficient.
- It also helps aircraft mission planners update their schedules.

TECHNOLOGY SOLUTION

- Integration of SAMPLE into existing flight planning tool
- Robust / prognostic based scheduling and dynamic rescheduling algorithms
- Maintenance cost and mission risk based optimization models
- Module that determines maintenance actions necessary for M successful missions (aircraft prognostic)



EXPEDITIONARY HYDRAULIC FLUID ANALYSIS

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

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

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

PROBLEM STATEMENT

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

BENEFITS

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

TECHNOLOGY SOLUTION

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

Field Lab 58M

REDUCING OPERATING COSTS WHILE INCREASING PERFORMANCE AND RELIABILITY

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Friction and wear are ubiquitous in lubricated mechanical systems, leading to inefficient transfers of energy to waste heat and expensive maintenance of fielded systems. TriboTEX has developed a novel, evolutionary approach to address the issues of friction and wear by synthesizing dual sided nanosheets that self-adhere to contacting surfaces during normal operation. The proprietary nanosheets are constructed on principles found in nature to exhibit distinct characteristics (sticky/slick) on each side. Due to their unique properties only one side of the nanomaterial can adhere to metallic surfaces leaving the slick side exposed. The slick side of the nanosheets is doped with carefully selected catalysts to promote the formation of a thin diamond-like (DLC) top layer on the substrate coating. This functionality creates a coating with superlubrisious properties that dramatically reduces friction and reverses existing wear on contacting surfaces. This approach offers many key advantages in the areas maintenance because the drop-in formulation can be added to variety of different lubricants without affecting the properties of underlying or carrier lubricating oils. The commercial version of TriboTEX has been deployed in consumer vehicles with documented improvements in fuel economy of 4-8% and increases of engine power outputs of up to 10%. TriboTEX has the ability to improve performance and increase the longevity of fielded systems without requiring traditionally necessary overhauls that require significant investments of time and resource.

PROBLEM STATEMENT

Major Activities/Milestones:
- Major Cap Ex (production reactor)
- Formulation and bench optimization
- 3rd Party testing (SWRI, BH Engines, Wedeven Associates)
- Shipping container design
- In field deployment and case studies

Deliverables / Measures of Success:
- Success: Fuel efficiency >2% Blow By >10% Longevity >30%
- In-field application formulation, application procedures
- GSA Schedule, eMall placement

Potential Risks:
- Production capacity not meeting growing demand
- Technical issues with scale-up

Cost (Estimated): $ 2,800,000 (24 months)

Benefits

TriboTEX offers self forming coatings from flat nanoparticles with two functionally different sides (sticky/slippery) to rebuild and upgrade friction surfaces of lubricated mechanisms during normal operation.

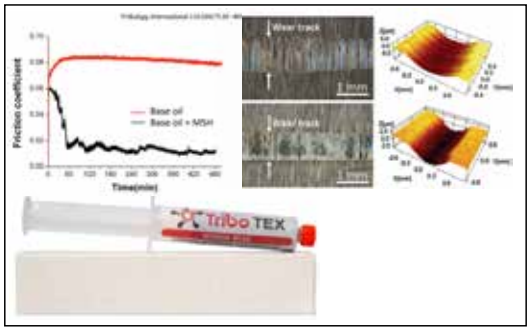
Relevance Including Transition to Military Systems or Programs:
- **Mechanical life extension and efficiency boost of existing machines and gearboxes**
- Mid-life in-field treatment to combat
- Lower barrier of entry point into navy
- Civilian edition (TRL 7) deployed in >10000 cars, demand grows
- Further expansion into other AF platforms
- TRL: Current – 6, Anticipated – 8

Technical Approach

Project Objectives and Scope:
- Application specific testing and procedures development
- Composition optimization for Production application
- Further Production Scale-Up (10x)

Related prior or current work:
- Founder's PhD funded by DOE, HRF, NASA
- NSF SBIR Phase I (2013) and Phase II (2015)
- ASEE fellowship for postdoc till Oct 2018
- Commercial product released via Kickstarter and Indiegogo ($300K+) for car engines
- Scaled up production (1000x to date) of nanomaterial to sub-kilogram scale a day

Awards: Best Technology UW 2015, LES Members Choice 2015, National Innovation Award Techconnect 2017



IMPROVED CORROSION PREVENTION THROUGH SPECTRAL IMAGING

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Inefficient and ineffective the Department of Defense (DoD) weapon system wash/rinse procedures drive up the cost of corrosion prevention, drive down weapon system availability, and consume limited resources. The military services depend on isochronal and exposure factors to determine when to wash/rinse equipment. This approach risks the impacts of unnecessary costs and downtime for washes/rinses when surface conditions do not warrant treatment, of preventable corrosion damage from not removing contaminants while awaiting calendar-based wash cycles, and ineffective corrosion prevention based on not being able to quantify the residual contaminant levels after washes/rinses.

Mercer Engineering Research Center (MERC) proposes to develop tools and procedures to quickly and effectively determine the amount of surface contaminants present so the services can transition to a condition-based maintenance philosophy for washes/rinses as well as provide a quantitative measure of the effectiveness of washing/rinsing techniques to adequately remove contaminants. For example, USAF aircraft are washed every 30, 90, or 180 days depending on the environmental severity of the basing location and rinses are dependent on operating near salt water. This strategy incorrectly assumes that all aircraft with similar basing history or all flights in close proximity to salt water will experience the same contaminant deposition. A customized condition-based approach would ensure that aircraft, or any type of system, are properly cleansed but only when necessary.

MERC proposes using spectral imaging technology for corrosive contaminant detection and quantification. This technology collects electromagnetic information (transmittance / absorption) which can be used to identify and quantify contaminants on a surface. A portable system can be used to readily detect contaminants on-site to determine the need for, or effectiveness of, a wash or rinse. Spectral imaging is a mature technology, which is used in a variety of industries, from agriculture to mining, to easily detect the presence of particular materials.

There is a solid foundation of research into the use of spectral imaging technology for military applications. One applicable study (Sandia National Laboratories, Report PP 1138, 2004) examined use of a Fourier transform infrared spectrometer and a tunable infrared-laser imaging system to detect contaminant residue for DoD applications. However, this technique has not been demonstrated for the detection of key corrosive contaminants, such as chlorides and sulfates, and has not been demonstrated on finished surfaces such as aircraft structures. MERC proposes to first study the feasibility of spectral imaging for corrosive contaminant detection on aircraft structures. Once proven effective and efficient, MERC will revise the wash/rinse guidelines for a condition-based corrosion prevention philosophy. MERC proposes this research to support the use of spectral imaging as a cost saving, time efficient, and resource conserving approach to maximize effectiveness of weapon system washes/rinses for corrosion prevention and control. The primary benefits to the DoD will be improved weapon system availability and reduced costs through decreased scheduled and unscheduled corrosion-related maintenance. Follow-on development should include the transition of this technology to aircraft from all military branches, additional weapon systems, ground vehicles, and support equipment.

PROBLEM STATEMENT

- Isochronal and exposure-based wash/rinse practices are not optimized for corrosion control
- Do not consider quantitative data on condition of individual weapon system with respect to the level of contaminants
- Do not provide quantitative capability to evaluate the successful removal of contaminants
- Unnecessary washes/rinses consume resources, incur additional expenses, and increase weapon system down time
- Needed washes can be delayed while awaiting calendar-based execution resulting in preventable corrosion damage

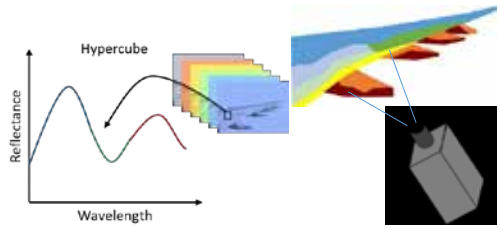
BENEFITS

- More efficient weapon system corrosion control maintenance
- Improved guidelines for washing / rinsing weapon systems based on quantitative methods
- New ability to determine the effectiveness of a wash / rinse
- Improved weapon system availability and reduced cost through decreased scheduled and unscheduled maintenance
- The technology solution is applicable across the DoD for aircraft, ships, ground vehicles, and support equipment
- Tools set has small logistics footprint for deployment
- The technology is transferrable to the inspection of large structures or for other corrosion related inspections

TECHNOLOGY SOLUTION

- Develop a corrosion control toolset and maintenance philosophy to ensure weapon systems are washed/rinsed based on condition and that is capable of quantifying the level of contaminant removal
- Use spectral imaging technology to detect and quantify weapon system surface contaminants such as chlorides or sulfates
- Create an algorithm to correlate the spectral imaging results to the need to wash/rinse a weapon system and to determine the effectiveness of a wash/rinse
- Imaging technology implementation can be hand-held, robotic, or drone-based

SPECTRAL IMAGING DETECTION AND MAPPING



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

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Annual corrosion related costs for Department of Defense (DoD) facilities, infrastructure, and equipment are $20 billion. Approximately 25% ($5 billion) occurs at depot-level maintenance for Air Force aircraft and missiles. Existing and emerging corrosion sensing, logging, and monitoring technologies are not applied as comprehensive, integrated corrosion management, maintenance, and mitigation solutions. Analatom has aerospace validated monitoring technologies, experience, and vision integrated into innovative, platform-wide solutions. This approach—applying localized and area corrosion sensing, environmental corrosion modeling, and assessment techniques—proposes to deliver cost-effective, integrated solutions and implementation strategies for DoD applications.

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

Benefits:

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

Proposed implementation is corrosion monitoring of C-130 aircraft in high corrosion regions like Patrick AFB, Florida. Accelerated tests evaluated µLPR corrosion rate sensor for AA 7075-T6, a common aircraft alloy. Comparing measurements from sensors and corrosion coupons demonstrated pit-depth computed from sensors agreed with coupons to a statistical confidence of 95%; indicating sensors can provide accurate measurement of corrosion rate for prognostic application. Patrick AFB's fabrication flight team has begun using sensor technology to measure changes in aircraft in real time—a huge maintenance-related information improvement—with the ability to calculate where and when corrosion is likely, enabling more effective maintenance decision making, and measuring maintenance effectiveness/shortcomings.

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

PROBLEM STATEMENT

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

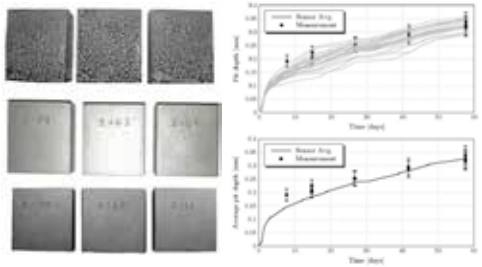
BENEFITS

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

TECHNOLOGY SOLUTION

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

GRAPHIC



Comparison of Coupon Measured &Sensor Data Computed Pit Depths.

ENHANCED FRICTION COATING CONSTRUCTION NONSKID PEEL AND STICK

CHARLES LIGON

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All known peel and stick nonskid are polymer based and wear out fast requiring removal and replacing often. The costs are huge, especially for the Navy.

Silva Non Skid Solutions (SNSS) manufactures a metallic-based peel and stick nonskid made of aluminum and ceramic (Silvagrip).

- Life cycle of 10 plus years, reducing cost with a long life cycle.
- Corrosion Proof - No rust, protects steel surface from corrosion
- Oil and chemical resistant
- Water proof - ideal for outdoor environment
- UV proof - unaffected by weather or sun
- Resistant to wear - Ceramic Rc60+ creates long life cycle
- Peel and Stick application - Ready for use immediately
- Adhesive withstands deck temperatures up to 270F
- Weighs almost half of polymer peel and stick nonskid -less weight
- Can be painted - we offer many colors with high temp ceramic paint
- Has a CoF of over 1.0 - very slip resistant
- Can be applied to any smooth dry clean surface
- No VOC's -safe
- Not environmentally sensitive

Silvagrip is fabricated with the most sophisticated technical alloys. These metals hold a matrix of strong durable ceramic abrasives, with hardness just under diamonds. National Stock Number (NSN) approved and applied by Navy and USCG. The Navy tested Silvagrip against 3M for 19 months and we still had almost same CoF as applied, 3M couldn't be tested it was worn out. Silvagrip is trademarked, patent pending, and told that the patent may be awarded in the near future.

PROBLEM STATEMENT

- All known peel and stick nonskid are polymer based and wear out easily, requiring removal and replacing often.
- Silvagrip provides a long life cycle of 10 plus years saving huge amounts of money in labor and material.

BENEFITS

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

TECHNOLOGY SOLUTION

- Silvagrip is a metallic based nonskid peel and stick offering long life cycle. This saves money, labor and material.
- Our product is the same material used on the USS Wasp for testing of the F35B to land vertically, but in a patented peel and stick application.
- It has been tested by the Navy for over four years.
- A Power Point presentation of Navy evaluation and testing is available.

CREATING A SOLUTION FOR LIGHT WEIGHT LONG LIFE CYCLE NONSKID

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

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

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

Thermal Sprayed Peel and Stick Nonskid

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

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

The Navy is testing this product in Bahrain and GTMO where the decks are hot. A metallic based peel and stick nonskid is a far superior, lightweight with Long Life Cycle nonskid for noncritical areas where nonskid is required.

PROBLEM STATEMENT

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

BENEFITS

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

TECHNOLOGY SOLUTION

Metallic based nonskid peel and stick offers a long life cycle of up to ten years. A Metallic based nonskid is created by using a thermally sprayed molten ceramic and aluminum to a flexible substrate. This saves money, labor, weight and material.. A Power Point presentation of Navy evaluation and testing is available

CHROMIUM-FREE CONVERSION COATING TECHNOLOGY (PRETREATMENTS) FOR MAINTENANCE OF ALUMINUM ALLOYS COMPONENTS

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Sustainable chromium-free conversion coatings (pretreatments) that can protect aluminum and Al-alloys surfaces from corrosion attack, and are equivalent or better in performance than those containing hexavalent chromium -Cr (VI) - are highly sought after materials.

This technology offers spray or dip application of conversion coating solution followed by curing to form a 4-6 μ thick highly adherent and dense organic-inorganic hybrid coating that provides excellent corrosion resistance and a sound foundation for adhesion of finishing topcoat. The primary components of this composition are multi-functional organosilane compound/s (Organo-silane precursors) that are meticulously designed with adequate alkoxy silane functionality and the chemical structure of the organic part. After application, curing takes place by hydrolysis and condensation (sol-gel reaction) of alkoxy silane groups, resulting into a uniform and dense organic-inorganic hybrid (OIH) network structure. Cure reaction and network structure can be enhanced by curing at higher temperature of about 120 C for 30 min. One of the most striking features of this technology is that the coating matrix is chemically bonded to the metal surface providing very strong coating/substrate interface, and hence excellent corrosion resistance. Additionally, nano-silica particles incorporated has shown to enhance corrosion resistance. The pretreatment solution can be fortified with specialty silanes to improve adhesion of the top coats, and it is tunable based on topcoat chemistry. The corrosion resistance performance on selected Al-alloys has been found superior to commercial Cr(VI) based systems and hence has significant potential for reducing maintenance costs.

This technology with US patent (US Patent 8900668 B-2 (2014)) is ready for scale-up and technology transfer process. The pretreatment systems have been successfully tested for two different Aluminum alloys – AA-2024 T3 and AA 3003 H14. Besides, a commercialization project funded by Michigan Initiative for Innovation and Entrepreneurship (MIIE) partnered with a Michigan company for automotive alloy wheels showed high potential for commercialization. Two research articles related to this work have been published in technical journals.

The corrosion performance of two families of silane pretreatment systems that we developed – Epoxy and Urethane type silane –have been compared with commercial chromate (Cr VI) conversion system, on structural aluminum alloy AA-2024-T3. The electrochemical tests, as well as salt-fog test ASTM B117–(Industry standard) clearly show that both of the silane-based systems outperform chromate conversion systems. These data clearly demonstrate that our sustainable silane-based systems can successfully replace hazardous Chromate based systems.

Among the most striking benefits of our silane-based pretreatment is that they are free from not only Chromium (Cr) but also any other heavy metals, making them environmentally sustainable. Besides, our silane components can be tunable to enhance their performance on specific Al-alloys as well as to complement with different primers and topcoat chemistries. This would provide high degree of acceptance in the field. As a next step, selected silane pretreatments systems need to be manufactured at the pilot scales, used in the field - side-by-side with currently used product- and data on their application, cure and performance collected and analyzed.

PROBLEM STATEMENT

- Sustainable *and* efficient chromium-free conversion coatings (pretreatments) for maintenance (long-term corrosion protection) and repair of Al-alloys are not available.
- There is need within DoD organizations for replacing hexavalent Chromium Cr(VI) (carcinogen) based systems with non-toxic systems with similar of better performance, without major changes in application process or need for additional equipment and training.

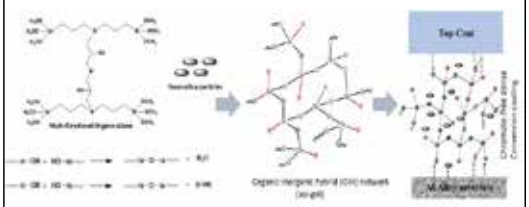
BENEFITS

- Chromium- and other heavy metal-free compositions
- Corrosion resistance superior to Cr(VI) based conversion coatings for Al-alloys (Gold standards for performance)
- Can be applied by dip or spray applications (suitability for on-site repair and maintenance jobs)
- Compositions can be easily tailored to suite top-coat chemistries for enhanced inter-coat adhesion and performance.

TECHNOLOGY SOLUTION

- Offers Chromium and other heavy metal-free conversion coating (pretreatment) system for Al-alloys that is more efficient (greater corrosion resistance) and environmentally friendly compared to currently used systems.
- Silicone-based chemistry (sol-gel technology) leverages potential of organic-inorganic hybrid materials and nano-silica particles to produce dense barrier coating that is chemically bonded to metal substrate to enhance corrosion resistance.
- Results of lab and commercialization efforts clearly prove their potential. A US patent and two publication supports these claims.

GRAPHIC



CONFORMING ANODES AND MASKS 76 PMXG PLATING

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Masking of engine parts for the electroplating process presents a unique challenge due to the requirement for exposing only the area to be electroplated and protecting the other areas of the engine part from plating solution. This masking material must be water tight and cable of holding up to acidic and caustic solution as well as high temperatures in the plating bath. In addition, engine parts require plating of inner and outer diameters, which often plate inefficiently across the plating area. This produces uneven build up, long in-tank times, and long machining times. Under an AF RIF contract, ES3 is working with PMXG engineering to develop masking and anodes customized to high volume and complex engine parts.

This effort has involved collaboration between ES3 and PMXG on design, in shop prototype, and implementation. Results to date are showing significantly reduced process time as well as increased quality of plated engine parts. One example is the conforming anode for TF33 #6 turbine hub. This part gets chrome plating on one inner diameter and two outer diameters. This part has roughly 60 recycles/year due to plating issues. With the new conforming anodes, this is expected to significantly decrease, the plating time has been reduced from 72 hours to 20 hours, and finish machine time has decreased by about a third. On this part, the conforming anodes are expected to save roughly $36,700/year in labor, $130,700 from WIP reduction, and about 421-flow days/year.

PROBLEM STATEMENT

- Masking of engine parts for the electroplating process is complex and time consuming.
- Most parts are masked with wax, resulting in high labor hours for masking and cleaning.
- Complex geometries have long tank time in plating process to allow appropriate build up of material.

BENEFITS

- Conforming anodes are reducing time (plating and machining) on some parts by 70%.
- Custom masking greatly reducing prep time.
- Masking and anodes increasing quality through repeatability.

TECHNOLOGY SOLUTION

- Under RIF contract, PMXG is working with ES3 to develop conforming anodes and reusable engineered masking.
- Conforming anodes are designed for specific part geometries.
- Masks must be sealed to prevent plating solution from contacting other areas of engine parts.

HIGH RESOLUTION SURFACE PROFILE TOOL FOR COATING APPLICATION SUPPORT

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Coatings and their application and replacement are a major contributor to the Department of Defense (DoD) maintenance costs. Their importance cannot be overstated in that coatings provide primary corrosion protection for metal substrates associated with ships, aircraft, vehicles and base and other support infrastructure. The adhesion, performance and service lifetimes of coatings can be significantly impacted by the specific surface profile, texture and roughness that are achieved when metal substrates are prepared prior to coating application. Recent work with many types of advance coatings has shown the importance of not only obtaining a specific "profile height" but also in obtaining a surface with an angularity or kurtosis within certain ranges.

The DoD maintenance community does not have an adequate an efficient means to properly characterize substrates in support of coating operations.

Battenkill Technologies, supported by the Naval Research Laboratory, has recently demonstrated a surface profile tool for assessing deck substrates. The evaluations of this system clearly showed that prepared metal surfaces are too complex to properly characterize either using one-dimensional measurement tools (replica tape and digital depth gauges) or using more advanced 2-dimensional stylus gauges.

The graphic provided on the left in the lower right quadrant of the quad chart helps put this into perspective. The larger red circle corresponds to the 0.25-inch diameter area that is evaluated using replica tape. The smaller purple circle provides the maximum area that is surveyed using a digital profile gauge. The red line corresponds to the line length that is typically characterized using high-resolution stylus gauges. The significant variability of profile (profile, pitting, etc.) that can be observed in the three-dimensional deck scan clearly shows that only three dimensional surface profile measurements over a reasonably large area provide the perspective that is required to assess prepared surfaces.

The first generation Surface Profile Tool's complexity and especially the time required (> 3 minutes) to make measurements made its routine use impractical. A new 3-dimensional scanning technology has recently been identified. A next generation Surface Profile Tool based on this scanner would provide higher measurement fidelity than 3-dimensional scanning systems that are currently used in the laboratory and would be capable of characterizing a surface's profile, roughness and texture in approximately 6 seconds.

This proposal addresses the transition and industrialization of a new Surface Profile Tool that will be configured using the recently identified structured light based 3-D scanner. This system will be capable of scanning an area in excess of ½ inch by ½ inch in less than six seconds while providing x and y resolution of at least 1 mil and z resolution of < 0.1 mils. The program's focus will be in developing this system into a fully industrialized, field worthy and battery powered configuration with appropriate analysis software for assessing surfaces and reporting results.

PROBLEM STATEMENT

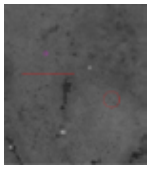
- Proper preparation of metal substrates is important to coatings adherence and impacts both their performance and service lifetimes.
- The DoD maintenance community does not have an adequate means to assess the surface profile, texture and roughness associated of metal surfaces that are prepared in support of coating application and replacement.
- To overcome this deficiency this proposal addresses the industrialization of a simple to use 3-dimensional Surface Profile Tool for the routine characterization of metal substrates being prepared for coating application

BENEFITS

- Widely applicable requirement across the DoD.
- Improved coating applications and service lifetimes through proper metal substrate preparation.
- Improved documentation and reporting of substrate surface preparations.
- Improved understanding of how substrate profile, texture, and roughness impacts coating adhesion and performance.
- Improved understanding of how to prepare metal substrates.
- Improved methods to prepare metal substrates in support of coating operations.
- Reduced time associated with making and reporting substrate profile measurements.

TECHNOLOGY SOLUTION

- Develop and transition a fully industrialized battery powered high resolution Surface Profile Tool to the maintenance community that supports coatings application. This surface profile tool will incorporate a recently identified and evaluated high fidelity high resolution structured light based 3-D scanner as its major sub-system.
- The proposed system should provide measurements of a surface's profile, texture and roughness with superior fidelity to that achieved using laboratory instrumentation.
- Software will be provided with the proposed industrialized system that extracts key profile, texture and roughness metrics from the 3-D scans and determines if metal substrates have been properly prepared in support of coating operations.



Scan image of a deck surface. The area evaluated using replica tape (red circle), a digital profile gauge (purple circle) and 2-D stylus gauges are superimposed on this image. Surfaces are too complex to describe adequately using 1-D or 2-D measurements.

Battery powered Industrialized Surface Profile Tool for the routine characterization of deck coatings on US Navy Ships This system was developed by Battenkill Technology and the Naval Research Laboratory

WHY LASER BEAM DELIVERY OPTICS MATTER

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Coated surfaces require repaint over time because aging and environmental conditions degrade surface performance. Over-painting impacts adhesion, adds weight, and impedes performance. Therefore, it is necessary to remove the existing coatings before applying new without affecting the base surface (steel, aluminum, composite). Sometimes, the original primer is desirable, which is challenging using traditional methods: manual scraping/sanding, media blasting, chemical strippers. Even with the significant shortcomings, these methods are acceptable. However, environmental, health, cost concerns and/or derogating composite/alloy materials are forcing change.

This last decade, laser methods emerged for stripping coatings. Laser ablation eliminates concerns. Laser methods: remove more paint per unit time, have few consumables, produce minimal waste (a volume smaller than that of the paint itself), produce no hazardous waste, use no water, and do not expose operators to hazardous chemicals. The primary concern associated with laser methods is lack of precision – that more paint may be removed than desired or damage the base materials. This concern is exacerbated, as paint application thickness are typically not uniform across the surface.

The first units used enhanced Galvo Optics from laser marking. These optics raster across, stop and return to the start position indexing to the next line. However, the laser light is still present and is dumped. This results in using only 50-55% of the laser output power. Next generation units employed Risley Prism or Polygon configurations. This improved the efficiency rating to 70-75%. SurClean has developed and tested the HyperDisc optic. This optic uses 95-99% of the laser output power providing enhanced performance and an economical advantage. The HyperDisc is programmable generating patterns for improved adhesion. The cost of a laser light source is based on its power. Increasing power increases speed-increasing throughput if the optic is using it. Beam delivery is the workhorse of any laser system.

SurClean started with development of a real-time, closed-loop laser process controller (LPC). The LPC analyzes material being ablated in real time and based on this analysis decides what laser power is best suited for aggressive coating removal. The LPC modulates the laser power such that high energy is emitted when paint needs to be removed and low (or no) energy is emitted when passing over the primer and/or substrate. This sensor is in its third generation.

The LPC proven attributes allow it to be used for a broad range of coating removal applications since:

- Sensing methods are not color dependent, the system can be tuned to remove a wide variety of 'coatings', such as anodizing and oxides.
- SurClean has demonstrated it discriminates 5 of the 7 Stealth coating layers.
- Control panel integrates with other sensors i.e. thermal detection providing optimum protection.

Laser professionals build SurClean products. Collaboration with COTS laser OEM, allows focus on the beam delivery system, the workhorse of all laser systems. Our testing with MDOT, NRL, Air Force and private industry provides third party validation of our products efficiencies and cost savings.

PROBLEM STATEMENT

Laser ablation addresses the shortfalls of traditional methods to prepare surfaces for coating. Traditional methods of chemicals, grit/sand/glass blasting, manual abrasives and high pressure water blasting generate hazardous waste, airborne particulates impacting the health and safety of the worker as well as contaminating water and soil, are time consuming, and are not compatible with composites and alloys used in today's manufacturing of planes, trains and other high dollar assets.
The laser beam delivery optics are key in how efficient the ablation process utilizes the laser output power. The output power increases the rate of removal. Traditional Galvo optics use only half of the power. Galvo optics teamed with camera based process control systems are slow and in some cases cannot distinguish multiple coating layers that appear to be the same as the color appears to be the same

BENEFITS

- SurClean HyperDisc Optic utilizes 95-99% of laser output power compared to 50-55% by Galvo Optics and 70-75% with Polygon or Risley Prism Optics. The laser source is the high dollar component of the laser system and utilizing the power is what is being bought.
- Cost reduction, improved paint adhesion, reduced manual labor, eliminate hazardous waste, extend life of asset, reduce unplanned maintenance costs.
- SurClean has established the ability to control laser output power with LPC Sensor to prevent damage to base material and control line width to establish profile
- Laser Ablation is currently being researched across multiple DoD platforms and programs, approved on non-nuclear steel vessels
- Addresses environmental and safety regulations
- Improves assets readiness.

TECHNOLOGY SOLUTION

- The patent pending HyperDisc optic is in continuous motion
- HyperDisc optic is programmable generating pattern creating a profile comparable to that of sand/grit blasting
- Laser ablation does not use water and is paint ready requiring no secondary processing
- Laser ablation is a clean process producing airborne particulate way below the OSHA guidelines
- The Laser Process Control Sensor (LPC) allows for selective layer by layer removal and it controls the output power of the laser safeguarding the base material from damage
- COTS laser sources, chillers, exhaust systems and robots are integrated with SurClean Beam Delivery Systems to complete the Laser Ablation Machine Tool (handheld or robotic)

PREDICTIVE ALUMINUM SENSITIZATION MEASUREMENTS

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The Department of Defense (DoD) use of aluminum AA5XXX series alloys has helped meet the demand for lighter, faster platforms such as the Ticonderoga class cruiser, the Littoral Combat Ship (LCS), the M113 armored personnel carrier, the UH-60A/L helicopter, and the M-102 weapon carriage used by the National Guard. However, the AA5XXX alloys are prone to sensitization and the sensitized sections of material can experience massive stress corrosion cracking which drives up maintenance costs requiring monitoring and replacement of large sections of the material especially in marine environments. Current tests that measure the degree of the sensitization (DoS) use toxic chemicals, have no predictive capability, do not measure the sensitization rate and are imprecise.

Heat flow calorimetry (HFC) will be used to quantify the DoS more precisely and determine the sensitization rate (under simulated service conditions) by measuring the heat released as the material sensitizes. Accelerated aging studies will be performed to predict in-service behavior. Heat flow calorimetry as a technique is well established but has never been used to measure aluminum sensitization. We will develop a procedure to measure the DoS and sensitization rate. Relationships between sensitization vs. temperature and time need to be determined. Accelerated aging studies (kinetics studies) will be conducted and parameters established to relate the data to in-service temperatures.

Initial testing has shown that HFC is sensitive enough to detect the small heat release associated with sensitization and that alloys that resist sensitization can be distinguished from those that do not. It is anticipated that DoS can be determined with 2-3% error compared to the 10% error of current tests. Phase diagram analysis indicates kinetics studies with HFC can reveal sensitization rate and accelerated aging parameters.

HFC testing can be used to determine the DoS with better precision and accuracy and determine the sensitization rate. Using a more accurate test will minimize maintenance costs by repairing on time, (not too early or too late, both waste resources). Thermal mitigation strategies may be employed to minimize sensitization rate and maximize maintenance savings. Future selection of sensitization resistant alloys and development of alloy heat treatments to minimize sensitization will be assisted by this measurement technique thus reducing total ownership costs of future platforms utilizing aluminum AA5XXX alloys.

PROBLEM STATEMENT

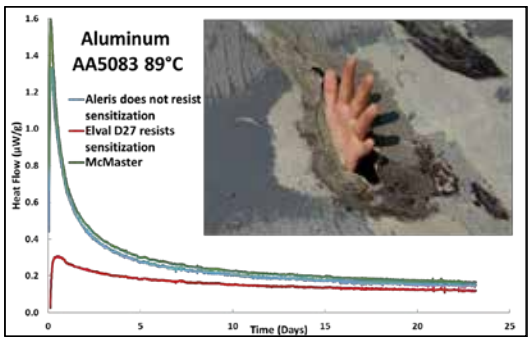
- AA5XXX series Mg-based aluminum alloys can experience intergranular corrosion and stress corrosion cracking as a result of the formation of β phase (Mg_2Al_3) at the grain boundaries. The β phase is more susceptible to corrosion than the aluminum alloy.
- Effects several systems such as: Ticonderoga class cruisers, Littoral Combat Ships (LCS), M113 armored personnel carriers, UH-60A/L helicopters, and M-102 weapon carriages.
- Current tests that measure the degree of the sensitization (β phase on grain boundaries) use toxic chemicals, have no predictive capability, do not measure the sensitization rate and are imprecise.

BENEFITS

- More precise than tests currently in use.
- Save money by correctly assessing when repairs/mitigating techniques should be performed.
- Better lot acceptance testing for aluminum sheet and plate than current tests.
- Predictive tests for new alloy development – ensure that new alloys will meet service life requirements without sensitizing.
- Predictive test for determining in-service behavior. How long will ships last when exposed to various temperatures given current sensitization levels?
- Assess the viability of repair techniques such as ultrasonic peening and resolutionizing.
- Avoid use of hazardous chemicals like concentrated nitric acid.

TECHNOLOGY SOLUTION

- The figure shows the heat flow at 89 °C for samples which sensitize easily (top – blue and green) and one that resists sensitization (bottom – red).
- We will use heat flow calorimetry (HFC) to measure the enthalpy associated with the formation of the beta phase to determine the degree of sensitization (DoS).
- Use HFC to determine relationships between sensitization rates versus temperature.
- Accelerated aging studies (kinetics studies) will be conducted and parameters established to relate the data to in-service temperatures.



IN-SITU COATING PROPERTY SENSORS 76 PMXG THERMAL SPRAY

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The thermal spray process is used frequently in the repair of engine parts to apply various coatings such as hard face coatings, thermal barrier coatings, abradable coatings, and coatings for material build up. Quality control in the thermal spray process is critical. Typically, this is accomplished by spraying a sample coupon simultaneously with the engine part and then cutting the coupon after the process is complete in order to metallographically evaluate the coating structure. Historically, very little information on the properties of the coating being sprayed has been available during the process. This leads to rework of the engine part in the event that the coating properties are determined unacceptable during coupon evaluation. As part of a SBIR effort, PMXG has been working with Reliacoat to implement in-situ coating property sensors into the PMXG thermal spray booths.

These sensors detect stresses in the coating, which can be correlated back to coating microstructure and mechanical properties. The sensors are installed into thermal spray booths and can provide real-time data on coating quality prior to the application of coating to the engine part. The ability to view this information real time has been used by PMXG process engineers to troubleshoot difficult coatings as well as quickly develop new coatings with the appropriate microstructure and strength properties. PMXG has had success with this innovative technology, and as data continues to be collected, expects to see further benefits. A future goal of this project is to work with Reliacoat and Air Force cognizant engineering to develop extensive coating properties maps that directly correlate the in-situ data to post process microstructure information in hopes of reducing dependency on post process coupon sectioning and replacing it with real time quality control, where applicable. This will result in reduced recycles and reduced labor time for coupon preparation and evaluation.

PROBLEM STATEMENT

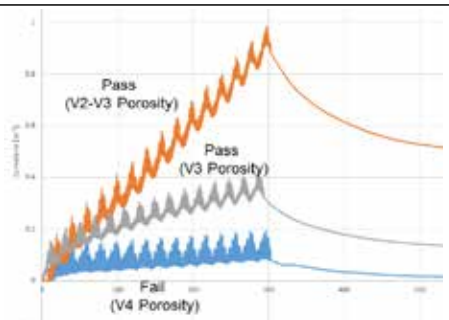
- Thermal spray process quality control is based on coupons sprayed with engine parts and metallographically evaluated after the process has occurred.
- Little information is available about coating quality *during* the process.
- Due to evaluation being after the part has been processed, rework sometimes occurs when coating is determined unacceptable.

BENEFITS

- In situ sensors provide real time parameters during process.
- 76 PMXG engineers are using sensor to troubleshoot difficult coatings and for faster coating development.
- Improved coating quality.
- Potential for reduced after-process testing, more development and data collection required.

TECHNOLOGY SOLUTION

- Under SBIR project, Reliacoat developed in-situ coating property sensors.
- Sensors measures stresses in the coating during deposition.
- Stresses are being mapped to evaluated coating properties such as microstructure and mechanical qualities.
- PMXG has installed sensors in 3 thermal spray booths.



MICRON MEASUREMENT SYSTEM FOR NDI OF TURBINE ROTOR COMPRESSOR BLADES

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Today, the general public and military maintenance schedules and routines for inspection of surface engineered finishes and structural dimensional accuracy requiring maintenance actions are primarily based upon the three following elements:

1. Time from past maintenance action
2. Routine schedules for maintenance
3. Fault detection discovered through routine use/mission of the equipment.

These routine schedules and behaviors for maintenance are costly and burdensome and must change. Especially challenging, however, is current routines for measuring and inspecting rotor compressor turbine blades. The opportunity lies where a new paradigm could be developed that consists of rapid, high precision surface finish/ dimensional measurement coupled with predictive analytics. Having the "big data" of high precision surface finish/dimensional information available to model through Conditioned Based Monitoring (CBM), will provide maintenance organizations surface engineered statistical decision making criteria reducing the high cost of inspection labor and added costs of scrapping rotor blades. CBM applied to rotor compressor turbine blades will make maintenance more efficient and more effective simultaneously.

Automated Precision, Inc. (API) in conjunction with FRCE – Cherry Point has launched an active project to develop a new, next generation NDI sensor technology called, 'Time-to-Spectrum Mapping Interferometer (TSMI). The sensor is an absolute interferometer having potential of measuring at high speed and with exceptionally high accuracy. In addition to the sensor technology development, a complete understanding of the existing rotor compressor turbine blade inspection techniques and maintenance criteria for acceptance will be studied and modeled. From this criteria and model, a specific one cell, turn-key NDI System for semi automating the inspection of the rotor compressor blades (T-64) will be created utilizing the new TSMI technology. This project truly applies emerging technologies into practical use for warfare readiness.

What is the importance of this next generation TSMI sensor to non-contact, high precision NDI?

One of exclusive features in the TSMI is the collinearity of light detection. The laser beam is emitted and received collinearly along the same axis while it is tightly focused at a targeted surface, which does not require triangulation among emitter, detector, and target. The collinearity helps not only sensing of holes, grooves and cracks in more depth, but also allows aiming the beam in any direction by using optical beam scanning mirrors.

Depending upon the application, TSMI can be flexibly designed to provide 1) single-point measurement or 2) two-dimensional area scanning. The Lens can be designed to have long focal distance (e.g. 500mm) to obtain large volumes of scanned data (300mm x 300mm x 100mm) with long depth of focus (100mm) or short focusing distance (e.g.. 200 mm) to obtain high transverse resolution (5 ~ 20 um) scanning.

The combination of the scanning flexibility and high-speed measurement enables unprecedented high quality (5 um uncertainty), high-speed (100,000 measurements/ sec), with programmable scanning ability. API's TSMI sensing technology proposes to rapidly assess the integrity of surface areas up to 0.5 square meter and see defects as small as 1 micron (1 one millionth of a meter).

PROBLEM STATEMENT

1. Depot maintenance departments across all services face the same common issues when inspecting rotor compressor turbine blades;
   - Each blade and vane goes through multiple levels of inspection prior to re-installation into engine assembly
   - Methods of inspection are skill driven – "Artisans"
   - Strenuous to human eyes - Operator "Judgement" Dependent
   - Process of inspection is long & arduous - Scrap rate high
   - Repetition of inspection drives scrap vs. rework
   - 1-D information is used in making decisions
   - Instruments used for measurement are rudimentary and basic
2. Conventional sensor metrology technology (CCD Camera Technology) uses fixed light measuring distortion of surface geometry with BEST precision accuracies of 25 microns.

A NEW SENSOR technology measuring < 5 microns must be developed for precision surface finish measurement

BENEFITS

The FRCE-Cherry Point /API project when completed will provide several major deliverables enhancing Non-Destructive Inspection for the public and military maintainers;

- The next generation NDI sensor technology (TSMI) will be packaged into a commercial application having unique capabilities;
  - Absolute interferometry; Long depth microscopic 3D imaging (Surface Finishes) ; Unmatched (Micron) accuracy; Collinear 3D scanning (Flexibility)
- Completed NDI non-contact, high precision, turn-key inspection cell at the Cherry Point facility;
  - Enhances the inspection efficiency, saving time & resources, while improving the quality of inspection

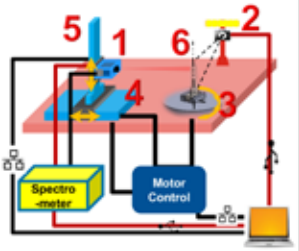
TECHNOLOGY SOLUTION

Next generation Non-Destructive Inspection SENSING TECHNOLOGY-Time-to-Spectrum-Mapping-Interferometry (TSMI)

- ✓ Based on **'absolute'** interferometry (no triangulation or fringe counting)
- ✓ High speed (up to 80,000 measurement points/sec) with high precision accuracy (<5 micron)
- ✓ Adaptable Ranging - from (0.02m) to (>20m) measurement
- ✓ Used as single point, line or area measurement
- ✓ Insensitive to ambient lighting conditions

- Dimensional blade profiles against CAD dimensional specs
- Surface geometry, plus roughness/finish measurement.
- Go/no go quality measurement report per blade.
  - ✓ Next Gen Sensing Technology Developed; Condition Based Measurement Rotor Compressor Blade Baseline Created.

1. TSMI Sensor head
2. 2D Imaging system - identifies part and performs coarse inspection of the blade
3. Rotary stage
4. Horizontal stage
5. Vertical stage
6. Rotor Compressor Blade - either scrapped or goes through precision inspection by TSMI the sensor head



ADVANCED IMAGE CAPTURE AND ANALYSIS FOR MAINTENANCE ACTIVITIES

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The Department of Defense (DoD) needs faster, lower cost, more accurate inspection methods for a wide range of platforms—ships, aircraft, and ground vehicles—and weapons systems in order to meet the objectives of "Maintaining the Joint Force through Innovative, Agile and Adaptive Capabilities." Toward this goal, NuForj has assembled a team that includes developers of leading edge creative commercial photography and imaging applications (such as Mark Schubin, Emmy-Award-winning SMPTE Fellow, and Trumbull Studios) to bring together emerging technologies that can meet this critical need. NuForj personnel have extensive expertise in airframe and propulsion design, materials, manufacturing, and maintenance in the defense industry. They are collaborating with the world's top experts in digital camera system architecture, design and manufacturing with experience primarily in entertainment photography and imaging. Together, this team provides the DoD with decades of experience and expertise in maintenance of a wide range of military systems and cutting edge, high resolution digital imaging utilizing state of the art automation and camera mobility. Commercial concerns are inventing and supplying the next generations of advanced digital imaging: spherical capture, volumetric capture, and four-dimensional media that is revolutionizing digital imaging and data acquisition for numerous industries and business sectors, including maintenance and sustainability. Mobile cameras are assembled into an array and capture multiple data points for analysis with advanced image processing and data management. A next generation live volumetric scanning capability is thus developed, resulting in advanced photo-realistic 3D rendering. In addition, these imaging tools support data storage architectures that enable far more accurate longitudinal analysis of system conditions, expanding opportunities for accurate predictive maintenance implementations. Working with the most capable imaging systems available today, the team will rapidly provide initial advanced maintenance functionality. In addition, the team will test next generation hardware (TRL7,8) that is close to commercial readiness to ensure that DoD has access to emerging capabilities and platform updates.

Applying these "ahead of the state of the art" image capture and analysis techniques to the needs of the Joint Force will enable new maintenance approaches that are defining "innovative, agile and adaptive capabilities." For example, these powerful new imaging and analysis techniques will provide more detailed visual data than is available today, faster and at lower cost, for a wide range of hardware, to speed data acquisition and analysis for current maintenance technology. This approach could also enable new methods such as on-wing engine inspection using high-resolution image capture systems on small, highly maneuverable drones.

The proposed tools offer an emerging and potentially transformative opportunity to accelerate accurate condition analysis and appropriate maintenance for an enormous range of systems and vehicles. The innovation opportunity and challenge presented here, and the team proposing to bring these capabilities to the DoD, represent a major new opportunity to improve the long term sustainability and operational availability of the Joint Force.

PROBLEM STATEMENT

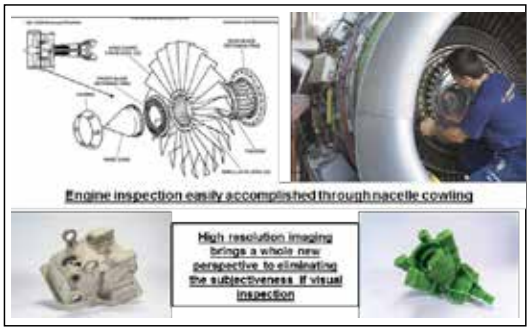
- The DoD is under continuous pressure to accelerate the rate at which maintenance is performed on a wide range of platforms and weapons systems, while at the same time improving maintenance technology and extending the service life of platforms and systems.
- New materials and systems mean that visual inspection techniques require updating and training of personnel to accelerate maintenance, particularly as high operation tempo in regions with varying service conditions mean that multiple wear and damage mechanisms are of concern.

BENEFITS

- Much faster capture of system/component condition data
- Greatly improved accuracy and resolution of system/component condition data
- Spherical capture, volumetric capture, and four-dimensional media that is revolutionizing digital imaging and data acquisition
- Ability to develop significant longitudinal data on system condition, and improve model responsiveness to system and operating conditions when identifying maintenance requirements
- Ease of use by maintenance personnel

TECHNOLOGY SOLUTION

- Improving and automating imaging techniques can radically speed up the rate at which condition information can be acquired and analyzed. Today, many of the most advanced imaging systems, as well as image capture, storage, manipulation and analysis methods reside in the gaming and entertainment industry.
- NuForj personnel have an extensive history of developing and implementing advanced manufacturing and maintenance solutions for military platforms and system. The team, with leading edge talent in the gaming and entertainment sector (Trumbull Studios, SMPTE Fellow/Emmy winner Mark Schubin) will bring these capabilities to image capture and analysis for maintenance activities.



PHASED ARRAY ULTRASONIC INSPECTION ON LOWER REAR SPAR CHORD HOLES AT TERMINAL FITTING AT BL 55

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The Aircraft Structural Integrity Program (ASIP) determines the structural life of a specific aircraft. An ASIP plan, developed in accordance with MIL-HDBK-1530, describes the mission, design requirements and operational assumption, inspection areas, proposed inspection methods, and critical crack criteria to assess the condition of the aircraft. Nondestructive Inspection data is used to determine the safe operating conditions of the aircraft. The structural engineers for the B-52 incorporated a new ASIP detail that needed immediate inspection. Analysis determined a hole on the B-52 rear spar chord at BL 55 required an eddy current bolt hole inspection. But, removing the fastener to perform the inspection is time consuming, difficult, can cause hole damage and the fasteners are not supportable. The 76th Aircraft Maintenance Group (AMXG) investigated shear wave ultrasonic inspection since the fastener could remain in the hole.

Theoretically, shear wave ultrasonic inspection meets the sensitivity requirements in the ASIP analysis. Upon further testing by AMXG Nondestructive Inspection Engineers, standard shear wave techniques would not work due to transducer placement and access. Phased array ultrasonic shear wave was tested and verified by using the ability to sweep many angles with one transducer at a fixed location. In order to ensure the hole was adequately inspected the transducer was placed on the forward and aft edges of the rear spar chord for the ultrasonic entry surface. This technique was validated on Probability of Detection samples provided by the Air Force Research Laboratory, which proved the inspection was capable of finding the desired crack size. The Procedure was verified and has been used to inspect eight aircraft to date in the depot at Oklahoma City Air Logistics Complex. The phased array ultrasonic equipment is not commonly found at Air Force operational bases, but the technique proved user friendly and the inspection need was immediate, so the equipment was purchased to perform the inspection in the field as well as at the depot.

PROBLEM STATEMENT

- Analysis of B-52 rear spar chord underneath the lower rear spar terminal fitting at BL 55, determined cracks could emanate from the terminal pin hole in the aft and forward directions.
- Requirement to remove fastener and perform bolt hole eddy current.
- Fastener has never been removed and it is not supportable.

BENEFITS

- Fastener does not need to be removed.
- Reduce damage to fastener hole in the terminal fitting, rear spar and wing skin.
- Replacement fasteners unavailable.
- Reduce risk of fuel leaks.

TECHNOLOGY SOLUTION

- Perform phase array shear wave ultrasonic inspection with the fastener installed.
- The transducer has a 60 degree shoe and the instruments sweeps the sound beam between 30 and 60 degrees.
- Transducer is placed in one location at the forward side of rear spar chord and one location on the aft side of the rear spar chord.

Ultrasonic image of notch and hole on reference standard

INNOVATIONS IN PRECISION INSPECTION AND CLEANING FIBER OPTIC AND COPPER CONNECTOR SURFACES

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A contaminated fiber optic connector results in signal loss. Called the "end face," fiber optic connector surfaces are viewed under auspices of standards that consider a limited two-dimensional surface area categorized as Zones: 1, 2, and 3. Debris, as well, is characterized in two-dimensional diameter.

Of course, connectors and contamination are three-dimensional. Since existing fiber optic inspection does not view complete and total fiber optic connector surfaces, proper cleaning is probable.

Characterization of the "end face" to include the complete horizontal surface, as well as 'vertical surfaces' is critical to support ever-higher transmission speeds to ultimate reliability. Inspection shall include connector sectors: adapters, alignment sleeves, and inter-surfaces between individual fibers. Since there are copper connectors, these can be inspected to assure pin alignment or possible corrosion.

Fiber optic transmissions regularly advance from 'theoretical to practical' and out-pace standards updates of five to ten years. Essential is a new understanding of the interaction of the three-dimensional nature of connector types, as impacted by the three-dimensional nature of contamination and, a method to clean the complete assembly. Existing standards recommend cleaning a limited surface area and these are verified using simplistic test soils and procedures. As speeds and capacities increase, the tenet "Worse Case Leads to Best Practice," assures the viability of transmissions and future of the industry.

Most existing fiber optic video inspection only 'sees' one-third of the actual horizontal surface. A new inspection device has been developed to view all connectors, adapters, alignment sleeves, and inter-surfaces. The imagery in digital color photography returns a virtual 3D portrait.

There is need to add additional surface area characterizing a total 'horizontal surface' as "Zone-4." As well, since vertical surfaces and alignment adapters can become contamination points, there is need to characterize a connector in 3D by including a "Zone-5." Three-dimensional characterization of neither fiber optic nor copper connectors has been practical until development of the new instrument.

To best understand the concept of precision cleaning, let us remind ourselves of age-old foundations.

1. Dry debris tend to stay in situ (by surface bond, static field attraction, or laying in place);
2. 'Fluidic' contamination is one that may move from beyond the field of view of existing inspection devices to an active fiber;
3. Contamination may be a combination of the two types.

There is an understated and inextricable interaction between inspection and cleaning.

PROBLEM STATEMENT

1. Process confusion and technical hearsay.
2. Standards lag technical advances. Training outdated.
3. Contaminated fiber optic surfaces result in loss of capacity.
4. Copper connectors require inspection: pin alignment/cleanliness
   - Some connector types have both fiber and copper termini
5. International standards limited to a 2-Dimensional surface.
6. As well, standards *consider debris* in 2-Dimensional diameter
   - Dry debris which tends to stay *in situ*
   - 'Fluidic' contamination tends to flow
   - 'Combinations types' presents complex cleaning problems
7. Existing video inspection is judged by a *magnification-conundrum*:
   - The greater the magnification the less area seen
   - The lower the magnification the more area seen
8. Existing cleaning based on product selection and not process
   - Multiple versions of similar products
   - Misapplications
9. Existing procedures do not inspect/clean 'test ports'
   - Skewed results

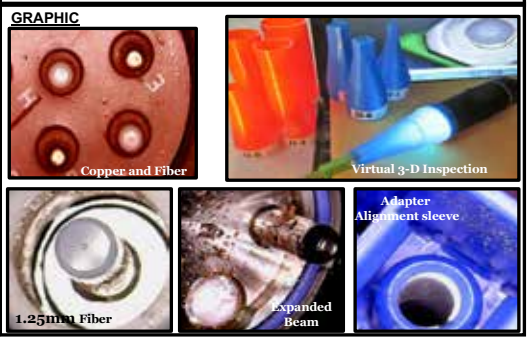
BENEFITS

1. Clarity
2. Effective observation of a complete connector in virtual 3D imagery.
   - Condense methods and procedures rather than multiply
   - Clear indication of debris type and location in digital color
   - Eliminate duplicity and confusion of choice
3. One inspection procedure results in:
   - Clean fiber optic end face and surrounding surfaces
   - Copper pin alignment and clean surfaces
4. Clean test ports to assure test accuracy
   - Eliminate skewed results
5. Clear and demonstrable training benefit imparts: "why" as well as "how" precision cleaning is impacted by enhanced inspection
6. Understand the 3D reality of debris and connector surfaces
   - Future proofed 1st time work
   - 'Condensed' applications-specific procedures
   - Trouble-free transmissions

TECHNOLOGY SOLUTION

1. Higher level erudition of inspection and contamination science!
   - Fundamental change to accept the reality of 3-D
   - Re-train trainers and update text books
2. Use of color digital photography imparts critical realism to field service inspection and cleaning applications
3. Unique 'rotating adapters' provide unparalleled views of standard surfaces (noted by existing standards) and a significantly enhanced field of view. (Images to right)
   - 3D printing enables variety, specials, prototypes
4. Advanced inspection identifies heretofore occluded surfaces.
   - Vertical surfaces, alignment devices, inter-surfaces.
   - If it is not seen, it can't be cleaned.
5. One device for fiber optics and copper connectors
   - Records in still and motion: verification or quality control
   - Functions in PC, wireless iOS and Android platform
6. New 'spray and go' cleaning process re-thinks all existing techniques into a first time procedure for all connector types.

GRAPHIC



VISION VERIFICATION SYSTEM

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The Blue Grass Army Depot (BGAD) automated grenade operation retrofits M228 grenade fuzes with Confidence Clips at a rate of approximately 6000 fuzes each shift. Completed fuzes are then manually placed by operators in Styrofoam trays and packaged before being returned to inventory. At such a high volume, the chance of an operator accidentally not filling a slot and packaging an incomplete tray of fuzes is a valid concern. To address this, at the end of each production day, the processed fuze count is compared against the incoming count by making sure the processed count is divisible by 45, which is the number of fuzes in an incoming tray. If a discrepancy is discovered, it must be immediately rectified in order to avoid inventory inaccuracies at the end of the fuze lot. Correction requires unpacking pallets of thousands of fuzes to find the one tray with the empty slot, inserting the missing fuze, repackaging them, and finally returning them to storage. In total, this process can consume as many as 360 manhours, depending on the lot size.

Until recently, redundant inspections and manual counting were the only preventative measures for detecting empty slots and avoiding inventory discrepancies. However, in June of 2017 BGAD operationalized a vision system that is custom-designed to scan completed fuze trays and immediately alerts the team if any are missing. The system was designed and programmed by Mechanical Engineering Technician, Michael Wilson, with assistance from local equipment suppliers. The heart of the system is a Cognex smart camera, which captures images of processed fuze trays and compares them against an image of an acceptable standard that is known to be a full fuze tray.

Since coming online, the system has been flawless in identifying incomplete trays and has secured the confidence of its operators, potentially having saved the depot hundreds of manhours already. During this period of initial usage, BGAD operators will continue to provide feedback regarding the system's performance and opportunities for further enhancement. If feasible, that input will result in requirements for improved capabilities that will be added in a future upgrade.

PROBLEM STATEMENT

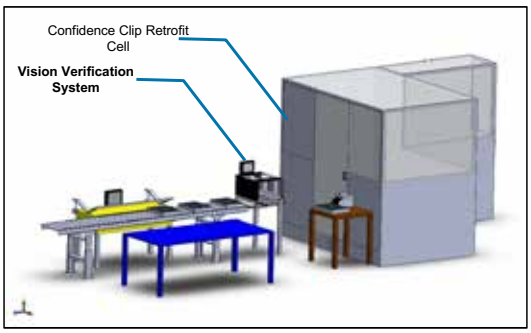
- The accounting of M228 fuzes being retrofitted with Confidence Clips was being performed by a completely manual visual inspection consuming at least 200 man-hours per year.
- Due to the large production volume (6000 fuzes per shift), and the eventuality of human error, discrepancies would occur.
- Correcting a discrepancy could consume as much as 360 man-hours per event for processed fuzes returned to inventory.

BENEFITS

- Improved Accountability
- Improved Inventory Accuracy
- Reduced Labor
- Lower Production Costs

TECHNOLOGY SOLUTION

- A machine vision system scans trays of processed fuzes.
- The system compares the captured image against an image standard.
- The system issues an alert if it detects a difference between the images, which indicates a missing fuze(s).



DURABLE ASSET MANAGEMENT TAGGING

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Currently 'automated' armories and maintenance facilities are not truly automated. A key component such as asset tracking still requires manual processes. Particularly, Radio Frequency Identification (RFID) tagging does not seem to be working, as it should. The problem is that tags used to track weapons tend to fall off because of actual product use and cleaning procedures. After significant analysis, Impact Resources (IR Tech) determined an improved approach. IR Tech's patent pending approach for Durable Asset Management is to embed an RFID tag (or other sensor) within a component of an asset such as a weapon. The component should be an item that can be retrofitted easily and inexpensively. Most weapons and equipment utilize a pin or a bolt, such as a Pivot pin, in their assembly that are low cost. IR Tech's concept is to turn the part into an RFID pin that could store identification data and can synchronize via the internet or closed wireless network to a management application. The concept is that any similarly manufactured device can now be tagged, tracked, or report in a similar fashion. Our system embeds the RFID tag or sensor into an assembly level component of any item. The host item will not appear to be modified in anyway (e.g. no visible sign – unless desired, of an RFID tag or other sensor). The antenna and tag is designed to overcome interference from metal components that make up the host system.

The system must be a component of the weapon or product: pivot pin, takedown pin, bolt, screw, and is modified to accept an RFID tag or other sensor as an internal embedded component. In order to mitigate the impact of the host object's metal construction on the reading of the tag, the following is offered:

1. A powerful reader is used to generate the necessary waves to penetrate the metal of the host object.
2. The host object is modified to act as an antenna

a. The internals are etched as a wave guide
b. Different metal or conducting material is inserted with the tag to serve as the antenna.
c. The most likely solution is a combination of the reader and host object modification.

When the weapon/product is issued or received the responsible person reads the weapons id by passing a reader over the tag or by direct contact (tapping) the host object. That information is fed into an asset management application.

Initial ad hoc prototype testing of an RFID M4 pivot pin was successful. Next steps are to refine the manufacturing processes to produce lab testable prototypes of the pin.

Benefits:

3. Seamless integration with weapons; no protrusions, external tags, or etching modifications.
4. The Tag/Sensor cannot be worn off, lost, or impacted by cleaning or other maintenance processes.
5. Removes requirement for manual entry of any weapon identification information.
6. Inexpensive to produce and retrofit into weapons already in the field.

This concept is patent pending.

PROBLEM STATEMENT

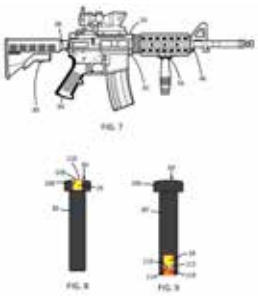
- RFID Tags and sensors, especially for smaller items such as weapons tend to not be durable and fall off or become inoperable due to use, cleaning, and maintenance processes.
- Tags and sensors in many instances protrude or require modification to the item.

BENEFITS

- Seamless integration with weapons/equipment; no protrusions, external tags, or etching modifications.
- The Tag/Sensor cannot be worn off or lost or impacted by cleaning or other maintenance processes.
- Removes requirement for manual entry of any identification information. Supports automated sensor feeds.
- Relatively inexpensive to produce and retro-fit into weapons/equipment already in the field.
- Similarly manufactured devices can now be tagged, tracked, or report data in a similar fashion.

TECHNOLOGY SOLUTION

- Most weapons and equipment utilize a pin, bolt, or other fastener such as a pivot pin, in their assembly that are low cost and easily replaceable.
- IR Tech's concept is to turn that part into an RFID or sensor pin that could store identification and other data and can synchronize via the internet or closed wireless network to a warehouse or asset management application.
- Patent Pending



Initial Prototype is for M4 with Pivot Pin. Initial concept test with off the shelf tags and readers was successful. Currently working on manufacturing processes.

SMALL UNMANNED AERIAL SYSTEM (SUAS) MAINTENANCE INSPECTION CAPABILITY

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

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

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

Inspections of aircraft upper surfaces that normally can take up to 2-hours were done in 30 minutes with a quadcopter; in the case of the C-17 a sUAS would spare maintainers using a lift to inspect its tail. Maintainers at Edwards AFB were able to use the sUAS' video to sign off their preflight external inspection -an Air Force first. This testing opens the aperture on flying a sUAS near the airfield, which has been frowned upon in the past. These initial missions are establishing baselines for how operations can be conducted safely at Edwards and other USAF installations.

With proper development, this technology presents potential for multiple uses. In addition, to real time monitoring of inspections; capabilities exist to record the inspection as well as tracking aircraft condition over time. Further development of automatic flight patterns, self-contained lighting, and improved camera capability would only enhance the capability of the platform.

PROBLEM STATEMENT

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

BENEFITS

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

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

TECHNOLOGY SOLUTION

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

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

REMOTELY CONTROLLED REPAIRS DURING OPERATIONS

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Naval operations in the 21st century require the ability to more rapidly repair and modernize systems than the present approaches support. Our current methods of addressing ships' damage and complex repairs require removal of Fleet assets to shore-based activities and extended schedules. The kinetic environment of naval combat will not support this for future prolonged operations.

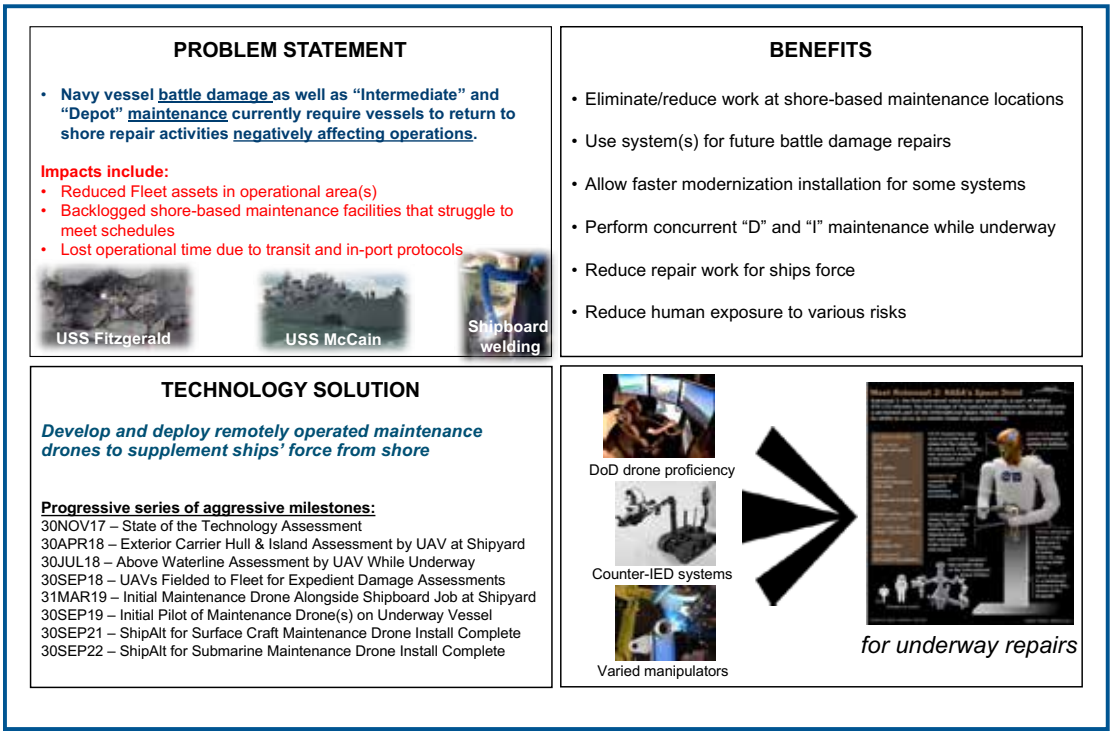
Opportunities abound to fuse solutions within the Department of Defense (DoD) and other federal entities to provide accelerated repair capabilities for the Navy's Fleet. The DoD has over a decade's experience operating drones for surveillance and target engagement around the world. Additionally, complex robotics continue development through conventional (e.g., counter improvised explosive devices) and non-conventional (DARPA) avenues. Other federal partners have already fielded solutions demonstrating the efficacy of remotely controlled repair efforts as evidenced by the Robonaut project that has been on-board the International Space Station since 2012. MilTech is currently working a Technology Scouting effort to identify the most appropriate solutions available to support the aggressive schedule and needed capability.

The project will field a series of remotely controlled assessment and repair systems to support the Fleet to increase its operational posture beginning next year. Initial objectives will be the fielding of existing DoD UAV and UUV capabilities to support immediate damage assessments within minutes of an event. Concurrent development of drone platform maintenance solutions will proceed initially at shore facilities and migrate to shipboard applications as the protocols and systems are refined for intermediate and depot maintenance evolutions. Increased throughput and underway maintenance performed by shore-activities are expected to yield at least a 30% reduction in in-port/dock maintenance durations within four years.

This effort is intended to produce new capabilities for the Navy including:

- Kits for UAV/UUV to support Battle Damage assessments
- Drone operators and facilities at shore activities
- Development and fielding of interchangeable robotic end-effectors for increased maintenance purposes

The future of naval combat requires more real-time repair and maintenance operations and this effort will yield more resilient and expedient capability for securing the world.



FLUORESCENCE NON-DESTRUCTIVE EVALUATION OF HEAT-DAMAGED COMPOSITES

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

Under ONR MANTECH funding, we recently developed a laboratory surface-fluorescence apparatus and demonstrated its capability to assess incipient heat damage in Epoxy- and BMI-based PMCs (Merdes, 2017; Merdes, et. al. 2017). That apparatus could be configured into a field-portable instrument that would be smaller and lighter than the aforementioned FTIR-based instrument. Due to the nature of surface fluorometry, various sensor probes could be devised that interrogate spots of different sizes—say, one for dime-size spots for large-scale damage assessment on flat or gently-curved surfaces, another for spots the size of eight-point type for interior structures having small clearance and high curvature.

The proposed effort would involve development of means to use a light-emitting diode (LED) in place of the diode laser currently employed, self-calibration, instrument engineering for portability and ruggedness, analysis algorithm refinement, and validation against PMCs subjected to heat damage under known conditions. The deliverable would be a field-portable prototype instrument that could be used for heat-damage assessment virtually anywhere on an aircraft's exterior or interior.

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

Merdes 2017. Daniel W. Merdes, "Fluorescence-Based Nondestructive Evaluation of Incipient Heat Damage in Aircraft Composites", presented at 2017 DoD Advanced Composite Maintainers TIM, Hill AFB, Utah, Aug 22, 2017.

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

PROBLEM STATEMENT

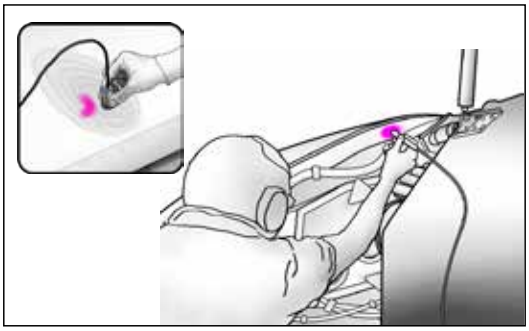
- NDE capability needed to assess incipient heat damage to polymer matrix composite (PMC)-based components of military aircraft
- Current FTIR-based commercial instrument
  - Works well on Epoxy-based PMCs
  - Sensor head size limits employment to flat or gently-curves structures (wings, rudders, …)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

BENEFITS

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

TECHNOLOGY SOLUTION

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



HIGH-RESOLUTION, HANDHELD 3D SURFACE GAUGE

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For many years inspectors in the aerospace, automotive, and precision manufacturing industries have requested an instrument to gauge the severity of surface defects and corrosion in order to rapidly determine if parts are safe for use or need rework, repair, or replacement. Current metrology methods are too low in resolution, too slow, or susceptible to vibration or operator error. The result is millions of dollars lost to the unnecessary scrapping of parts that meet specifications as operators err on the side of caution, as well as the potential passing of bad parts due to lack of quantification. 4D Technologies is developing the first handheld, non-contact 3D surface gauge, allowing inspectors to measure even large, complex surfaces with micrometer resolution right on the shop floor.

Polarized light is focused through a specialized phase grating onto the test piece, and imaged at a different angle onto a camera that has differently-oriented micro-polarizers in front of each camera pixel. The resulting image is then parsed and the 3D surface reconstructed through dynamic interferometry techniques. The surface gauge additionally utilizes custom optics and additive manufacturing techniques to maximize standoff distance, resolution, and field of view while maintaining a compact package size that weighs less than one pound.

Sophisticated analysis software automatically finds pits and protrusions that meet customer thresholds and reports critical statistics for all defects within the field of view. The software performs powerful surface shape removal and filtering, yet single-button operation via a touchscreen monitor makes it extremely easy to learn and repeatable to use. Use of a optical fold mirror even allows measurement for areas without direct line of sight.

First generation units have been fielded at multiple aerospace new-make and service shops, a corrosion research center, and other precision manufacturers. Current units have a 0.3”x0.3” field of view, 1.3” standoff distance, and a single cable from the measurement head to the computer for both power and data. The ideal unit will be fully wireless, incorporate a larger field of view, and have further software enhancements for different specialized surface analyses.

4D has worked with customers to verify that surface defects can be measured to 0.0001” with greater than 95% confidence. Nationally certified standards verify accuracy of better than 0.5% over a .1” vertical range and a field of view of 0.3”x0.3”. Representative defect results are shown in the quad chart, as well as measurements of various components on the shop floor.

Wireless capability, enhanced field of view, and customized software will enhance the final released product. Already, benefits to production and repair are obvious to users: “The 4D InSpec is an innovative measurement system that the aerospace industry has needed for years—beyond years.” Sean MacKendrick, Production Manager at StandardAero, a leading maintenance, repair/overhaul provider. 4D believes the final gauge will greatly benefit inspection of precision components for aerospace, naval, and land-based machinery, reducing scrap and needless repairs while ensuring quality of everything fielded.

PROBLEM STATEMENT

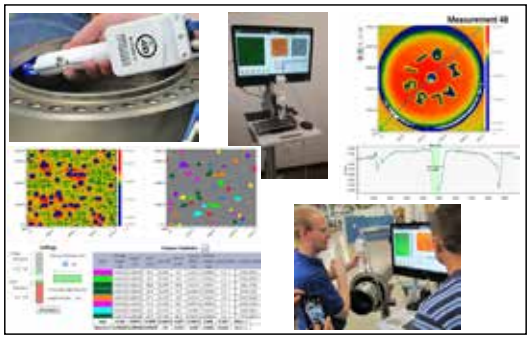
- Millions of dollars are lost currently because inspectors cannot adequately quantify surface defects on the shop floor
- No quantitative, in situ measurement capability for corrosion, pitting scratches, dents, nicks, and edge break exists.
- Operators rely on qualitative visual inspection or scribe checking, or replicated defects are sent to metrology labs with long delays for results and feedback
- Without quantitative results, operators err on the side of ‘reject’ or ‘rework’, adding needless expense and time to repair and new-make operations
- An easy, handheld system for 3D feature quantification in the shop or field would dramatically improve inspection throughput and reduce costs

BENEFITS

- Handheld, portable measurement of components throughout the factory or repair facility
- Quantifies features from 0.0001” to .1” (2.5 um to 2.5mm)
- Automatically finds pits/protrusions and calculates max height, volume, area, % area, length, width and aspect ratio
- Vibration-immune—measure despite factory noise
- Measurement cycle reduced from minutes to seconds
- Robust unit for shop floor use: resists dirt ingress, can be dropped 3’ onto concrete without damage
- Fold mirror option bends the light - measure sidewalls, between turbine blades, and other places without line of sight
- Measure large areas per measurement (0.3”x0.3”)
- Short learning curve; fast operation and reporting

TECHNOLOGY SOLUTION

- Combination of polarized light, dynamic interferometry, and fringe projection enables vibration-immune 3D measurements
- System focuses a polarization grating onto the test piece and images the grating back onto a camera that contains differently oriented micro-polarizers over each pixel
- The 3D surface can be reconstructed from the resulting single image
- Additive manufacturing and custom optics allow a compact, handheld design about the size of a flashlight, < 1lb weight.
- Optical design enables long standoff distance (1.3”), large field of view (0.3”x0.3”) and high resolution (.0001” vertical, .001” lateral)
- Intuitive software automatically finds and quantifies, pits, scratches, dents, nicks, edge break and other key metrics



BRIDGE HEALTH MONITORING

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TARDEC has developed a passive, remote bridge monitoring system for the Maneuver Support Engineer soldiers responsible for maintaining portable Army bridges. This system allows maintainers to look back at vehicle crossing logs that are passively collected, get a structural engineers perspective of the data, and advises on deploy, inspect, repair, or replace decisions based upon the bridge history and usage profile. The maintainer can keep at a distance and interrogate the system to gather the latest status report, which is viewable on a tablet or laptop with the appropriate encryption interface. This information will allow the unit to deploy the right capacity of bridge for each mission, make data supported decisions for inspections, and rotate bridge components to extend the usable life of the fielded bridge sets. Data is transmitted wireless to a collector. In this case, it can be an overhead drone that comes close to or lands on or near the bridge and receives cumulative crossing data and then flies away to an operations center for data unload and analysis.

The modular system design allows for different types and numbers of sensors to meet a particular bridge's monitoring requirements. Since the system is programmable and uses standard interfaces, applications outside of monitoring bridge structures could be developed that simply uses the same modular hardware, interfaces, and application-programming environment with appropriate sensors.

This system will allow the transition of knowledge gathered in the lab or testing environment to be brought to the maintainer to predict maintenance cycles, identify overload and abuse events, extend the life of bridge assets, and reduce the likelihood of premature failure.

PROBLEM STATEMENT

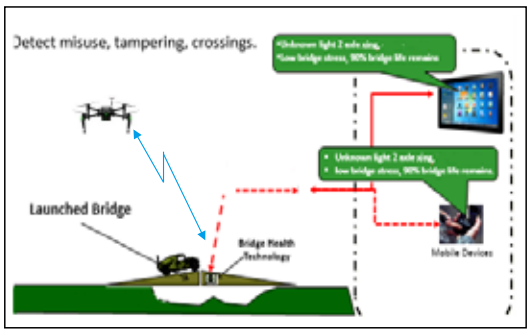
- Army portable bridges are left in remote areas where the environment can be harsh and no power is available
- Local residents often use the Army bridges which are not intended for highly concentrated tire loads that often result from residents fleeing the area with overloaded vehicle suspensions
- Army needs the ability to remotely monitor portable bridges to avoid unnecessarily exposing soldiers to inspect bridges that have not seen significant use, abuse, or overload and to alert maintenance unit of excessive use or abuse.

BENEFITS

- Remove soldiers from harms way.
- Relieve soldiers of burden of monitoring portable bridges.
- Predict bridge maintenance and logistics actions based on use data such as repair and/or replacement
- Gather usage data to inform future bridge needs / designs.
- Provide real time operational information on bridge crossings
  Into the logistics net for synthesis and action.

TECHNOLOGY SOLUTION

- Remotely monitor bridges using integrated-sensor-produced data translated with onboard logic into simple text messages that can wirelessly report the bridge status to users and maintainers using ultra-low power.
- In this concept, data is transmitted wirelessly to an overhead Commercial off the Shelf (COTS) drone that is traveling on a preplanned collection route to collect data and deliver to an Operations Post for analysis
- The drone will need the associated charging pad at its home operations center and the ability to transmit and received digital data packages. This capability already exists. The Bridge Health Monitor is a TARDEC developed product that already is in prototype but requires final development.



ELECTRICAL GREMLIN VIEWER

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Historically efforts at Eclypse have focused on providing maintenance personnel with the capability to rapidly find faults in complex electrical distribution systems. This capability also provided dramatic improvement and accuracy over existing field techniques and tools. Our most recent project involvement by Eclypse implemented what is now known as Certification Test Protocol (CTP) to Special Operations Aviation Regiment (SOAR) at the 160th located on Ft. Campbell, KY. The CTP allows maintenance personnel to identify those intermittent symptom type problems that normally occur during flight under vibration, moisture, heat and other environmental factors.

CTP provides a solid technology that identifies these "Gremlin" type issues to be constantly observed. The next logical step is to provide a Gremlin Viewer. If awarded this contest, Eclypse will progress the CTP Viewer software to allow maintenance personnel to view the measurement information in a color graphic mode to include key controls for filtering and report generation. This new capability will ensure electrical diagnosis remains at the point of failure and disposition can be determined immediately. This will ensure that NFF and CND are dramatically reduced and that they good avionics and components are not shipped back through the logistics chain only to be returned with additional costs for retest. Impact to maintenance cost reduction realized to date is AMC (Aircraft Maintenance Costs)/2= EMC (Electrical Maintenance Costs)/2= Amount AWTS saves in Maintenance $; a 50% reduction in the EMC for each platform.

PROBLEM STATEMENT

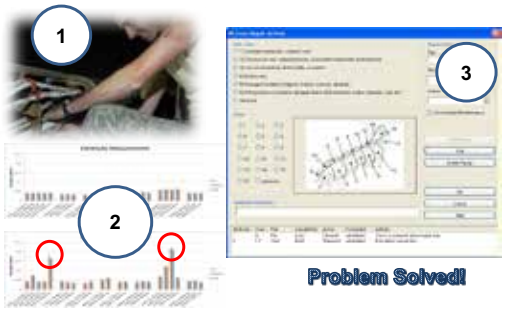
- Electrical wiring distribution subsystems become more complex for each generation of weapon system. Wire degradation produces costly and difficult-to-identify faults that can endanger operators, limit aircraft readiness, and lead to additional failures down the road. No feasible method exists today that can be used by maintenance personnel to accurately and feasibly detect and verify repair of these types of electrical failures.
- Without a proper method in the field, weapons systems continue to "fly until failure" in regards to electrical systems energizing them. The current approach leads to loss of life, mission, time, and money.

BENEFITS

- Rapid identification of nuisance type faults with a reliable method that does not require shaking or manipulating the electrical subsystem components.
- Problems can be displayed on to each maintenance level (technician, engineer, operator) using visual color and 3D graphics.
- Provides decision on go/no-go for avionics or wiring in decision tree.
- Accommodates zonal location of failure by reference designation thereby reducing disassembly of the aircraft/vehicle.

TECHNOLOGY SOLUTION

A method to detect the fault and validate the repair using an interactive graphical interface and consideration to augmented reality is the solution needed by our front line personnel. Visual representation of complex Electrical Wiring Interconnect Systems is now simplified, allowing rapid detection and verification of hard to find failures. End result is improved safety, higher mission readiness rates, and lower costs. The Electrical Gremlin Viewer (EGV) will provide a visual aid to personnel performing aircraft/vehicle inspection, troubleshooting, and preventive maintenance. Simple to use software with controls for filtering tolerance levels and methods to select alternate views of the issue.



DRIFT COMPOSITE HEAT DAMAGE EVALUATION OF V-22 WING

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Over the last 35 years, the Department of Defense has been flying aircraft that include flight critical components constructed of advanced composite materials. These materials reduce the weight of the aircraft, while maintaining superior strength characteristics and corrosion resistance when compared to previously utilize metallic materials; however, the composites used on DoD aircraft are less tolerant to extreme temperature than traditional metallic materials.

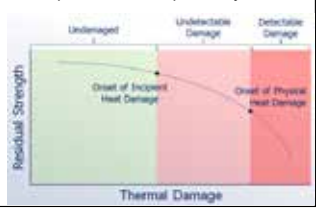
Issue: While physical damage due to extreme temperature such as charring and delamination can be detected using conventional non-destructive inspection techniques, chemical damage—often called incipient heat damage—may remain undetected. The uncertainty of undetected incipient heat damage in the composite after a high temperature event can lead to scrapped parts or scrapped aircraft, which may have otherwise been repairable.

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

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

PROBLEM STATEMENT

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



BENEFITS

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

TECHNOLOGY SOLUTION

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

Evaluation of Wing Skin

AUTOMATIC TEST SEQUENCE GENERATOR (ATSG)

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The creation of test program sets (TPSs) is a complex, labor-intensive process that culminates in the delivery of test software, test assets (e.g., interface devices and cables), and documentation describing the programs, assets, procedures, and other test and tuning activities. An important part of a TPS is stimulus signals that are specifically designed for maximum observability of the faults in a unit under test (UUT). Test engineers, guided by the interface control documents, by specifications, and by circuit diagrams produce these stimulus signals by studying actual UUT responses to stimulus signals in a development environment. The most effective stimuli will become a part of the TPS software. Currently, development of the TPS and stimulus signals is an analytical process involving the building of fault trees using UUT circuit diagrams and industrial-strength circuit simulation models. TPS software is currently coded manually, and can cost millions of dollars and take 12 months to 18 months to produce.

The Automatic Test Sequence Generator (ATSG) allows for TPSs to be created automatically. It is possible to greatly reduce schedule and budget, while improving accuracy of fault coverage. The ATSG automatically generates an optimal set of stimulus signals specific to a UUT by the use of stochastic optimization, called the Genetic Algorithm (GA). The optimization process improves fault detection and isolation, while simultaneously reduces the ambiguity. The candidate set of stimulus signals are proposed by GA and, then, each stimulus candidate is assigned a fitness index by a classifier analyzing all good and faulty circuit responses. GA uses the results of evaluation to produce a new, improved, set of candidate solutions. This process is repeated continuously until a set of optimal stimulus signals are created that best detects and isolates faults for that specific UUT. In addition to the optimized stimulus, this process produces a trained diagnostic classifier for a given UUT for a predefined fault universe.

The Automatic Test Sequence Generator has reached a Technology Readiness Level (TRL) of 4, after being validated in a laboratory environment. An analog bandpass filter circuit, with ten fault possibilities, was modeled, built and tested. A hardware system with reconfigurable inputs and outputs was used to output the set of optimal stimulus signals generated from ATSG, in place of what would normally be a TPS controlling automatic test equipment assets (such as I/O pins, tolerances, limits, timing, delays, signal generators, etc.). The system then read in the responses from the UUT and used its diagnostic algorithms to detect and isolate each of the faults within the analog circuit board. Thus, it was proven that automatic test set generation is possible and practical on small-scale analog circuits. Moving forward, the team will investigate whether the technique will scale on highly integrated, real-world circuit cards.

PROBLEM STATEMENT

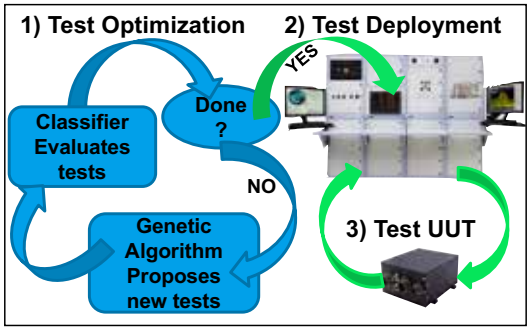
- Developing test program sets for electronic systems is expensive. The Naval Aviation Enterprise (NAE) spends approximately $40M yearly in acquiring new TPSs.
- Developing test program sets is time-consuming. Each TPS developed for the NAE may take up to 5 years to develop.
- There are accuracy issues and no-fault-found issues with current TPSs. When diagnosing a Unit Under Test (UUT), there exists a fault ambiguity group where a fault is known to exist, but the root cause cannot be isolated.

BENEFITS

- ✓ Automatic generation of test program sets (TPSs)
- ✓ Higher correct fault isolation than the current 70-75% rate
- ✓ Generation of tests at a fraction of the current 3-5 year development time needed
- ✓ Generation of tests at a fraction of the current $5M organic development and current $3M small business production costs

TECHNOLOGY SOLUTION

- ❖ Diagnostic unit that automatically optimizes stimulus signals for a UUT, allowing for higher fault coverage without increasing the number of test points
  1. Evaluates a set of possible candidate stimulus signals by classification
  2. Conducts selection of best candidates
  3. Evolves best candidates by mixing and retaining characteristics of previous candidates
- ❖ Automatically generates optimal set of signals to stimulate a UUT in order to detect and isolate faults, eliminating the need to create test program sets through manual methods



ENHANCED NDI CAPABILITIES USING THE WORLD'S LARGEST SCANNING ELECTRON MICROSCOPE

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The Oklahoma City Air Logistics Center (OC-ALC) located at Tinker AFB performs maintenance, repair, and overhaul (MRO) of military aircraft and jet engines. With multiple program offices, the Metallurgical Analysis Section (a resource of the ALC) supports mishap investigations, performs failure analyses, material consultations and/or characterization, and first article testing. Depot maintenance challenges are numerous, especially when considering supply chain demands and parts availability. This is true for large components facing obsolescence, long lead times, or high procurement costs. Large components such as disks, engine cases, shafts, fan blades are regularly overhauled and occasional discrepancies are found during inspection. One common challenge is characterizing non-destructive indications that are too small for visual or optical microscope examination. Consequently, the risk of uncertainly of the indication is too high for critical safety items and require destructive testing.

One lab-unique capability found at the OC-ALC that has facilitated the inspection of large engine parts is the world's largest scanning electron microscope (LCSEM). With the aid of this instrument, as-cleaned parts are inspected without having to condemn for high magnification inspection. This creates the opportunity to accomplish large part, non-destructive health assessments for indication characterization. Other uses of this instrument include inspection of used components for continued service viability and/or life extension considerations. Many rotating parts have service lives that have been established via modeling, historical performance data, and test data on fatigue crack growth rates. Often times, these operational lives must be decremented based upon a number of considerations. The Metallurgical Analysis Section at Tinker AFB, in cooperation with the Air Force Sustainment Center (AFSC) propulsion group and the Air Force Research Labs (AFRL) at WPAFB, has been evaluating specific parts identified as candidates for life extension, that is, the attainment of the full safe component life. To date, three components from the F100 engine have been successfully re-inspected via traditional non-destructive methods, visual inspection, and large chamber SEM analyses. In addition, in-situ Foreign Object Damage (FOD) is routinely performed on large fan blades without the need for sectioning.

With the addition of fixtures for staging large, geometrically complex components, the LCSEM is being used as enhanced NDI on a research level with the hope to save thousands of dollars per part from having to be condemned. To date, the LCSEM has saved well over $13 million in parts since 2009.

PROBLEM STATEMENT

- Current NDI methods, especially for high magnification imaging, provide indications of discrepancies on the surface of parts. When indications are too small for visual confirmation of a crack, enhanced inspection techniques are required. Large parts, whether new or used, for the world of engine propulsion is a high risk and high cost game when inspecting flight safety critical items like rotating disks. Condemning parts for the sake of in depth analysis can be quite costly.

BENEFITS

- LCSEM inspection uses conventional technology in a unique way that enables the inspection of large parts. Using a large vacuum chamber, high magnification inspection (100X-30KX) and qualitative chemical analysis (via EDS) is possible in order to validate surface discrepancies.

TECHNOLOGY SOLUTION

- Using the world's largest SEM provides the opportunity to non-destructively inspect large components to characterize indications, discrepancies, or anomalies. Workloads include material review boards (MRBs), FOD impacts on large blades, overtemperature inspection, and parts qualified for "Retirement for Cause" Program.

CECOM VIRTUAL LOGISTICS ASSISTANCE REPRESENTATIVE (VLAR)

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The lives of U.S. soldiers in combat depend on complex weapon systems and advanced technologies. Operational command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems provide the tools to conduct operations against the enemy and to maintain life-support. When C4ISR systems fail, fast and accurate diagnosis and repair may mean the difference between life and death. However, in combat conditions, the resources available to support the maintenance of these systems are minimal. Following a critical system failure, technical support personnel may take days to arrive via helicopter or ground convoy—leaving soldiers and civilian experts exposed to battlefield risks. A means to translate experiential knowledge and scientific theory is needed – the collective C4ISR system knowledge base – into a fingertip-accessible application for soldiers at the point of need. To meet this need, the U.S. Army Communications Electronics Command (CECOM), developed a suite of systems, Virtual Logistics Assistance Representative (VLAR), with a single purpose: to enable a combat soldier to diagnose C4ISR system failures with certainty and without outside assistance.

CECOM is responsible for life-cycle management of C4ISR systems and for connecting soldiers, wherever they are, to the C4ISR knowledge base. The CECOM VLAR team uses an Operations Research (OR) approach to codifying expert knowledge about C4ISR weapon systems and applying that knowledge to troubleshooting in combat situations. VLAR infuses a classic knowledge-management spiral with OR techniques: from socializing advanced technical concepts and eliciting tacit knowledge, to encoding expert knowledge in Bayesian Belief Networks, to creating an intuitive, instructive, and learning interface, and finally, to making VLAR a part of a soldier's daily life.

VLAR development starts with a counter-factual: what would have happened differently had a soldier been able to diagnose a critical system failure. Could a correct diagnosis and repair have prevented an injury or death? The VLAR software process, then, takes on all the rigor of a scientific experiment and is developed assuming the most extreme combat conditions. For example, it is assumed that VLAR is in the hands of a soldier who is engaged with the enemy. The soldier is in extreme environmental conditions with limited knowledge of and experience with troubleshooting the system that has failed, with limited tools, but with fellow soldiers depending on them to take the necessary steps to bring their life-saving equipment back into operation and get the unit out of danger. VLAR is changing the Army's sustainment paradigm by creating an artificial intelligence capability and applying it to equipment diagnostics. In the process, it has generated a sustainable cost-savings model and a means to mitigate combat risk. Through 2016, VLAR saved the Army $27 million in direct labor costs by reducing the requirement for technical support personnel. More importantly, VLAR has proven to reduce requirements for helicopter and ground-convoy movements. This translates directly to reductions in combat casualties. The foundation of maintenance is accurate diagnosis of the problem. By balancing analytical complexity and usability, VLAR teaches soldiers to think and act like experts and apply their knowledge in combat.

PROBLEM STATEMENT

Soldiers need:

- *Fingertip access to expert knowledge* on complex weapon systems, to ensure fast and accurate diagnoses of critical equipment failures in combat situations
- *Expert-based training integrated with the diagnostic process*, so they can internalize effective troubleshooting procedures and learn to act on causes instead of effects

Program Managers and their teams need:

- A foundation of *quality, on-platform maintenance data* for readiness management
- A means to *mitigate reductions in support personnel*
- A means *to capture expert knowledge* on weapon systems
- A means to *insert technology in technical and training publications*

BENEFITS

- VLAR has proven to *reduce requirements for onsite support personnel missions in combat* by enabling soldiers at platform level to diagnose equipment failures. Reducing convoy and air mission requirements in theater has a direct impact on casualty rates, reducing personnel support requirements reduces support costs
- VLAR has proven to *improve Operational Availability of systems by 30%* by using the software to analyze all equipment failures
- VLAR has proven a minimum *50% reduction in troubleshooting time with 100% accuracy*
- VLAR has proven a *significant training effect*

TECHNOLOGY SOLUTION

VLAR is a device-based, stand-alone diagnostic system for soldiers. It combines three technical innovations to provide a comprehensive troubleshooting network:

- ***An advanced Operations Research (OR) technique*** for eliciting expert knowledge
- ***Bayesian Belief Networks*** to codify that knowledge, qualitatively and quantitatively, into a causal network
- ***A custom Graphical User Interface (GUI)*** to move in and between networks and to represent that knowledge to soldiers in an efficient and intuitive manner.

This combination is an artificial intelligence that functions as a probabilistic expert system, helping soldiers navigate through and solve complex problems by entering evidence based on simple observations and tests.

THE USE OF INTERNET OF THINGS (IOT) AND AUGMENTED REALITY IN DEPARTMENT OF DEFENSE (DOD) MAINTENANCE APPLICATIONS

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New technology is available for use by the Department of Defense (DoD) Agencies to help drive up readiness rates by providing new Human Machine Interfaces through the use of the Industrial Internet of things technologies - Augmented Reality and the Digital Twin. This technology will revolutionize the way information is created, managed and delivered to and absorbed by future DoD maintenance personnel.

This initiative will capitalize on the DoD's effort around the "Third Off-Set Strategy" - introducing the digital thread with the human factor

- Enabling the digital thread for better interaction/harmonization of systems with humans
- Third Offset Strategy for Autonomous "Deep Learning" Human-Machine Collaboration, Human-Machine Combat Teaming, Assisted Human Operations, "Cyber hardened" semi- autonomous.

Profound changes are on the horizon due to connecting smart, sensored assets and operating them as a system of systems. This will affect how the military operates and sustains its equipment and how logistics decisions are made to optimize the weapon systems performance and readiness.

With the service life of military aircraft being in the realm of 30-60 years, and next generation aviation platforms such as F35, FTX, B21 coming into service, we need to take a fresh look at how the maintainers of tomorrow (which are the school children of today) will be supplied with the right job performance aids to complete their mission.

Traditional tech order delivery still is based in the paper/PDF world and requires many thousands of pages of complex text to relay technical orders. New technology advances in Augmented Reality and wearable computing devices change the way that information is displayed, delivered and executed. Step-by-step instructions and system information such as sensor readings and diagnostic information can be digitally overlaid onto the physical products. This greatly speeds up the maintainer's ability to access just the right piece of information to complete a task and allows them to see into/inside the product they are working on. This technology has the potential to revolutionize military sustainment.

We have to equip the war fighters of tomorrow with the technology of tomorrow, not that of the 1970's.

PROBLEM STATEMENT

- Aircraft service life = 30 - 60 years
- Complex systems that require 10's of thousand of textual pages and illustrations to describe service instructions
- Military maintainer technician age = 18-24
- Readiness rates are down in commands such as USMC aviation (*62 % Of F-18 Hornets Unfit To Fly, Up To 74% In Marines
- Generation X don't absorb or retain information like their parents did (a stack of paper books isn't going to work)
- How do we create the right job performance aids to ensure readiness rates in the future?

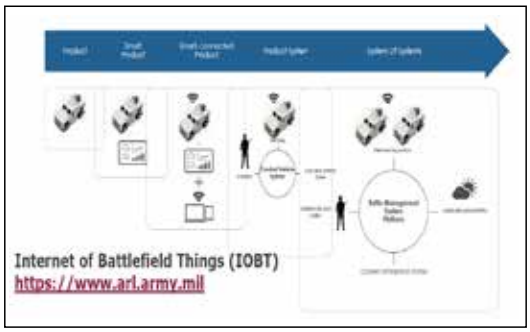
*http://breakingdefense.com/2017/02/62-of-f-18-hornets-unfit-to-fly-dod-hill-focus-on-readiness/

BENEFITS

- Utilizes wearable devices for true "hands free" operation
- Allows maintainer to talk to the equipment
- Voice activated search and maintenance commands
- Augmented view of the physical product (i.e. "show me the tire pressure"
- Inline with youth gaming culture and computing interfaces of today. – Our maintainers are young people.

TECHNOLOGY SOLUTION

- Augmented Reality and the Digital Twin
- Guided, step by step work instructions with both hands free
- Allows for access to legacy T.O's as well
- Voice activated, speech recognition
- Maintainer interacts with the equipment in ways not previously possible



DEPLOYABLE MOBILE RAMP

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The United States Army Europe (USAREUR) leadership identified the need to have a "portable" ramp solution in order to conduct rail operations in support of contingency operations within the EUCOM AOR.

TLSC-E developed and fabricated the first ramp by using an old Bailey bridge. This ramp's load capacity was rated at 75 tons and was portable but not conducive to transporting by flatbed or rail due to its oversized dimensions. The ramp's width exceeded the normal range by 24 inches, which voids transport by M872 trailer series trailers and rail. The Bailey bridge parts-based ramp is currently in use at MK Airbase in Romania.

Various Army organizations have collaborated on this joint effort in order to solve this challenge including the U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC) and the Rock Island Arsenal-Joint Manufacturing & Technology Center (RIA-JMTC) to Germany-based ramp manufactures. The estimated costs ranged from $300-700K.

Due to the cost and difficulty in transporting this type of ramp, our subject matter experts within the Maintenance Activity Kaiserslautern conducted numerous brainstorming sessions IOT develop a new concept by utilizing both ramps from an Armored Vehicle Launched Bridge (AVLB). This AVLB based ramp yields 2 ramps both consisting of a modular design that can be rapidly assembled and disassembled in a field environment. The load capacity is 85 tons and requires no special road clearance or waivers for transportation.

The ramps load capacity will ensure its future utility when loading and unloading modern, fully combat loaded, armored vehicles. It is easily transported by rail car, M872 trailer series, or commercial equivalent platforms.

The total cost for both ramps was less than $12 K including parts, supplies and certification. The MAK team worked tirelessly, using approximately 500 man-hours of effort by both mechanics and welders. The total time required spanned approximately 10 weeks including design and fabrication.

The ramps were used during SABER GUARDIAN 17 as a Proof-of-Principle and employed for the first time at the Port of Gdansk, Poland in support of the deployment of the 2nd Armored Brigade Combat Team, 1st Infantry Division, out of Fort Riley, Kansas.

The ramps were instrumental in ensuring the smooth and efficient uploading of approximately 87 M1 Abrams tanks, 103 Bradley Fighting Vehicles, 18 Paladin self-propelled Howitzers, and other equipment onto rail cars at the port of Gdansk. This is the first replacement of troops as part of continuing "heel-to-toe" rotations to maintain a U.S. armored brigade in Europe and the first time tanks have arrived directly to Poland by sea.

These mobile ramps have proven that "innovation is a combat multiplier."

PROBLEM STATEMENT

Problem: Develop a "portable/mobile" ramp solution in order to compliment rail operations and improve "speed of assembly" in support of operations within Europe.

Scope: The project focused on a modular, deployable, mobile ramp that can be rapidly assembled, disassembled, transported, and utilized on a permanent, semi-permanent, or field environment. The ramp's load capacity must be a minimum of 80 tons.

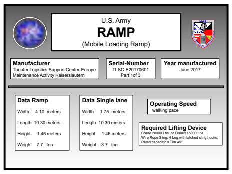
Achieved Goal: Fabricate the mobile ramps with the least cost and ensure its sustained utility in order to accommodate current and future fully combat loaded, armored vehicles.

BENEFITS

- Minimum Investment
- Modular Design
- Quick Assembly and Dis-assembly
- Sustained Utility
- Load Capacity
- Transportability
- Field Expedient

TECHNOLOGY SOLUTION

Beginning in May 2017, the Maintenance Activity Kaiserslautern (MAK) proposed the reinforcement and modification of an excess M60 AVLB bridge. MAK designed the required changes and contacted an external engineer company to calculate the static. The proposed materials and reinforcement technical drawings were accepted and calculated with an initial load capacity of 80 tons. MAK ordered additional material, disassembled the bridge, and began the process of improving and reinforcing the original base structure. The initial test included assembly and disassembly with a load test being conducted using an M88A1 on 26 May 17. Further minor improvements were implemented i.e., adding required tools, stenciling, painting, and the development of a deployable user and instruction manual with final completion on 31 May 17.



U.S. Army
RAMP
(Mobile Loading Ramp)

Manufacturer
Theater Logistics Support Center-Europe
Maintenance Activity Kaiserslautern

Serial-Number
TLSC-E20170601
Part 1of 3

Year manufactured
June 2017

Data Ramp
Width 4.10 meters
Length 10.30 meters
Height 1.45 meters
Weight 7.7 ton

Data Single lane
Width 1.75 meters
Length 10.30 meters
Height 1.45 meters
Weight 3.7 ton

Operating Speed
walking pace

Required Lifting Device
Crane 20000 Lbs. or Forklift 15000 Lbs.
Wire Rope Sling, 4 Leg with latched sling hooks.
Rated capacity: 8 Ton 45°

CRUSHLOCK PERMANENT NUT

JAMES KARINS
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From the skyscrapers making up our largest cities, to the trains and cars we travel millions of combined miles in Millions of lives rely on the strength and vibration resistance of nut fasteners every single day, even without knowing it. Ranging in several grades, designs, and purposes, they have all run into the problem of “nut dilation”.

Nut dilation results from the maximum torqueing of the nut during installation. Under the high stress load, the wedging action of the threads results in an increase of the minor diameter of the nut, essentially reducing the effective shear areas of both the external and internal threads. This leads over time to the loosening and eventually failure of the nut and bolt, expedited by increased vibration.

The CrushLock(TM) newly patented vibration resistant nut has been found to eliminate the forces causing nut dilation. The design of the nut converts the traditional friction forces from the wedging action into permanent internal compression and redirecting the lateral forces upwards insuring that all CrushLock Nut threads are intact with minimal thread stress, and maximum thread strength.

It is a one-piece, all-metal nut fastener that functions like a jam nut and a conventional nut installed and welded together. CrushLock’s patented design presses a permanent locking component into the nut body. This has resulted in what many fastener professionals thought impossible, a nut fastener that is not only vibration-proof but also greatly exceeds the industry standards in strength and performance. The CrushLock nut is free spinning and resembles a conventional nut, it installs easily with standard tools on standard bolts and studs.

The CrushLockTM nut is engineered for extreme performance from its inception by using computer modeling in 2D, 3D and Finite Element Analysis(FEA). The performance is permanent, once installed on a bolted joint. The nut retains the bolted pressure even if the nut is destroyed and profile-cut into quarter-pieces. It continues to function and retain pressure even after nut integrity failure. All other nut fasteners on the market today would violently release its pressure and fall-off once nut integrity fails. Keeping its pressure even after being cut into four, removing a CrushLock nut is essentially destroying it. This is the strength and vibration resistance needed to maintain the continued safety of those millions of lives.

PROBLEM STATEMENT

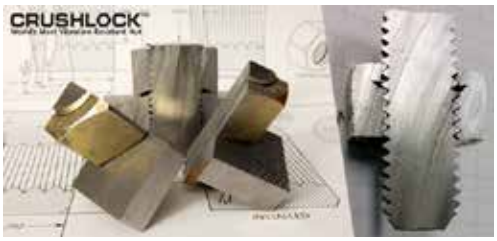
Nut dilation results from the maximum torqueing of the nut during installation. Under the high stress load, the wedging action of the threads results in an increase of the minor diameter of the nut, essentially reducing the effective shear areas of both the external and internal threads. This leads over time to the loosening and eventually failure of the nut and bolt, expedited by increased vibration. This can create safety issues in buildings, bridges, railroad tracks, pipelines, ships, aircraft, and ground vehicles

BENEFITS

- Permanent, does not vibrate free
- Holds up to 500% of the torque of standard nuts
- As vibration resistant as a welded nut but does not require the additional work and tooling
- Threads on to the bolt like a standard nut
- Uses standard tooling
- Reduces maintenance and increases reliability
- Holds by internal pressure instead of friction
- Manufactured in standard sizes and pitches

TECHNOLOGY SOLUTION

The key is understanding that the vast majority of nut thread stress is on the first two threads. In our design, which includes a notched wedge in the threading, these first two threads are pressed into the nut body creating "permanent internal pressure". The action of these two threads being pressed into the nut body prevents the first two threads from stripping and allows superior applied torque and pressure. The increased holding pressure may greatly increase bolted joint strength. Junker and several other tests have shown the CrushLock Nut performing far above the competition, even exceeding all the DIN 25201 vibration standards by over 300%. To handle such great forces the CrushLock Nut is designed to be permanent and must be destroyed to remove.



Still holds onto bolt after cut in quarters

"7M" ADVANTAGE OF OMAX JETMACHINING CENTERS

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

The OMAX JetMachining® Centers® (JMCs) addresses all of these concerns. The core abrasive waterjet (AWJ) technology allows a single machine to cut virtually any material, from metals to nonmetals (composites, glass, and ceramic) and from thin sheets to thick blanks. Advances in cutting head technology allows for 6-axis cutting, and the cold cutting process facilitates weld-ready bevels to be cut without the need to grind away the HAZ. The two product lines of OMAX and MAXIEM JMCs are available for precision machining from macro to meso scales, with position accuracy of +/- 0.003" or better. A mobile skid-mounted JMC that features all the necessary equipment was proven for in-theater emergency repair **(http://sme.org/MEMagazine/Article.aspx?id=78461**). It just needs water and abrasives (recyclable) and power to machine armor and prosthetic components made of various materials anywhere in the world.

The MicroMAX, a Finalist of the 2016 R&D 100 Awards **(http://www.mmsonline.com/suppliers/OMAX/content/1575b7c8-ac62-15a2-fbdf-6fcbe33f854c**), has a position accuracy within +/-0.0006" and is designed for precision meso-micro machining. The fully enclosed MicroMAX, is compatible for certain classes of cleanroom operations. With the MicroMAX added to the product lineup, OMAX has established an unparalleled capability of precision multi-mode machining of most materials from macro to micro scale (i.e., the "7M" advantage) for a wide range of part dimensions. The market demand for the MicroMAX, released for production in 2013, has greatly exceeded our expectation.

Common across all OMAX systems is the latest waterjet controller software. Extensive research coupled with real-world testing has resulted in a system capable of cutting faster while using less resource than any other system. The 4th Generation cutting model in OMAX software advances waterjet cutting to new levels, opening up greater potential and reducing overall operating costs.

A maintenance facility equipped with OMAX JMCs would meet most needs from micro to macro machining, minimizing the need for laser and plasma cutters and complement CNC mills. For heat-sensitive materials, AWJ cuts over one order of magnitude faster than solid-state lasers and EDM; lasers and EDM must pulse at high frequencies and cut with multiple passes, respectively, to minimize the HAZ. In addition, hardened steel with high RC values that wears out CNC tools rapidly presents no difficulty to AWJ. For extremely precision parts, AWJ has served as a near-net shaping tool to further shorten turnaround while extending the lives of expensive precision tools.

PROBLEM STATEMENT

- Today's maintenance facility encounters challenges such as material diversity and wide range of part dimensions
- Multiple machine tools supported by different operators with high levels of training and expertise are required
- Finishing a complex part often requires multiple part transfer
- Ideally, a DoD modern maintenance facility should establish a high degree of versatility with
  - Specialized single tools qualified for multimode machining
  - Automated machining processes maximizing productivity and preserving the integrity of material properties
  - Machine tools that are cost effectiveness with fast turn-around and environmentally safe
  - Fieldability for deployment in battlefields and remote areas
- The versatility of waterjet can meet the above challenges

BENEFITS

- AWJ possesses merits unmatched by most machine tools
  - Material independent and preserving material properties
- Cut reflective and thick materials (not for lasers) and nonconductive materials (not for EDM)
- No heat-induced damage (warping, slag, and burnt thin webs) as induced by CO_2 laser and plasma cutting
- Cut 10+ times faster than solid-state lasers (pulsed) and EDM (multi-passes) for heat-sensitive materials:
  - Flexures for micro splines (JPL/NASA), bonding extender (440C steel hardened to Rc58), and slot-less copper armatures for high-efficiency motors (MIT)
- A single tool qualified for 2D/3D macro-to-micro machining
- An invaluable tool to be integrated into DoD maintenance facilities for just-in-time and lean manufacturing practice

TECHNOLOGY SOLUTION

- One machine to cut virtually any material
- Multi-axis accessories allow for 6-axis cutting
- Cold cutting cuts weld-ready bevels with no heat-affected zone (HAZ), mitigating secondary grinding process
- JMCs available for cutting small and large parts
- Award-winning MicroMAX for meso-micro machining
- Mobile system deployed by the US Marine Corps
- Gen 4 cutting model advancing performance to new levels
- One operator to control multiple OMAX machines

CRANE BUDDY

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Naval shipyards use portal cranes to perform complex operations in support of intermediate and depot level maintenance on Navy ships and submarines. These cranes are used for loading supplies, removing critical components, and relocating complex facilities. Portal cranes traverse a complicated system of rails at each maintenance site and are operated by skilled professionals with extensive supporting personnel.

During portal crane movements, skilled crane operators employ “walkers” to ensure the safety of the crane and surrounding areas. The “walkers” visually identify obstructions and switch configurations. Skilled operators know where many of the switches and constricted areas are on an installation, but no system is in place to provide real-time understanding of proximity to these areas in the cab without interaction from the “walkers”. Each Shipyard has rail and dry dock loading restrictions, unique to crane model.

Similar to a car GPS navigation system, Crane Buddy has been designed to provide visual and audible in-cab indication upon approaching potential hazards and ensures the heightened sensitivity of the crane operator to safeguard the load, personnel, and the portal crane. Crane Buddy uses a smart phone or tablet to plot the crane position and compare that position with stored hazards, restrictions, and switches on a dynamic map. The smart device sits on the dash of the portal crane and is independent of the cranes’ systems. This allows Crane Buddy to be locally updated and deployed easily as a stand-alone solution not requiring any modifications to the equipment. Development is underway to depict multiple crane positions and provide status updates to crane management personnel.

The heavy lifting in naval shipyards will be dramatically improved through the use of a Navy constructed app – Crane Buddy.

PROBLEM STATEMENT

- Naval shipyard portal crane operators require concentration and awareness of their surrounding and crane position to ensure safe operations and prevent potential contact with existing structures
- Switch positions require verification to ensure intended crane travel and direction, but lack positive indication or distance to switch approach
- Crane derailment may occur due to communication error or crane intent
- Crane mishaps of any nature places the crane and shipyard operation in jeopardy and cause operational delay
- Wireless technology not vetting to support shipyard/rail position sensor employment

BENEFITS

- Increased awareness of potential hazards
- No equipment modifications required enables rapid fielding
- Ability to provide updates on outages to crane operators
- Ability to understand location of heavy lift assets over large geography

TECHNOLOGY SOLUTION

- ✓ Develop assistive technology to complement crane operators
- ✓ Utilize existing commercial off-the-shelf technology (COTS) to deliver low-cost smart device applications
- ✓ Determine existing needs and requirements for app inclusion
- ❑ Test shipyard enclave GPS coverage inside crane cab and potential environment/operational effects on GPS reception
- ❑ Test and evaluate assistive technology to determine best use and ROI

INCORPORATION OF SYNTHETIC LUBRICATING AND HYDRAULIC OIL ABOARD MULTIPLE CLASS SUBMARINES

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Problem statement:
The current practice of using MIL-PRF-17331 (2190 TEP) lubricating oil in SSN 688 Class submarine high-pressure air compressors (HPACs) results in excessive carbon formation. Hard carbon acts as an abrasive on close tolerance rotating or sliding internal parts (connecting rod bearings, piston rings, etc.). This causes more frequent planned and corrective maintenance, and reduced operational availability leading to higher maintenance costs and increased frequency of expensive HPAC overhauls.

The current practice of using MIL-PRF-17331 (2190 TEP) lubricating oil in SSN 688 Class submarine Ship Service Hydraulic and Steering and Diving systems results in sticking or sluggish hydraulic control valves (HCVs) due to varnish deposit formation. The average cost to overhaul an HCV is $150K.

Technology solution:
Under NAVSEA SBIR N04-160, METSS Corp. developed the replacement for 2190 TEP oil in Steering & Diving, Ship Propulsion Lube Oil, Ship Service Turbine Generator (SSTG) and SSTG Control Oil systems, Lube Oil Full, Transfer, and Purification, and Ship Service Hydraulic Systems.

- MIL-DTL-32353 Synthetic Oil is installed in HPACs in 10 SSN 688 Class submarines resulting in saving 67 man-hours in preventative maintenance per year.
- MIL-DTL-32353 Synthetic Oil is installed in all ship systems and components in one SSN, currently being installed in a second SSN.
- MIL-DTL-32353 Synthetic Oil is scheduled for installation in eleven SSNs in FY18 – FY21.
- Alterations are under development for SSBN/GN 726 and SSN 21 Class submarines.

Benefits:
LESS FRICTION AND WEAR: Data indicates improvement in performance of tight tolerances and rotating machinery resulting in less wear on machinery due to operation; including better fluid flow through equipment in cold temperatures.

REDUCTION IN MAINTENANCE: Significantly, extends duration between oil changes and maintenance, and results in less corrective maintenance downtime; increased performance of currently sluggish valves and hydraulic operations, reduction in corrective machinery downtime due to carbon/varnish build-up and failure.

SIGNIFICANTLY INCREASED oxidation stability and resistance to oxidation and corrosive degradation.

Alterations are under development for SSBN/GN 726, SSN 21 and SSN 774 Class submarines.

PROBLEM STATEMENT

- Problems with MIL-PRF-17331 (2190 TEP) hydraulic oil:
  - Elevated insoluble contaminants
  - Excessive moisture content
  - Reduced oxidative resistance
  - Off-gassing
  - Poor viscosity index
  - Flash point depressions
  - Unpredictable coloration
  - Sticky and sluggish hydraulic control valve operation
  - Excessive carbon build-up in SSN 688 Class submarine high pressure air compressors (HPACs)

BENEFITS

- LESS FRICTION AND WEAR: Data indicates improvement in performance of tight tolerances and rotating machinery resulting in less wear on machinery; including better fluid flow through equipment in cold temperatures
- REDUCTION IN MAINTENANCE: Significantly extends duration between oil changes / maintenance and results in less corrective maintenance downtime; increased performance of currently sluggish valves and hydraulic operations, reduction in corrective machinery downtime due to carbon/varnish build-up
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- MIL-DTL-32353 Synthetic Oil is scheduled for installation in eleven SSNs in FY18 – FY21

2190 TEP METSS Corp. synthetic oil

Before and after pictures of oil from hydraulic control valve testing at Sargent Controls and Aerospace

REPAIRING HELICOPTER GEARS WITH ISOTROPIC SUPERFINISHING TO REDUCE FLEET SUSTAINMENT COSTS

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High value, helicopter gears are currently scrapped at high rates for only minor amounts of damage. This scrap rate is due to the lack of a robust, machine-controlled process capable of removing 0.0001 – 0.0002" of metal uniformly from a complex shape such as a gear tooth.

The ISF® Process (a chemically accelerated vibratory finishing technology which is classified as isotropic superfinishing) has been proven to be capable of maintaining gear tooth geometry and quality rating while demonstrating consistent material removal of as little as 0.0001". Isotropic superfinishing technology has been publicly acknowledged as having been applied to helicopter platforms such as the Bell 427, 429, and 525; the Sikorsky S-76 and S-92; and the Leonardo AW189, and the ISF Process technology has been validated through multiple technical studies and proprietary customer evaluations for application on new aerospace gears.

Separately, the ISF Process technology has been validated as being capable of repairing damaged helicopter gears such that subsequent dynamic performance testing (including pitting fatigue testing, scoring testing, and single tooth bending fatigue testing) yielded equal or better results than those of new, non-ISF Processed gears. Applicable damage types found on repairable helicopter gears include but are not limited to micropitting, "frosting", and FOD damage.

The ISF Process has been widely implemented as a repair tool in high value gear industries such as Wind Turbine and Heavy Equipment. The process has proven to be beneficial in both repairing gears that may otherwise be scrap (as is the case with helicopter gears) and improving the performance of these gears, effectively upgrading and repairing these components simultaneously.

Recent technology developments have allowed for the repair of multi-feature components including multi-gear shafts and gears with integral bearing races, nitride components whose case layer is too thin for regrinding, and even gear assemblies thereby reducing the risk of scrapping a component during separation/disassembly.

With a cost often exceeding $5,000 per helicopter gear and potential lead times in excess of twelve months, the potential to reduce sustainment costs by repairing helicopter gears that are currently designated as scrap is significant (easily reaching into the millions of dollars). Further, the technology could be easily applied to additional gear and bearing applications including ground vehicles, and the like.

PROBLEM STATEMENT

- Helicopter gears are scrapped with only minor damage because there has not been an identified and validated process that is capable of controllably and repeatedly repairing the complex geometry of a gear tooth while removing no more than 0.0001 – 0.0002" of material from the tooth flank. The scrapping of these gears represents a cost burden to the US armed forces that is in the millions of dollars, considerably increasing fleet sustainment costs.

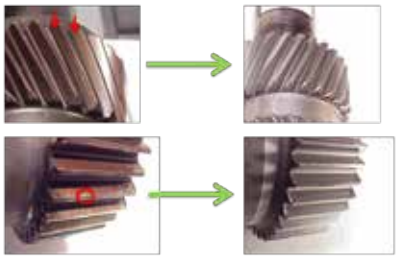
BENEFITS

- Machine controlled, robust technology capable of repairing the minor damage present on many otherwise scrap helicopter gears
- Repaired gears exhibit equal or better performance as compared to new, non-ISF Processed gears
- ISF Processed components exhibit performance increases including: increased resistance to contact fatigue, bending fatigue, and scuffing; extended operating life during oil-out conditions; and increased load carrying capacity/power density allowable
- Overall, the potential to reduce sustainment costs via the reduction of gear scrap rates and gear failure rates

TECHNOLOGY SOLUTION

- Isotropic superfinishing ("ISF®") is a proven technology in the helicopter industry as applied to new gears with publicly acknowledged application on platforms such as the Bell 427, 429, and 525; the Sikorsky S-76 and S-92; and the Leonardo AW189. It has been shown to be capable of removing as little 0.0001" of material while maintaining tooth geometry and gear quality rating on complex helicopter gears. The process is capable of repairing multi-feature components, nitride components, and all gear steels. ISF as a repair technology has been implemented broadly in the Wind Turbine Gearbox and Heavy Equipment industries and thus has potential applications outside of helicopter gears (ex. ground vehicles gears, bearings, etc.).

CH-46 Sun Gear & Input Pinion



Complete Removal of Micropitting and FOD Damage

AUGMENTED REALITY SAFETY GLASSES

CHASE MINNET

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Depot level maintenance requires constant interaction with various systems/data sources. The artisans require real time access to all of the systems and information for their jobs, and they need it be displayed in a manner that allows them to work at the same time. Currently, the artisans are required to stop work in order to access these systems. They also need a way to provide two-way feedback to quickly and accurately solve problems.

We are looking for a system that can integrate everything into augmented reality safety glasses or similar technology. This system would allow the artisan to use his safety glasses to access technical manuals and schematics, access step-by-step processes, capture labor hours, document technical issues and deviations, manage required tasks, and all other aspects of maintenance. This system would use voice, visual, and touch technology to access the systems.

PROBLEM STATEMENT

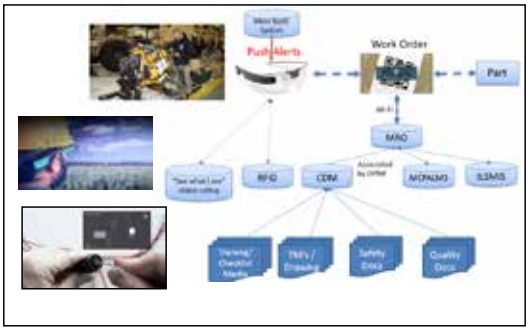
- Depot level maintenance requires constant interaction with various systems/data sources.. The artisans require real time access to all of the systems and information for their jobs, and they need it be displayed in a manor that allows them to work at the same time. Currently, the artisans are required to stop work in order to access these systems. They also need a way to provide two way feedback to all of these systems to quickly and accurately solve problems.

BENEFITS

- Connect workers with data and systems
- Real-time visibility of inventory locations
- Resolve exceptions in real-time
- Digital audit trails
- Accelerate training and knowledge transfer
- Improve cross-team collaboration
- Reduce rework and errors
- Improve productivity in common tasks

TECHNOLOGY SOLUTION

- Optical head-mounted display
- Voice and touch commands
- Connect to Wi-Fi & Bluetooth tooling
- QR Code Scanning
- Guided instructions & Workflows
- Real-time task assignments
- Capture, share & view media
- Stream live data from equipment
- “See what I see video” calling
- Integrated into ANSI approved Safety Glasses



AIRCRAFT RECHARGING PANELS

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In the aviation community, an aircraft battery loses charge too frequently due to the aircraft being settled on during scheduled maintenance being performed and on the weekends. Until now, each individual aircraft that is being charged by at least 2 workers and 20 to 30 minutes per aircraft which results in loss of unnecessary manpower and man-hours.

Here we propose a solar panel as a piece of protective equipment for the F/A18 A-F/EA-18G that straps around the front aircraft and connects to a connector in the nose landing gear wheel well to keep a constant charge on the battery or as a rechargeable device. Solar panels work through what is called a photovoltaic process – where radiation energy is absorbed and generates electricity (voltaic). Radiation energy is absorbed by semi-conductor cells normally silicon and transformed through photo energy or light into an electrical current. A newly modified solar panel protective equipment on an F/A-18A-F/EA-18G can absorb the radiation from the sun, which will provide an electrical current that will travel through the wire harness going directly to the battery for a constant charge.

In doing so this will reduce unnecessary use of man-hours that could be utilized for other scheduled and unscheduled maintenance actions that can increase our work force. It also reduces wear and tear of the A/M32A-108 Mobile Electric Power Plant and minimizes that use of JP-5 (Jet fuel) which in the end will save the commands money and manpower for the upkeep of the support equipment and aircraft.

PROBLEM STATEMENT

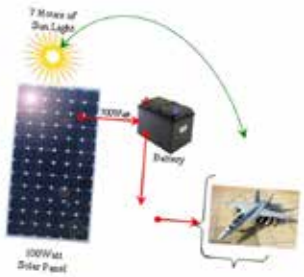
- Aircraft batteries are being drained from not being utilized over the weekend
- On an average five to six aircrafts are being fully drained which takes 30 to 45 minutes per aircraft to be fully recharged.
- A minimum of 13 man-hours are wasted from a two worker evolution on aircraft to aircraft battery recharge
- Rely on support equipment to have the availability of an External Power cart

BENEFITS

- Creating a piece of red gear/ protective equipment for the F/A-18E/F& EA-18G into a solar panel which will allow the aircraft battery to have a constant charge
- Operating / maintenance cost for panels are low
- Unnecessary use of man-hour will be cut down drastically by 90 percent
- Solar panels do not have any moving parts, relatively maintenance free and FOD free
- Provide clean energy without combustion or green gas emissions.

TECHNOLOGY SOLUTION

- A piece of red gear/protective gear for the F/A-18A-F/EA-18G can be created to connect in the nose landing gear wheel well through a minor modification to the test set power interface adapter.



INTERNET OF THINGS (IOT) CYBERSECURE ARCHITECTURE

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There is an increasing demand and budgetary pressure to employ efficient tools and processes across maintenance depots. Due to this trend, maintainers are continually looking to various forms of automation (e.g., automation of process, tool-based automation, etc.) as a means to achieve peak levels of efficiency. Current potential improvement areas along these lines include, for instance: converting paper-based systems to digital systems; integrating data and systems that are currently fragmented and stove-piped; and instituting the use of sensors to automatically measure and track workflow, tool usage, and overall readiness. Although some initiatives are already in-progress or completed to implement these types of improvements, most are using legacy architectures (e.g., NIPR-based) that limit flexibility and scalability due to the additional hardware infrastructure and Information Technology (IT) manpower necessary to manage it.

Internet of Things (IoT) is an emerging concept that involves the global networking of everyday objects and devices. Emerging IoT platforms supported by industry offer extensive potential to fully network and integrate tools and processes of many kinds, enabling not only the integration of disparate systems within a depot, but across distributed complexes as well. There are two main hurdles yet to be sufficiently addressed, however. 1) Being that IoT is still relatively new; its use has not been formalized or standardized across the DoD maintenance community; 2) IoT architectures are commercially driven and have not yet attained the level of necessary cybersecurity for government utilization.

In collaboration with Air Force Sustainment Center (AFSC), our team has been designing and prototyping an IoT based architecture with both of these issues in mind. This innovation has originated as part of the Confined Space Monitoring System (CSMS) research and development program. Through this effort, the IoT architecture will be applied to facilitate the exchange of live data from distributed health, atmospheric, and location sensors for real-time monitoring of maintainer health and safety while working within confined spaces. However, the application of this IoT architecture extends significantly wider, as our team is already leveraging the concept to streamline and expedite confined space entries/exits, as well as to digitally track the start and finish of maintenance tasks. The secure cloud-based infrastructure allows convenient automated storage and access of digitally tracked workflow across all Air Logistics Complexes, including integration with existing tools as necessary. In addition to the augmented availability of digital workflow data that is often sparsely available, there is further time saved by reducing the overhead associated with paper-based tracking of work activities.

The IoT cybersecure architecture will protect sensitive data with cybersecurity measures via Risk Management Framework (RMF) that meet/exceed high standards set by AFSC Information Technology Review Board. Furthermore, it provides a foundation on which to build future IoT applications within maintenance depots. Ensuing work will aim to set the benchmark for IoT based applications across the maintenance community.

PROBLEM STATEMENT

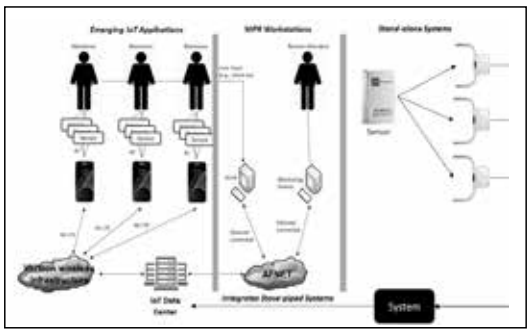
- Increasing demand and budgetary pressure to employ efficient tools and processes
- Automation of processes emerging as a leading means to achieve peak level of efficiency
- Current improvement areas include, for instance: converting paper-based systems to digital systems; integrating data and systems that are currently fragmented and stove-piped; and instituting the use of sensors to automatically measure and track workflow, tool usage, and overall readiness
- Prior initiatives in these areas use legacy architectures that lack flexibility, while new Internet of Things (IoT) are commercially driven and can lack necessary cybersecurity

BENEFITS

- Flexible and scalable architecture for new tools and processes to plug-in as means to automate digital tracking
- Facilitates converting paper-based systems to digital systems, thus reducing time, effort, and waste
- Facilitates integrating data and systems that are otherwise fragmented and stove-piped, thus reducing data fragmentation and increasing complex-wide awareness
- Enables the use of sensors to automatically measure and track workflow, tool usage, and overall readiness
- Protects sensitive data with cybersecurity measures via Risk Management Framework (RMF) that meet/exceed high standards set by AFSC Information Technology Review Board

TECHNOLOGY SOLUTION

- IoT is an emerging concept that involves the global networking of everyday objects and devices
- In collaboration with Air Force Sustainment Center (AFSC), our team has been designing and prototyping an IoT based architecture for digital health and workflow tracking
- Initial IoT architecture applied to facilitate live data from distributed sensors for real-time monitoring of maintainer health and safety while working within confined spaces
- Architecture design leveraging latest advancements in cybersecurity technology and best practices tailored for government applications
- Provides foundation for future applications such as digitally tracking tool use, task allocation and bottlenecks, etc.



ULTRA-SPEED MACHINING WITH ROTARY TANGENTIAL MOUNT CUTTING TOOLS

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Manufacturing facilities are regularly challenged to reduce costs by being as productive as possible with the equipment they have. Running machines faster to reduce cycle times often means running the cutting tools faster — this translates into exponentially reduced tool life. As workloads increase, cost reduction challenges deteriorate to capacity-constraint agony. Once tooling is running as fast as reasonably possible, the remaining alternative is purchasing additional equipment. However, at Endres Machining Innovations (EMI) we have developed an alternative solution. Our Rotan™ rotary tangential mount technology offers a lower-cost, speed-multiplying alternative in OD turning, boring, face milling, and peripheral milling.

Our solution employs a round cutting insert that passively rotates due to chip formation. This yields thermal management and continual indexing. Thermal management means comfortably running at higher cutting speeds, speeds 2-4 times those of conventional fixed-insert cutting tools. Continual indexing means running longer between tool servicings, a result of (depending on depth of cut) 8-20 geometric equivalent cutting edges on each side of the two-sided insert.

Rotating-insert technology does not eliminate the natural tradeoff between cutting speed and tool life; but, it does shift that tradeoff to a different level — a significantly higher speed regime. Building on the academic expertise of EMI's founded, Dr. William Endres, in cutting mechanics, EMI began work on rotating-insert cutting tools 11 years ago. Having developed radial-mount rotating-insert products, we stand firm that the future is in the rotary tangential mount technology due to its greater breadth of application, especially in high-value, difficult-to-machine materials common in land, air and sea military equipment. Compared to a radially mounted rotating insert, lab testing in long-chipping materials (steel and Inconel 718) indicates Rotan provides many potential benefits:

- free-er chip flow for long-chipping materials (e.g., steel, stainless steel, titanium, nickel alloys)
- geometric edge toughness leading to more positive rake geometry and lower cutting power
- large corner radius that is also effectively "settable" for tailoring to roughing or finishing
- transition from high-feed to "ultra-feed" machining
- less propensity to chatter
- scalability on insert diameter for larger mills and boring tools, and large-part turning

On January 3, 2017, Dr. Endres visited a plant for the first turning tool trial outside EMI's lab. The operation was finish turning of AISI 5120M automatic transmission gear blanks. Combining the ultra-feed capability (up to 3 mm/rev) and innovative application strategy, cutting time was reduced by 85% relative to the conventional tool it is replacing while maintaining roundness of 5-10 µm and Ra of 0.25-0.3 µm. Tool life testing is forthcoming after prototype refinements/updates. With our initial focus on turning (TRL 7) with three early adopters, we are prepared to take the next steps of moving the Rotan platform to face milling, boring, and peripheral milling (TRL 5).

With your changes in tool paths/conditions and our standard tool interfaces for drop-in replacement, cycle-time reduction comes safely and easily. With significantly reduced cycle times, maintenance man-hours and turn time are positively impacted leading to quick payback on tooling transition cost through (burden rate) cost savings.

PROBLEM STATEMENT

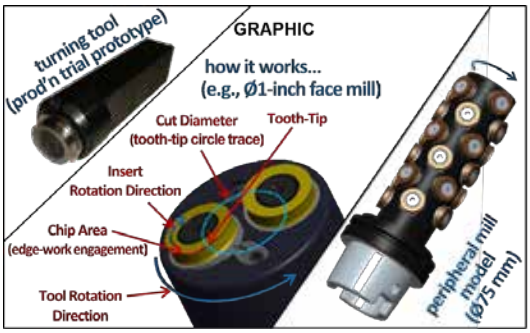
- Challenged to reduce costs by being as productive as possible with current equipment.
- Reducing cycle times means running cutting tools faster and exponentially reduced tool life.
- As workloads increase, capacity-constraint becomes an issue.
- Already running tools fast, the remaining alternative is purchasing additional equipment.
  - EMI has developed an alternative solution.
  - Rotan™ rotary tangential mount technology.
  - a lower-cost, speed-multiplying alternative in OD turning, boring, face milling and peripheral milling.
  - YouTube video of initial turning tool in action (link).

BENEFITS

- Compared to a radially mounted rotating insert, lab testing (steel and Inconel 718) indicates Rotan's potential benefits:
  - free-er chip flow for long-chipping materials (e.g., steel, stainless steel, titanium, nickel alloys)
  - more positive rake geometry and lower cutting power
  - large corner radius; "settable" for roughing or finishing
  - transition from high-feed to "ultra-feed" machining
  - less propensity to chatter
  - scalable for larger mills & boring tools, & large-part turning
- Production trial: finish turn, AISI 5120M auto trans gear blanks:
  - Ultra-feed (up to 2-3 mm/rev) + innovative app strategy.
  - Cutting time reduced by 85% relative to conventional tool.
  - Maintained roundness of 5-10 µm and Ra of 0.25-0.3 µm.

TECHNOLOGY SOLUTION

- Employs a round cutting insert that passively rotates due to chip formation.
  - Yields thermal management and continual indexing.
  - Thermal management means you run comfortably at cutting speeds 2-4 times those of conventional tools.
  - Continual indexing means you run 8-20 times longer between tool servicing using 1 side of the 2-sided insert.
- Cycle-time reduction comes safely and easily.
  - Standard tool interfaces for drop-in replacement.
  - Reduced cycle times lead to cost savings.
- Maintenance man-hours and turn time are positively impacted.
  - Leads to quick payback on tooling transition cost through (burden rate) cost savings.



EFFICIENT AND EFFECTIVE FLEXIBLE DUCT CLEANING

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The requirement for ventilation during ship repair work is paramount to ensure a healthy and safe working environment for shipyard repair and maintenance workers. Exposure to various hazards include poor air quality due to stagnant air caused by insufficient air flow, contaminants produced as result of ongoing work in the spaces (e.g., dust, welding fumes or vapors) and from source pollutants such as residual sewage. At the Ship Repair Facility-Japan Regional Maintenance Center (SRF-JRMC), ensuring that flexible ducts are cleaned thoroughly between uses is a constant concern and time-consuming effort.

Since all flexible ducts are reusable across the shipyard they are required to be cleaned after each use to remove any particles, dust or other contaminates. Cleaning flexible ducts present a unique challenge, and a time-consuming effort due to the curves, folds, bends and accordion like properties of the ducts.

The Japanese workforce at SRF-JRMC have a can do spirit called "NanDemo Dakimasu" or "We can do anything". The Command has a robust Improvement Activity program that encourages innovation at the deck-plate level to tackle unique challenges to find solutions that increase safety and reduce time, material and costs.

The flexible duct cleaning process spurred the Production Shop personnel to develop a method to wash these ducts more effectively and efficiently. A washing machine/tool was developed that decreased labor time, decreased material, decreased water usage, and reduced costs that also increased safety by reducing worker back strain.

The labor time reduction went from 3 workers to 2 with a decrease in time from 5 minutes per duct to 1.8 minutes for a total of 230.6 Man-hours per year. Water usage was reduced from 8.4 gallons per duct to 2.5 gallons per duct for a 70% reduction in water use. Workspace required to perform the task went from 500 square feet to 60 square feet for a reduction of 440 square feet. Lastly, back fatigue was reduced or eliminated.

This is one example on how the innovative ideas of production shop personnel can bring about savings, efficiencies and increased effectiveness of daily work in any maintenance and repair environment.

PROBLEM STATEMENT

- The production shop (X99V) cleans the inside of flexible ducts with water and wipes the outside by hand with rags. Due to the accordion style ducting and length as long as 16 feet, it is not easy to reach inside making washing difficult. Washing a duct requires approx. 8.4 gal of water and 5 minutes by 3 workers including cleaning with rags. 500 ft² of space is necessary to clean each duct as they need to be stretched out. Workers have back fatigue from this work.

BENEFITS

Water Usage Reduction:
- From: 8.4 Gallons -> 2.5 Gallons
  = **70% water reduction**

Man Hour (MH) Reductions:
- Reduced 3 workers to 2 workers
- Reduced MH from 5 mins/duct to 1.8 mins/duct
  = 230.6 MH savings per year

Work Space Reduction:
- Reduced space footprint from 500sqft to 60sqft
  = 440sqft space reduction

Reduced or Eliminated Back Fatigue

TECHNOLOGY SOLUTION

- Shop personnel developed and built a machine/tool that provides a powerful spray of water to the inside and outside of the flexible hose simultaneously, reducing the cleaning time, reducing space required to clean, reducing water usage and waste water treatment/processing, and reduction of worker fatigue WHILE increasing efficiency of the removal of contaminants.

Stage 1

Cylinder for ducts

Stage 2

Internal spray nozzle

Stage 3

Finished Tool

MASTER MAINTENANCE PERSONNEL TRACKER (MMPT)

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Special Projects Patrol Squadron TWO (VPU-2) performs millions of dollars of maintenance every day, but its most invaluable expenditure is its sailors' time. VPU-2 is a Navy P-3C squadron that executes two missions, research and development testing and deployment augmentation. However, it is minimally manned with only 200 sailors in the Maintenance Department. As such, sailors' time is at a premium. What matters most, of course, is actual maintenance, which is accomplished by training brand new sailors with virtually no experience, indoctrinating them into complex Navy maintenance culture, and sending them overseas for real world experience. The Master Maintenance Personnel Tracker (MMPT) relieves the administrative burden on VPU-2's sailors so they can spend their time on the maintenance that matters most.

The MMPT is a set of organizational business practices and Visual Basic-enabled Excel worksheets that draws data from Naval Aviation's Advanced Skills Management (ASM) database. ASM outputs volumes of data in an archaic, largely illegible format, but the MMPT transforms the data into actionable information. First, the MMPT automatically updates personnel information, such as leaving and entering the command as well as rank changes. It provides a snapshot of every notable qualification for each person in the Maintenance Department. Then, by leveraging division leaders' knowledge of their sailors' schedules, the MMPT predicts the number of qualified personnel the Maintenance Department will have available to work at any given time.

For instance, the MMPT informs leadership if too many electricians will be on leave and/or detachment during an upcoming inspection. Leadership can then make informed decisions on how it wants to distribute its sailors. Next, the MMPT leverages the same division leaders' knowledge to produce a muster report for the entire maintenance department in both the past and the future; the utility here is boundless. Maintenance leaders can view departmental organization in the past, such as during a holiday leave period, to inform the decisions in the future. They can also see the sailors on hand today to verify work attendance or muster personnel during an emergency.

Lastly, they can visualize the department in the future to ensure adequate distribution of experience. With regards to experience, some sailors inevitably work harder and deploy more often than other sailors. With the MMPT, however, deployment operational tempo is automatically tracked for every sailor in the Maintenance Department. Maintenance Leaders are thus capable of allocating sailors abroad equally and optimizing sailor pedigree. Finally, the MMPT graphically illustrates sailor qualification progression. By leveraging division leaders' knowledge of their sailors and fusing this information with ASM data, the MMPT shows when a new sailor is not meeting expectations or when a division is outperforming others with regards to qualification progression. The MMPT, with a concept of operations that has been refined iteratively over the last 18 months, is a successful, tried-and-true maintenance innovation that has transformed VPU-2 and will continue to reap dividends in the future.

PROBLEM STATEMENT

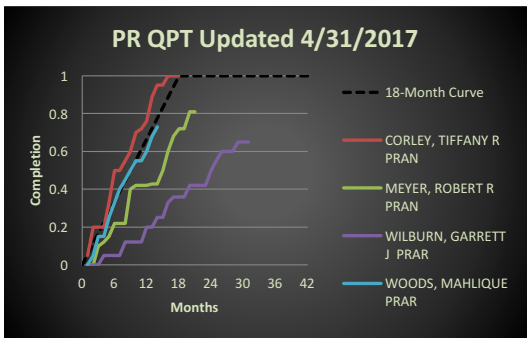
- Special Projects Patrol Squadron (VPU-2) Maintenance Department is minimally manned
- Sailors' time is best spent performing maintenance, but too much of it is spent completing administrivia
- Maintenance leadership needs to be able to
  - Track sailors' qualifications
  - Forecast personnel shortfalls
  - Allocate sailors abroad
  - Monitor sailors' qualification progression

BENEFITS

- Saves 500+ man-hours each year while informing optimized maintenance leadership decisions
- Unambiguously accurate information straight from ASM
- Automated sailor rank, duty, and qualification updates
- Visually appealing, condensed information display
- Tracks sailor operational tempo automatically
- Musters maintenance personnel:
  - In the past to inform the future
  - In the present for emergency recall
  - In the future to expand sailors' pedigree
- Graphically displays unbiased sailor qualification progress to identify individual and divisional outliers

TECHNOLOGY SOLUTION

- Visual Basic-enabled Excel worksheets
  - Draws data from Naval Aviation's antiquated Advanced Skills Management (ASM) database
  - Automatically updates changes within the Maintenance Department
  - Presents data in an actionable visual information format
- Paradigm shift in business practices through tried-and-true concept of operations
  - Division leaders provide simple, comprehensive inputs regarding their sailors in order to receive valuable, forward-looking outputs
  - Product of 18 months of refinement



KZO FIELD SERVICE REPRESENTITIVE VIDEO PLATFORM

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Today's battlefield in replete with advanced technology and weapons systems that require a dedicated support team. For most technologies, this requires Field Services Representatives (FSR's) to co-locate with combat troops to rapidly diagnose and repair failures, and perform preventative maintenance (PM). According to CBO and Department of Defense (DoD) analysis, starting in mid-2011 through current operations, there were more contractors than active duty servicemen deployed in Iraq and Afghanistan, by a factor of three to one. The cost associated with such heavy non-combatant deployment is estimated to be in excess of $220B over the two campaigns. In addition to the financial cost, there are non-monetary issue such as the lack of accountability of contractors, and the logistic burden of accounting for, tracking, and maintaining contractors in theater etc.

The KZO Platform was In-Q-Tel funded work program with the primary focus on remote training and agency wide communications, essentially an agency wide, secure, YouTube-like environment, with enhanced functionality. KZO was approached by one of our defense related commercial clients, concerned over the volume of FSR's they had to deploy. Through an iterative process, KZO and our customer added functionality to the platform that allowed then the flexibility to maintain staff in non-hostile and remote locations, taking advantage of the indigenous and Third Country National (TCN) work force, while still maintaining their commitment to the customer and their equipment. The KZO Platform allows for quick mobile uploads of video from any source or device, allowing TCN, indigenous and deployed service members to securely video document disruptions or serviceability issues with equipment. Once uploaded the video can be accessed by company technician or SME's. Through the platform's collaborative features, multiple SME's throughout the world can comment on the issue and dialogue with the deployed service member in real time to resolve the issue.

For PM and routine servicing, the KZO platform offers the company the ability to create a comprehensive video library of preventative maintenance and common service disruption issue. The KZO platform is multilingual, allowing it to be viewed in native languages, and supports the upload of closed captioning that can also display host or native country language. The library can be accessed and viewed by Third Country Nationals and indigenous personnel, with appropriate access credentials, supporting the campaign. The library provides information on the required procedures, and provides a collaborative link back to the SME if there are additional questions. Follow on information and collaboration ten become part of the video for future users. It is on demand, constantly evolving, and can be used as a searchable reference as needed.

KZO's platform is currently being used by large corporations to train their service staff in the latest methods and equipment, similar to the current role of the field based FSR. Deploying FSR's is costly, and in many cases, the same functionality can be achieved by technology. The KZO platform is the link between headquarters and the field, minimizing, and in some cases eliminating, the need for FSR's all together.

PROBLEM STATEMENT

- Field Service Representative (FSR) deployments in support of ongoing operations world wide is a continued burden on both the Government and the individual company.
- Deployments of FSRs are:
  - Costly to both the company and the government
  - Logistically difficult to monitor and maintain
  - Places individuals at risk unnecessarily
  - Has in the past complicate policy objectives
  - Has in the past create public affairs issues

BENEFITS

- Leveraging technology allows companies to decrease FSR deployments while maintaining support
- Significant savings to both the Government and individual companies
- Lessens the logistical burden on deployed forces
- Reduces CONUS contractor administration requirements
- Reduces the number of non-combatants in areas of operation
- Removes the risk to life and limb for the individual FSR
- Engages indigenous population in work programs

TECHNOLOGY SOLUTION

- The KZO platform allows for quick mobile uploads of video from any source or device, allowing TCN, Indigenous and deployed service members to securely video document disruptions or serviceability issues with equipment. Once uploaded the video can be accessed by company technicians or SME's. Through the platform's collaborative features, multiple SMEs throughout the world can comment on the issue and dialogue with the deployed service member in real time to resolve the issue.
- For PM and routine servicing, the KZO platform offers the company the ability to create a comprehensive video library of preventative maintenance and common service disruption issue.
- Platform works on all devices no additional downloads required.

AUTOMATED GENERATION OF TEST DIAGRAMS TO SUPPORT AUTOMATIC TEST SYSTEMS

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When automatic test programs fail to properly test and/or diagnose an electronics unit from a weapon system, the operator of the Automatic Test Equipment (ATE) often struggles to troubleshoot the system. The operator will likely not possess a knowledge of the test program source code functionality, the test assets and the signal paths being used in the tests. Test diagrams show the routing of signals for each test in an automatic test program, which tests a Unit Under Test (UUT) on an ATE, and can greatly enhance the troubleshooting process. It is crucial that the test diagrams are accurate and are consistent with the current test station assets, interface hardware and test program source code.

As part of a NAVAIR SBIR Phase II program, we have developed and demonstrated a software tool to automate the creation and update of test diagrams without requiring an intimate knowledge of the test program source code, interface hardware or paths used. This automated process for test diagram generation significantly decreases the time required to generate them by eliminating many hours of analysis of test stations, test programs and associated interface hardware. The solution also enhances the update process and eliminates errors and inconsistencies typical of manually generated diagrams. Relying on the Institute of Electrical and Electronic Engineers (IEEE) Automatic Test Markup Language (ATML) standards for the format of data in this process is a key component of this solution and provides an open systems approach.

This tool has garnered much interest in the Department of Defense (DoD) as well as in the commercial test community. It was initially designed for the Navy Consolidated Automated Support System (CASS) test station, which uses the ATLAS programming language, however, the tool can be updated to support other DoD and commercial test stations which use other test program languages. Benefits include savings in manpower, time and costs by automating the process. This tool can be a valuable component in the weapons systems maintenance process and will help minimize weapons system downtime to ensure the warfighter has the tools to complete the mission at hand.

PROBLEM STATEMENT

- Ensuring weapon systems are fully operational is critical to support the mission of the warfighter. Providing accurate reference data to the operator of Automatic Test Systems (ATS) in the testing of this equipment is essential. Test diagrams, which identify the routing of signals for each test in a Test Program Set (TPS), are a valuable resource to support the operator when testing the weapon system hardware. Test diagrams are typically generated manually, which is a labor intensive process and the resultant diagrams tend to be error-prone and difficult to update.

BENEFITS

1) Help ensure weapon system is fully operational.
2) Minimize weapon system downtime.
3) Reduce cost to maintain weapon system.
4) Utilizing the Automatic Test Markup Language (ATML) standards for the format of data provides an open-system approach and yields interoperability with other support tools.

TECHNOLOGY SOLUTION

- The process and the automated software tool generates test diagrams automatically using data compliant with the IEEE ATML test industry standards. The automated process for test diagram generation promises to reduce the time to generate test diagrams by eliminating countless hours of analysis of test stations, test programs and associated interface hardware. In addition the solution simplifies the update process and minimize errors and inconsistencies typical of manually generated diagrams.

STANDARDIZED CWP USER DATABASE (SCUD)

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For decades, Sailors serving our Navy and Civilian Employees have spent millions of hours generating Controlled Work Packages (CWPs) for the purpose of conducting Quality Assurance (QA) Maintenance. Each maintenance item no matter how simple the task, could result in hours of preparation. Some relief is provided by the governing document, the Joint Fleet Maintenance Manual (JFMM), with regard to Standardized Formal Work Procedures (FWPs). In accordance with the JFMM, "FWPs which have been performed and proven may be retained on file to lessen the effort in preparing for a future task of a similar nature." (See JFMM Volume 5, Part 1, Chapter 2, Page 17, Paragraph 2.3.7.10) However, a CWP is an FWP with QA documentation. Most of the work and time invested in the preparation of a CWP is spent researching drawings, researching and filling out forms, and the routing/revision/approval phase. Moreover, in many cases this labor will be repeated time and time again for the conduct of the same maintenance.

The idea presented here is for a standardized CWP database loaded with proven CWPs that can be searched by class of ship, then individual component to be worked. These would include all forms and current drawings required for the conduct of maintenance. All forms and drawings would automatically update as current instructions, manuals, and drawings are updated. Any qualified individual would be able to search the database, simply enter their respective hull number, print and route and accurate CWP.

The goal would be to accurately standardize a cumbersome process for the purpose of saving time and reducing errors.

PROBLEM STATEMENT

- Sailors and civilians spend countless hours preparing Quality Assurance procedures and documentation regardless of maintenance complexity.
- Research that has already been done and approved on one ship, is not readily available to any other ship of the same class in the fleet.

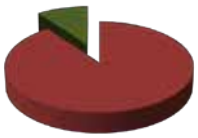
BENEFITS

- Standardizing Controlled Work Procedures (CWPs) reduces errors and saves time. Putting these Standardized CWPs in a fleet wide database will save time as well.

TECHNOLOGY SOLUTION

- Once in place, a qualified individual would be able to search the database for the component to be worked and simply print and route the CWP through the QA chain of command.
- This would reduce the amount of time invested from, for example, 5 hours to 30 minutes.
- Future developments could eliminate the need to print during routing and require digital signatures.

TIME INVESTMENT GOALS



Maintaining the Joint Force Competitive Advantage through Innovative, Agile, and Adaptive Capabilities.

THE 2018 DEPARTMENT OF DEFENSE MAINTENANCE SYMPOSIUM

December 17-19, 2018 | Tampa Convention Center | Tampa, Florida, USA

MAINTENANCE INNOVATION CHALLENGE

CALL FOR INNOVATIONS

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

Revolutionary or Evolutionary; showcase your discoveries to the maintenance community at the 2018 Department of Defense Maintenance Symposium and shape the future of the industry.

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

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

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

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

All abstracts that meet the minimum criteria listed above will be posted on a public website and included in a Maintenance Innovation Challenge summary booklet, that will be distributed to symposium attendees on site. From the eligible abstracts, an evaluation board comprised of maintenance subject matter experts will select six finalists to present at the 2018 DoD Maintenance Symposium. Each presenter will be allocated exactly 15 minutes, including audience Q&A. The winner will be selected by the Maintenance Executive Steering Committee and Joint Group on Depot Maintenance Senior Leaders, and recognized at a Symposium Plenary Session.

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

If you have any questions or need further information regarding the 2018 Maintenance Innovation Challenge please contact Kristie Saber of SAE International at kristie.saber@sae.org.

Submit your abstract today to participate in the 2018 DOD Maintenance Symposium.

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

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