MAINTENANCE INNOVATION CHALLENGE

Monday, December 7. 2015
Room: 129B
3:00 – 4:30 p.m.

P151367

LOGISTICS AND
MATERIEL READINESS

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE

3500 DEFENSE PENTAGON
WASHINGTON, DC 20301-3500

December 7, 2015

MEMORANDUM FOR 2015 DOD MAINTENANCE SYMPOSIUM PARTICIPANTS

Maintenance innovation is a key to DoD's strategy to continuously improve maintenance effectiveness and efficiency. In keeping with the theme of the 2015 DoD Maintenance Symposium, *Achieving Uncommon Results though Innovation, Collaboration and Leadership*, we initiated the maintenance Innovation Challenge (MIC). Based on the success of Great Ideas Competitions" from past Symposiums, the Mic aims to elevate and expand the call for maintenance innovation beyond solely novel technology to also include unique partnerships, resourcing strategies, business practices or processes that promise to make maintenance more capable, agile, and affordable. We are pleased to announce that 69 excellent submittals were received from DoD, industry and academia.

With assistance from the DoD Joint Technology Exchange Group (JTEG), all 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 7, 2015 from 1500 – 1630 in the Phoenix Convention Center North, room 129 AB. We 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 8, 2015. Additionally, we encourage you to please interact with these maintenance innovators throughout the Maintenance Symposium in their dedicated exhibition hall space.

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

John B Johns
Deputy Assistant Secretary of Defense
(Maintenance)

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MEET THE JOINT TECHNOLOGY EXCHANGE GROUP (JTEG)

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. Composed of representatives from 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 is a strong advocate for new solutions with the potential to increase efficiency or effectiveness across the Services.

The JTEG collects, analyzes and disseminates depot maintenance requirements, makes information exchange easier, and serves as an advocate for new technologies and efficiency-improving opportunities that facilitate joint service technology development.

The JTEG community includes anyone in DoD or industry interested in exchanging information associated with DoD maintenance. Overseen by a panel of representatives from each of the military Services, OSD (Maintenance), and DLA, the JTEG's core activities include:

- Compiling information on the Services' current and future maintenance technology insertion projects, initiatives, and depot maintenance technology needs
- Formatting and disseminating relevant technology information for use throughout the depot maintenance enterprise and all relevant activities
- Review of maintenance requirements and capabilities to assist cross-Service coordination and knowledge sharing for efficiency improvement
  - Consider technologies applicable to like or similar platforms
  - Minimize technology duplication
  - Promote emerging technologies that meet current and future joint requirements
- Conduct gap analysis on the Services' technology needs and existing capabilities
- Advocate for projects that improve industrial processes, increase efficiencies, and/or reduce the environmental impact of depot maintenance.

The JTEG website, http://jteg.ncms.org, provides a forum for the exchange of information on new technology, processes, and equipment developments involving depot maintenance. Industry and DoD personnel can use the site to share technology ideas and needs. Visitors are welcome to review new and exciting technology projects posted on the website, or submit project ideas of their own. In addition, all JTEG technology forums are posted on the website.

The following is a list of technology forums scheduled by the JTEG:

- Dec 15 - Composite Material Repair Update
- Jan 26 - Maintenance Innovation Challenge Finalists
- Feb 23 - Cyber Security; Overcoming Challenges to Innovation
- Mar 29 – Laser De-Paint Update / Automated Painting & De-painting
- Apr 26 – Environmental Impacts & Worker Safety
- May – CTMA Partners' Meeting
- Jun 28 – Ergonomics; Protecting the Workforce
- Jul 26 – Alternate Energy / Energy Efficiencies
- Aug 30 – Welding Inspection, Operations, and Training
- Sep 27 – Asset Visibility; What, Where and Condition
- Oct 25 – Fiber Optic Systems Repair, Test, and Training
- Nov 29 – Technology Enhanced Workforce Development
- Dec 20 – Additive Repair Supporting Maintenance Operations

The JTEG Principals and key representatives are below:

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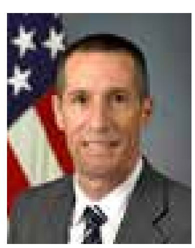

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COMMERCIAL TECHNOLOGIES FOR MAINTENANCE ACTIVITIES

The Commercial Technologies for Maintenance Activities (CTMA) program is a joint Department of Defense/NCMS effort promoting collaborative technology development, demonstration and transition within DoD. Its objective is to ensure American troops and their equipment are ready to face any situation, with the most up-to-date and best-maintained platforms and tools available. Under CTMA, government/industry teams form collaborative partnerships between DoD, private industry and academia to enhance warfighter readiness by providing new and innovative sustainment solutions that meet their needs.

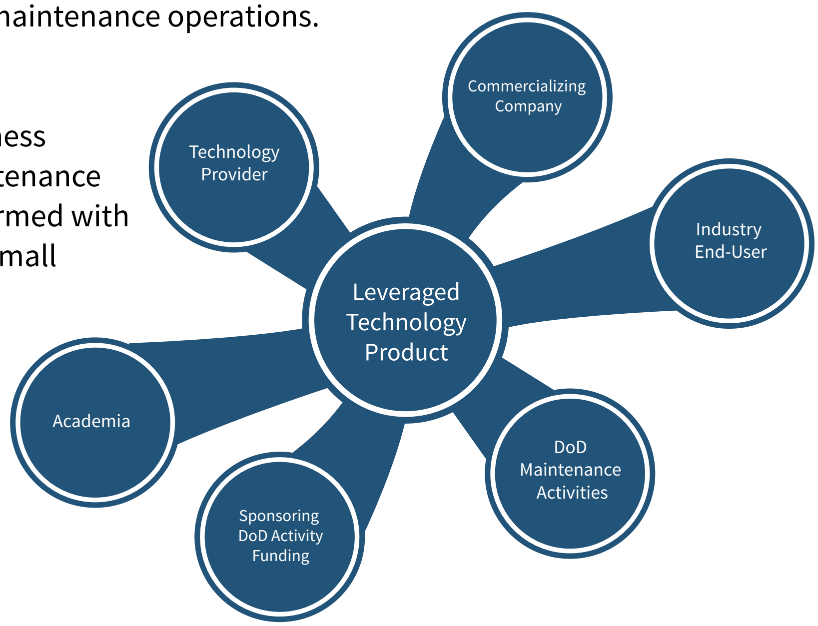
STREAMLINED TECH TRANSITION:

For over 17 years, CTMA collaborative teams have been successfully pioneering innovative, award winning Mx technologies such as laser coating removal, advanced electrical wiring test systems, expeditionary fluid analysis, additive Manufacturing and big data across multiple depots, ALCs, Naval shipyards, as well as field-level maintenance activities and headquarters organizations. CTMA offers a tremendous competitive advantage for your technology deployment and offers our industry partners a venue for increasing the visibility and validation of their technologies throughout the DoD.

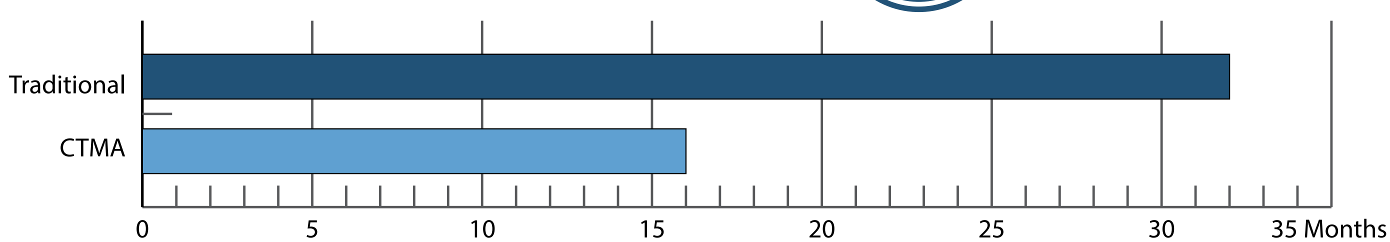
NEUTRAL FACILITATOR & IP PROTECTION:

NCMS forms and manages the project teams, and facilitates technology development, deployment and validation for use with the DoD's sustainment activities. IP ownership is protected through an iron-clad collaborative agreement between NCMS and each team participant. OSD serves as the advocate for the diffusion of technology solutions within the DoD maintenance operations.

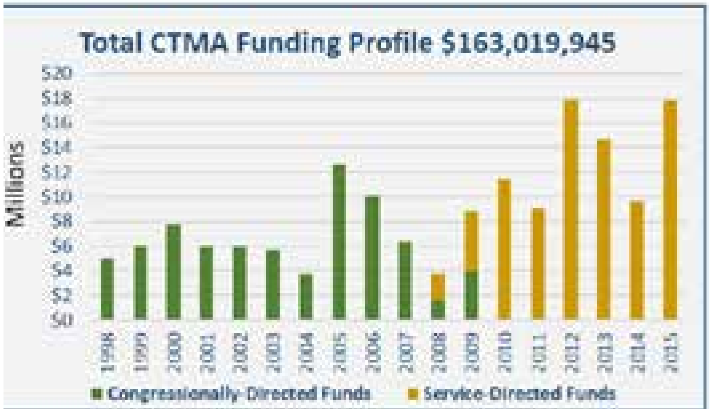
Collaborative Business Model - The CTMA business model starts with a DoD entity, typically a maintenance depot with a defined need. A team is quickly formed with one or more technology providers (oftentimes small entrepreneurs) who can address the need, and a technology integrator who has the ability to combine multiple technologies into a workable system leading to a demonstrated solution.

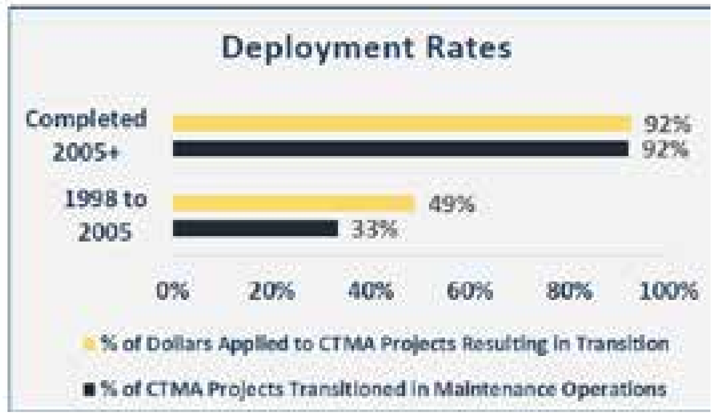


TIME TO PROCUREMENT



NCMS/CTMA TRACK RECORD





Cooperative Agreement

Under the CTMA Cooperative Agreement, the DoD maintenance activities have a unique contract vehicle to demonstrate commercial developments for application to solve issues prior to full acquisition.

Streamlined Process

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.

Cross-Industry

A robust collaborative environment with private industry participants and academia to perform research, development, and deployment that is relevant to both industry and the military.

AGILE COLLABORATION

CTMA “Agile” Collaboration is our experience-driven way of quickly organizing initiatives and securing the most effective technologies at best cost up front that best meet the needs of the government sponsor. We continually look for new technologies, innovative methods and designs that, if paired with complementary COTS technologies, oftentimes allows a more rapid transition satisfying a maintenance or sustainment need.

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Maintenance Innovation Challenge

Monday, December 7, 2015
3:00 - 4:30 p.m.
North 129 AB

Moderator:
Greg Kilchenstein, Director, Enterprise Maintenance Technology OSD Maintenance Policy and Programs

Finalists:

Automated Debris Analysis for At-line Maintainers
- Steve Odom, GasTOPS

Using Voice Directed Technology for Transforming Maintenance & Inspection Ops -
- Prakash Somasundaram, Honeywell

Phased Array Ultrasonic Testing for Increased Accuracy and Repeatability -
- LT Chris MacLean, Pearl Harbor NSY/IMF

NOKOMIS Advanced Detection of Electronic Counterfeits (ADEC) -
- Bryan Neva, NAVAIR AAT IPT

USCG Aviation Bonded Material Inspection System
- Rusty Waldrop, USCG

Assembled Replacement Integrated Circuits (ARICs)
- Corey Kopp, NUWC Keyport

Automated Debris Analysis for At-line Maintainers

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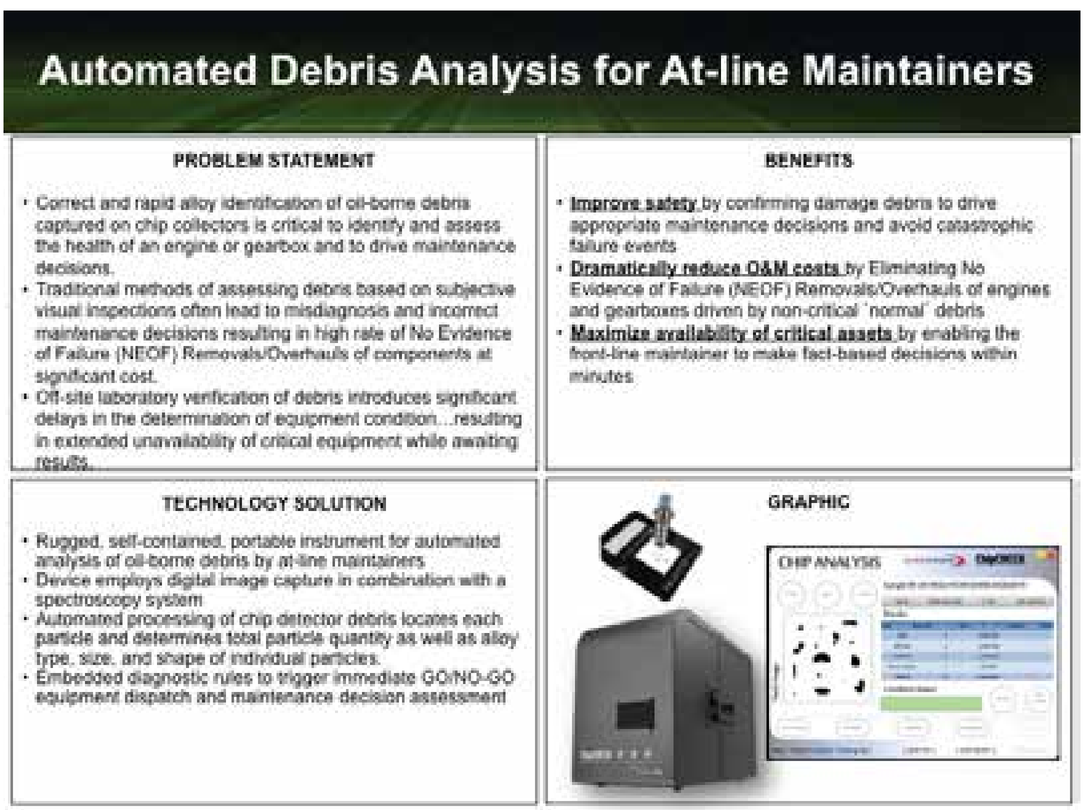
Damage of oil-wetted components within engines and gearboxes are a major safety concern and a significant cost driver for major weapon systems across all branches of the DoD.

Correct and rapid alloy identification of oil-borne debris captured on chip detectors, filters, sump screens and magnetic plugs is critical for the maintainer to identify and assess the health of an engine or gearbox and to drive maintenance decisions. Traditional methods of assessing debris based on subjective visual inspections often lead to misdiagnosis and incorrect maintenance decisions resulting in high rate of No Evidence of Failure (NEOF) Removals/Overhauls of components at significant cost. Off-site laboratory verification of debris introduces significant delays in the determination of equipment condition, resulting in extended unavailability of critical equipment while awaiting results. The ability to have rapid, accurate, quantitative analysis of debris by non-expert at-line maintenance personnel is not available today and represents a significant change to the current state of the art that will result in major reductions in O&M cost, improved safety and maximized availability of critical weapon systems.

This presentation describes a new and innovative diagnostic tool that brings the unique capability of providing at-line maintenance personnel with immediate information on the quantity, alloy type, size, and shape of debris particles allowing them to make non-subjective, conclusive fact-based decisions regarding the health of the equipment asset and take appropriate maintenance actions.

The instrument uses digital image capture in combination with an innovative spectroscopy system to automatically locate and analyse particles placed on a sample sheet inserted into the device. The analysis determines the particle quantity, as well as size, shape, composition, and alloy type of all particles on the sample sheet and applies embedded diagnostic rules to trigger GO/NO-GO maintenance decision assessment. The instrument has been designed for operation by at-line maintainers, provides full automated analysis at the touch of a button, requires no special training to operate or assess results and is rapidly deployable by the using unit for expeditionary operations.

The device has been successfully demonstrated in several field trials including at two Air Force bases under an AFRL/RTOC project (final report: AFRL-RZ-WP-TR-2010-2151). Test data from this project confirmed that the device is capable of analyzing and correctly identifying key materials commonly found within the oil systems of critical DoD weapon systems.



The device has also been fielded at GasTOPS in Dartmouth processing damage debris from the CH149 Cormorant aircraft. Results of this activity have demonstrated complete correlation of the results with traditional laboratory analyses performed on via SEM-EDX. Simplicity, reliability, portability, low cost and powerful analysis capabilities combine to make this automated debris analysis device a truly innovative and practical maintenance support tool that is available today.

Using Voice Directed Technology for Transforming the Maintenance & Inspection Operations

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Maintenance and inspections of mission critical assets - from aircraft to ground based vehicles - require the use of well-defined checklists to be followed by the maintenance technicians and detailed documentation of services performed for record keeping.

This process is beset by inefficiencies. It requires the technicians working in these hands-busy, eyes-busy environments to enter their observations and findings as a separate step from the actual visual and manual asset inspections. Honeywell's VocollectTM voice-directed solution enables technicians to elevate their documentation and compliance to levels never before attainable. Most importantly, it will enable the DoD to standardize and modernize maintenance processes to better support the warfighters' mission goals.

The solution consists of a wearable mobile device and a wireless headset with microphone. Technicians listen to checklist instructions and capture their observations by simply speaking their responses. This eliminates outdated back-and-forth manual data entry and look-up time on a laptop, handheld device or paper forms. The solution also ensures that the technicians strictly adhere to the standard operating procedure for a given type of asset. The data captured is automatically transferred to any DoD EAM/back end system for record keeping.

The use of this technology for aviation maintenance at Hill Air Force Base and other commercial customers such as Lufthansa Technik has significantly improved the quality of service, asset turn-around time and error rates.

For example, the use of voice for inspection of auxiliary power units at the Honeywell Aerospace Phoenix facility resulted in a 30%+ reduction in data entry cycle time. A large truck fleet maintenance operation has reduced asset inspection time by 25% while enabling quicker training of new employees. Lufthansa Technik has eliminated significant time spent on using spreadsheets for the induction of APUs in their Hamburg, Germany facility. Other sites such as Cherry Point—USMC Air Station for induction on F16 and Osprey APUs, US Army ANAD—Anniston for A1A tank parts inspection and USMC Blount Island—MPS for inspections/repairs on Assault Amphibious Vehicles (AAVs) have recognized the value of voice and see the potential for substantial process efficiency gains .

The simplicity and intuitiveness of spoken interactions have enabled rapid adoption of this technology by the technicians. For DoD leadership, it provides detailed real-time visibility into the status of every inspection and helps to identify bottlenecks. As the solution continues to evolve, the combination of voice technology with scanning, photo capture, touch screen and gestural interactions will transform every aspect of performing asset maintenance.

Affordable, leading edge technology that is easy to deploy, quickly adopted, and offers a quick return on investment will enable DoD maintenance operations to stay ahead of the curve and realize significant cost savings and service quality improvement.

Phased Array Ultrasonic Testing for Increased Accuracy and Repeatability of Structural Hull Weld Inspections

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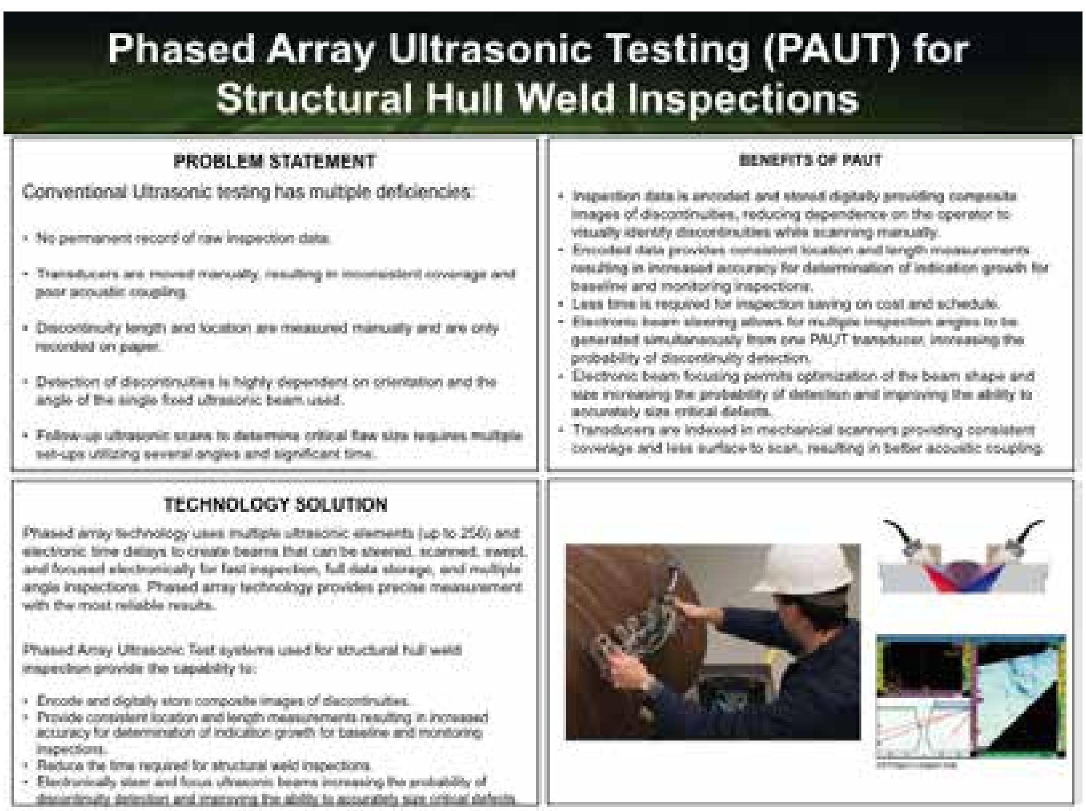
As part of the Navy's SUBSAFE Program, non-destructive testing and inspections are required to provide maximum reasonable assurance that submarine hulls remain structurally sound and watertight. This includes periodic testing as well as certification of critical elements affected during submarine maintenance periods. The traditional method of ultrasonic non-destructive testing is burdensome in both time and cost. The development and evolution of Phased array Ultrasonic testing (PAUT) technology has not only proven more accurate and reliable over traditional methods, it's also faster and less expensive. Successful implementation of PAUT for Naval Shipyard pipe weld inspection has resulted in cost savings, to date, in excess of 2.5 million dollars.

Conventional ultrasonic systems have been used successfully for years but are lacking in various areas. They don't have a permanent record of raw inspection data for post-inspection analysis. Data must be collected at the work site, which can be extremely cumbersome given the complex geometries and confined spaces associated with submarine maintenance. Conventional transducers are moved manually resulting in inconsistent coverage. Discontinuity length and location are measured manually and recorded on paper. The detection of weld discontinuities using the traditional system is highly dependent on the orientation of the discontinuity and the angle of the single fixed ultrasonic beam used. To precisely determine measurements of critical flaws using convention methods, follow-up testing is required using multiple inspection set-ups with several fixed inspection angles.

Utilizing Phased Array Ultrasonic Test systems, inspection data is encoded and stored digitally, providing composite images of discontinuities. This reduces dependence on operators to visually identify discontinuities on the display while simultaneously manually scanning the site. Encoded data can be analyzed off-site and provides consistent location and length measurements resulting in increased accuracy for determination of indication growth. Electronic beam steering allows multiple optimum inspection angles (e.g., 40° to 70°) to be generated simultaneously from one PAUT transducer increasing the probability of discontinuity detection. Electronic beam focusing permits optimizing the beam shape and size at the expected defect location. Additionally, this beam focusing increases the probability of detection and improves the ability to accurately size critical defects. Transducers are indexed in mechanical scanners providing consistent coverage and requiring less surface area to scan, resulting in better acoustic coupling and reduction of the influence of human factors on scanning reliability (e.g., inattention, fatigue, stress).



PAUT technology requires less time for inspection and boosts operator confidence given the additional information provided and electronically recorded for post-inspection analysis. Follow-up inspections are reduced due to increased ability to characterize and size discontinuities during initial scans, resulting in cost and schedule savings. Lastly, Time of Flight Diffraction techniques can also be utilized, for increased detection and sizing.

Side-by-side comparisons of field (shipboard) and mock-up inspections utilizing conventional UT and PAUT are ongoing at PHNSY&IMF to identify and validate the applicability and cost savings of PAUT for structural hull weld inspections.

The Detection and Prevention of Counterfeit/ Defective Electronic Integrated Circuits (ICs) Using the NOKOMIS Advanced Detection of Electronic Counterfeits (ADEC) Sensor System

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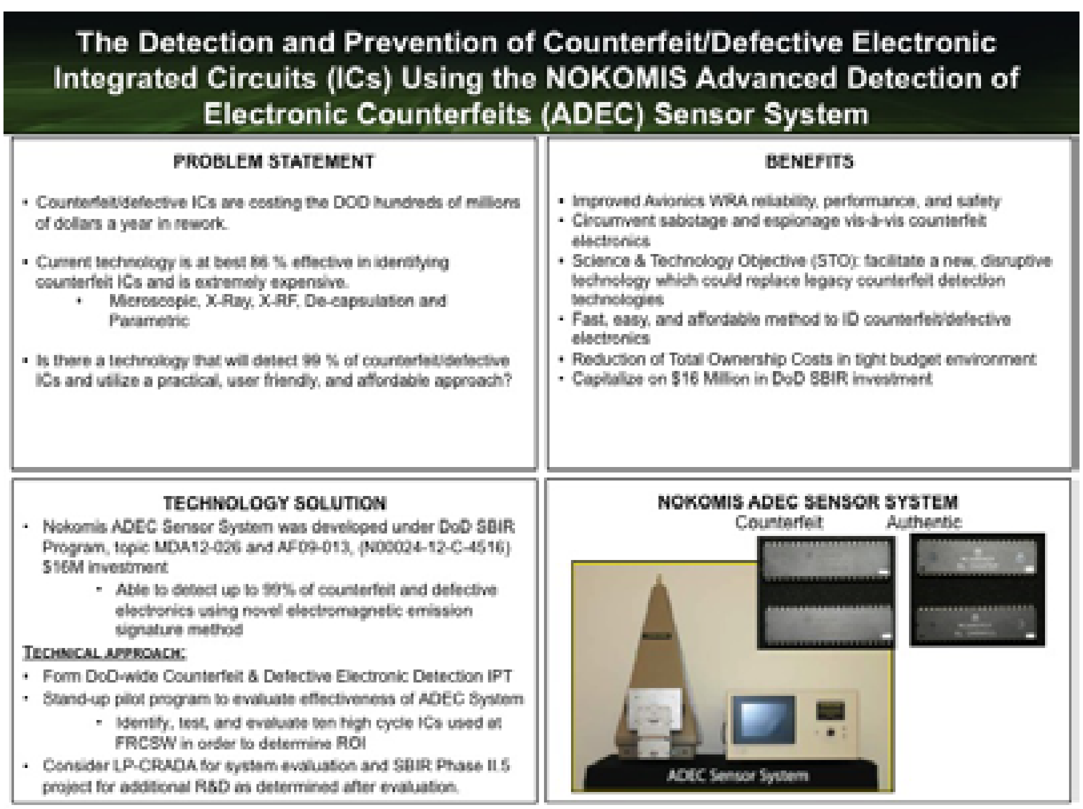
Counterfeit/defective electronic Integrated Circuits (ICs) have been infiltrating the DoD supply chain for years, wreaking havoc, and costing the DoD hundreds of millions of dollars. In fact, SAE International Director, Bruce Mahone, at the December 2013 SAE G-19A meeting, estimated the cost per counterfeit incident to be $2.8M. This estimate is consistent with LTG Patrick O'Reilly, Director of the Missile Defense Agency (MDA) from 2008 – 2012, who stated that a single counterfeit part for the THAAD missile system cost the program $2.78M. Furthermore, the need for advanced counterfeit/defective electronic IC detection technology is well established in the requirements of the 2012 National Defense Authorization Act (NDAA), DoDI 4140.67, DoDI 5200.44, Air Force Pamphlet (AFPAM) 63-113, DFARS 252.246–7007, and SECNAVINST 4855.20.

Like many other DoD organizations, the Fleet Readiness Center Southwest (FRCSW) Avionics Manufacturing/Repair department has been victimized by counterfeit/defective ICs. These counterfeit/defective ICs have resulted in quality control issues, latent/premature failures, and increased life-cycle maintenance costs for the FRCs customers. Unfortunately, FRCSW has not been able to effectively detect and prevent counterfeit/defective ICs using standard, visual inspection methods. Legacy detection methods (which are 82% accurate) are either impractical or too expensive to implement here.

A newer, more practical, and elegant testing method to detect counterfeit electronic ICs (which is 99% accurate), called the Electromagnetic Emission Signature (EES) testing method, has been developed by NOKOMIS, Inc., topic MDA12-026 and AF09-013. The NOKOMIS Advanced Detection of Electronic Counterfeits (ADEC) Sensor System uses the characteristic electromagnetic signatures that all electronic devices give off in order to spot counterfeits and immediately alert the technician. It's fast, easy to use, requires minimal training to perform, and is relatively inexpensive compared to other legacy detection methods. The FRCSW Advanced Aircraft Technologies (AAT) team believes the EES testing method to be the most advanced and cost effective technology for counterfeit detection available today and will eventually replace many of the legacy counterfeit detection technologies (Microscopic, X-Ray, X-RF, De-capsulation, and Parametric).

By investing in the NOKOMIS ADEC Sensor System, FRCSW could immediately see cost savings, recouping their investment in less than a year. (Preventing a single counterfeit/defective IC from being integrated into one avionics devices would pay for the entire effort.) Further, Inserting the NOKOMIS ADEC Sensor System at all FRC facilities is a cost effective way to comply with the SECNAVINST 4855.20 directive to implement counterfeit detection at Navy repair sites. The FRCSW AAT recommends considering LP-CRADA for system evaluation and SBIR Phase II.5 project funding for additional R&D.



USCG Aviation Bonded Material Inspection System

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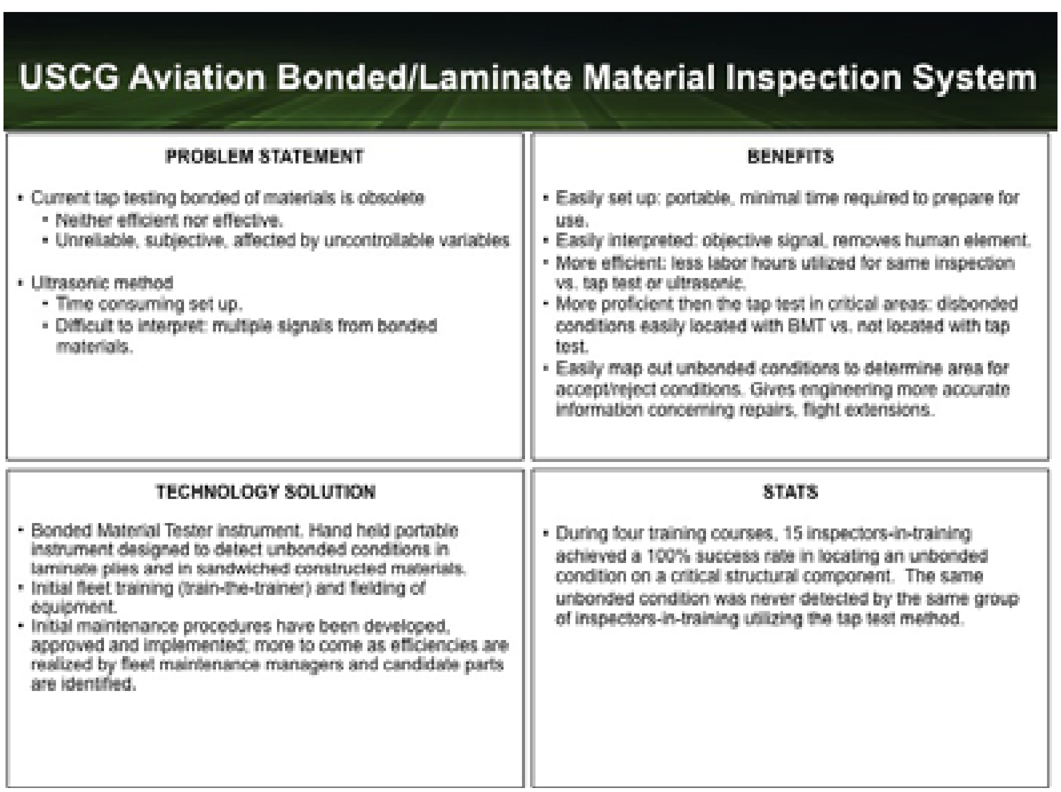
Many United States Coast Guard aviation assets contain lightweight composite materials in their construction. These advanced materials realize reduced fuel consumption, increased corrosion resistance, and, in many applications, increased strength-to-weight ratio. In turn, these types of materials present unique challenges when non-destructively inspecting them to ensure serviceability.

The Coast Guard has been inspecting these components using the dated method of tap testing, literally using a solid metal object to tap the surface while the technician listens for aural indications of an anomaly. This technique is obviously subjective in nature and has many unreliable variables. An ultrasonic method of inspection was prototyped as well and found to be an acceptable replacement for some tap test applications, but was time consuming to set up and did not remove much of the subjectivity and therefore not adopted wholesale. However, recent technological advances in the field of non-destructive inspection produced Bonded Material Tester (BMT) technology. This method is actually the next generation of ultrasonic inspection and interrogates bonded materials for skin-to-core and inner ply separations layer by layer, allowing for minimally-invasive in-service inspections to evaluate on-wing component condition, typically during scheduled maintenance evolutions.

The Coast Guard has invested in BMT technology; it has trained unit-level instructors across its operational and depot maintenance facilities, developed and implemented maintenance procedures, and fielded portable BMT units. The investment in the technology has shown promising returns on labor efficiency, maintenance proficiency, and airworthiness. Set up time is minimal and inspection evolutions are more efficient, realizing significant labor savings over conventional testing methods and allowing maintenance managers to reallocate saved time to other maintenance tasks. In addition to being more efficient, these inspections are more proficient; they are based on an objective signal return from the equipment, removing human error derived from deciphering subjective signals. A high probability of accurate detection has been achieved by inspectors-in-training: 100% success rate in locating an unbonded condition on a structural component when the same inspectors-in-training achieved 0% success in locating the same unbonded condition utilizing tap test methodology. This success highlights BMT's viable role in ensuring airworthiness through safe, effective maintenance and repair.



Assembled Replacement Integrated Circuits (ARICs)

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BLUF: Naval Undersea Warfare Center (NUWC) Division Keyport has developed and been utilizing a means to fabricate drop-in replacements for obsolete integrated circuits.

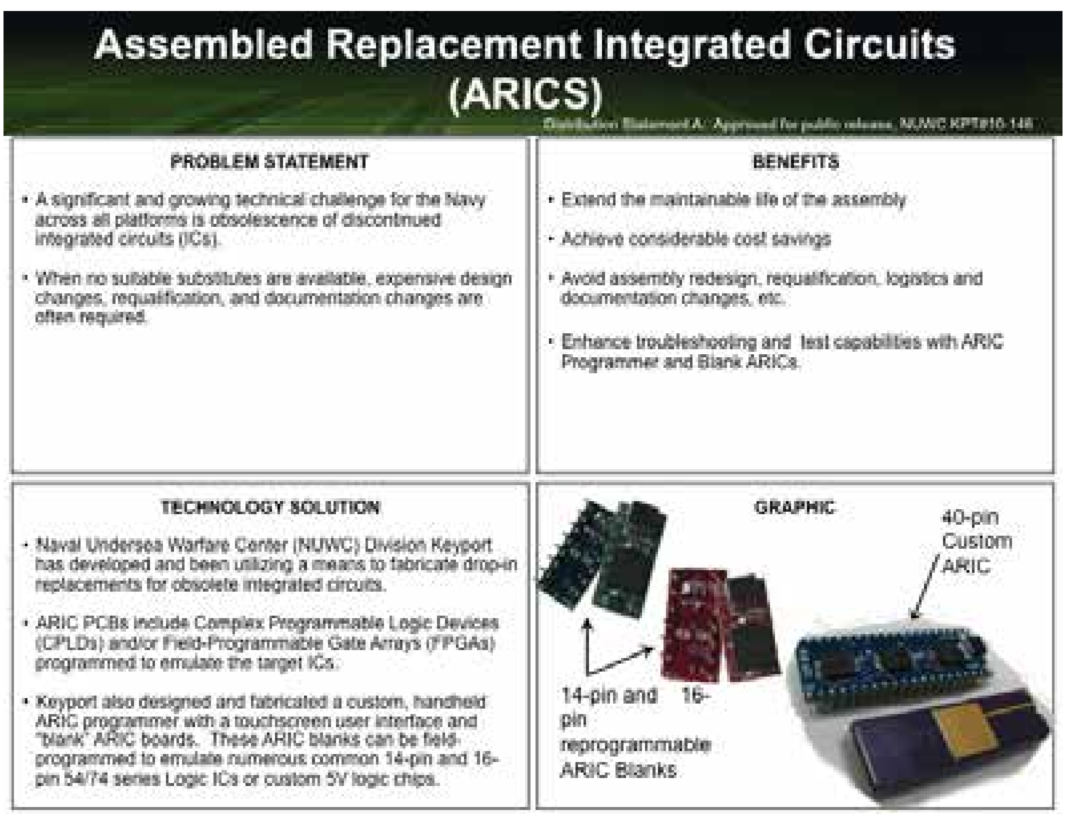
Abstract: A significant and growing technical challenge for the Navy across all platforms is obsolescence of discontinued integrated circuits (ICs). When no suitable substitutes are available, expensive design changes, requalification, and documentation changes are often required. Naval Undersea Warfare Center (NUWC) Division Keyport has developed a means to fabricate drop-in replacements for these ICs, extending the maintainable life of the assembly and achieving considerable cost savings by avoiding assembly redesign, requalification, logistics and documentation changes, etc.

As an early example of this, NUWC Keyport completed an obsolescence study of the RT-1379A/ASW System. It contained a total of 217 unique electronic components, including semiconductor devices. Of these, 59 components were no longer available. As part of a RT-1379 life extension, Keyport was contracted by NAVICP Philadelphia to reverse engineer two circuit card assemblies and to stand up a depot.

The focus of the effort was twofold: (1) to minimize qualification and documentation changes and (2) to extend the reparability of the radio. To accomplish these goals, three obsolete ICs were replaced with small circuit cards made to mimic the ICs' form, fit, and performance: IO Port, Majority Gate, and Line Driver ICs. These chips were completed, installed in circuit cards, and delivered to the fleet in RT-1379 radios repaired in the Keyport depot. For the RT-1379A system, use of these ARICs enabled an estimated cost-avoidance of $2M in qualification testing alone, not even considering other cost drivers.

The fabricated substitute ICs came to be known as Assembled Replacement Integrated Circuits (ARICs). The basic concept is to build IC-sized replacement assemblies to resolve chip obsolescence as drop-in replacements. ARIC PCBs include Complex Programmable Logic Devices (CPLDs) and/or Field-Programmable Gate Arrays (FPGAs) programmed with custom Very High Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL) to emulate the target ICs.

Using this concept, Keyport has also developed ARIC replacement for an obsolete Airborne Low Frequency Sonar system (ALFS) Analog to Digital Converter (ADC) chip, replacement AM2942 Programmable Timer/Counter DMA Address Generator ICs and resistor network ICs for B1-B Bomber CPU Assemblies, and several others.



To further enhance this capability, Keyport also designed and fabricated a custom, handheld ARIC programmer with a touchscreen user interface and "blank" ARIC boards. These ARIC blanks can be field-programmed to emulate numerous common 14-pin and 16-pin 54/74 series Logic ICs or custom 5V logic chips. These programmable ARICs can be used as troubleshooting aids or as permanent solutions to replace obsolete or failed ICs.

Encourage Innovation

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In the last several decades, Department of Defense applications of innovative manufacturing technology as applied to maintenance operations has lagged behind that of similar commercial corporations. Part of the reason is that global competition has driven competitiveness and cost cutting measures across all levels of commercial business including maintenance and repair programs. While there are innovative and enthusiastic people within the DOD, making change to legacy process and procedures proves difficult in a predominately non-technical environment.

Various methods of making change exist within Department of Defense, some of these are the suggestion program, engineering change proposal and even value engineering. Yet even with these programs, change is at a snail's pace or not at all. Innovation, creativity or invention has come to be seen as a philosophy that only exist in the commercial world and not within the confines of government. Innovation is nothing new, so why does it not seem to happen within the government? Are the people within DOD tasked with evaluation of applications of emerging technologies the correct people to be performing these task and do they have the tools necessary to properly do their job? Is there a method of convening a cohesive, technically competent team that can make decisions related to applications of evolving manufacturing technologies and plan out required supporting task such as testing? Currently there are commercial companies that remain innovative even with business, engineering and manufacturing sites scattered across the globe.

A physiological study of behavior in even the most primitive creatures reveals that behavioral response can be positively altered or encouraged by simple positive reward, that is, something that is truly desired such as time off or money. Understanding this, the lack of function of the current system is due to either insufficient reward or frustration related to dealing with bureaucracy and a nonfunctional administrative processes.

The suggestion program needs a suggestion for improvement and value engineering needs to be re-engineered. Indications are that the current systems are insufficient for supporting applications of innovative manufacturing technologies and possibly a restructuring needs to occur that will result in streamlined professional evaluation of proposals by technically knowledgeable people. Rather than an extensive analysis of the existing system, a better approach might be to establish or transition to a system which is based on the architecture currently used by a commercial business. As an example, Honeywell has GRMS (Global Repair Management System), a system that routes proposed technology applications electronically though designated departments and archives inputs and evaluations.

Applying the Intermittent Fault Detection & Isolation System (IFDIS) to Enable Cost Effective Readiness, Reduce No Fault Found (NFF) and Provide Superior War Fighter Support

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Today's defense environment requires responsive and affordable solutions to global weapon system support challenges. United States 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 Department of Defense's (DoD's) ability to economically sustain them has become increasingly challenging. The high, sustained operations tempo over the past decade in harsh environments has eroded weapon system readiness and reduced expected life span. Recapitalization of systems has been complicated by sequestration and the cancellation of weapon systems modernization programs. In light of these realities, the Services are seeking ways to improve maintenance capabilities, reduce NFF and increase operational readiness while simultaneously reducing life-cycle and maintenance costs.

No Fault Found 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 system components driven to the depot for repair, less than half have the actual root cause of the problem identified and repaired. The other half 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 expense for 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 System™ (IFDIS™) was specifically designed to detect and isolate intermittent faults in electronic wiring. Its initial adaptation 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 $114 million has already been realized with an investment of only $2.2 million. Because of this tremendous success, IFDIS has been expanded to in order to interrogate the F-16 AN/APG 68 Radar Programmable Signal Processor (PSP). The PSP has over 8,000 internal connection points and the IFDIS ability to monitor all these circuit points simultaneously and continuously has provided a return on investment in just six months.

IUID Transparent Data Collection with RFID

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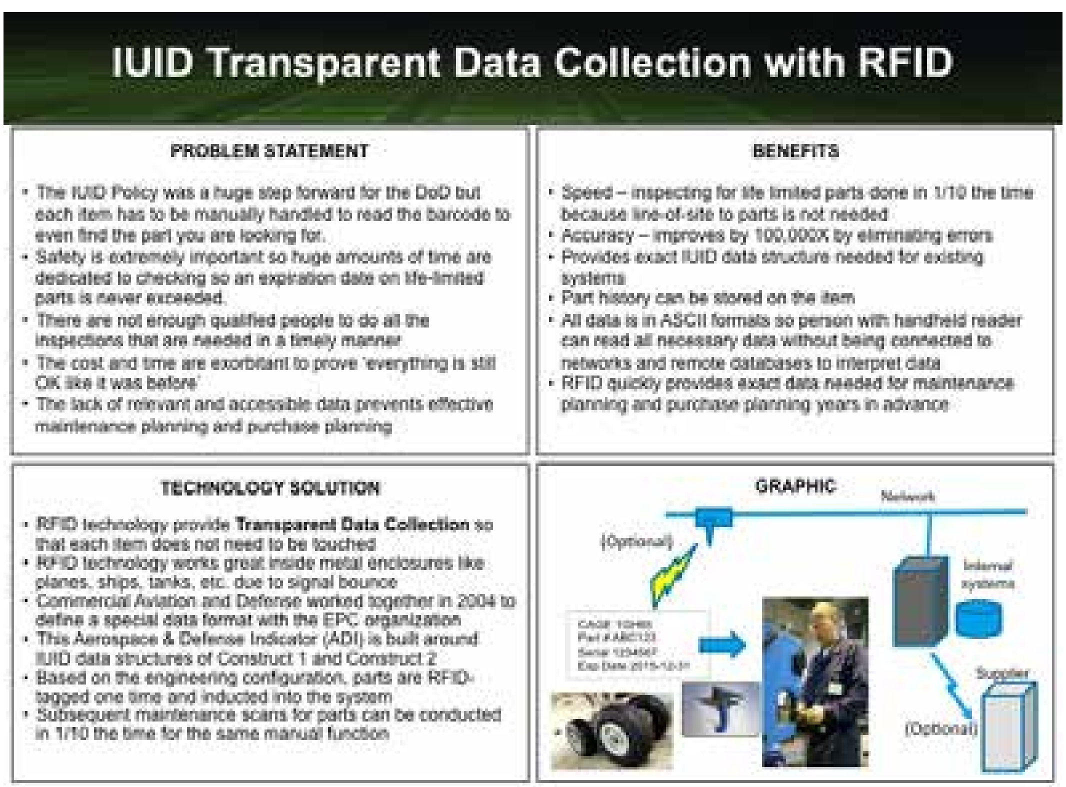
Establishing the UID Policy was a huge step forward for the DoD. Giving every important part a cradle-to-grave social security number establishes the data foundation needed effective maintenance, warranty, reliability and so many other areas of the business. The 2D barcodes that are required for IUID are good, but requires that each part be touched and seen by a barcode reader. That same IUID data structure can now be replicated in an EPC Gen2 RFID tag that does not require line-of sight to each part. This opens the door to an order of magnitude improvement on the IUID data collection side of the business.

Shortly after the IUID Policy was established, commercial aviation ramped up on the use of RFID technology for marking parts and the standards that were created were built around the need for the DoD to identify parts with a IUID. In 2009 the GS1/EPC Global organization granted a new RFID identifier called the ADI format for Aerospace & Defense Indicator. The unique strength of the ADI format is that it allows the RFID tag to be encoded with the actual CAGE Code, Serial Number and Part number of the item it is attached to, as well as a multitude of additional data like expiration date, test date, overhaul date, etc. In addition, this data is encoded in ASCII characters. The huge advantage of the data being in ASCII is that a handheld RFID reader can read the data at point of use and make sense of what the part is or what the date is, and it can do this without being connected to a network or connected to remote databases to interpret that data. This greatly reduces the cost to effectively deploy RFID and get a quicker ROI on the investment.

As an example of the effectiveness of this Transparent Data Collection to read the parts without seeing them, commercial aviation can read the presence and expiration dates of life vest installed in the cockpit, under F/A seats, under First, and Economy seats and 20 spare vests stored in bags in the rear galley – 254 vests in all - by walking down one aisle of a twin aisle aircraft from front to back in 36 seconds! Contrary to popular opinion, reading RFID tags in the interior of metal aircraft, tanks, ships, etc. enhances the benefit of the technology so similar benefits can be achieved in military maintenance situations. Labor reductions and data accuracy are easily enhanced by an order of magnitude over the current way to collect data.



The Benefits of Condition Based Overhaul

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Under the auspices of the authority given the organic industrial base to partner with private industry, Red River Army Depot (RRAD), established a public-private partnership with Caterpillar (CAT) in 2009. As a result of this partnership, the depot and CAT worked towards reducing the costs associated with the repair of CAT engines for Army supply programs. Achieving this required integrating best business practices that CAT uses commercially. Specifically, condition based overhaul (CBO). What this process entails is a very common sense approach to repair of an engine. It requires the repair or replacement of only components necessary to bring the engine back to a fully operational status. This does not mean that the engine is a lower quality engine than one that the depot had previously repaired using the National Maintenance Work Requirement (NMWR) standard which calls for the required replacement of certain items when doing an engine overhaul. This repair process provides a high quality engine that RRAD and CAT stand behind. In fact, these engines are covered by the RRAD/CAT partnership warranty. RRAD provides the warranty for the labor and CAT provides the warranty for their parts. These CBO repaired engines go back into the Army inventory and are available for use by any Army asset worldwide. This CBO process saves the government approximately $12k per engine. This analysis is based on a comparison of RRAD's labor rates and parts costs for the CBO process and the NMWR process. Parts costs were taken from FEDLOG and based on the use of DLA as the parts provider or DLA approved vendors. As indicated in the chart below, the total cost (parts and labor) for the CBO process is only slightly more than just the parts alone for the NMWR process. The following table illustrates the savings that the CBO process provides per engine based on previous years' workload at RRAD.

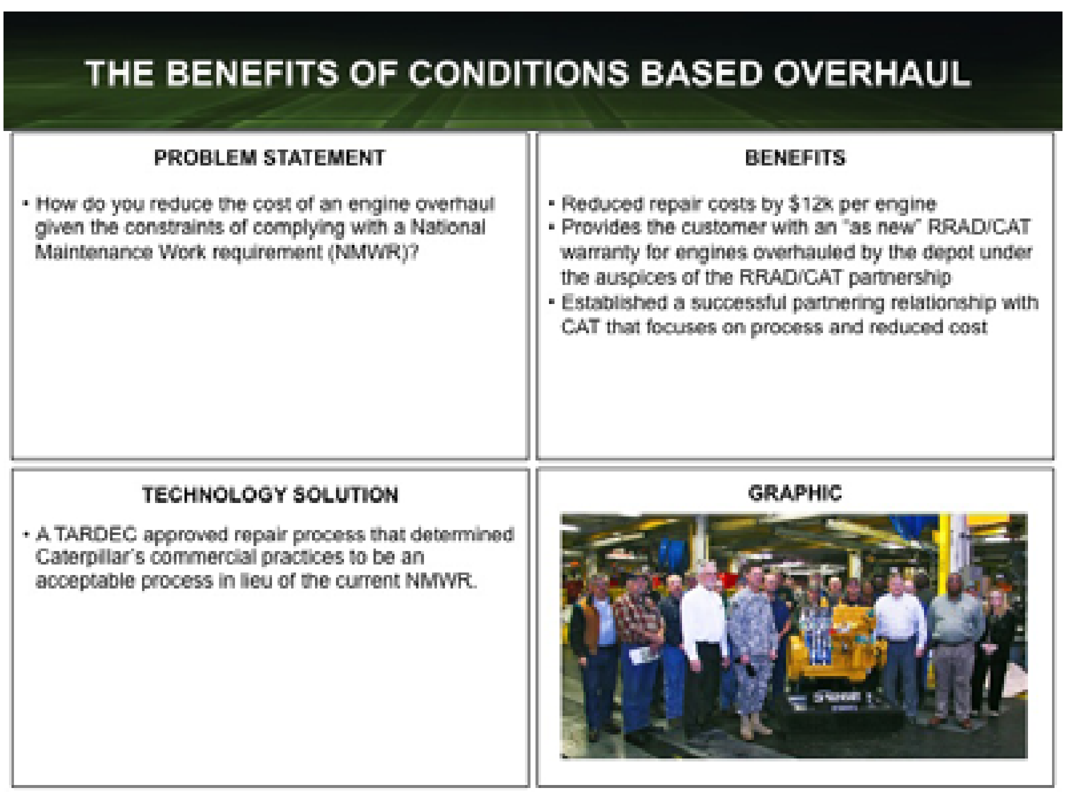
FY	CBO Parts	CBO Labor	NMWR Parts	NMWR Labor	CBO Total Cost	NMWR Total Cost	Delta
2011	$11,763	$4,793			$16,556		
2012			$16,181	$10,695		$28,369*	
							$11,813

* NMWR Total cost includes container refurbishment - listed as other - at $1,493 per engine

FY11 - 3rd Program using CBO standard (100 engines 65 ea C7 and 35 ea 3126 engines) Sole-source for material and services to Caterpillar approved by RRAD Contracting.

FY12 – 4th Program using newly developed C7 NMWR – 49 engines direct funded from TACOM using DLA parts.

In Feb 09, Tank Automotive Research Development and Engineering Center (TARDEC) conducted a thorough analysis of Caterpillar's overhaul process utilizing "best commercial practices." This included review of the engineering data and interviewing engineers associated with the original engine design, the authors of Caterpillar's Reuse and Salvage guidelines and their engineering staff for Caterpillar REMAN. Key to this CBO process is the pre-inspection of each engine, including review of the Electronic Control Module (ECM) data. This helps to determine the initial targeted repair process. Also on the other end of the process, all engines are dynamometer tested to ensure the requisite horsepower is achieved. As a result, TARDEC determined Caterpillar's commercial practices to be an acceptable process in lieu of the current NMWR.



This CBO process is a best practice that the depot is working to expand to other repair processes. The key to success is a successful partnering relationship with the original equipment manufacturer, and a willingness to look for innovative ways to improve processes.

Automated Optical Scanning and Computer Modeling of Engine Depot Components for Extended Part Use

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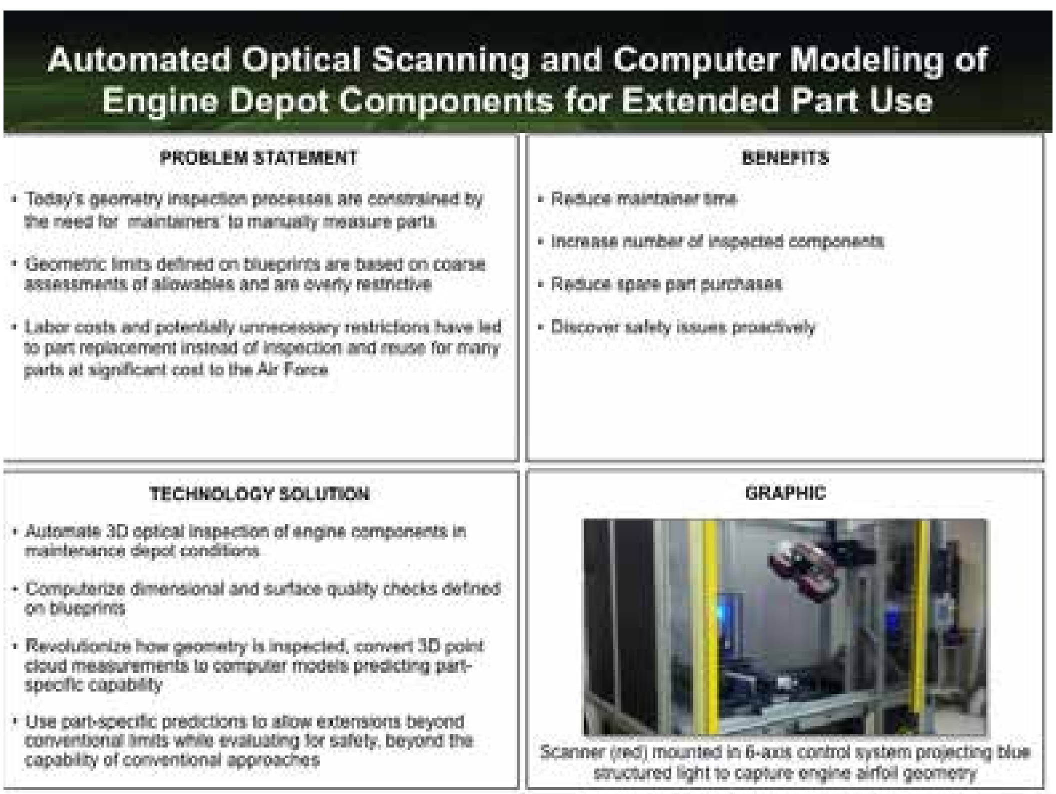
Today's engine depot inspection practice is limited to maintainers' hand measuring parts and comparing to blueprint geometry allowables defined decades in the past. Because of labor costs and potentially unnecessary blueprint restrictions, many airfoils are not inspected for reuse and lead to significant cost to the US Air Force. The Air Force Research Laboratory (AFRL) has been collaborating with Oklahoma City Air Logistics Center (ALC), the military engine industry, and innovative small businesses to develop the technology to automatically inspect the geometry of turbine engine components using automated optical 3D measurement systems that capture full surface geometry to within 0.0005 inches. The computer controlled collection of measurements can be are then compared to existing blueprint requirements for significant maintenance savings. While automating the legacy practice of geometric tolerance measurements has significant payoffs, the true revolution in maintenance will be to replace the blueprint specifications with capability- based predictions based on computer models generated from the 3D geometry measurements collected at the depot. AFRL has developed unique software tools that automatically morph available design process computer models to the measurement data collected from optical systems. The AFRL morphing system is capable of adapting models to the minute deviations inherent to manufacturing processes and to the large geometric variations that are found from depot repairs such as airfoil blending. The morphing system provides part-specific models that can then be used to determine if components meet their intended function rather than limiting parts to long-ago developed blueprint limits. Inherent to these models is a thorough evaluation of part safety, likely beyond the capabilities of conventional approaches. With automated optical inspection and part-specific models, engines will be safer, used longer, will be more repairable, and new doors open on understanding how operational usage is changing part geometry and performance to lead to better prognostic capabilities and maintenance planning.



External MORTORQ® Super Spiral Drive System

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Phillips Screw Company is proud to introduce the newest addition to the MORTORQ® family of high performance fastener designs, the External MORTORQ Super bolt design. This new wrenching system is quickly gaining acceptance as a high performance light weight replacement for hex head, bi-hex, and six lobed bolt head designs in both aerospace and automotive applications. First introduced as a weight savings option for high performance special alloy aerospace bolts the new design reduces head height by 20% compared to the 12-point bolt it replaced. In addition, the new design provides 1.4 times the drive surface contact area and 2.5 times the removal surface contact for improved torque transmission and assured serviceability and maintenance. Weight savings were 30 pounds (13.6kg) per 1000 pieces compared to the original ¾” (19mm) diameter bi-hex head multiphase alloy bolt.

The new design is also easier to forge with fewer secondary operations required to achieve the final product. The innovative design creates the lightening hole during the initial forging operation eliminating an entire secondary operation while filling the head form completely. When used to replace a standard hex flange bolt the new design has a 30% lower head height and provides 2.1 times the contact surface area on the removal faces of the drive due to the unique spiral engagement of the socket and bolt head. The new design is available in a size range from #10 (M5) up to 2” (M50) from a global network of licensed manufacturers. All manufacturers are subject to initial qualification and regular quality monitoring to assure the global compatibility and performance of bolts and sockets in all applications. Available in materials ranging from grade 5.8 to ultra-high strength multi-phase aerospace alloys like MP159 these bolts are the latest addition the MORTORQ family of fasteners that have proven themselves in applications from the front seat bolts of cars to the window bolts of the space shuttle.

The External MORTORQ® Super design increases the fasteners reliability and maintainability reducing maintenance man-hours, fastener replacement costs, “drill outs”, engineering disposition costs, awaiting parts impact, lost production time/TAT, and secondary damage to component or airframe.

E-2D Rotodome Assembly Maintenance System (RAMS)

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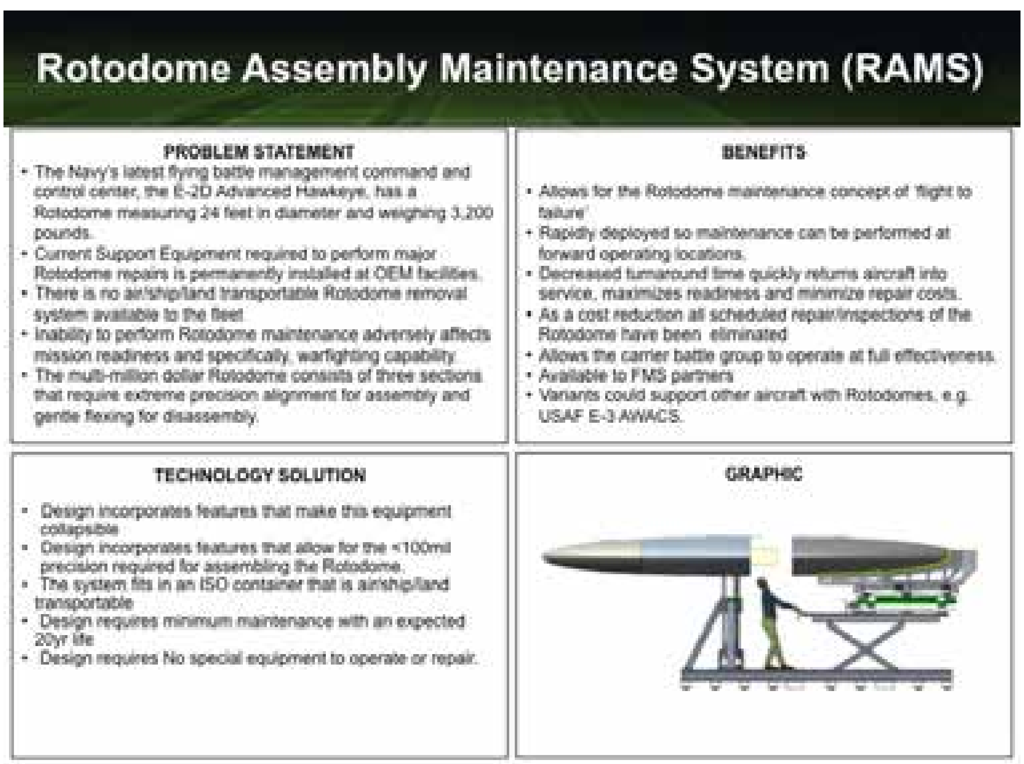
Current Support Equipment required to perform major Rotodome repairs to the E-2D is permanently installed at OEM facilities. This is not a viable option for either fleet maintainers/ facilities, or even depot/FRC environments. Simply stated, there is no air/ship/land transportable Rotodome removal system available to the fleet or depot/FRCs in support of the E-2D Rotodome. This technology gap creates an inability to perform timely Rotodome maintenance which will have a direct and negative effect on mission readiness and specifically, warfighting capability.

The E-2D Advanced Hawkeye is the Navy's latest flying battle management command and control center. The new 'D' version of the E-2, in addition to incorporating an advanced new Radar Antenna (Rotodome), has introduced a completely new maintenance concept for the Rotodome Antenna. The new Antenna is to be flown to failure, which has prompted an innovative approach to maintenance of the Rotodome. In order to facilitate this maintenance concept, the Support Equipment required for assembling the 24 foot diameter Rotodome needs to be transportable to anywhere in the World. This transportability challenge engendered an innovative design to the traditional Support Equipment concept and hardware.

This new maintenance concept will greatly reduce the maintenance cost by eliminating unnecessary scheduled repairs, as well as increase mission readiness. In response to this new maintenance concept a major piece of SE being developed at NAWCADLKE is the Rotodome Assembly Maintenance System (RAMS). The RAMS represents a major departure from legacy Support Equipment (SE) found in aircraft depots that is non-transportable. In the case of a catastrophic damage (e.g., bird strike) or failure the air/ship/land transportable RAMS can go anywhere in the world with an artisan team to repair the Rotodome on site, saving a sometimes impossible trip to the depot at North Island or relegation to "hanger queen" status. RAMS meets the stringent requirements for aligning the 24 foot diameter, 3,200 lb. Rotodome, to 100 mils or less (30 mils objective), allowing easy assembly of the composite sections. Disassembling the rotodomes will be easier than in the past due to the innovative pneumatic system, which will gently flex the sections to break joints which are stuck together by dirt and debris.

NAWCADLKE is 100% organically designing, manufacturing, testing, and deploying the RAMS. A production representative RAMS with a representative rotodome is expected to enter preliminary test by the end of November 2015, finishing with operational suitability testing in October 2016. Initial Operating Capability is scheduled for 2nd Qtr FY17. Assembly of highly precision Rotodome sections in an O-Level environment is a technical challenge. Course alignment is done with a scissors jack and a system of linear screws and bearings. Fine alignment is done with the pneumatic system, which controls standard shop air to inflate a system of pads, allowing RAMS to precisely position rotodome sections without damaging the composite material.

Three RAMS units are being built in support of domestic E-2D aircraft maintenance. Additional units could be manufactured for Foreign Military Sales (FMS) requirements without the need to go through a competitive procurement, as the data is owned by the Government, and the RAMS itself is manufactured at NAWCADLKE. This, or future aircraft with rotodomes could benefit from RAMS variants and further applications could be supported if we adapt it to assemble other large precision aircraft parts.



Reliability Engineering Data Integration

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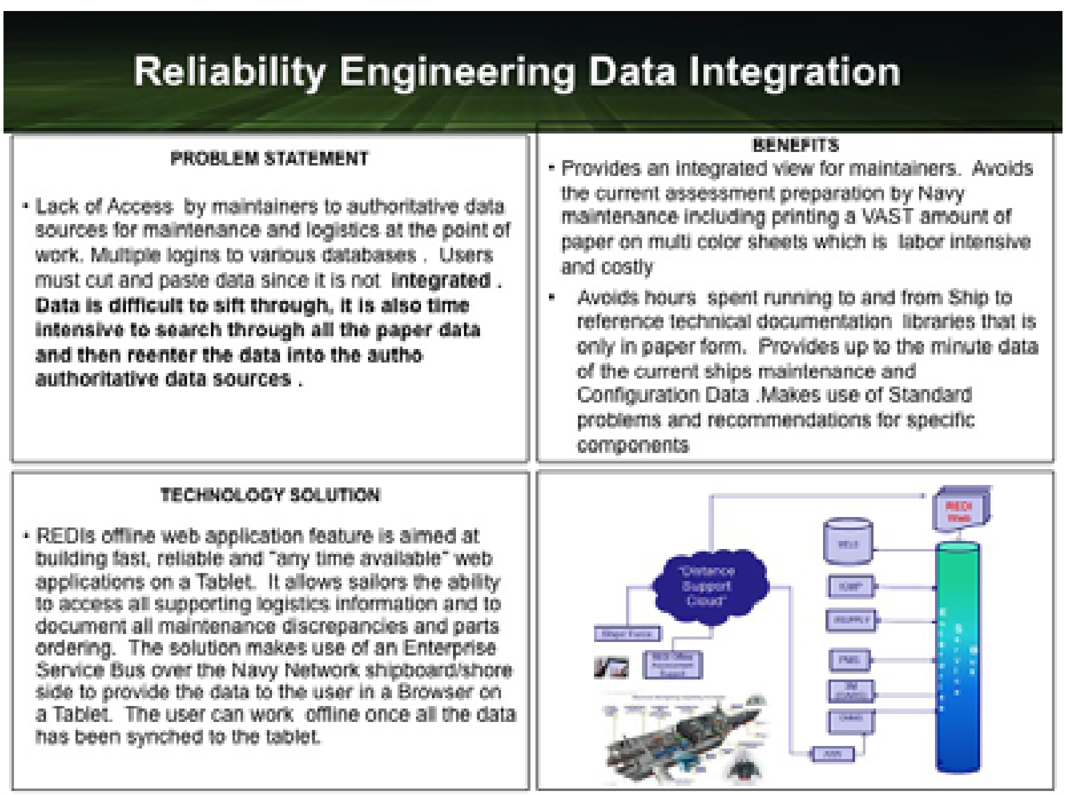
The present innovation relates to methods and systems for integrating data pertaining to reliability engineering. Reliability engineering is engineering that focuses upon reliability (dependability) in the lifecycle management of mechanical systems and components. Reliability concerns the ability of a system or component to function properly under given conditions for a quantified period of time. Many commercial and military entities seek to balance maintenance needs versus practical constraints with regard to their machinery and equipment. The United States Navy endeavors to modernize and sustain an aging fleet and to achieve target numbers of ships. As the Navy transitions, many facets of operations and maintenance are impacted. Mission requirements are expanding, while resources (e.g., manpower, money, and time) are diminishing. The accessing of necessary maintenance data is time-consuming, and data is not readily available in a particular shipboard system for a user to access. The Navy uses diverse legacy maintenance systems and databases that support execution of shipboard work. The Navy's maintenance and logistics systems and databases include the following: Maintenance Management System, Planned Maintenance System, planned/preventative maintenance scheduling software; Integrated Class Maintenance Plan (ICMP); Configuration Data Managers Database-OA (CDMD-OA); Supply database and parts ordering and the technical publications information sytem.

The many maintenance informational groupings (e.g., maintenance systems and maintenance databases) of the Navy are "separate" in the sense that they may use or share data from or with each other, but they are not linked or coupledirectly with each other. The Navy's conventional approach to all- encompassing maintenance documentation requires manual data searches and entries that are numerous, inefficient, unwieldy, and repetitive due to the multiplicity of legacy maintenance systems that are required to be used in execution of such maintenance documentation. The primary system that will improve maintenance is the Reliability Engineers' Data Integration (REDI) System. The REDI system, developed by the Naval Ship Systems Engineering Station (NAVSSES) provides maintainers with a bridge to the maintenance and logistics systems, including ordering parts, accessing documentation, and technical support. Maintainers access this information shipboard through a user-friendly tablet.

REDI makes use of state of the art technology Enterprise Service bus to form a navy network on the ship linking and integrating all the databases behind the scenes on the shipboard network. The innovation takes that data using modern HTML5 and transfers the data over the network to a tablet allowing the users to browse to the authoritative systems via a single login web interface. The user can work in an offline mode as if connected to the server at the point of performance. Once he completes his work he synced back up to the network and all the data is transferred back to the authoritative sources.



Asset Information Management Solution (AIMS)

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The AIMS project addresses two of the most pressing DoD logistical issues: maintenance effectiveness and asset accountability.

The DoD has mandated that CBM+ be employed to increase maintenance effectiveness while reducing costs and manpower requirements. This must be accomplished through the employment of technology solutions. Asset accountability is among the most serious issues addressed by the DoD today. Failure to account for critical assets carries dangerous and costly consequences.

In addition, the time required to accomplish the accountability task on paper is unnecessarily burdensome. When operational pressures take precedence, costly shortcuts are taken. With the proper tools, operational requirements can be met, with reduced manpower, while maintaining control over assigned assets.

Currently, most Marine Corps asset health monitoring and accountability is accomplished on paper or in separate, unintegrated, and often manually loaded databases. An automated asset tracking system using modern IT technology designed to enable best business practices is necessary to provide clear visibility of asset health and 100% asset accountability.

AIMS leverages hardware, software, existing DoD programs and policies, such as Item Unique Identification (IUID), to seamlessly automate asset tracking, visibility, condition, history, and usage. Deployable in cloud based, networked, or stand-alone environments, AIMS is adaptable to the requirements, capabilities, and regulations of the organization. AIMS is platform agnostic available on mobile devices and modular. Each module, tailored to a specific use, provides a GUI interface to a single data base, secured by industry best practices and compliant with DoD and NIST implementation guidance.

The heart of AIMS is a software application that processes and collates inputs from various hardware sources, related databases, and manual entries if desired. AIT sources within AIMS include both digital and biometric authentication, matching the responsible person to the assigned asset. If there is a discrepancy, an alarm is actuated, alerting the issuer.

AIMS effectiveness and value is successfully demonstrated in a pilot project at the USMC School of Infantry-West armory. During that project, accuracy of issue and recovery improved from 80% to 98%. Automating and integrating the check-in process for students saved 33 man-hours during in processing of an incoming class. AIMS saves time, reduces cost, and increases accuracy. AIMS allows Marines to do what they're meant to do: focus on the fight.

Affordable Maintenance Through Partnership

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AEROWING RAPID RESPONSE TEAM

Aircraft fuel leaks remain one of the top 3 reasons for non-mission capable (NMC) status. Why?

Aircraft wings are built to flex, naturally, against turbulence and the weight of the fuel load. Over time, sealant becomes brittle and cracks, allowing fuel to escape from the structure. Visible fuel seepage equals non-mission capability.

Even with experienced technicians, fuel leak repairs have been known to take weeks to accomplish. A difficult leak may lead to an aircraft being sent to Depot, a costly process. Just locating the leak source location is a long and tedious task. Sealant removal and cure times can take the bulk of the repair time.

Using state of the art, patented processes, Aerowing Rapid Response Team, remove most all variables from a fuel leak repair. Our technicians can pinpoint damaged sealant using a reverse leak mapping process. Sealant is removed using rapid removal devices. Sealant is cured using groundbreaking, automated equipment, in less than half of the time it takes for ambient cure. A tracer gas, pressure test device, is then utilized to verify a successful repair, before a final fuel soak check.

Aerowing Rapid Response Team can typically complete a repair, from leak chase to repair verification, within 24 hours (elapsed time) after arrival to the aircraft.

All Aerowing repair techniques are in accordance with the T.O. 1-1-3. We add value to these processes by eliminating the need for the procurement of specialty repair equipment. Our teams can arrive on site within 24 hours, prepared to work alongside the local fuel shop or depot technicians, to achieve mission capable status much faster than traditional methods.

Laser-Cladding: The Future of VLS Tube Repair

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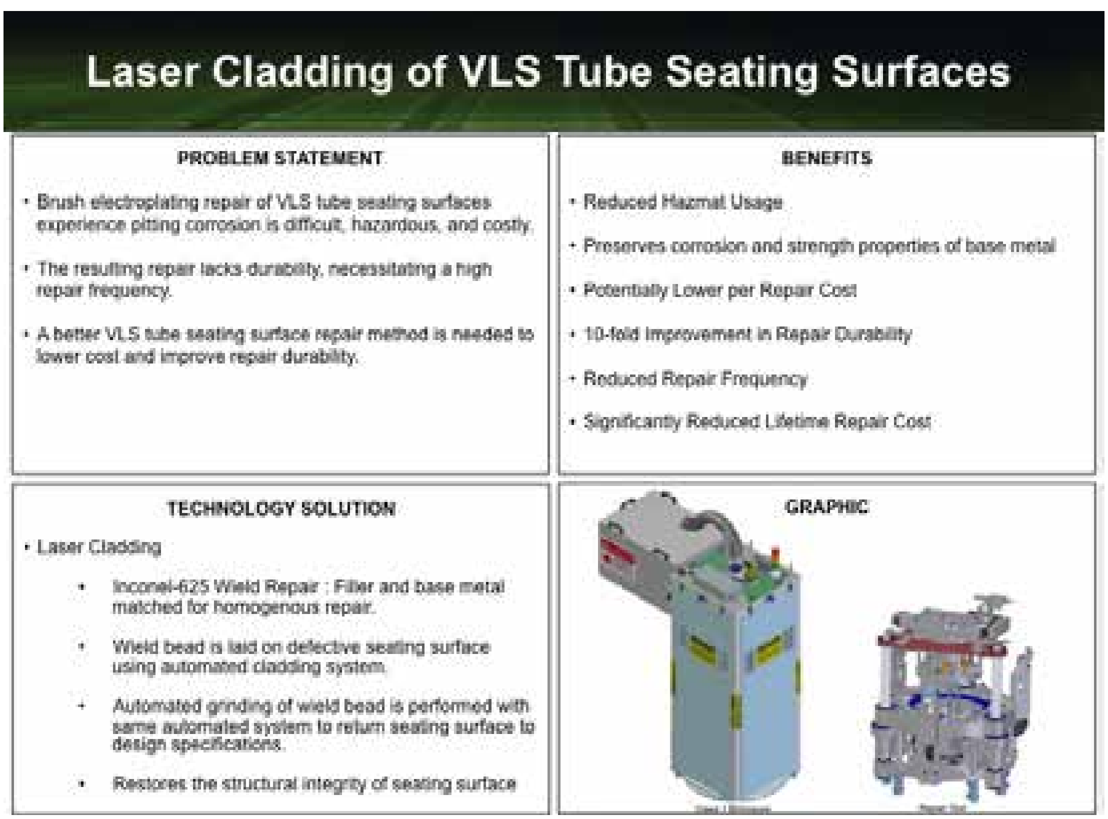
Brush electroplating has long been the repair method of choice for saltwater-induced pitting corrosion of Vertical Launch System (VLS) tube sealing surfaces. Effective in preventing the continued degradation of the Inconel-625 cladding, the repair process is limited in application (only permitted for corrosion or damage less than 0.030” in depth); highly manual and labor intensive; requires toxic and/or carcinogenic chemicals; and produces a “soft” repair susceptible to mechanical damage. Additionally, repairs suffer from poor durability. On average, a single repair lasts 12-18 months and cost 18-20 man-days to complete.

Pearl Harbor Naval Shipyard (PHNSY), in conjunction with the Pennsylvania State University Applied Research Laboratory (ARL), Naval Sea Systems Command (NAVSEA), and Naval Undersea Warfare Center (NUWC) - Keyport, has improved the VLS tube repair process with the introduction of automated laser cladding. Laser cladding offers two principle benefits over brush electroplating: improved durability and decreased cost.

Improved durability is achieved by restoring the material properties and structural integrity of the Inconel-625 base metal. Unlike electroplating, laser cladding rapidly deposits Inconel-625 weld metal to the sealing surface. The weld metal is then grinded to return the sealing surface to a like-new condition. PHNSY is conducting an accelerated corrosion study with Navy Research Laboratory (NRL) to quantify the durability of the repair, but initial estimates anticipate the repair will last 10 years.

Decreased cost has yet to be realized at PHNSY. The most recent VLS tube laser cladding repair conducted cost 108 man-days. This increase is associated with mechanical failures, first-time setup, and process/equipment familiarization. PHNSY anticipates cost to fall to electroplating levels as the process is refined and updated to include a machining phase within the year. A cost-benefit analysis conducted by PHNSY estimates 21 man-days per repair. Cost savings is realized with the decrease in repair frequency.



Resource Constrained Activity Network (RCAN)

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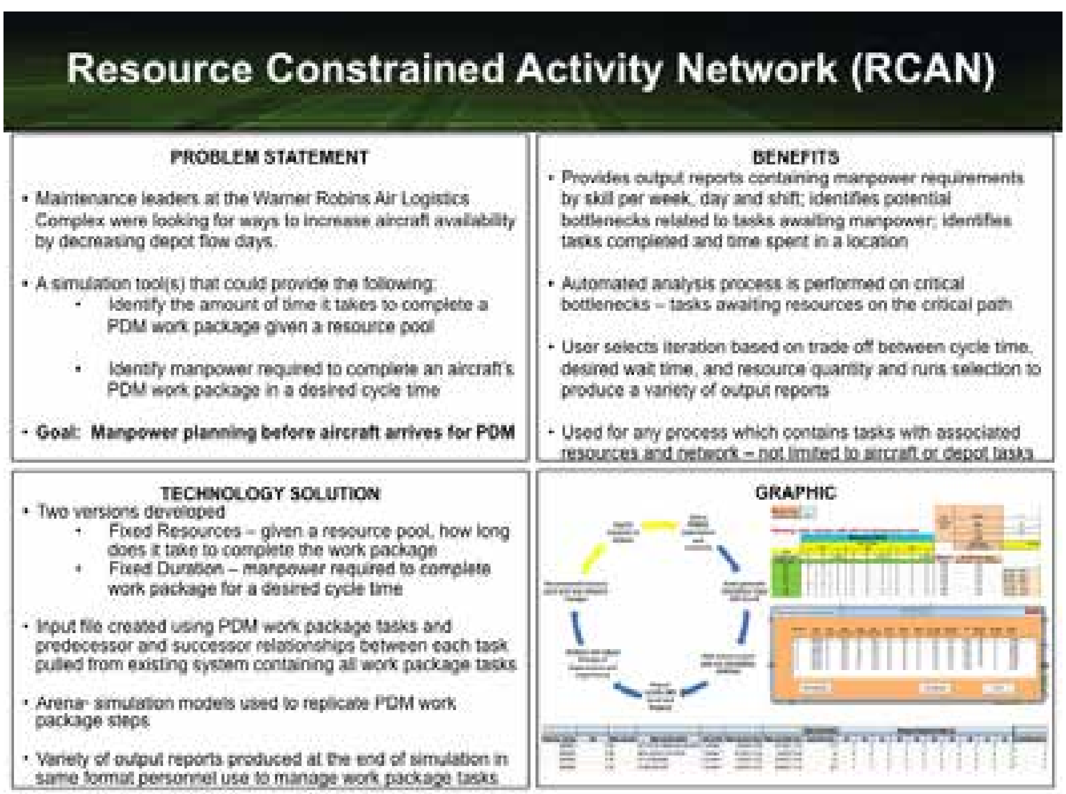
Maintenance leaders at Warner Robins Air Logistics Complex needed insight into ways of reducing the time aircraft spent undergoing Programmed Depot Maintenance (PDM). One of the issues causing delays was manpower availability and scheduling. Mercer Engineering Research Center (MERC) was awarded an Air Force contract to develop a simulation tool for analyzing how the makeup of a resource pool impacted the time in PDM. A resource pool is the available number of personnel by skill code.

MERC developed a software tool known as the Resource Constrained Activity Network (RCAN), comprised of an input file, simulation models, and output reports. Two versions of RCAN have been developed; Fixed Manpower and Fixed Duration. The Fixed Manpower version of RCAN determines the amount of time it takes to complete the work package for a given resource pool. The Fixed Duration version determines how much manpower is needed to complete a specific work package in a desired period of time. The two versions of RCAN were tested on work packages from a C-130 and C-5 aircraft; however, both versions of RCAN are compatible with any process which contains tasks with associated resources and predecessor and successor relationships. Both versions of RCAN provide decision makers the ability to conduct PDM manpower planning before the aircraft arrives.

An RCAN simulation begins by reading an Excel® file containing information about an aircraft's work package. The input file includes the man hours by skill code required to perform a task; the minimum and maximum number of personnel that can perform the task; and the predecessor and successor relationships between each task. Customized simulation models using Arena® are used to replicate current PDM work package procedures and determine how certain factors impact the efficiency of the process. After the simulation has run, a variety of output reports are produced using Microsoft® Excel and Microsoft® Project. These reports include the number of personnel, by skill code, used each shift during an aircraft's PDM work cycle and the total time in PDM.

RCAN has the capability to provide manpower requirements for a single aircraft or for multiple aircraft. If desired, RCAN could be used by a Planner to run what-if scenarios as part of the yet to be developed Ramp Scheduling and Analysis Simulation Tool. The Ramp Scheduling and Analysis Simulation Tool would allow schedulers and planners to assess and mitigate the impact of induction schedule changes and unplanned work across a center or complex. The tool would also provide a what-if capability to quantify the impacts and analyze the potential recovery plans necessary to maintain on time deliveries of aircraft, tanks, or other equipment. Another use of RCAN across a center or complex would be to assist with manpower planning to support programming and budgeting decisions for all weapon systems. A "library" of manpower reports for all work packages and all airframes could be produced using RCAN. The user could use these manpower reports to assist with setting up the flow of aircraft, tanks, or other equipment by work package and induction date.



Plasma Spray of Ceramic Coatings for Component Longevity

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BLUF: The use of advanced plasma sprayed ceramic coatings, in particular alumina-titania nano-material, have considerable potential to increase the longevity of Fleet components and reduce maintenance costs.

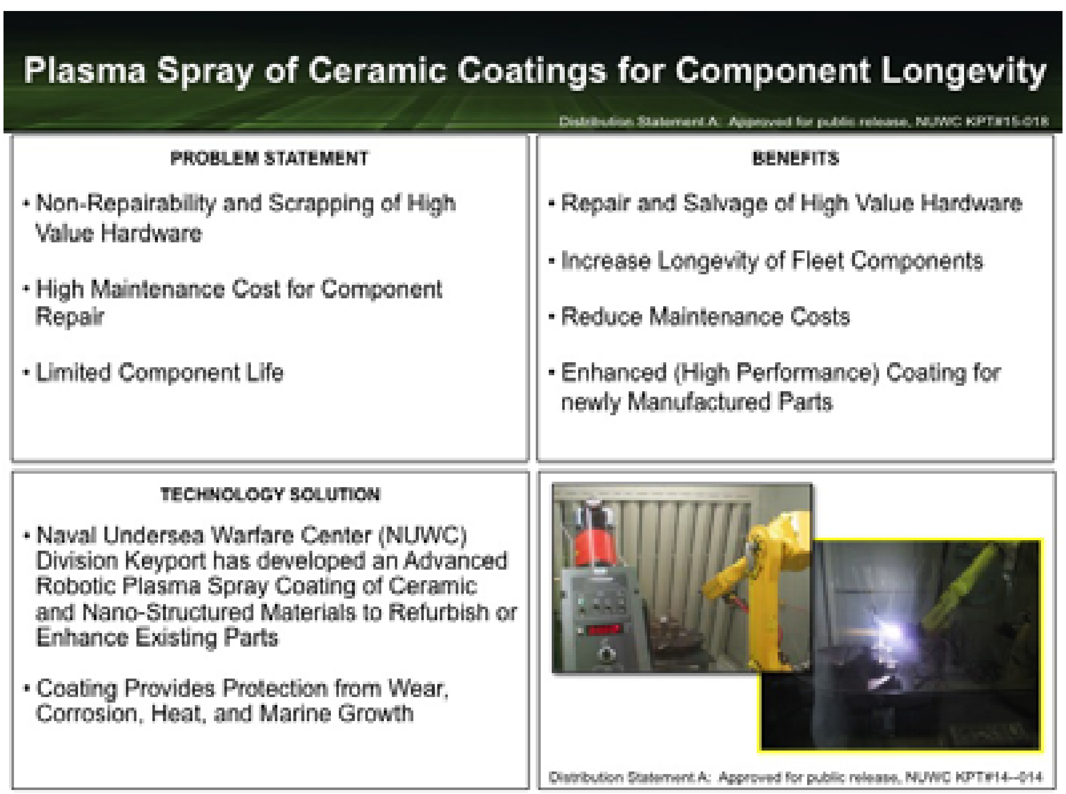
Abstract: Naval Undersea Warfare Center (NUWC) Division Keyport has developed an advanced robotic Plasma Spray facility which is specializing in the development of new ceramic deposition and other coating processes for Fleet component repair. The further development and application of this technology has significant potential to increase the longevity of Fleet components and reduce Fleet maintenance costs.

Naval Supply (NAVSUP) and Naval Sea Systems Command (NAVSEA) field activities are seeking to develop innovative, new processes and advanced technologies for the repair of high value Fleet components. The Advanced Plasma Spray team at NUWC Keyport implemented a coating process with an integrated robotic system to deploy a robust new coating technology. It has made significant improvements depositing ceramic nano-materials while developing material science expertise, new processes, and quality assurance testing. The coating may be applied on newly manufactured parts or as an “after-market” process to refurbish or enhance existing parts. This technical achievement will significantly reduce future maintenance costs for the Navy.

Plasma Spray deposits a broad variety of coatings by placing a high power electrical charge across a gas mixture causing it to ionize, forming a plasma. Metal or ceramic powder is injected into this stream of hot gas, melting and propelling the material at supersonic speeds onto a substrate forming the coating.

As opposed to other thermal spray processes, plasma spray, due to its high operating temperature, is capable of depositing ceramic materials. Benefits of plasma sprayed ceramic coatings are wear-, corrosion-, and abrasion-resistance, as well as providing a low friction surface. Parts typically coated with ceramics include: Pump Components, Seal Surfaces, Pistons/Plungers/Shafts, Ball Valves, and Electrical Connectors (as a coating to reduce cathodic corrosion).

One of the ceramic materials in particular, an alumina-titania nano-ceramic, has shown huge potential for application to Fleet component repair. When applied properly, the ceramic coating provides protection from wear, corrosion and heat, far beyond any known metal alloy, and is fairly impervious to marine growth, which is a constant problem for submarine and ship components exposed to salt water. The alumina/titania nano-ceramic coating is superior to other ceramics because it is less brittle and more flexible. The use of these coatings in a limited number of submarine applications has already demonstrated significant benefits in increasing component longevity.



The Office of the Secretary of Defense (OSD) has estimated that the cost of corrosion to Navy ship/submarine maintenance is $2.4B to $3.2B per year. The future use of ceramic coatings for wear and corrosion protection in NAVSEA ship and submarine applications has huge potential to help reduce these costs and the opportunity to solve a significant Fleet material issue and expand this advanced coating technology into other ship/submarine applications.

In-Situ Robotics for Fleet Maintenance

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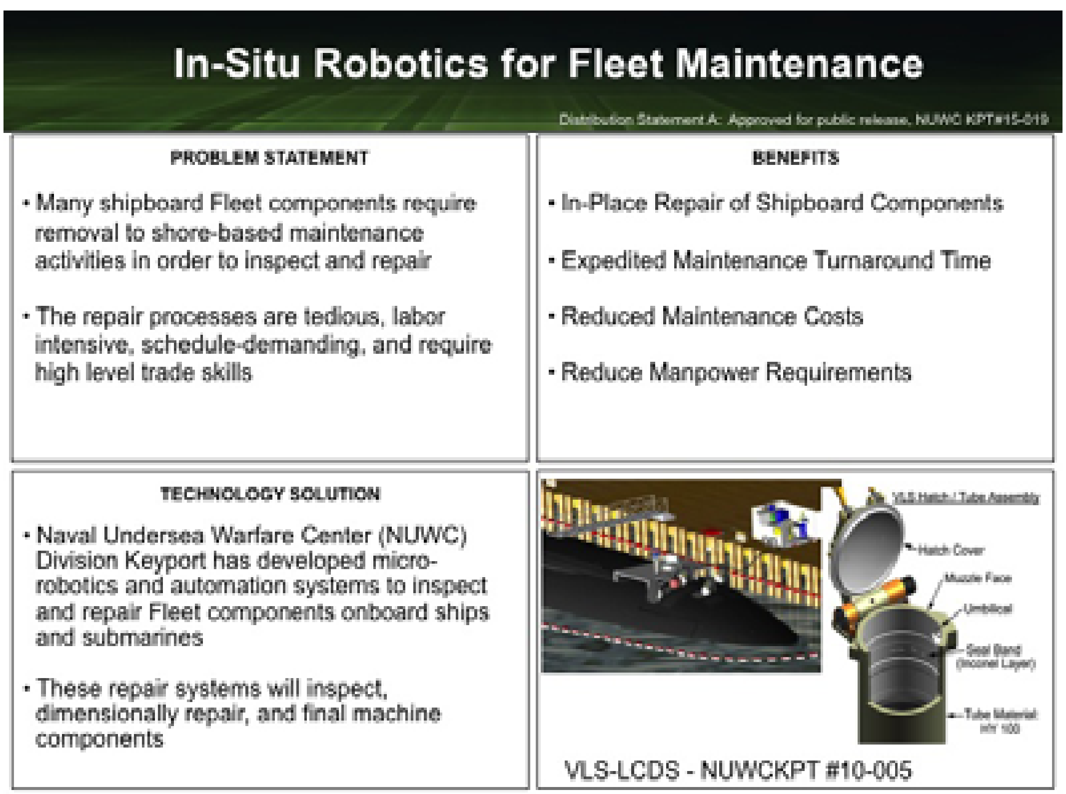
BLUF: The use of new technology robotics and automation to perform "in-situ" maintenance operations on board ships and submarines will reduce repair costs and increase Fleet operational availabilities by performing repairs on components that cannot be removed during ship maintenance availabilities.

The Navy Fleet has been faced with extended deployments of ships and submarines the past few years to support multiple areas of conflict in the world. Not only do extended deployments add significant wear and tear on Fleet assets, there is a need to perform shipyard maintenance in an expedited manner to maximize the operational availability of ships and submarines. One of the most costly and labor intensive maintenance operations is the repair of vessel machinery that experiences wear and corrosion. Fleet components such as valves, pumps, actuators, compressors, impellers, fittings and piping require repair operations on board the ship during maintenance availabilities because these components cannot be easily removed. Additive repair processes such as welding and electroplating are commonly used to build up worn and corroded surfaces. After a surface is dimensionally restored with these processes, subsequent machining or hand work is necessary to restore the surface to the drawing requirement of the component. These repair processes are tedious, very labor intensive, schedule-demanding and require high level trade skills.

NUWC Keyport is a leader in the development of sustainment technologies and is at the forefront of developing "in-situ" repair devices for automating the repair of Naval machinery. This concept involves the development of micro robotics and automation systems to inspect, dimensionally repair and final machine Fleet components on ships and submarines. Specifically, this objective is to develop generic, multipurpose robotic systems that can perform repair operations on multiple types of ship/submarine components using laser cladding for dimensional repair and CNC grinding for machining. Development of micro-automation for these types of repairs will reduce manpower, reduce repair schedules and provide repairs with greater longevity. Keyport will continue developing the use of micro-robotics and laser material processing to develop a family of in-situ repair devices that can perform maintenance tasks on ships and submarines. Further development of in-situ robotic applications have considerable potential to increase the longevity of Fleet components and reduce Fleet maintenance costs.



Use of Additive Manufacturing for the B-52 Stratofortress Radar Blower Motor Assembly

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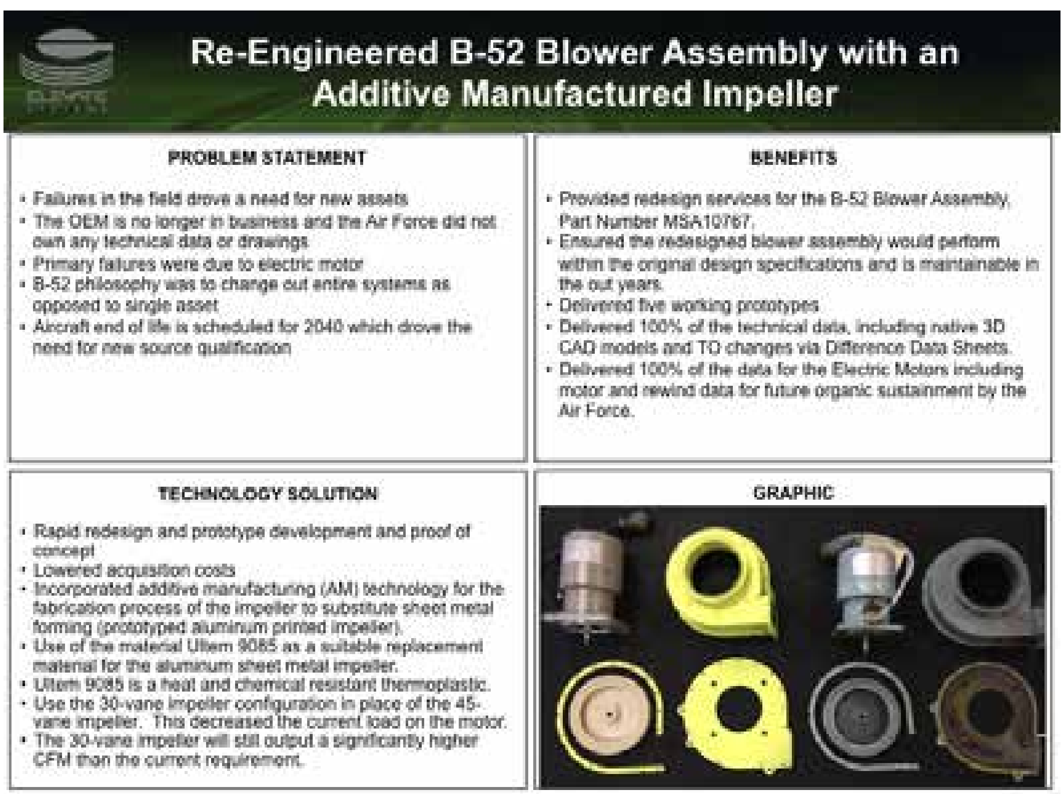
Elevate Systems is flying an asset with a 3D printied impeller currently on 4 B-52 Stratofortresses. The scope was to reverse engineer and create a technical data package and provide five zero-time assets utilizing Additive Manufacturing (AM) also known as 3D printing, for the impeller. The initial approach was to print the impeller in aluminum using a process called Direct Metal Laser Sintering (DMLS). A thermoplastic material called Ultem 9085 was also used to “print” the newly modeled impeller. It was printed using an AM process called Fused Deposition Modeling (FDM).

Elevate Systems was provided no data on the asset and had to reverse engineer and then create 3D solid models to use for drawing creation and production. Once the metrology and 3D models were complete, Elevate Systems printed in ABS plastic (FDM) first for fit check (we have 3 3D Systems Printers in house). After completion and validation of the ABS impeller, it was printed in aluminum (DMLS) and then Ultem 9085 (FDM). The material ULTEM 9085 was selected because of its heat and chemical resistant properties as well as increased strength compared to other plastics. Drawings were created for the backplate and filler strip and specs were developed to refurbish the original housing. The OEM, aluminum printed, and the Ultem Printed impellers were each performance tested and compared. Based on the results of the testing, Elevate Systems modified the impeller 3D model because of a high Amperage draw that the all tested impellers created. A total of three configurations of the Ultem 9085 impeller were tested (45, 30, and 23 vane impeller configurations). The 30-vane impeller was selected because it had the most volumetric flow output without exceeding the current limit.

The Ultem 9085 had equal or better performance, costs factors less, and the material is readily available and can be ordered and received in days as opposed to weeks and months. Had Elevate Systems attempted to have the impeller recreated and manufactured in its original sheet metal formed configuration (49 formed parts and 15 rivets), the tooling would have had to be design and manufactured. In this case, the initial costs to produce the first article (not including engineering time to design and manufacture the tooling) would have exceeded $10K and it would have taken 3-4 months for production. Utilizing additive manufacturing we were able to drastically reduce the manufacturing time as well as the associated costs. The aluminum DMLS impeller production costs were $3,500 and the ULTEM 9085 impellers cost approximately $350 each and realized a cost savings of 10X.

In terms of relative strength and weight of the Ultem Impeller, we determined that the Ultem 9085 is about 60% the strength of the OEM aluminum sheet metal impeller and the printed aluminum impeller. Elevate Systems increased the wall thickness of the Ultem Impeller (the final version) by 40% to add additional strength. In terms of weight, the Ultem impeller is 52% lighter than the OEM Impeller with no noted changes in performance.



Membrane Dehydrator

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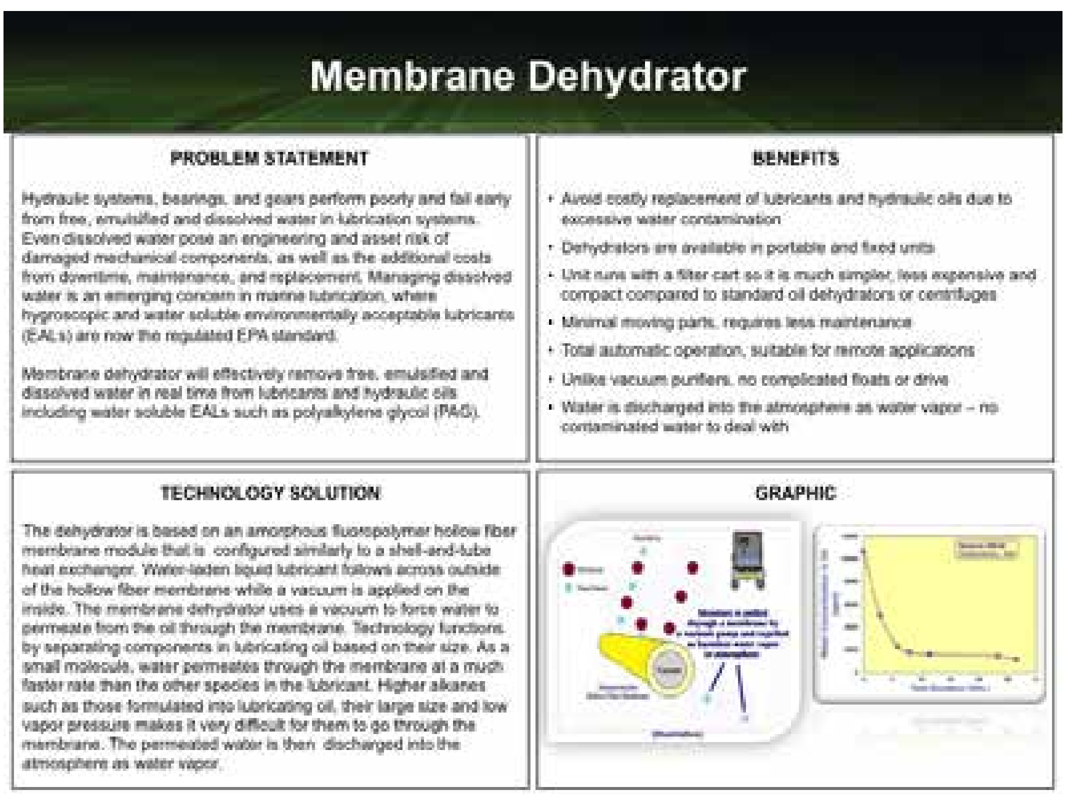
Ingression of water or ambient moisture over time into industrial lubrication and hydraulic fluid systems causes major operational and maintenance problems. Water can be present in such systems as free, dispersed and dissolved water. The contamination level of water in lubrication oil adversely affects the service life of the associated components. Industry studies show gear/bearing life can be increased fivefold (from 5 to 25 years) by reducing the dissolved water concentration to a very low level.

Managing dissolved water is an emerging concern in marine lubrication. Environmentally acceptable lubricants (EALs) are now US EPA regulated standard for 'oil to sea' interfaces and affects approximately 200,000 marine vessels in US waters. EALs are hygroscopic, attracting a high concentration of water, even in dissolved states. In fact, EALs are often designed to be water soluble and hold water in a dissolved state in order to meet EAL standards of biodegradability, a design feature that creates a challenge as it solves a problem. Use of suitable real time drying technology is needed in order to prevent excessive amounts of water from accumulating in the lubrication system.

A new membrane dehydrator system is available commercially to remove free, dispersed and dissolved water from lubricating and hydraulic fluids in real time. The system extends the reliability and life of gearboxes, reduce maintenance costs, and increase uptime and is designed for easy installation into an existing lubrication circuit using a kidney loop configuration. It is a simple, reliable, portable, and lightweight system with low energy usage, requiring only a common 120 volt connection. The unit is compact enough to fit through ship hatches and down steps carried by one person. It avoids flooding, foaming and the constant attention required with standard vacuum oil purification systems. Unlike centrifuges it is effective against dissolved water. Membrane dehydrator removes water without removing performance additives; works effectively with EALs in the presence of both fresh and sea water.

At the initiative of United States Coast Guard (USCG), bench scale oil dewatering studies were undertaken with KEMEL ST-77 Polyethylene Glycol (PEG) and Neptune AW-46 Polyalkylene glycol (PAG) EALs using a membrane dehydrator. KEMEL ST-77 was spiked with water to generate an oil-water mixture containing ~25,000 ppm water. Neptune AW-46 was spiked with water to the level of ~10,000 ppm. The final water concentration of KEMEL oil at the end of testing was only 570 ppm and that of Neptune oil was only 1150 ppm. These are well below the recommended values by the manufacturer. Water removal was slightly slower when sea water was used to spike the Neptune EAL.

Based on the above bench scale results, USCG carried out an oil dehydration demonstration trial on USCGC WAESCHE in the June 2015. USCG has now decided to implement this new membrane dehydrator technology on USCGC ALDER CPP oil system using portable filter cart. Installation is targeted in the fall of 2015.



Removal of Polyurea-Based Coatings

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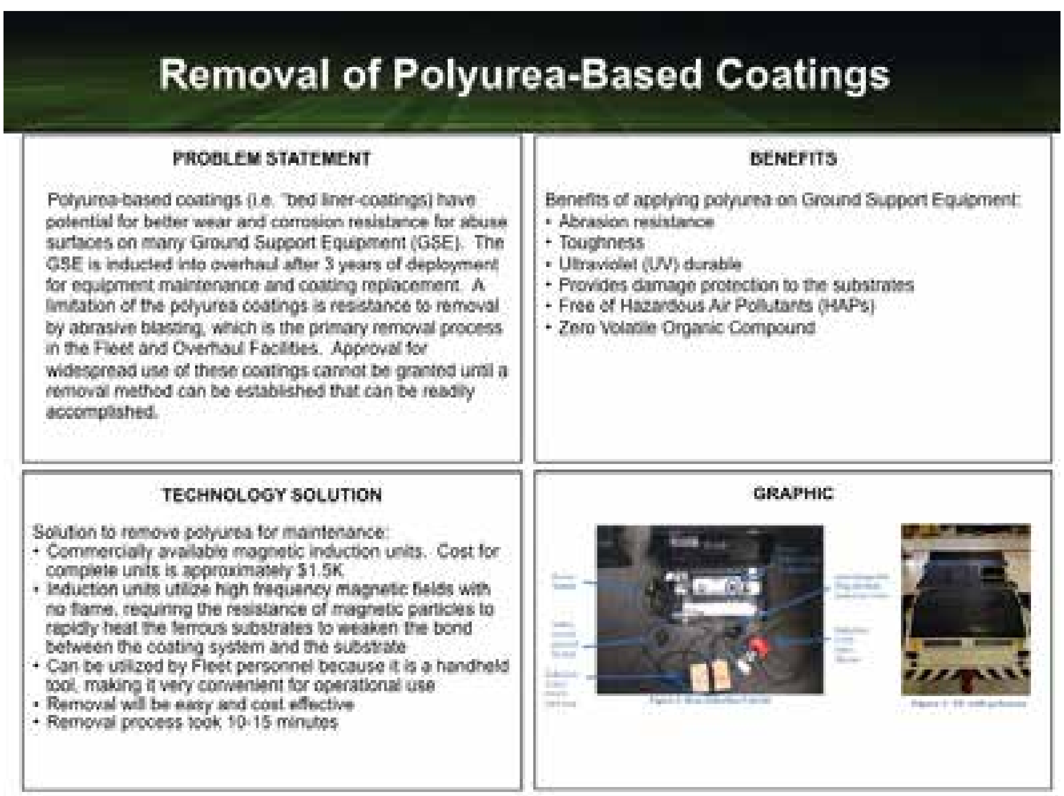
NAVAIR Materials Engineering, Code 4.3.4.2, was requested to develop a test plan to evaluate methods to remove polyurea-based coatings. The coatings have been used on Naval Aviation Support Equipment (SE) A/S32A-32 Aircraft Tow Tractor and the A/S32A-31B Aircraft Tow Tractor on a limited basis to equipment surfaces that are prone to operational abuse and mechanical damage where traditional coatings do not hold up. The Fleet has requested permission to use the coatings on a larger basis, due to the coatings' benefits. The benefits of using polyurea-based coatings include abrasion resistance, UV durability, coating toughness, and flame resistance.

Additionally, the coating is zero Volatile Organic Compound (VOC) and Hazardous Air Pollutant (HAP) free. While the polyurea coating has shown improvement over the current coatings, the SE Type Commander has been resistant to provide overall permission because the Fleet is not equipped to remove this coating once applied. The coating is resistant to abrasive blasting, which is the predominant coating removal process available to both the Fleet and overhaul facilities.

A technological solution to the removal problem was found in the use of a magnetic induction tool. These induction units are handheld tools, which are very convenient for operational use. They utilize high frequency magnetic fields to degrade the coating, but are only effective in heating ferrous metal substrates. The high-frequency AC current flows from one end of the electromagnet through ferrous substrates to the other end of the electromagnet. This field of flow generates an eddy current through ferrous substrates, causing the substrate to heat rapidly. This weakens the bond between the coating system and the substrate. The coating can then be scraped from the surface as the bond is weakened. This technique removes the polyurea coating, but not the primer residues, which can then be removed by conventional abrasive blast. The removal of polyurea and primer coating from the base metal can be accomplished in about 10-15 minutes per square foot.

Based on the successful demonstration of coating removal using the magnetic induction tool, we are recommending approval from the Type Commander for general SE use. This technology will be transitioned by revision or change notice to the NAVAIR 17-125 SE Maintenance Manual. If this coating proves as durable as reports have stated, the SE rework cycle may be able to be lengthened from the current three year cycle.



MRO Business Process Innovation - How Optimizing Flow Rather than Resource Efficiencies Creates Breakthrough Performance

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Based on over 10 years of research and field work with organizations in the DoD as well as the private sector, Realization has perfected a business process innovation for MRO. Called MRO Flow Optimization System, the core of this innovation is Flow Optimization rather than Resource Optimization.

We started our innovation journey with two simple questions:

1. Why, even after investing significant time and money in their continuous improvement efforts do MRO operations continue to struggle in dramatically improving their cycle times and reducing costs?

2. The Ford Assembly Line and Toyota Production System work well in high volume, low variability operations. Is it possible to create a similar system for the high variability, low volume environment of MRO?

Working with customers, we found that traditional processes aim to improve the efficiency of a resource, e.g., how to optimally perform a specific repair process step, or how to optimize labor utilization within a depot.

We discovered that this focus on resource efficiency created misalignment throughout the value chain, causing either work waiting for people, tooling, and information or people waiting for parts, tooling, and information. In either case, projects were not moving forward, costs continued to accrue and due dates slipped, while everyone felt busy and frustrated.

Similar to Ford and Toyota, we minimized waiting times by changing the focus to optimize flow and shortening the time from the very first process step to product or asset delivery. Flow optimization techniques were designed for high variability, low volume environments like MRO.

This system is comprised of a few simple rules and tools. It has been implemented in the F-18 depot maintenance. By moving optimization focus from resources to flow, cycle times improved by 50%, throughput increased by 42% and asset availability by 5%. This innovative technique can be applied to managing flow within a line, between lines and shops in the depot and between depot and other entities in the supply chain. The wider the scope of flow is the more the benefits.

We will share details of this MRO Flow Optimization System as applied to the F-18 depot maintenance.

The Superfreeze Initiative

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Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility (PHNSY & IMF) has the task of replacing a propulsion plant valve on multiple LOS ANGELES class submarines that cannot be isolated from the reactor through separate valve protection. This will require a complete depressurization of the reactor plant or a temporary isolation for a 10 week period. Schedule impact and cost to the maintenance availability make the use of a freeze seal isolation the preferred choice. Design and operation of the freeze seal must provide reliable isolation due to the radiological consequences of freeze seal failure as a single isolation. Based on reliability and plant safety being the utmost priority, PHNSY & IMF's choice of freeze sealing method is the Superfreeze, which utilizes a stand-alone, enclosed Freon system to establish the freeze seal. PHNSY & IMF will realize an estimated labor savings of 5,400 man hours resulting in $161,000 saved per valve replacement with Superfreeze.

Three freeze seal methods were considered for the isolation: vortex freeze, remote liquid nitrogen freeze, and Superfreeze. The vortex freeze sealing method, the previous method of choice for PHNSY & IMF, uses low-pressure compressed air for pipe freezing. Reliability of this method relies on the shipyard's capability to provide low-pressure compressed air, requiring the operation of multiple air compressors which service the entire shipyard, and backup generators (if needed due to power outages). The vortex freeze sealing method is too large to include multiple freeze jackets on a single freeze site for redundancy. A separate carbon dioxide system must be routed to the site for backup reliability. The remote liquid nitrogen freeze sealing method currently provides adequate isolation at other shipyards; however, execution of this method at PHNSY & IMF would require additional resources since liquid nitrogen is less obtainable in Hawaii and is susceptible to disruption due to natural disaster or an event that could inhibit routine delivery. Based on recent quotes, the price of liquid nitrogen is approximately 12-13 times higher than in the continental United States. Attributes that led to the selection of the Superfreeze method, which significantly lowers the risk for total loss of cooling to the freeze seal relative to the other methods discussed, are the following:

(a) Multiple units installed provide redundancy against individual mechanical failures.

(b) Ability to easily generate 120V AC power on-site using diesel generators during a loss of shore power.

(c) Individual units can be replaced while the freeze is established.

(d) Uninterruptible Power Supply allows for continuous operation during transition from primary power to backup power.

PHNSY & IMF's decision to incorporate Superfreeze has resulted in considerable maintenance cost savings. The electrical power required for a single vortex freeze can run approximately 20 Superfreeze units. The utilization of Superfreeze eliminates the continuous need for 3 skilled trade personnel, equating to an estimated savings of 72 man hours per day resulting in an estimated $2,300 total labor savings per day, allowing for an individual Superfreeze unit to be paid in full with 4 days of use.

Rotorcraft Optimized Structural Health Monitoring (SHM)

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Corrosion is a large and growing problem in the US Army. While there has been significant activity in the area of corrosion prevention, very little effort has been focused on automated corrosion detection, localization, and display. This abstract summarizes Optimized Structural Health Monitoring (SHM) system to detect, localize, and display crack/corrosion on various air and rotorcraft parts currently under advanced development by the US Army Aviation & Missile Research, Development, & Engineering Center (AMRDEC), Diagnostics and Prognostics Laboratory (DPL) located on Redstone Arsenal, Huntsville, AL.

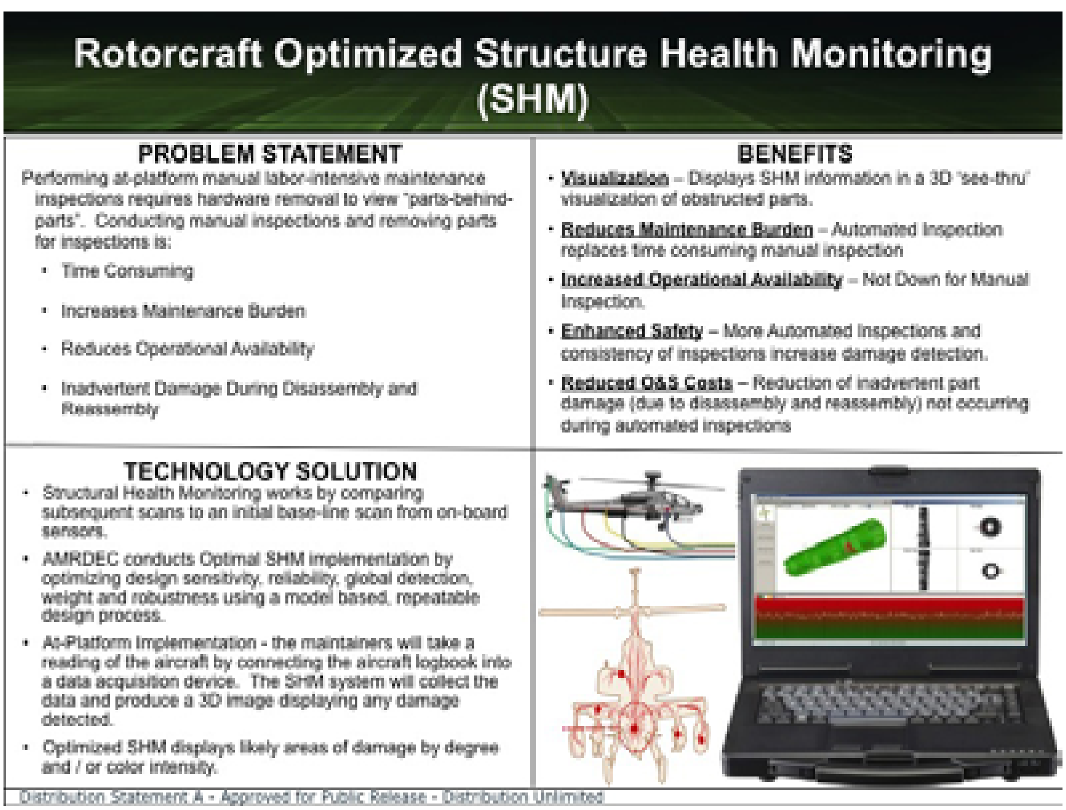
Technically Accurate: The DPL's work involves an Optimized SHM system vs heuristic SHM to detect, localize, and display corrosion on various air and rotorcraft parts. The SHM system consists of two parts. The first is a sophisticated process using machine learning techniques to provide an optimized sensor layout for the aircraft. This technology approach provides 6-7 times the sensitivity to detect damage with 50% fewer sensors than a heuristically designed system. This process produces potential design layouts to reduce the number of sensors required, while gaining maximum sensitivity. Once the optimal design layout is determined, the sensors are permanently mounted on the aircraft.

The second part is the Structural Health Monitoring Interface Software (SHMIS) that has three functions: 1) to determine the existence of damage or calculate damage detection, 2) to determine likely areas of damage location; and, (3) display that information in a 3D Graphical User Interface (GUI) to maintainer personnel. The software is designed to allow for instant and easy recognition of problem-areas even if these areas are hidden from normal visual and hands-on inspection techniques. The sensitivity of the system allows for detection of damage as small as 0.01 inches, while minimizing weight due to the fewer sensors required as compared to heuristic design approaches.

Valid Simulation Support: The SHM system was tested using matrix valued simulation data generated using MatLab. This data was used to generate the Vonmises strain values to plot onto a Finite Element Model (FEM). A series of simulation data sets were generated to verify the Vonmises calculations. A set of element IDs within the FEM were used as the targets of damage. The calculations were performed in MatLab providing a set of calculated results. Those results were inputs to the SHMI software and the FEM displayed.

Practical: The SHM system for crack and corrosion detection and localization with a 3D GUI display is a practical application in reducing the Soldier maintenance burden such that the soldier/maintainers can conduct an automated inspection and visualize areas where damage potential is of concern without having to disassemble and reassemble hardware.

Thus, the Soldier in the near future will have a reliable and accurate system to perform automated structural inspections that will detect structural changes, identify the most likely area that changes occurred and characterize those changes in terms of actionable events (cracks and, or corrosion; and quantify the damage) for immediate or scheduled maintenance actions.



Real-time Aircraft Structural Health Monitoring Systems

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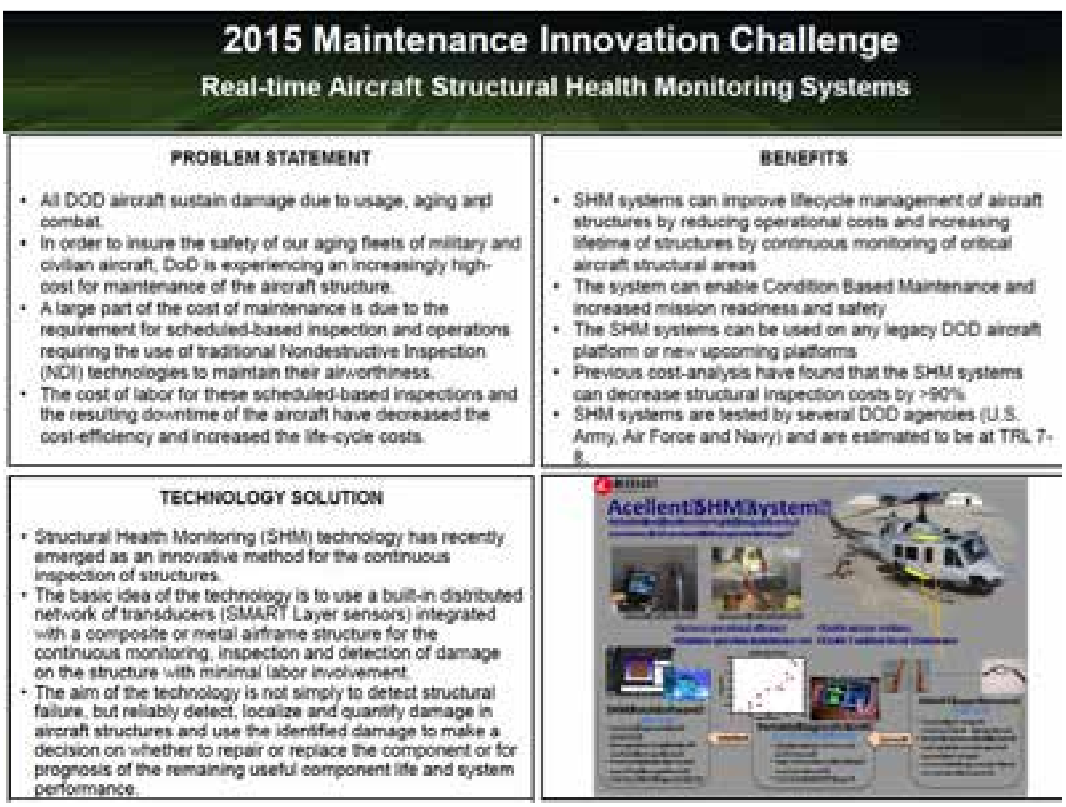
In order to insure the safety of our aging fleets of military and civilian aircraft, DoD is experiencing an increasingly high-cost for maintenance of the aircraft structure. A large part of the cost of maintenance is due to the requirement for scheduled-based inspection and operations requiring the use of traditional Nondestructive Inspection (NDI) technologies to maintain their airworthiness. The cost of labor for these scheduled-based inspections and the resulting downtime of the aircraft have decreased the cost-efficiency and increased the life-cycle costs. Traditional NDI techniques such as ultrasonic NDE, Eddy current, or X-rays typically require access to the structure on at least one side and professionally trained technicians to assess the problematic areas. This can result in high-cost due to the need for structural disassembly of airframe components to expose the areas to the NDI technicians.

Over the past several years, Structural Health Monitoring (SHM) technology has emerged from the research environment into initial applications in a wide variety of fields and is perceived as an innovative method for the continuous inspection of structures. The basic idea of the technology is to use a built-in distributed network of transducers (typically PZT sensors/actuators, temperature sensors, and strain gages) integrated with a composite or metal airframe structure for the continuous monitoring, inspection and detection of damage on the structure with minimal labor involvement. The aim of the technology is not simply to detect structural failure, but also provide an early indication of physical damage.

The SHM systems can decrease structural inspection costs by >90%, increase mission readiness, and enable service life extension of DOD aircraft. The systems can enable Condition Based Maintenance (CBM) by in-situ monitoring of damage thereby eliminating flight hour based inspections, which in turn lead to reduced O&S costs. Current maintenance is reactive to faults, not proactive, resulting in an excessive logistics support burden and high O&S costs. The SHM System provides the ability to continuously monitor the health of critical structures without the need for costly disassembly and reassembly. Accordingly, it offers cost savings as well as increased mission readiness and safety.

Supported by a number of DoD projects (SBIR's and others), SHM systems have been developed and commercialized by Acellent Technologies, Inc. The basic components of the system are (1) a network of miniaturized sensors/actuators integrated with the structure called the SMART Layer, (2) diagnostic hardware and (3) data acquisition software that is used to collect and process diagnostic signals obtained by the SMART Layer during the monitoring process. The signals obtained are then analyzed to determine the integrity of the structure. The system is easy to deploy in the field utilizing a data fusion and damage analysis framework that is fast and efficient for damage detection and quantification. A description of the system will be presented along with examples of applications demonstrating the reliability of the system for the detection of damage such as fatigue cracks, corrosion, composite impact damage etc. in rotorcraft (OH-58, UH-60, CH53K etc.), fixed-wing aircraft (KC-135, F-15), Spacecraft and Unmanned Air Vehicles.



The "Pacman" Wrench – Don't Just Find the Right Tool for the Job, Design a Better One!

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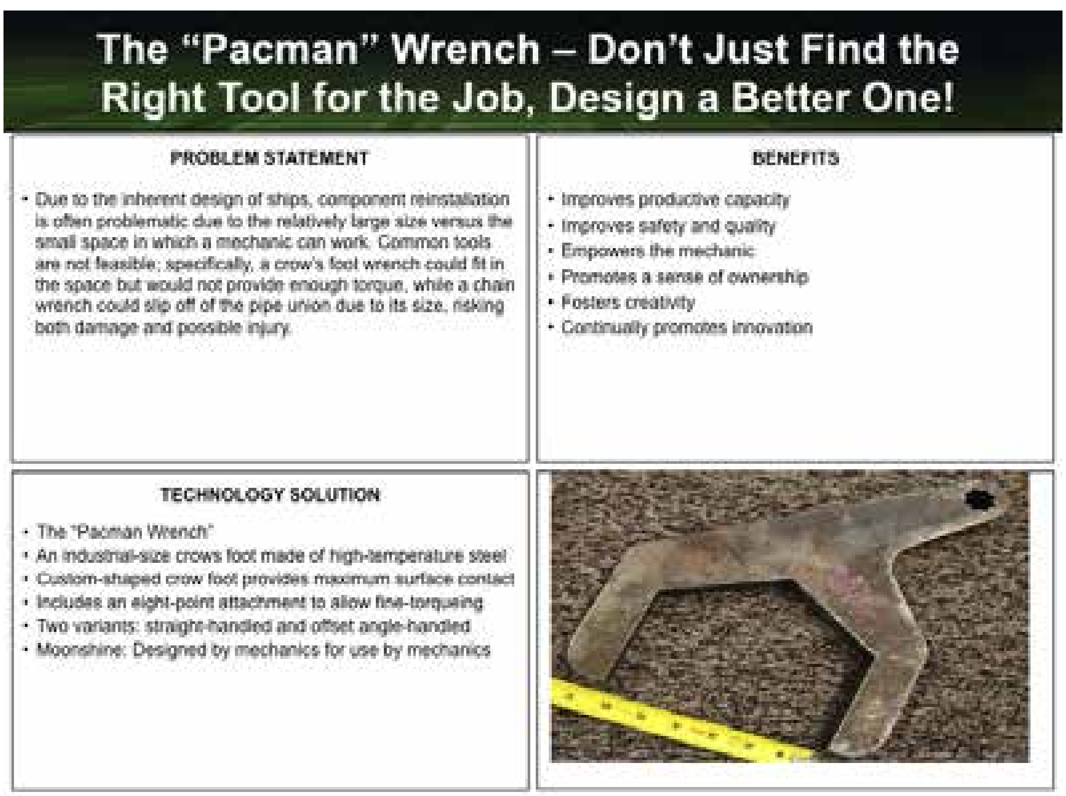
Have you ever been missing the right tool for a job? Most of us would scrounge, scrap and find some tool resembling the one we need and make it work. Our determination and shear will to accomplish the job clouds our judgment and drives us to take unnecessary risk. We risk damaging the component or even worse, hurting ourselves.

At Pearl Harbor Naval Shipyard, we find ourselves in this situation more often than we would like due to the complexity of the maintenance we perform. A common theme echoed throughout the shipyard community is that our ships are "designed more for warfighting than for maintenance". We often work on large, bulky components in very tight spaces. One mechanic recently encountered such a problem while removing submarine shaft vibration reducer piping. He quickly recognized that, while the piping could be removed easily, the reinstallation would be problematic due to its relatively large size versus the small space the mechanic he had to work with. The common tools he had were not feasible to effect the work; a "crow's foot" wrench could fit in the space but would not provide enough torque, while a chain wrench could slip off of the pipe union due to its size, risking both damage and possible injury.

This was the inception of the "Pacman wrench", aptly named due to its resemblance to the 1980's video game character. This custom tool combines the maneuverability of an industrial-size crow's foot with the durability of a high-temperature steel slugging wrench. A custom-shaped hex head allowed for maximum surface contact with the pipe joint, allowing the mechanic to apply large amounts of slugging force with minimal risk of damage. It also includes an eight-point attachment to allow fine-torqueing via a connected box wrench and extender bar. Both straight-handled and offset angle-handled variants were produced to allow adaptability based on the direction of the shipboard pipe union relative to surrounding interferences. Rather than searching for the right tool for the job, our innovative mechanic designed the best tool to make his job more efficient.

This innovative design and ingenuity leveraged human capitol to increase production efficiency and improve safety. This simple tool will save 16 man-days worth of work during reinstallation and avoid costs in excess of $15,000 in component damage. Although the monetary scale of this innovation is small, elimination of rework and increased mechanic safety are unquantifiable. The potential for future application is also quite large; the vibration reducer "Pacman" wrench model has served as a launching point to discover other possible applications throughout ship maintenance. More importantly, however, is the concept on which the design was born. Pearl Harbor Naval Shipyard believes we can manufacture the right tool for any job. We call this "Moonshine". This idea fosters a bottom u



Data Driven Overhaul Scheduling of Aircraft Support Equipment

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Large scale maintenance and overhaul of most Naval Aviation Support Equipment (SE) is based on the time interval of three years. This interval is fixed, with no regard for equipment condition, condition of coating or durability of corrosion preventive compound (CPC) system. This fixed interval has been a barrier to the implementation of new materials and the resolution of long standing corrosion issue and problems with SE. The development of platform maintenance schedules is a key focus area of any program. A data-driven scheduling method that accounts for equipment condition is necessary to break the time-based method. A revised and flexible rework schedule may permit SE to remain in service for longer periods prior to rework. A method to develop corrosion data and model corrosion degradation is presently under development, and has great promise for application to SE. It will identify high corrosion risk areas. These high risk areas will be investigated for current degradation, and platforms with little to no degradation even in high risk areas will be candidates for extended maintenance schedules. The method is based on an OSD funded effort that developed a corrosion sensor for corrosion data and computer modeling protocol for degradation prediction of H53K health monitoring. FY16 startup funding has been obtained to begin collecting data from corrosion sensors installed on SE, and to establish corrosion focus areas. Potential for new coating systems, with increased durability is likely outcome from data driven decisions as well. Corrosion data combined with improved durability in CPC system will give an opportunity for the optimization of the SE maintenance schedule.

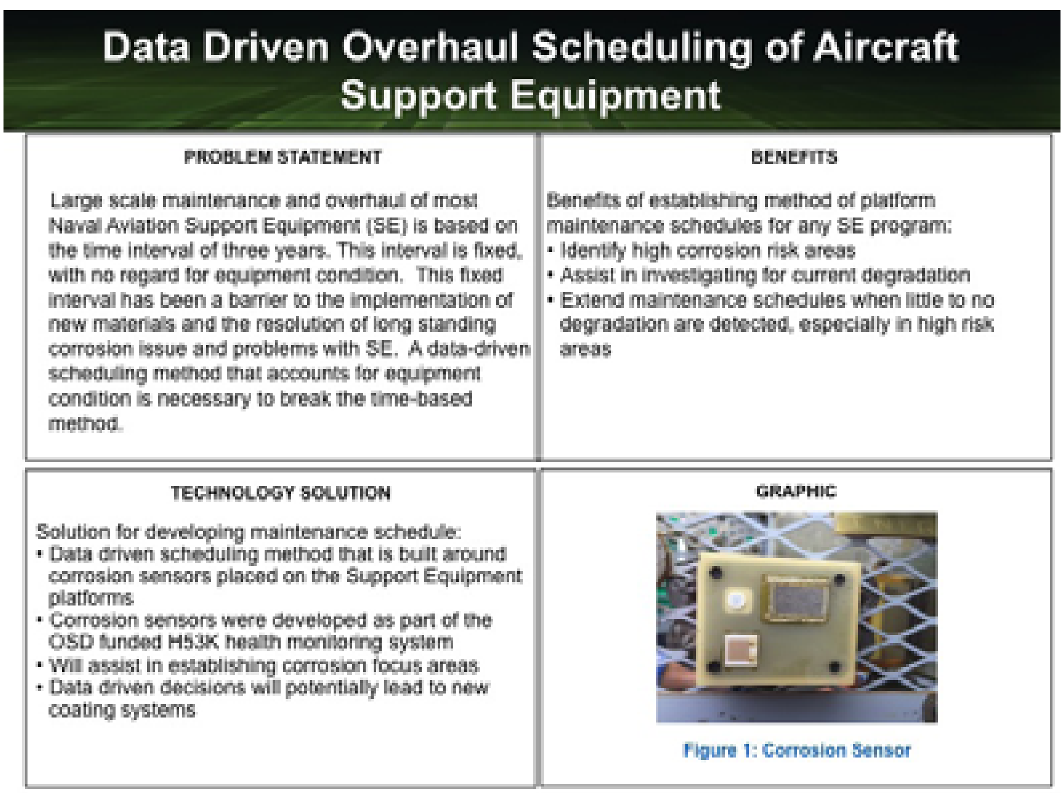

Figure 1: Corrosion Sensor

Assessment of impacts of commercial practices to F117 Engine

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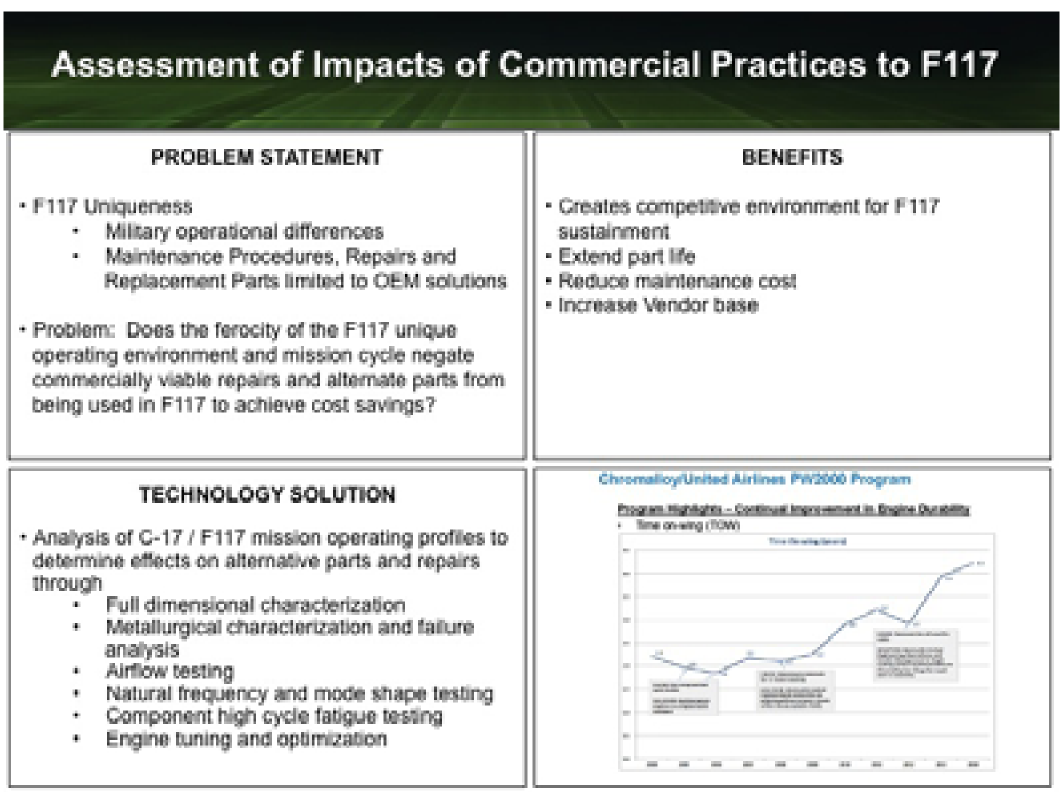
The Pratt & Whitney F117-PW-100 jet engine which powers the U.S. Air Force's C-17 transport aircraft is a derivative of the PW2000 commercial engine family found on the Boeing 757. The F117 engine utilizes approximately 91% of the parts and components of the PW2000 engines. The key portion of that identically are the gas path core components, which account for a significant share of the engine and maintenance costs. Significant cost savings for the F117 engine can be leveraged from the PW2000 engine family supply chain management experience even when the F117 engine operational differences and requirements are incorporated.

F117 engine operational differences due to military use, mission cycle, gearbox system and other airframe related hardware are recognized. Considering these differences within the context of the identical features, particularly the gas path parts, does not negate the significant cost savings that can result by leveraging the use of commercially derived parts, repairs and services into the F117 engine. The two engines share the same FAA Type Certificate Data Sheet (E17NE) and the same maximum redline Turbine Exhaust Gas Temperature (EGT), representing the gas path components in those two engines cannot be subjected to any significant temperature differences. The cost savings resulting from privately funded research and development as well as the economies of a larger scale production supply management chain can continue throughout the life span of the F117 engine.

From a foundational aspect, Chromalloy is uniquely capable to provide gas path cost savings based on Chromalloy's wealth of experience managing 100% of the major parts for the world's largest PW2000 fleet, Chromalloy's undisputed leadership in providing new repairs for the PW2000, such as the industry's first repair of the HPT Stage 1 Duct Segment, and Chromalloy's cumulative gas path management where Time on Wing increased by greater than 75% over a 10 year period.

From the unique operational aspects of the F117 engine, Chromalloy is capable to analyze the ferocity of the F117 engine operating environment and mission cycle. Chromalloy has demonstrated over many years the ability to analyze and develop repair offerings to fully comply with FAA airworthiness regulations. An exciting addition to Chromalloy's analytical and testing capability has been centralized at Chromalloy's Engineering Center of Excellence (ECoE) in Palm Beach Gardens, FL. The ECoE has fully developed OEM-like analyses and testing capabilities to calibrate existing repair and parts to the F117 engine environment. Diagnostic and prognostic processes such as CFD analysis, turbine aerodynamic or secondary flow design and analysis tools combined with laboratory capabilities such as metallurgical, modal and fatigue testing assure today's offerings and future advanced solutions will properly assess the safety, reliability and durability impacts for any given component type and its effects on engine systems and account for specific Life Limit differences prescribed in the Airworthiness Limitations section of the F117 engine Technical Data.

Chromalloy's ability to account for the uniqueness of the F117 engine within the context of almost 30 years of PW2000 experience will provide significant cost savings opportunities over the F117 engine life span.



Ultrasonic Shot Peening Yields Significant Savings on Repairs

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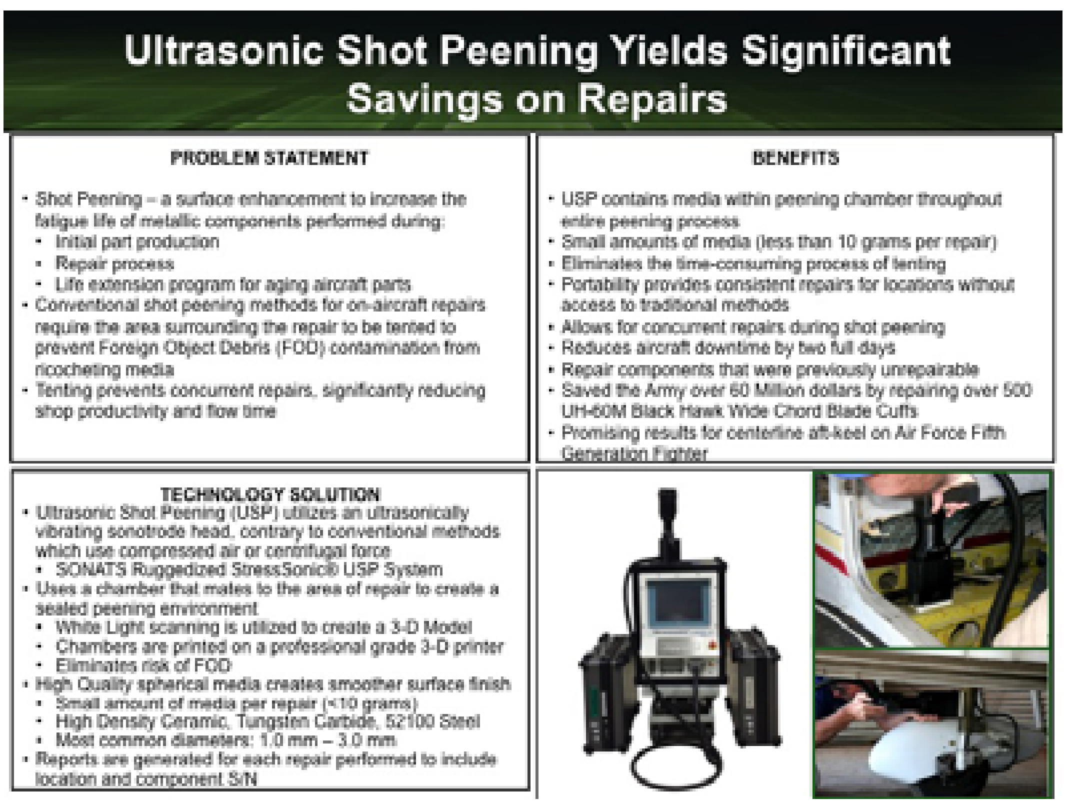
Shot Peening is a surface enhancement process used to increase the fatigue life of metallic components. This process can be used during initial part production, as a repair process, or during a life extension program for aging aircraft parts. When shot peening is required for on-aircraft repairs, conventional shot peening methods require the area surrounding the repair to be tented to prevent Foreign Object Debris (FOD) contamination from ricocheting media. However, this tenting prevents concurrent repairs in areas adjacent to the area being shot peened, significantly reducing shop productivity and flow time. Avion Solutions is creating innovative repair solutions utilizing SONATS StressSonic® Ruggedized Ultrasonic Shot Peening (USP) unit which alleviates the need for tenting, thereby by allowing for concurrent repairs. This innovative technology uses a small sealed chamber to contain the media used during peening to expose only the repair area to the shot stream. At the initiation and conclusion of each USP repair, the USP operator precisely measures the media to ensure all media is accounted for and reclaimed. Therefore, there is no risk of FOD damage. Because this technology confines the peening process and media to a small chamber, repair facilities can continue additional work around the repair reducing the overall downtime of the aircraft and eliminating the cumbersome and time-consuming requirement of tenting the area to reclaim ricocheting shot. In addition to on-aircraft repairs, USP is ideally suited for areas with complex geometry, where conventional shot peening may be ineffective or impossible. Since this process utilizes a chamber mated to the repair area, difficult to reach areas can be peened with ease with this USP system. Avion currently executes USP repairs at the U.S Army's Aviation and Missile Research Development and Engineering Center's (AMRDEC's) Prototype Integration Facility (PIF) on UH-60M Black Hawk Wide Chord Blade (WCB) Titanium Cuffs. To date, Avion has repaired over 500 blades at a cost avoidance to U.S Army of over 60 Million dollars! Another repair that holds promising results is for the centerline aft-keel on an Air Force Fifth Generation fighter. By replacing conventional peening methods with this USP process, the repair facility can recover an estimated two full days of aircraft downtime.



USCG MH-65 Tail Rotor Maintenance Stand

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The Tail Rotor Hub of an MH65 Dauphin Helicopter is overhauled during the depot maintenance cycle of each helicopter. When the hub is being disassembled and reassembled, it needs to be mounted to a rigid fixture, but must also have the capability to rotate due to the 10 blade configuration. Because there were no OEM work stands available, the shop assembled a work cart with tubing on each corner to mount the hub assemblies while performing maintenance on them. This method of disassembly was awkward due to the instability of the roll-around cart as well as the difficulty the artisan had in getting close to the hub during disassembly and torque procedures. It was also too low for artisans to stand while working on the tail rotor hub and was difficult to prevent the hubs from rotating while working. These deficiencies slowed production and increased the possibility of damaging the tail rotor.

The primary artisan on this work is Chuck Sawyer. He teamed up with another artisan in the shop, Eric Lappe, and they sketched a rough design for what they wanted. They worked with the Division's CAD/CAM and Machine Shops - Ryan Williams, Mark Midgette, Joe Waugaman, and Craig Dean and collectively created the final design.

The Maintenance Stand they designed has two work areas enabling two artisans to work at the same time. The two hubs are mounted on Spline Shafts from a Tail Gear Box and are mounted on opposite sides for balance purposes. Mounting the tail rotor hubs on the exact same splines they would be mounted to on the aircraft allows the hubs to be firmly mounted while also enabling them to rotate as they are worked. These mounting arms are inclined at a slight angle to ensure the hub assembly cannot work its way off the stand. The stand positions the tail rotor hub higher than the old carts enabling artisans to work either standing or sitting in an ergonomic manner. Each side of the stand also has a lock pin so the hub can be locked in any position the artisan requires to facilitate tightening attachment bolts. The base of the stand is wide for stability and it has notched areas so the artisan can ergonomically work on it from a shop stool or standing. The base also has wheels that can be extended outward for even more stability if required.

The stands have been drafted and approved with an ALC part number so additional stands for field units can be manufactured to enhance field maintenance in addition to their use at the Aviation Logistics Center.

3D Metal Printing for the Factory Floor

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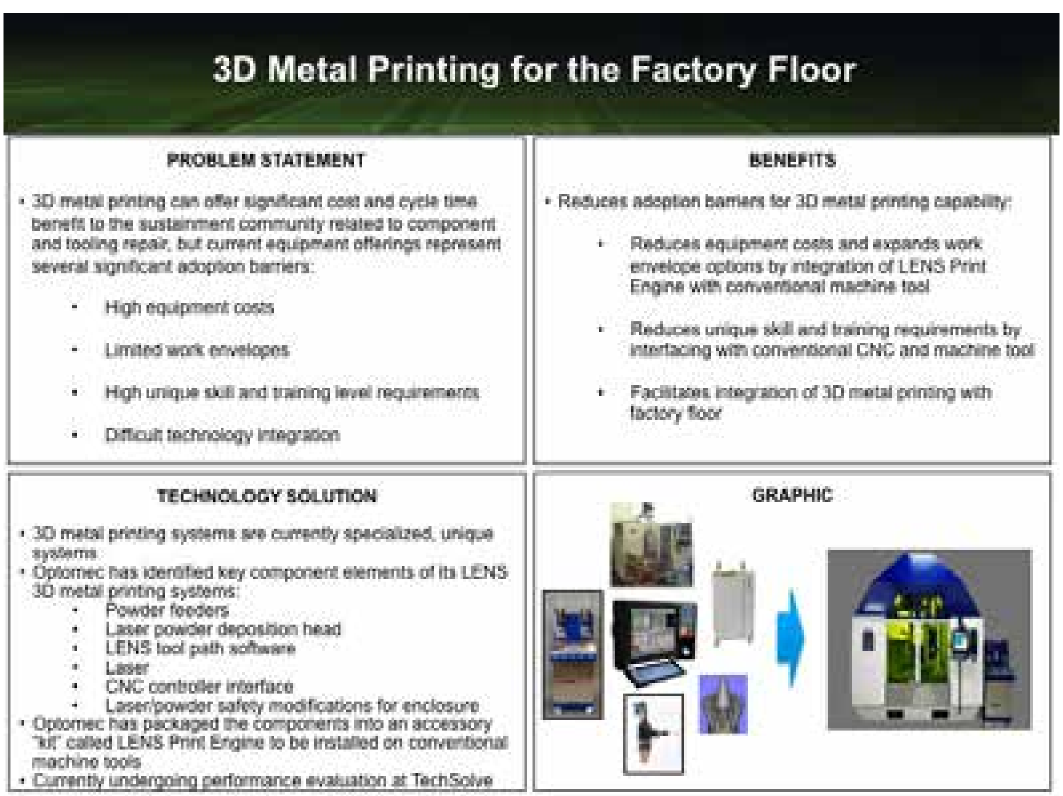
Additive manufacturing (AM) technologies have been utilized as rapid manufacturing techniques supporting the DoD maintenance and sustainment community for more than twenty years. These technologies have included numerous polymer/resin, ceramic and metal 3D printing methods relating to a wide range of applications including casting molds/inserts, plastic injection molds, fixtures and tooling for component part replacement and low volume production as well as component repairs. 3D metal printing has been primarily focused on small tool and mold insert fabrication, tool repairs and the direct repair of metal components. The range of 3D metal printing applications is often limited by the work envelope available for utilization of this innovation. Regardless of the 3D printing method or application, AM technologies have a well-documented potential for reducing sustainment/maintenance costs and cycle times, but have consistently been confronted by significant barriers to adoption.

3D metal printing is encountering many of the same adoption barriers that the other 3D printing methods have experienced. Cost of the equipment, limited work envelopes and the unique training and skill requirements for operating the equipment relate to both the metal and other methods. An additional adoption barrier that 3D metal printing in particular is experiencing is the compatibility of the equipment with the factory floor, especially as this technology relates to the direct repair of metal components or large metal tools. If discreet, complete parts are being fabricated on a flat platform it is not important that this equipment be integrated with the factory floor; it basically represents another resource for the supply of a raw component like a casting or forging that needs finish machining and post-processing. In the case of direct repairs, integration with the factory floor is extremely advantageous.

Optomec has traditionally offered a line of 3D metal printers known as LENS (Laser Engineered Net-Shaping) systems which are laser powder deposition machines used for both discreet part fabrication and direct repairs. These LENS systems incorporate all of the adoption barriers previously mentioned. In order to address these adoption barriers, Optomec developed and, with funding assistance from America Makes, has demonstrated a LENS Print Engine (LPE) concept which is a "kit" of all of the essential LENS process components that can be installed as an accessory on an existing CNC machine tool, either used or new. This significantly reduces the cost of the 3D metal printing capability and opens up the work envelope size options. This LPE interfaces with traditional CNC controls, reducing the skill and training requirements for the technology and significantly facilitating its integration with the factory floor. The LPE concept thus represents a pathway to significantly reduce several 3D metal printing adoption barriers and advance the technology transition.



Optomec is currently working with TechSolve where it has an LPE installed on a used Fadal vertical milling machine. The advanced machining experts at TechSolve are evaluating the performance of the LPE 3D metal printing capability as well as its combined capability as a hybrid additive and subtractive manufacturing machine.

Sourcing Broker

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The Marine Expeditionary Unit (MEU) is one of the nation's most flexible means for providing a forward presence anywhere in the world. A MEU, composed of ground combat arms, aviation, and logistics units is embarked aboard three United States Navy amphibious assault ships. The MEU requires a minimal logistics footprint to provide operational flexibility. Reduced footprint and a wide spectrum of operational environments means that MEUs must rely on multiple, ever-changing external sources of support for maintenance parts.

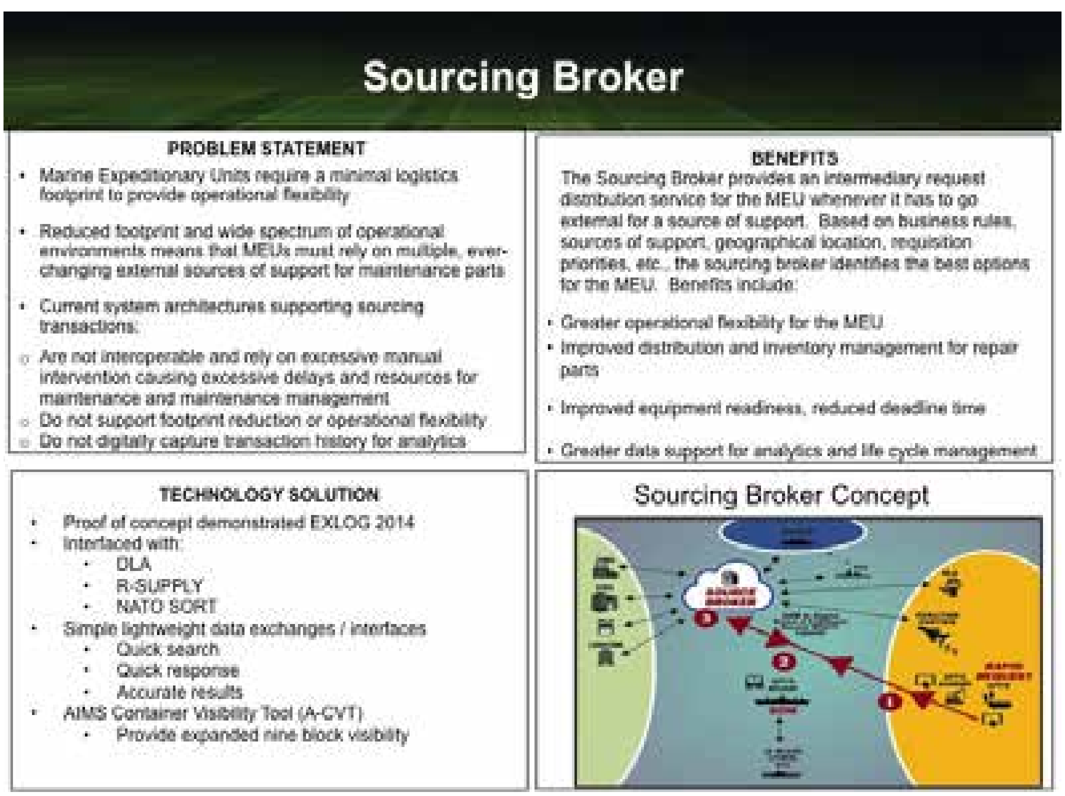
The MEU's sources of support is a wide variable, depending on location, distribution channels, type of product; and the most responsive source may change several times over the course of the deployment.

The MEU must use multiple organic and non-organic systems to conduct transactions. This requires an abundance of manual interventions ("swivel chair") as most of the array of systems are not interoperable and rely on excessive manual intervention causing excessive delays and resources for maintenance and maintenance management. It also means that the MEU conducts a preponderance of its sourcing via a process that is akin to driving from store to store until they find the one that has the part they need ("fill or kill"). Most of the transactional data and history is never captured digitally, completely undermining the ability to conduct the necessary analytics to improve sourcing and inventory management as well as life cycle management.

Innovation: The Sourcing Broker is an emerging innovation concept that provides an intermediary request distribution service for the MEU whenever it has to go external for a source of support. Based on business rules, sources of support, geographical location, requisition priorities, etc., the sourcing broker identifies the best options for the MEU. Without a sourcing broker, the distribution of the requests is heavily dependent on manual means (phone calls, emails or message traffic), or requires a system interface from the MEU's single order manager (SOM) to the system of use by the provider.

With a sourcing broker providing a request distribution service, the MEU only needs one connection when going external for support. Part of the intent is to reduce or eliminate the "swivel chair" and manual procedures, system to system interfaces, and "fill or kill" workflows common to requesting external support. More importantly it accomplishes the following:

- Optimizes distribution and inventory management
- Ensures the digital trail necessary to provide analytics for inventory and life cycle management
- Reduces the MEU's logistics footprint, thus enabling greater operational flexibility
- Improves equipment readiness, reduces deadline time



Solution: A proof of concept was demonstrated at the Marine Corps Expeditionary Logistics Wargame in August 2014. As part of the demonstration, the Marine Corps' order management capability interfaced with systems from the Defense Logistics Agency, the U.S. Navy, and NATO coalition partners. The demonstration proved the ability to: Provide simple lightweight data exchanges / interfaces that include a quick search, quick response, and accurate results; interface with the AIMS Container Visibility Tool (A-CVT), and provide expanded visibility or repair parts.

All-Metal Thermal Control Valves

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Thermal control valves are used in aircraft engine thermal management systems. Conventional thermal control valves us a rubber diaphragm to encapsulate a temperature sensitive media. As the media is heated up, it expands and the rubber allows for axial motion, which actuates the valve. The rubber deteriorates over time resulting in shifting valve performance and failure. Poor performance and low cycle life is particularly evident when operating at temperature extremes.

The All-Metal Thermal Control Valve uses a welded metal bellows to encapsulate the expansion media. The metal bellows is impervious to temperature extremes, exhibits uniform, consistent performance over its life and is capable of ten times or greater the cycle life of conventional thermal valves. Severe cold soak conditions have no effect on the All-Metal Thermal Control Valve and these units can operate at far higher actuation temperatures.

Testing has been performed to demonstrate the high cycle life capability of this technology. Three different types of tests include:

- Bellows Deflection Cycling
    - Sample bellows were subjected to 3.1 million deflection cycles without a single failure and were confirmed to have remained hermetic by helium mass spectrometer leak testing.
- Bellows Pressure Cycling
    - Sample bellows were subjected to 1.1 million hydraulic pressure cycles without a single failure and were confirmed to have remained hermetic by helium mass spectrometer leak testing.
- Thermal Cycling (thermal cycling of completed valve assemblies)
    - Sample thermal valve assemblies have accumulated 184,000 thermal cycles without a single failure and without any degradation in performance.

The All-Metal Thermal Valve technology is ready for implementation.

Large Sensor Arrays for Navigation

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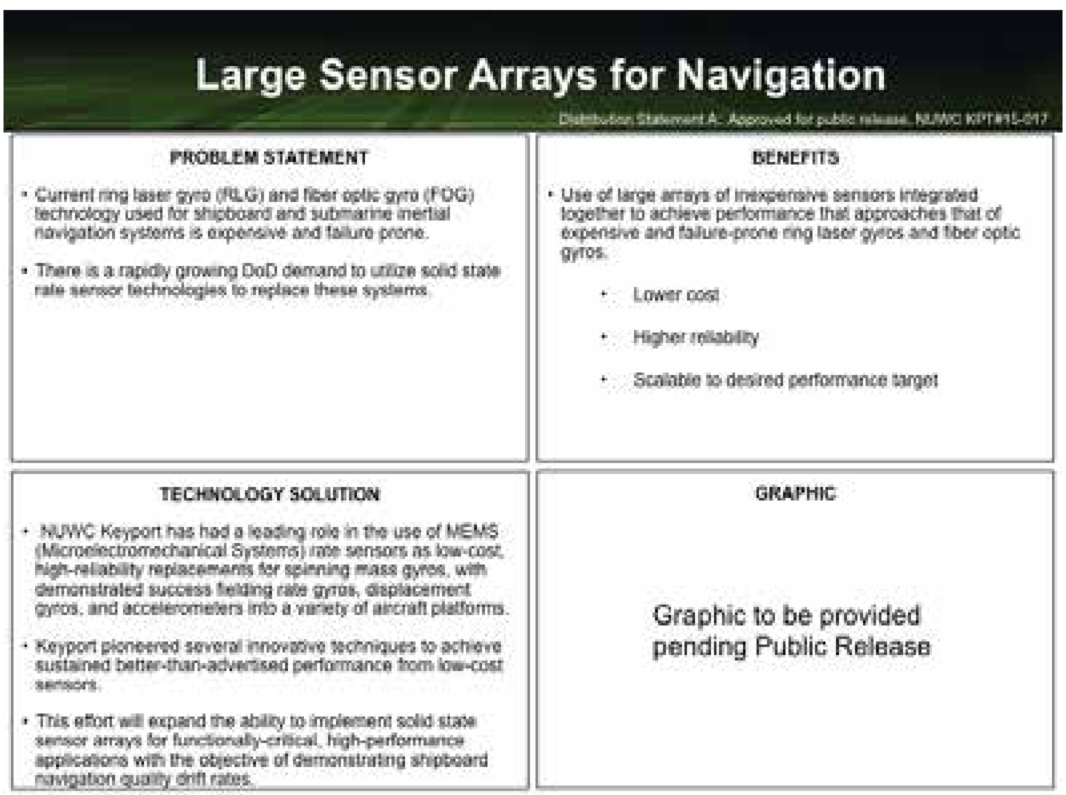
BLUF: The purpose of this initiative is to investigate the use of large rays of inexpensive sensors integrated together to achieve performance that approaches that of expensive and failure-prone ring laser gyros and fiber optic gyros.

Abstract:
NUWC Keyport is performing applied research and fabrication process development to advance solid state array rate sensor capabilities to solve critical Fleet sustainment needs. This effort will expand the ability to implement solid state sensor arrays for functionally-critical, high-performance applications with the objective of demonstrating shipboard navigation quality drift rates. There is a rapidly growing DoD demand to utilize solid state rate sensor technologies to replace expensive, failure prone ring laser gyro (RLG) and fiber optic gyro (FOG) sensors in shipboard and submarine inertial navigation systems.

NUWC Keyport has had a leading role in the use of MEMS (Microelectromechanical Systems) rate sensors as low-cost, high-reliability replacements for spinning mass gyros, with demonstrated success fielding rate gyros, displacement gyros, and accelerometers into a variety of aircraft platforms. In doing this, Keyport pioneered several innovative techniques to reduce sensor errors, compensate for error terms over temperature and over time, and achieve sustained better-than-advertised performance from low-cost sensors. One such method involves utilizing specially-arranged and processed arrays of sensors combined into a single output term.

This effort builds upon this existing expertise and previous large array research to pursue the scaling of larger arrays of sensors to increase the overall performance. The project will take advantage of 330 high quality Micro-Electronic Mechanical System (MEMS) sensors purchased with Naval Innovation Science and Engineering (NISE) funds and package them into a 3 axis rate gyro. Potential beneficiaries of these efforts include PEO-IWS6, NAVSEA, NAVAIR, NAD, NAWC, NSWC, SPAWAR, SSC, and others.



Big RUPHIS: Rotor Universal Positioning & Handling Integrated System

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The six Main Rotor Blades (MRB) on a CH-47 helicopter are frequently removed during aircraft maintenance.

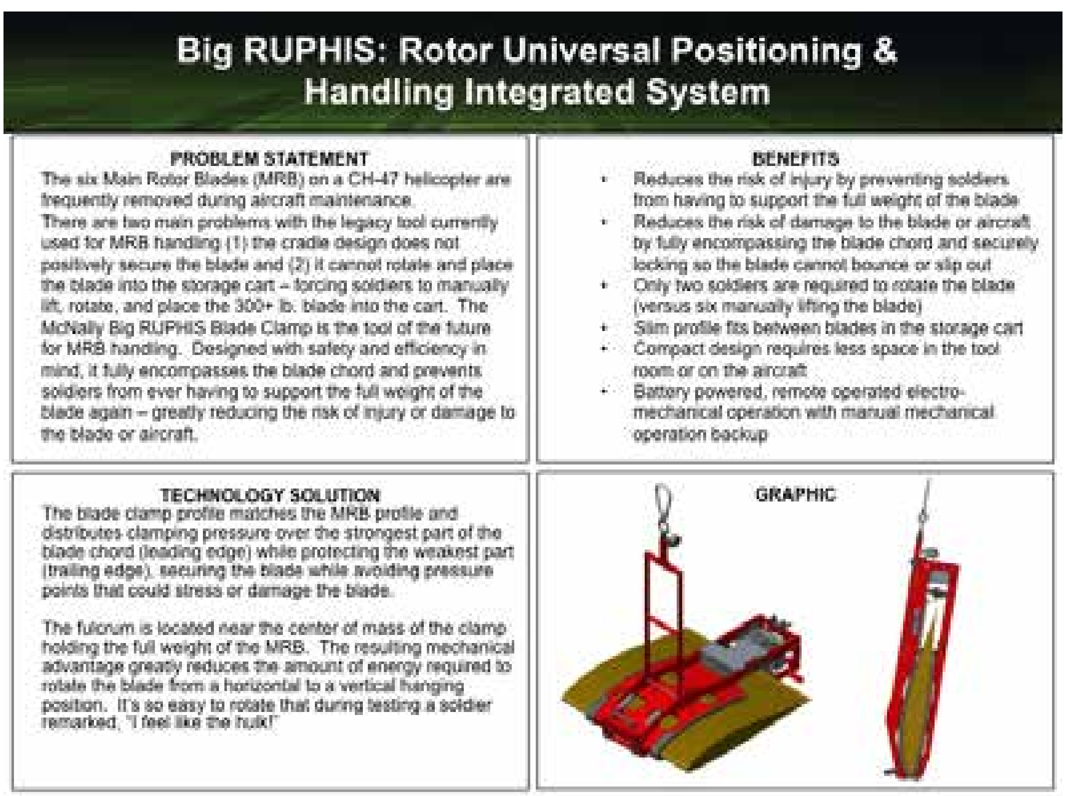
The legacy tool currently used for MRB handling has two main problems: (1) the cradle design does not positively secure the blade and (2) it cannot rotate and place the MRB directly into the blade storage cart – forcing soldiers to manually lift, rotate, and place the 300+ lb. blade into the cart.

The McNally Big RUPHIS Blade Clamp was designed with safety and efficiency in mind, reducing the risk of injury by preventing soldiers from having to support the full weight of the blade and reducing the risk of damaging the blade or aircraft by securely encompassing the blade chord.

Supporting the full weight of the blade greatly increases the risk of injury and damage to the blade

By matching the MRB profile, clamping pressure is distributed over the strongest part of the blade chord (leading edge) while protecting the weakest part (trailing edge) to secure the blade from bouncing or slipping out while avoiding pressure points that could stress or damage the blade.

The fulcrum located near the center of mass of the clamp while holding the full weight of the blade provides a mechanical advantage that greatly reduces the amount of energy required to rotate the MRB from a horizontal to a vertical hanging position. Two soldiers can now accomplish a task that would normally take six soldiers with less risk of injury or damage to the blade or aircraft.



Big RUPHIS: Rotor Universal Positioning & Handling Integrated System

PROBLEM STATEMENT

The six Main Rotor Blades (MRB) on a CH-47 helicopter are frequently removed during aircraft maintenance.
There are two main problems with the legacy tool currently used for MRB handling (1) the cradle design does not positively secure the blade and (2) it cannot rotate and place the blade into the storage cart – forcing soldiers to manually lift, rotate, and place the 300+ lb. blade into the cart. The McNally Big RUPHIS Blade Clamp is the tool of the future for MRB handling. Designed with safety and efficiency in mind, it fully encompasses the blade chord and prevents soldiers from ever having to support the full weight of the blade again – greatly reducing the risk of injury or damage to the blade or aircraft.

BENEFITS

- Reduces the risk of injury by preventing soldiers from having to support the full weight of the blade
- Reduces the risk of damage to the blade or aircraft by fully encompassing the blade chord and securely locking so the blade cannot bounce or slip out
- Only two soldiers are required to rotate the blade (versus six manually lifting the blade)
- Slim profile fits between blades in the storage cart
- Compact design requires less space in the tool room or on the aircraft
- Battery powered, remote operated electro-mechanical operation with manual mechanical operation backup

TECHNOLOGY SOLUTION

The blade clamp profile matches the MRB profile and distributes clamping pressure over the strongest part of the blade chord (leading edge) while protecting the weakest part (trailing edge), securing the blade while avoiding pressure points that could stress or damage the blade.

The fulcrum is located near the center of mass of the clamp holding the full weight of the MRB. The resulting mechanical advantage greatly reduces the amount of energy required to rotate the blade from a horizontal to a vertical hanging position. It's so easy to rotate that during testing a soldier remarked, "I feel like the hulk!"

GRAPHIC

Successful prototype testing was performed at Hunter Army Airfield in Savannah, GA in August of 2014. McNally Industries is currently in production of three first article units and holds a contract with the U.S. Army to deliver 90 units over the next year and a half.

Inspection, Corrosion, and Repair Reporting (ICARR-3D) for Improved Maintenance Data Collection

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Complete, accurate, and timely collection of maintenance data, including inspection results, defects, and repair activities, is critical to ensuring a safe, mission-capable, and readily available weapons platform fleet. As budgets decline and existing platforms are pushed further beyond their original design life, activities such as Reliability Centered Maintenance (RCM) and Condition Based Maintenance Plus (CBM+) that seek to increase availability and reduce cost are becoming critical. Additionally, functional and structural systems integrity programs and digital thread/digital twin initiatives seek to ensure safety, address system deficiencies, and optimize repair processes. These initiatives require high-quality, error-free usage, inspection, and repair data for analysis and trending.

Current data collection methods are inefficient and error-prone. They typically involve notes taken by an inspector or maintainer, which are transcribed later onto official paper forms and then entered, often by someone else, into a data system. This process leads to mistakes in the data, lack of detail, missing critical data components, and key information buried in free-form comments. Colloquial and inconsistent language, non-uniform abbreviations, and spelling errors contribute to "messy" data. To be useful for sustaining engineering initiatives, the data has to be cleaned up and corrected. Despite data mining tools that can help, it is a slow and expensive manual process.

The Inspection, Corrosion, and Repair Reporting 3D (ICARR-3D) tool was developed to support CBM+. It provides a digital point-of-maintenance data collection tool that minimizes impact to the maintainer's workflow while collecting accurate, engineering quality data, primarily in the background. ICARR-3D provides a 3D graphical model of a part or component, and defects are drawn directly on the model using a pointing device. The tool has been integrated into the C-130 Automated Inspection, Repair, Corrosion, and Aircraft Tracking (AIRCAT) system, the mandated Individual Aircraft Tracking Program for C-130. ICARR-3D serves as an inspection and repair data collection, analysis, and visualization tool for critical inspections.

ICARR-3D features the following capabilities: (1) Data Collection: Defects are drawn directly on 3D model of inspected part. 2D drawings can be substituted if 3D model is unavailable; System automatically populates system codes, part identifiers, inspection information, and precise defect location in body coordinates; Optional details include repair actions, references, hours, and material costs, Capture or attach and draw annotations directly on photos; Attach relevant data files (Non-destructive Inspection (NDI) results, video, reports, design data, analysis models, etc.) in any file format; Includes inspection checklists and work descriptions; Maintains completion status of inspections in progress; Point-of-Maintenance data collection enables near-real-time engineering technical support. (2) Data Analysis and Visualization: All data stored in approved data system and available enterprise-wide; Findings plotted visually on 3D model down to individual part level; Reports and visualizations can be filtered for analysis and visualization; All recorded and attached findings and data are available through reporting tool.

ICARR-3D is non-proprietary, government-owned software deployed in production since 2010. Its modular, data-driven design allows for the rapid addition of any weapons platform to improve maintenance data accuracy and usefulness.

USCG MRS On-Wing Flight Control Balance Tool

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The U.S. Coast Guard operates a fleet of 18 HC-144 Ocean Sentry aircraft from four air stations to perform its eleven congressionally mandated missions including search and rescue, migrant, and drug interdiction, and ports, waterways, and coastal security operations. The Coast Guard's unique mission spectrum poses a variety of maintenance challenges not seen by any other operator of similar type aircraft in the world. In particular, high annual usage rates at low level altitudes in harsh maritime conditions is very demanding on the aircraft due to the increased stress from buffeting and operational maneuvering coupled with the constant threat of corrosion.

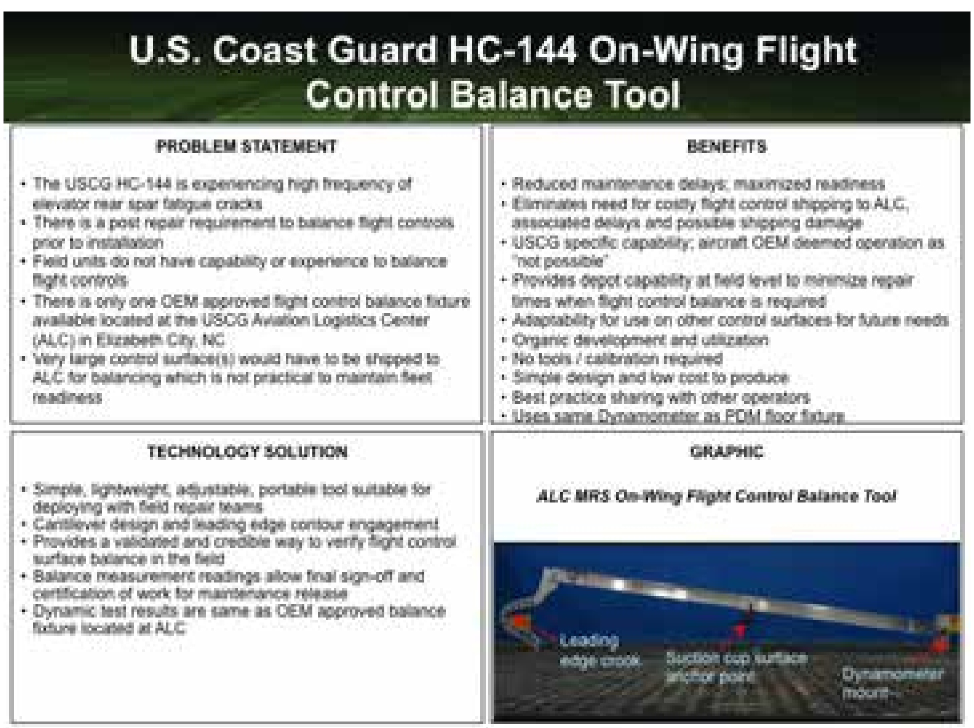
The severity of the Coast Guard's mission spectrum was most recently exemplified in the form of fatigue cracks found in the rear elevator spars. As the aircraft manufacturer develops a long-term solution to make this component more resistant to fatigue, ongoing inspections and repairs are required in the field to allow for continued airworthiness. The challenge that had to be overcome was how to satisfy the mandatory balance requirement of a repaired flight control at the field level. Prior to this, the requirement to conduct field level flight control balancing did not exist and consequently the only approved method to balance a flight control was to use a specially designed "off-wing" balance fixture located at the Coast Guard's Aviation Logistics Center, in Elizabeth City, NC.

Figure 1: Portable "on-wing" prototype balance tool

While this fixture is ideal for Programmed Depot Maintenance activities, it is not suitable for field level use.

In order to close this capability gap and effectively respond to multiple reports of cracked rear elevator spars, the HC-144 engineering team initiated an effort to develop a validated method to conduct field level flight control balancing. Prior to commencing this project, the airframe manufacturer was consulted to provide a technical solution. After some preliminary discussion, it was determined the manufacturer was unable to provide a satisfactory solution that met the requirement for field level, "on-wing" balance capability; so our team took over.

The total time from design concept to prototype fabrication took less than a week to deliver a portable, "on-wing" balancing tool suitable for maintenance field teams to use following elevator repair efforts (Figure 1). Testing of the tool was accomplished by comparing back-to-back dynamometer (force) readings recorded from a serviceable elevator assembly. The manufacturer-approved flight control balance floor fixture was used to validate the on-wing tool's performance and accuracy using a calibrated force dynamometer and digital inclinometer.



The ingenuity and problem-solving acumen that went into developing this special tooling received high praise from the Coast Guard Commandant during his recent visit to Elizabeth City, NC. This tool has greatly increased available options for maintenance planners when addressing emergent flight control discrepancies and has enabled Coast Guard operations to remain - Semper Paratus!

SUBMISSIONS

Health Monitoring of Helicopter Dampers Using Analytical Modeling and Sensor Inputs

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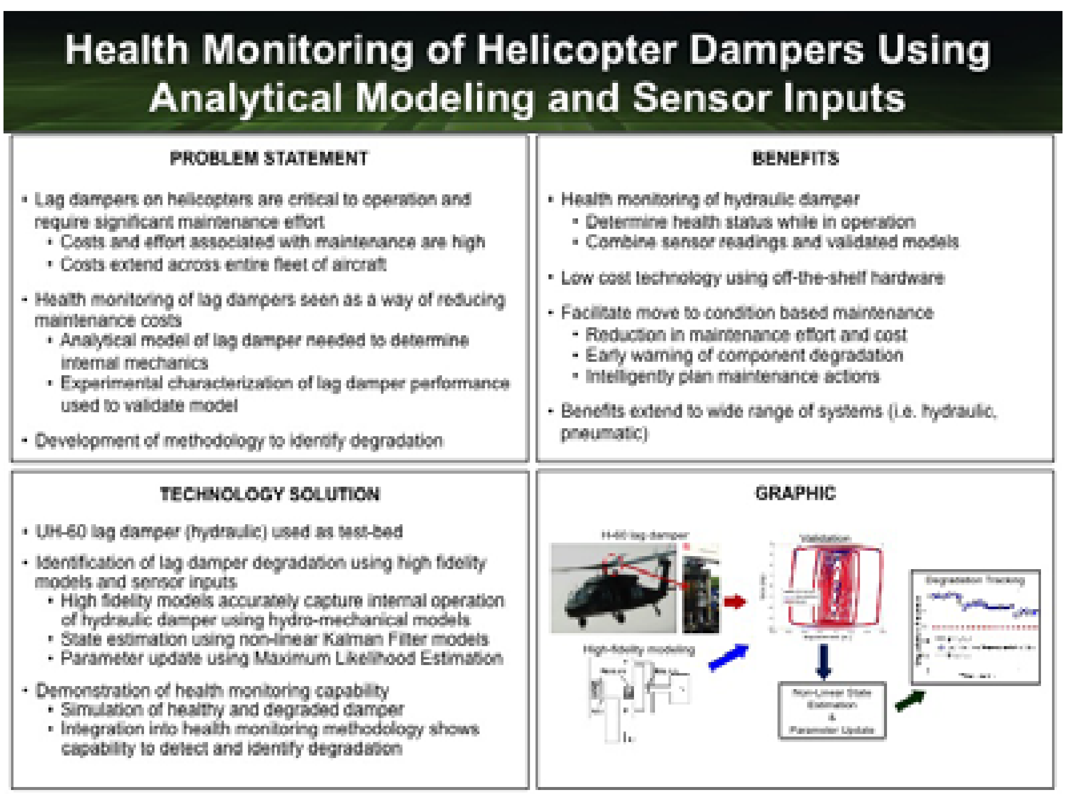
The main rotor for the UH-60 helicopter is equipped with hydraulic lead-lag dampers to alleviate aeromechanical instabilities. Lag dampers require regular inspections and maintenance actions. These regular maintenance actions are a driver of total costs for the helicopter. A health monitoring approach to maintenance of the lag dampers is envisioned as a way of reducing costs using an in-situ methodology.

Two UH-60 helicopter lag dampers were tested in the laboratory environment on a servo-hydraulic testing machine. Testing was conducted to acquire force versus stroke at the main rotor frequency and the lag frequency for a range of stroking amplitudes and temperatures varying from -40°F to +122°F.

A hydro-mechanical analysis was developed to predict the force versus stroke behavior of the UH-60 lag damper. The model was based on the internal layout and volumes of the damper flow modelled through orifices, inlets, and outlets internal to the damper. Analytical predictions from the model were subsequently validated using experimental data.

A state estimation algorithm was developed which used global measurements such as stroke and force to estimate internal states of the lag damper model. The state estimation was performed using a non-linear Kalman Filter algorithm. A parameter update algorithm based on Maximum Likelihood estimation was also developed to identify and track changes to the model.

Using the experimentally validated UH-60 hydro-mechanical model, simulations were conducted to generate damper performance profiles for a variety of conditions and simulated degraded states. Performance profiles corrupted with white noise were input into the state estimation and parameter update algorithms and showed the ability to track slow degradation of the damper. Results show promise for use of the technique as a condition based maintenance technique for hydraulic systems.



RFID Network System for Automatic Item Inventory Taking and Readiness

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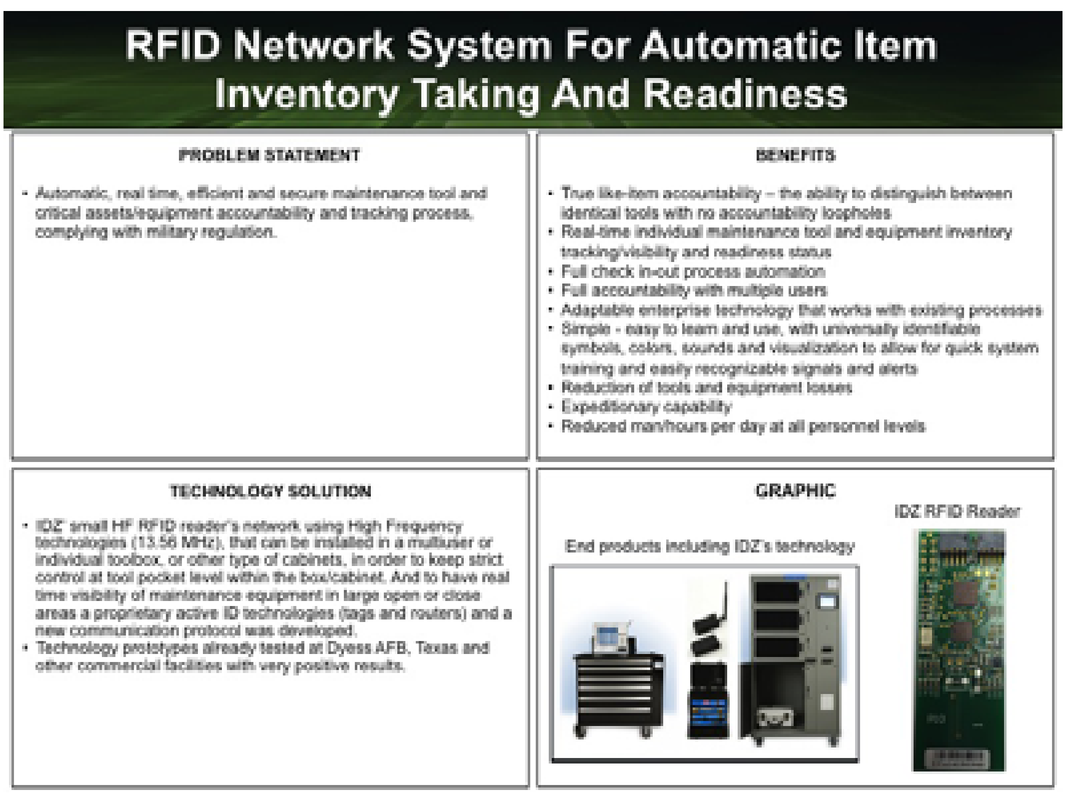
IDZ Technologies, Inc. (IDZ) has developed an innovative technology that really addresses the specific need of a more efficient and secure accountability and tracking process of the maintenance tools and equipment, complying with military regulation, an RFID Cloud based unmanned maintenance critical item control system.

IDZ's researchers designed a small RFID reader using passive High Frequency technologies (13.56 MHz) in order to keep strict tool real time inventory and readiness at pocket level in a multiuser toolbox or individual toolkit (i.e. Pelican case), also developed a new communication protocol and a set of commands required for this task. This technology is able to work in a network of several of these HF RFID readers managing collisions properly while allowing getting response of all readers in the network in a fraction of a second (measured in milliseconds). Additionally, an intelligent hubs and IO-HUBS was developed to communicate with the IDZ's proprietary master brain, as well as a safety mechanism to block access to the toolbox in case of catastrophe.



In order to transmit the information such the inventory inside the toolbox or location of any other item every predefined period of time to a centralized database, another technology was designed and developed. This technology includes a new communication protocol, custom 802.15.4 based mesh network, and an active ID hardware (tags and routers). This technology was designed to be able to operate with a very simple and private, stand-alone network, covering a very large geographic area using mesh-network capabilities.

Accuracy of the item control system of the IDZ's technology in a toolbox relies on the IDZ's RFID reader's network placed in it. This network topology allows for one reader to be placed for each tool-pocket. The level of accuracy of the real time tracking in large areas is given by the combination of the IDZ's active ID technology and the communication protocol. Any of these network topology provides accurate information through a cloud based software application, also developed by IDZ, that support user to make holistic and strategic decisions such maintenance equipment and tools reallocation.

Comprehensive tests were conducted for the different IDZ's inventions. In one test, 1100 readers were connected on the same main rs422 bus via 10 hubs with 110 readers each. This setup was operated for a month while continuously reading the tags placed on top of the readers. 80% of the readers had tags, the rest did not, giving a complete test of both reading and rejecting noise to conclude no tag was present. External noise sources were introduced at random intervals (electric drills, machinery, power tools) and no ill effect was noticed. Readers had 100% read and rejection rate.

Cloud based software embedded, stand-alone and server were also tested using simulation mechanisms as well as use-cases testing traditionally used when testing this type of applications. Thirteen patents have been granted to IDZ related to the technology described in this document. Prototypes tested at Dyess AFB, Texas and other commercial facilities.

Tinker Integrated Data for Maintenance (IDM)

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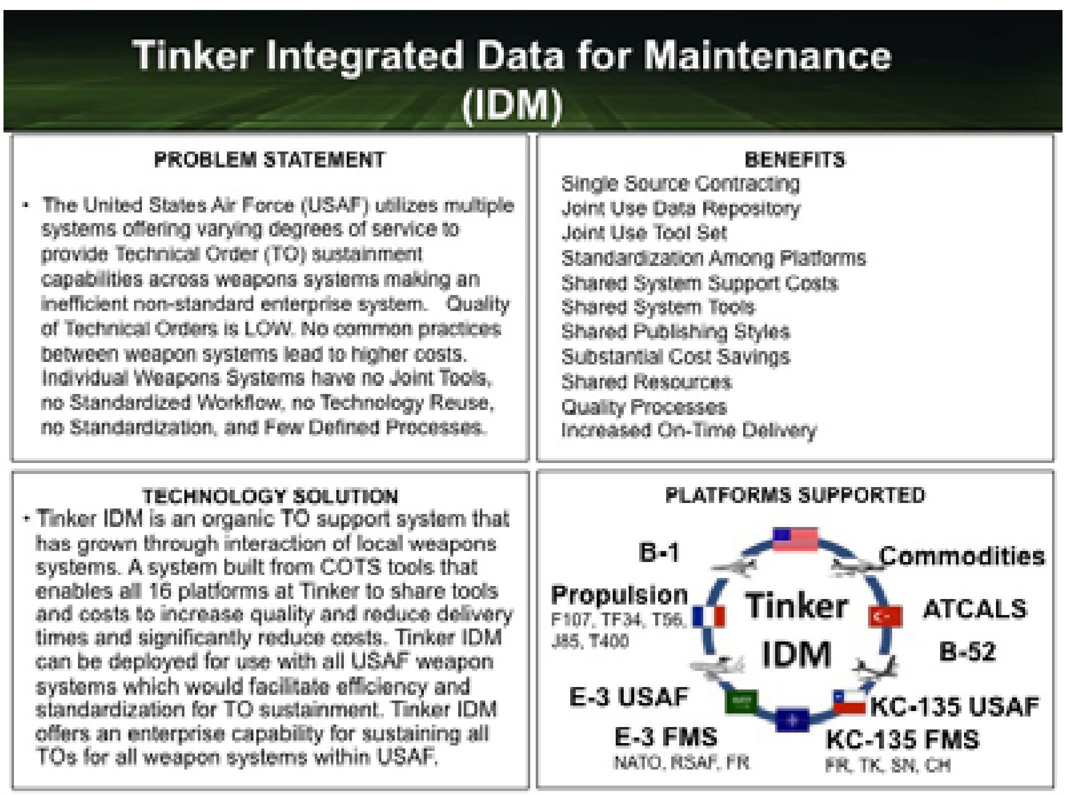
The United States Air Force (USAF) utilizes multiple systems offering varying degrees of service to provide Technical Order (TO) sustainment capabilities across weapons systems making an inefficient non-standard enterprise system. Quality of Technical Orders is LOW. No common practices between weapon systems lead to higher costs. Individual weapons systems have no Joint Tools, no Standardized Workflow, no Technology Reuse, no Standardization, and Few Defined Processes.

Tinker Integrated Data for Maintenance (IDM) provides Government owned organic technical order (TO) sustainment capability and digital data support services including data management and electronic capture, conversion, and update processes and services to manage, maintain, and administer all software utilized to support the management, creation, sustainment, storage and distribution of Tinker AFBs technical orders for United States Air Force (USAF) and Foreign Military Sales (FMS) systems. Tinker IDM platform members are B-1, B-52, E-3, E-3 FMS NATO, E-3 FMS RSAF, E-3 FMS France, ATCALS, C/KC-135, and KC-135 FMS (France, Singapore, Chile, and Turkey), Tinker Commodities, and Propulsion.

Tinker Integrated Data for Maintenance (Tinker IDM) is a collection of Commercial Off -The-Shelf (COTS) and Government Off-The-Shelf (GOTS) components which serves as a complete content management solution for editorial workgroups. Tinker-IDM stores and manages document and content components (of technical orders) in a dynamic database repository, allowing users to reuse information objects.

Tinker-IDM is a workflow controlled environment which ensures repeatable processes wherein documents can be easily assembled from components in the system and content can be shared and reused throughout multiple deliverables.

Restricted access style libraries built exclusively against Air Force Document Type Definitions, Format Output Specification Instances, and Air Force Business Rules guarantees that all output is fully compliant with governing Air Force Technical Manual Specifications and Standards (TMSS) and DOD Defense Standardization Program digitization requirements for rendered outputs.



Tinker IDM can be deployed for use with all USAF weapon systems which would facilitate efficiency and standardization for TO sustainment. Tinker IDM offers an enterprise capability for sustaining all TOs for all weapon systems within USAF.

GBU-X/AGM-X Logistics Analysis

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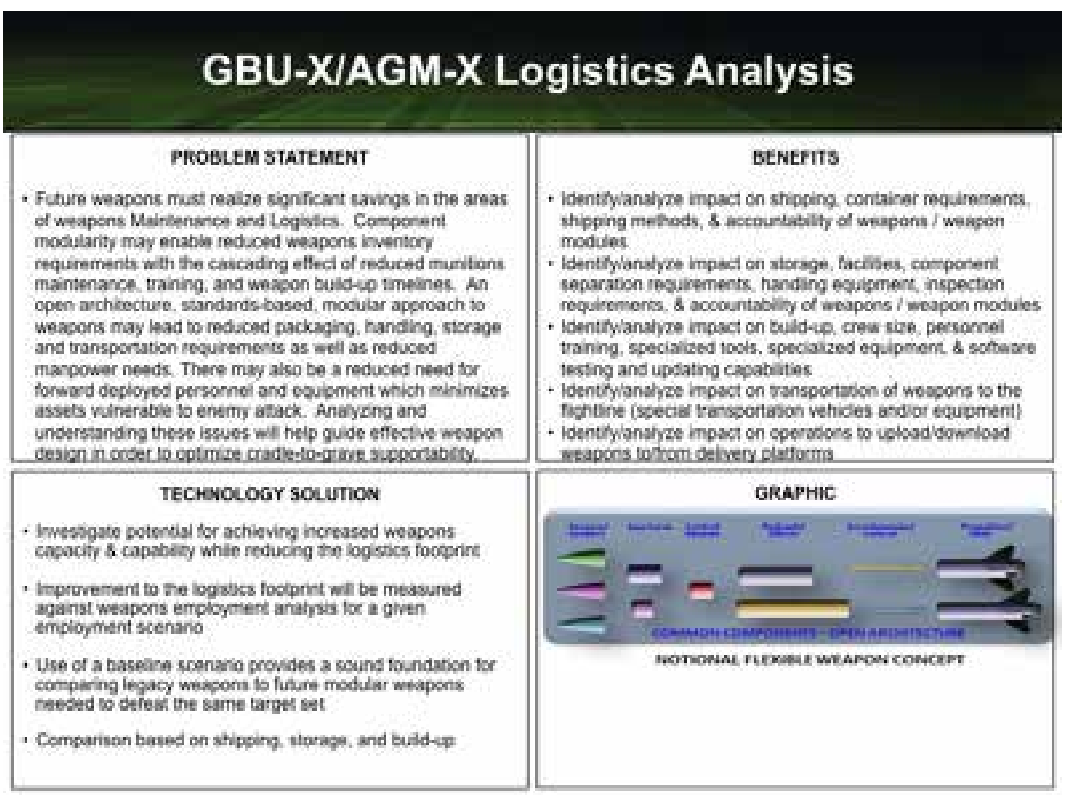
The overarching objective for GBU-X/AGM-X is to mature key technologies that could enhance current weapons or lead to a new family of weapons made up of flexible, interchangeable, open system architecture components for 6th generation aircraft. The Air Force is entering a rapidly changing geo-political scene where the concept of global stability will change the way the AF views combat and weapons. Added to this issue is the reduced weapons capacity because of limited carriage of internal weapons bays. The reduced capacity, both weapon size and loadout, creates a requirement for these weapons to greatly improve their efficiency in target defeat. GBU-X/AGM-X will develop a common architecture to enable modular subsystems to achieve flexible weapons capability while allowing capability refresh at the pace of technology discovery in an affordable and sustainable design.

In order to improve the logistics lifecycle ownership for a new, modular-based weapon, the GBU-X/AGM-X program is conducting a Logistics Analysis of air-to-surface weapons. Specifically, the GBU-X/AGM-X team is characterizing the current (legacy) conventional munitions logistics footprint and the associated elements that support that footprint. Key to this effort is establishing measurable elements of lifecycle management. These metrics or "tenets" were derived from the 2005 Memorandum for Secretaries of the Military Departments which identifies the measurable logistics metrics of Inventory, Equipment, Personnel, Facilities, Transportation Assets and Real Estate. Ultimately, the findings will be used for comparison purposes to support future GBU-X/AGM-X designs.

The team compiled conventional munitions data for a specific set of A2G munitions including GBU-10/12/31/38/39/54, AGM-65, AGM-158 and CBU-103/105. Physical characteristics, such as component makeup, accessory, storage and packaging requirements, were collected along with associated test equipment which supports legacy munitions. A "munition matrix" was created for each legacy munition, listing each configuration and the components that make up that configuration to show how expansive the logistics footprint for munitions really is. For example, there are at least 90 configurations of GBU-31 made up of 39 different components. The USAF has to procure, store, maintain, upgrade, handle, and transport 39 components for one type of A2G munition. As the size of the current A2G munition inventory has grown, the care and feeding costs have grown as well. The team also gathered task specific data relating to munitions buildup and loading requirements and the time required to perform those tasks. The goal of the Logistics Analysis is to identify trade space in the areas listed above to decrease future munition lifecycle ownership costs.



Gathering accurate and relevant logistics data was a priority and proved challenging. Numerous data sources were available, making the identification of physical characteristics, inventories, munition expenditures, support equipment requirements and methods of storage and transportation relatively easy albeit time consuming. Data sources used included munition specific Technical Orders, Air Force Instructions, Table of Allowances, and the Global Ammunition Control Point. Similarly, current manpower authorizations and end-strength data were available through the respective functional managers and the A-1 Community of Practice website.

Proposed Study of Hexavalent Chromium Conversion Secondary to Laser Ablation

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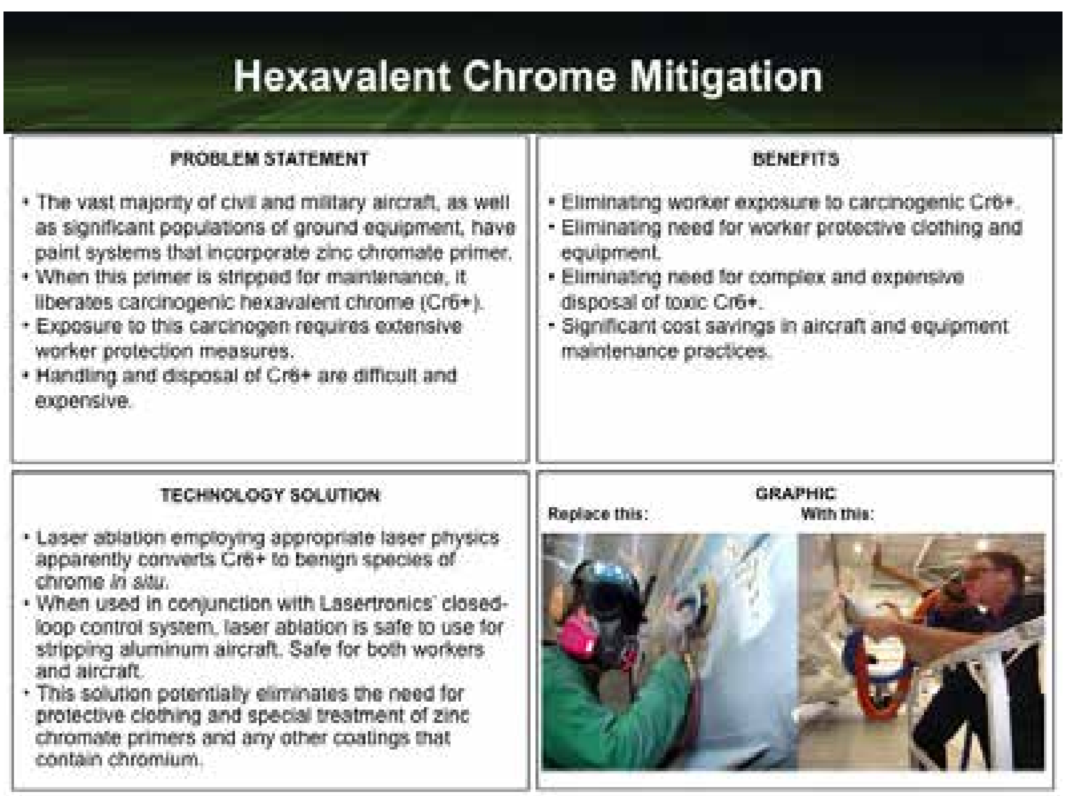
Primers used on aircraft and ground equipment have until recently contained zinc chromate, ZnCrO4. The vast majority of civil and military aircraft employ this primer. When stripped for maintenance, it releases carcinogenic hexavalent chromium (Cr6+). In 2006, OSHA lowered permissible exposure limits (PELs) for Cr6+ by a factor of ten and instituted a National Emphasis Program (NEP) to mitigate related health hazards. Compliance with regulations governing working with and disposal of Cr6+ is complex and expensive. Notably, chromium in any valence other than +6 is non-toxic, requiring neither special handling nor worker protection.

Lasertronics demonstrated this stripping capability on a B727 aircraft, removing paint, primer, and sealant from lap and butt joints to facilitate nondestructive inspection (NDI). Because the primer contained zinc chromate, an experienced industrial hygienist monitored air quality during the operation. Five air samples were collected from proximate locations, and a sixth from the vacuum waste capture system. All samples were expected to contain measureable volumes of Cr6+.



Key Finding: Contrary to expectations, none of the seven samples contained *any* detectable Cr6+. Test instrumentation used had a lower limit of detection (LOD) of 0.06 micrograms (µg). Each sample spanned the full 187 minutes of the demonstration and contained on average some 580 liters. OSHA's "Action Level" (2.5 µg/m3) and "Permissible Exposure Limit" (5.0 µg/m3) for Cr6+ are approximately 24 and 49 times higher, respectively, than these lower-bound detection limits.

Subsequent to this test, an analysis of the fundamental surface thermochemistry (employing a NASA computer model) indicated that with appropriate process parameters, laser ablation should convert Cr6+ to benign valences when removing chromate coatings. To effect this beneficial conversion, the laser must produce high irradiance (power per unit area) over short pulse duration. Lasertronics' systems produce exactly these conditions. Lasers producing different photonic outputs could cause spalling.

Each laser pulse photoablates (vaporizes) a small volume of zinc chromate. This energy transfer induces a vapor-phase mass flux of dissociated zinc, chromium, and oxygen, expanding away from the surface. This hot mass flux reacts efficiently with ambient oxygen. The dissociated Cr6+ apparently converts to benign valence(s) in this process.

Hypothesis: The Lasertronics ablation system converts Cr6+ to chromium of some different, benign, valence. If this hypothesis is correct, this system could strip zinc chromate primer in real-world conditions *in situ with no resulting operator exposure to toxic Cr6+, and no need for PPE or special disposal procedures*. The next steps are testing by a certified lab to positively confirm that following photoablation of zinc chromate, no Cr6+ remains, identify the presence of chromium by valence, by percentage, and identify all end species, solid and gaseous, by percentage.

Handling and Installation Impact on Rotary Carbon Face Seal Performance

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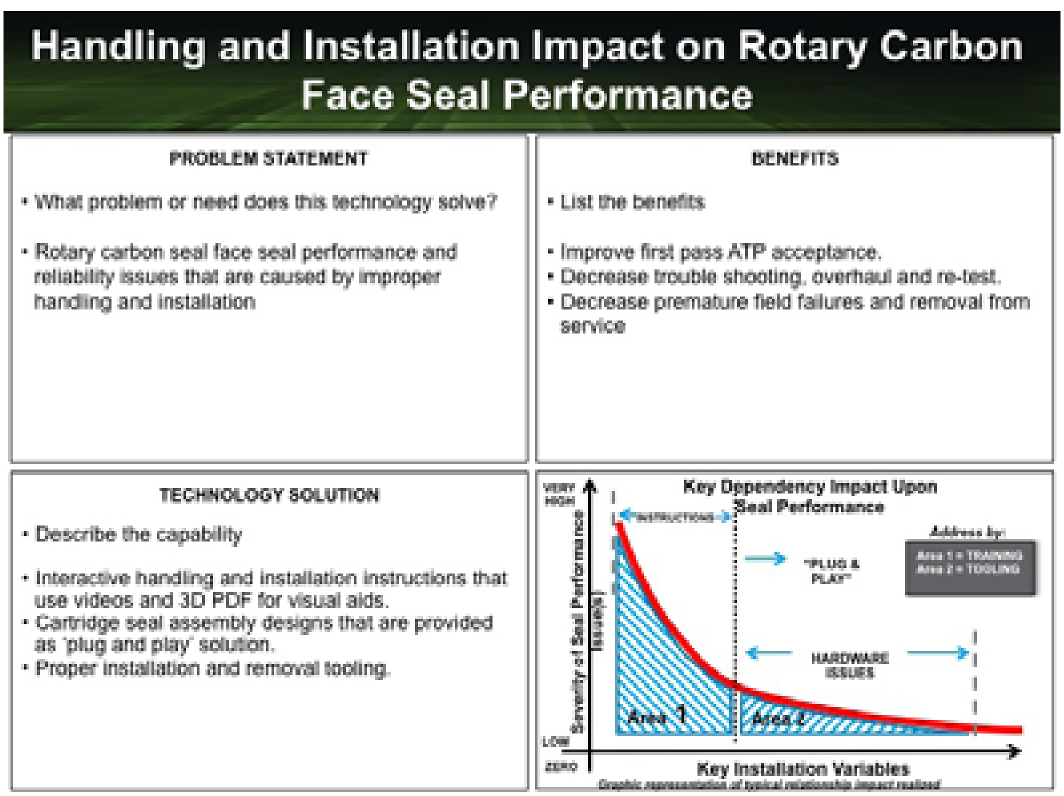
Rotary carbon face seals are used in numerous applications, such as, but not limited to; transmissions, gearboxes, and accessories (hydraulic pumps and motor, fuel pumps, starters, and generators). There are many factors that influence the performance of rotary carbon face seals while in service, from the overall seal design to the equipment cavity, and the platform definition. All of them have a profound impact on the seal performance and service life. The seal design must address all of the performance requirements along with the proper materials for compatibility with the equipment and platform media, and the equipment cavity definition must be configured for optimum seal performance. But the best seal design even when placed into the optimum equipment cavity will not be able overcome improper handling and installation which will result in premature service life and leakage. The vast majority of customer returns for seal leakage have been identified as improper installation practices.

There are a couple of solutions to this issue, with the first one being the most obvious, follow the suppliers' handling and installation instructions. Ensure compliance with their recommended lubricants, assembly and removal tooling, and proper lubrication procedure of the secondary seals (packings) and their interfacing surfaces. In some cases there is a difference between the seal supplier and the OEM handling and installation instructions due either misinterpretation or the time it takes for the OEM to update their document. The second solution is to update the seal design from a component assembled item to a completely assembled item (cartridge), plug and play.

Enhanced installation practices was identified in Phase II of SBIR A12-076 as a primary process for improved seal performance that is being addressed with using a cartridge installation along with installation and removal is included in Phase II of SBIR A12-076. The vast majority of handling and installation instructions are documents that contain written and instructions along with figures to assist in visualizing the components and their interaction during the assembly process. A newer version utilizes 3D PDF to construct installation instructions that include the written instructions along with 3D CAD generated figures that visually depicts the interaction of interfacing parts. Utilizing the 3D PDF instruction along with a certification training program that contains videos has dramatically reduced the number of customer complaints and return requests for leaking seals.

In summary, it is very important to verify that the proper handling and installation procedure and process are being utilized prior to investing the time and money to qualify a new seal design.



Leveraging Weapon System Data to Drive Efficient Depot Maintenance Induction

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As the Defense budget continues to decline, the DoD sustainment community is increasingly challenged to become more efficient in all areas of operation. This is especially true in the organic industrial base given the past 13+ years of wartime OPTEMPO and the requirement to repair/overhaul returning weapon systems and equipment.

Workloading the depots is an intricate process and requires application of available support models and tools to ensure efficiency. To assist in this process, Booz Allen has developed the Maintenance Prioritization Model (MPM) to provide decision makers in industrial base workloading organizations with the ability to rapidly rank-order induction candidates by leveraging a number of variables. MPM allows the user to consider multiple critical system attributes (e.g., remaining useful life, maintenance life cycle cost of the item) in addition to traditional factors such as system "age". As an example, the US Army's fleet of HMMWV vehicles would require over $14B to comply with fleet reset requirements using the age only attribute – an unaffordable requirement. By including additional factors in the analysis, the Army can adopt an affordable program and induct the most "needy" candidates into depot repair/overhaul programs on a priority basis.

By accessing an abundance of data through sensors and other instrumented and non-instrumented sources, MPM additionally allows the user to evaluate fleet performance and to identify unusual and unexpected behavior of components. Using ~500 GB of uncompressed US Army TACOM data sets on the Family of Medium Tactical Vehicles (FMTV) fleet from 2012-2014, two truck models – the M1083A1P2WOW and M1083A1P2WW – were identified to have high transmission malfunctions as compared to other trucks in the fleet. Using advanced "big-data" analytical techniques, such as Decision Tree Regression Models, enabled MPM to capture complicated relationships between variables within the entire dataset and determine that transmission oil temperature for these two models varied significantly and required further engineering analysis. When considering the number of assets that can be aligned for induction based on "need" instead of traditional metrics such as "age", the potential savings to the DoD is enormous to say the least.

MPM leverages available weapon system and equipment data (both on/off platform) and ranks/scores weapon systems and equipment in a 1-n serial number/tail number order to determine the best induction candidates to satisfy Core depot requirements for a given FY. Users can weight categories according to their specific Service and organization needs, e.g., budget limitations, critical mission requirement, and availability of asset for induction. MPM is part of the Life Cycle Management Process (LCMP) platform, a DIACAP certified web-based environment, which allows for near-real time transmission/processing of serial/tail number data. LCMP is currently deployed to support the Air Force (e.g., KC-135, B-52, and ICBM) and the Army (JLTV and MRAP). New LCMP instances in FY15/16 include KC-46 in the Air Force, M&HTV/LTV in the Marine Corp, and fleet management in the Army Materiel Command (AMC).

Direct Measurement of Energy in Additive Manufacturing (AM)

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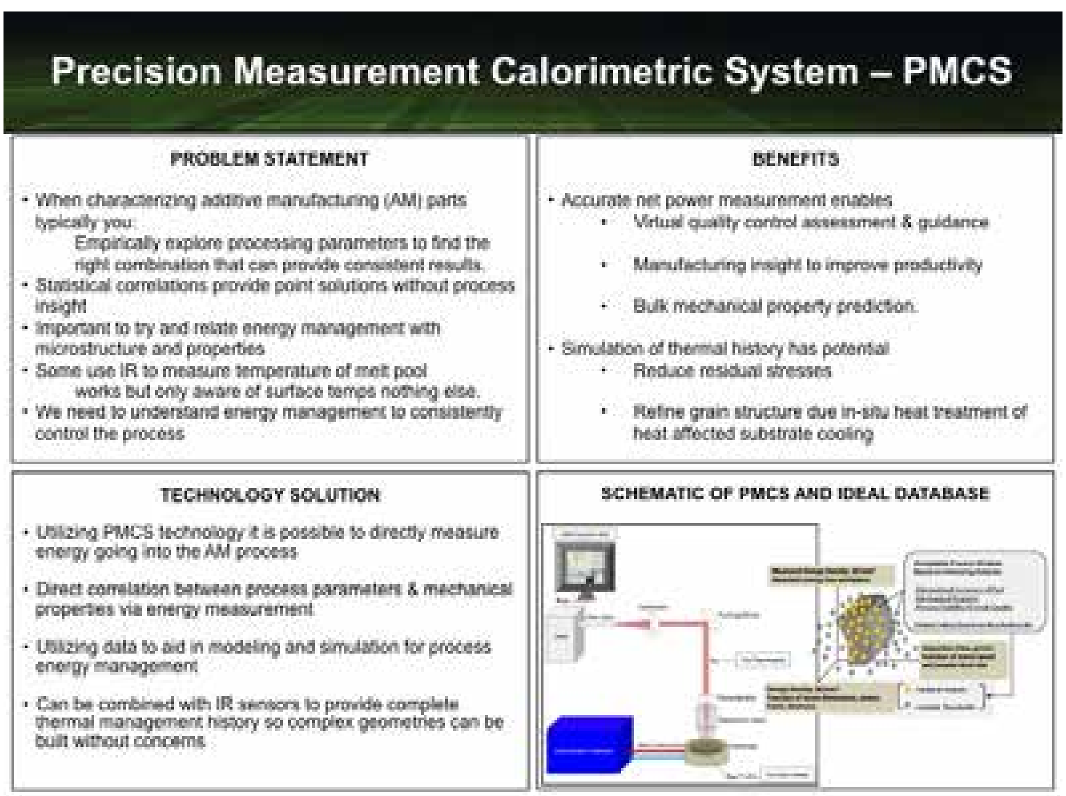
Thermal energy input is the fundamental parameter that governs microstructure evolution that dictates mechanical properties for all AM components. Understanding the energy temporal and spatial distribution are critical to ensure AM produced components meet application requirements. To date, there has not been a production tool to measure the energy that ensures the material properties. To date manufacturing researcher measure the surface temperature (with IR) during AM builds and empirically correlate properties as processing parameters are changed. This point solution provides exception reporting but is absent manufacturing insight and understanding. AM thermal energy absorption provides a systematic, fundamental and complete understanding to optimize productivity and control consistent quality.

The amount of energy absorbed per unit inch for the AM process is defined as thermal energy input (H). To determine H, two variables must be known: the net power of the laser heat source (Pnet) and the travel speed of the heat source or part (S):   H = Pnet / S

If input power (Pin) is the power generated by the laser, (measured by power meter), then, Pnet is the portion of input power that is transferred into the substrate. The remaining energy is lost due to radiation and reflection. At a constant travel speed, Pnet (rather than Pin) is responsible for all physical and metallurgical changes in the parts, local solidification rates and subsequent heat treatment exposure control component integrity, metallurgical phase changes and mechanical property variations caused by thermal processing history.

Despite the importance of Pnet,, this variable is unavailable to industry and replaced by Pin because a cost efficient and robust technology was not available to accurately measure Pnet. The measurement of Pin is common for electrical power fusing welding processes and is generally sufficient for bulk joining. When critical components (i.e. implants) produce by micro welding like AM, bulk measurements are insufficient. The ratio Pnet/Pin is the thermal efficiency factor of the heat source, k. Reported data for thermal efficiency 'k' of GTA welding obtained via calorimetery over the last 5 decades varies from 21 – 80%. This range of efficiency is exasperated when spatial and temporal resolution of micro cast AM parts are produced.

Without an accurate and robust calorimeter, Pnet assumptions are made from measuring Pin despite the fact that the relationship between them is non-linear and poorly known, at best, in many applications such as AM. For example, in the AM power delivered to the part (Pnet) is clearly not the same as programmed input power. This is due to the thermal energy losses associated with laser radiation and reflection. The precision measurement calorimetric system measures the net power under a NIST measurement science for additive program. It shows repeatable measurements regardless of the approach taken. This technology opens the potential of virtual quality control as well as manufacturing insight to improve productivity.



Easy Machining of Hard Materials (EMHM)

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Over the last three decades, structural ceramics have moved from low strength applications to high temperature (impellers) and high stiffness and wear (bearings) applications, based on remarkable improvements in strength, fracture toughness, and impact resistance. The demand for advanced ceramics is expected to increase as they continue to infiltrate applications such as: cutting tools, joint implants, capacitors, military armor, aerospace, and automotive components. Advanced ceramics (silicon nitride (Si3Ni4), silicon carbide (SiC), zirconia (ZrO2), etc...) offer higher temperature capability, lower density, higher stiffness, and better wear/corrosion resistance when compared to metals.

Despite their many benefits ceramics remain extremely difficult materials to machine due to their high hardness and brittle nature. The expensive cutting tools and long machining times that are required to machine these materials make these materials cost prohibitive in all but the most demanding applications. An estimated 70-90% of the costs of precision structural ceramic parts are due to diamond grinding critical dimensions and features. Regardless of these challenges ceramics remain a desirable alternative for metal components. The ability to machine ceramics easily and cost effectively can be a monumental leap in industries where critical material properties for resisting extreme environments is a must. Easy Machining of Hard Materials (EMHM) is a laser assisted machining (LAM) process that can make the machining of hard materials (i.e. ceramics) a cost effective alternative to traditional diamond wheel grinding. This enables the use of these materials that are currently not available due to high cost.

EMHM helps mitigate some of the costs associated with these materials and makes them a more affordable solution for current applications as well as applications where cost of machining was previously a barrier.

Studies have shown:

1. EMHM is 4× faster than conventional diamond grind

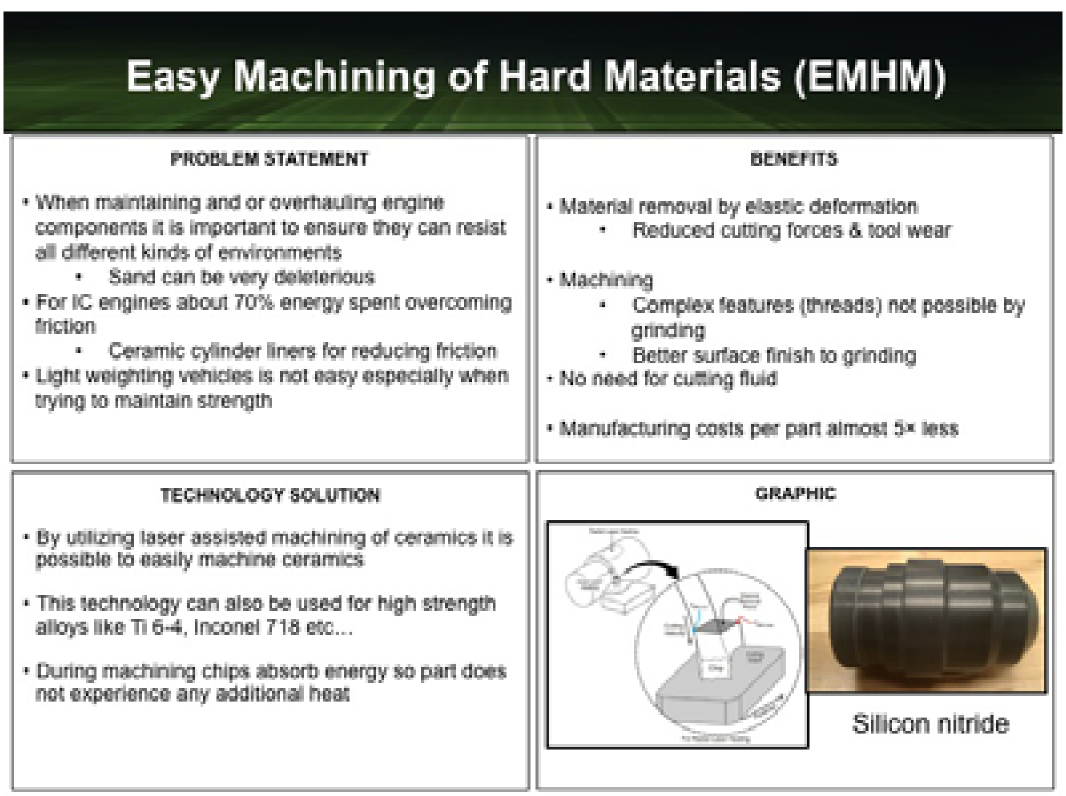
   Time lost on switching from 4 different grinders

2. Manufacturing costs per part almost 5× less (via EMHM)

   EMHM ~ $6.00 / part

   Diamond grinding ~ $28.00 /part

The graph below highlights the advantages of improved surface finish and increased flexural strength for laser-assisted machining of ceramics (i.e. Silicon Nitride) when compared to as ground ceramics. The LAM components not only have better surface finish but higher flexural strength. In addition it is shown that statically the samples that underwent LAM are much close in range than those of diamond grind.



In situ powder flow monitoring for DED AM Systems

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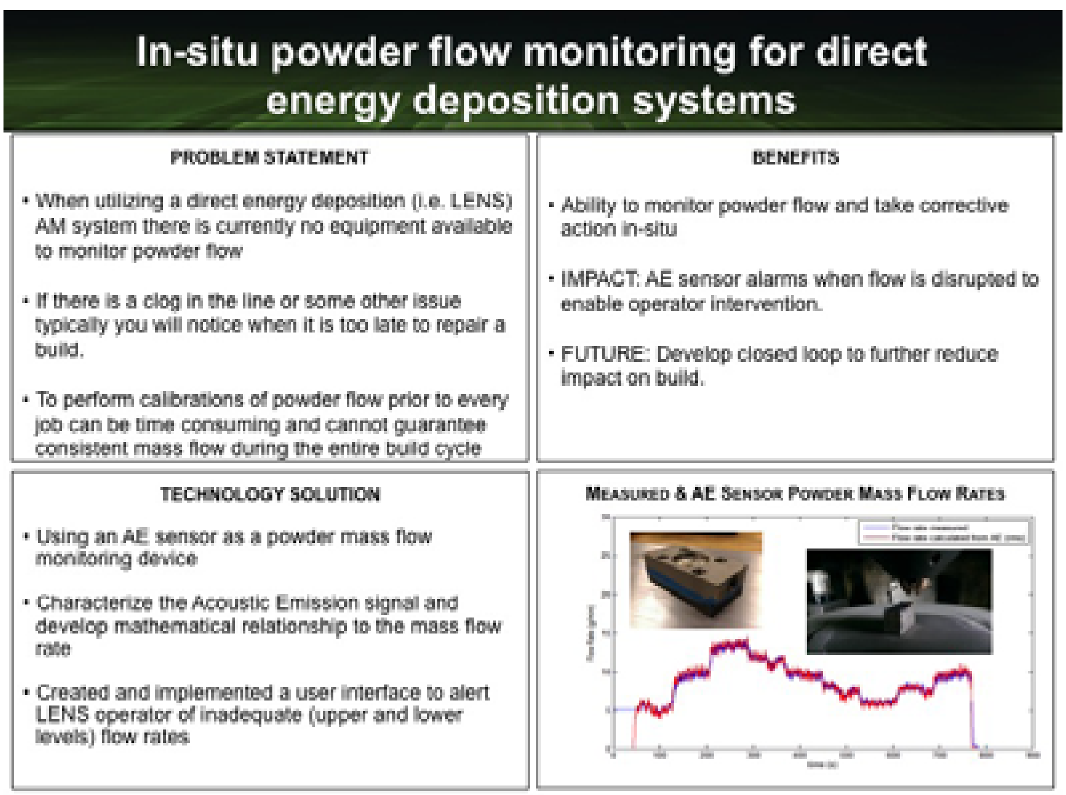
Inconsistent powder delivery can cause non-uniform melting and melt pool dimensions leading to inaccurate build geometries and inconsistent quality. Actively controlling the build powder requires an accurate sensor that provides feedback on the actual mass flow rate. NIST funded work uses AE to monitor two-phase fluid flow in a Laser Engineered Net Shaping (LENS) machine.

The LENS process uses an argon stream to direct metallic particulates at a molten pool generated by the laser. This two-phase gas-solid fluid, makes the measurement of mass flow rate difficult using conventional sensors. The NIIST work conducted by NIU explored using an acoustic emission (AE) sensor to monitor the rate of the metal powder flowing through the build head nozzles. Pressure waves are created by the collisions of the powder with one another as well as the walls of the channel. This pressure is transduced by the piezo-electric element in the base of the AE sensor into electro-motive force. A mount was designed and manufactured to facilitate non-intrusive flow monitoring using AE. The actual powder mass was measured using a scale with a powder capture apparatus. The measured powder mass and the RMS of the AE signal had a high linear correlation coefficient. The system was implemented on a LENS 850-M machine to provide feedback to the machine's operator regarding the condition of the powder delivery system. The relationship between the AE RMS and the measured flow rate was characterized and used to estimate the actual flow using only AE. The results shown in the quad-chart demonstrate how accurate the powder flow is picked up by the AE system as compared to measuring the weight of the powder over a period of time. The powder flow is accurately monitored and provides detection during process when flow is too high which lead to a low quality build. Low temperature thermal pre-treatment of powders designed to remove atmospheric absorbed water vapor shown to improve the flow characteristics of metal powders and prevent pneumatic line clogging in a commercial 4-nozzle build head.

$$E_d = \frac{P}{v \cdot d}\left[\frac{J}{mm^2}\right] \Rightarrow$$

- E_d = Global Energy Density, J/mm^2
- P = laser power, W
- v = scan rate, mm/s
- d = laser beam diameter, mm



SUBMISSIONS

Interrogative Diagnostics Solutions (IDS)

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Any technician will tell you that diagnosing and repairing Weapons platforms and vehicles is not as simple as reading a code and replacing a part. State of the art systems are complex and are highly integrated. The integration and functional interdependences increase ambiguity groups and greatly complicate troubleshooting. This significantly drives both false removals and increased maintenance times which reduces availability and increases life-cycle costs.

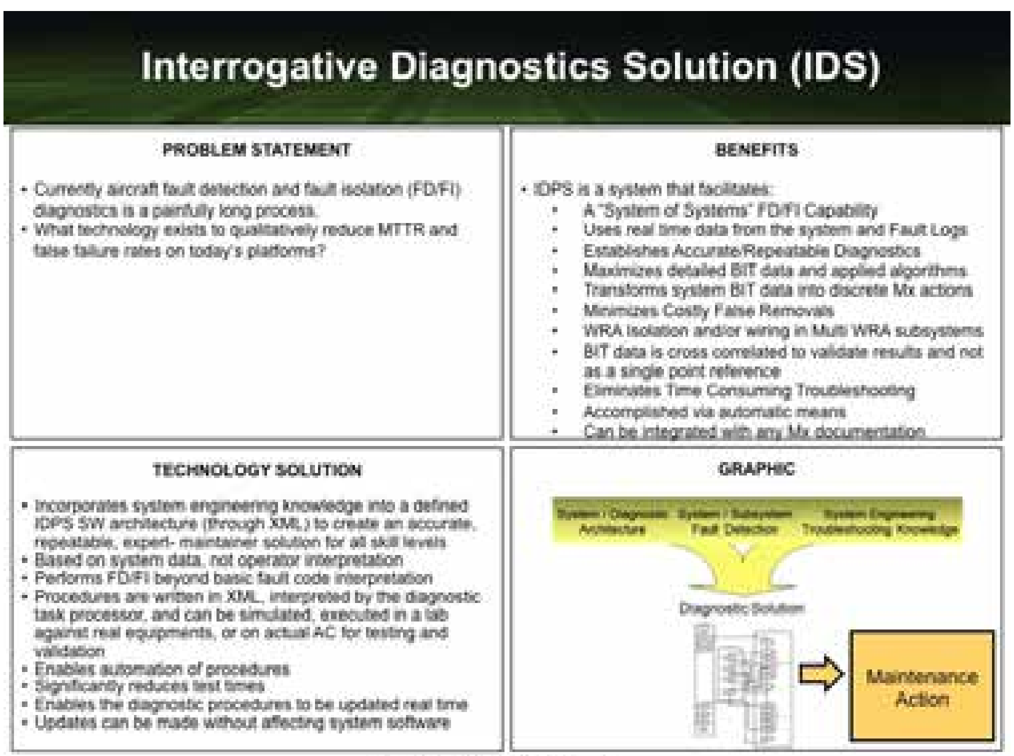
Most modern weapon systems are equipped with some level of Built in Test (BIT). This capability within a complex system is typically a self-diagnostic capability, primarily designed to detect faults in particular circuits or systems within the subsystem and/or replaceable unit. BIT often does not specifically tell you which component has failed, nor will it discriminate between (input/output) I/O faults, discretes, wiring or subsequent root cause failures due to external functions (other failed box and/or replaceable unit(s)). Root cause analysis can only be determined after applying advanced diagnostic techniques and utilizing expertise to isolate the fault accurately. This is where a robust systems diagnostics architecture and interrogative diagnostics capability come into play.

The Diagnostics Development team from Lockheed Martin Mission Systems and Training - Owego has developed an Interrogative Diagnostics Solutions (IDS) that significantly reduces maintenance time, false removals and overall support costs. IDS is the core of troubleshooting on US Navy MH60R/S helicopters and Tactical Wheeled Vehicles. It has also been successfully demonstrated on the F-16 and the IDS technology has also been demonstrated on the F-22. It is used for diagnosis, equipment monitoring and as a maintenance command-center console.

Lockheed Martin diagnostics enhances system safety, decreases maintenance times, and reduces Life Cycle Costs.

- Demonstrated over 95% FD and 95% FI using our interrogative diagnostics approach on MH-60R
- Exceeds SRD requirements
- Diagnostics interfaces with IETM to reduce maintenance times and supply chain responsiveness
- Facilitates on-condition based maintenance.

The IDS provides real-time diagnostic evaluations by processing system and subsystem diagnostic data in a defined sequence that provides effective detection and isolation of faults using applied algorithms. In addition, the IDS utilizes fault logs to analyze faults recorded during operational use. This allows detection and isolation of faults that cannot be duplicated by maintenance. Immediately upon diagnosing to the root cause of failure, the IDS communicates to the Interactive Electronic Technical Manual (IETM) and is presented with the applicable remove and replace, or repair procedure(s). Upon corrective action, IDS is used to validate the repair and verify the operational integrity of the system.



IDS removes on-board diagnostics to a portable laptop solution. This allows the diagnostic capabilities to be updated to support system availability requirements without affecting operational software. The IDS may be interfaced with existing IETM, Electronic TOs, PDF files, or other technical data through a portable device to provide automated access to graphics, intelligent schematics and procedures to support the maintenance action.

IDS is operational now; helps solve Time-To-Repair and False Failure challenges experienced across both airborne and ground platforms.

USCG MH-65 Main Gearbox Housing Repair Fixture

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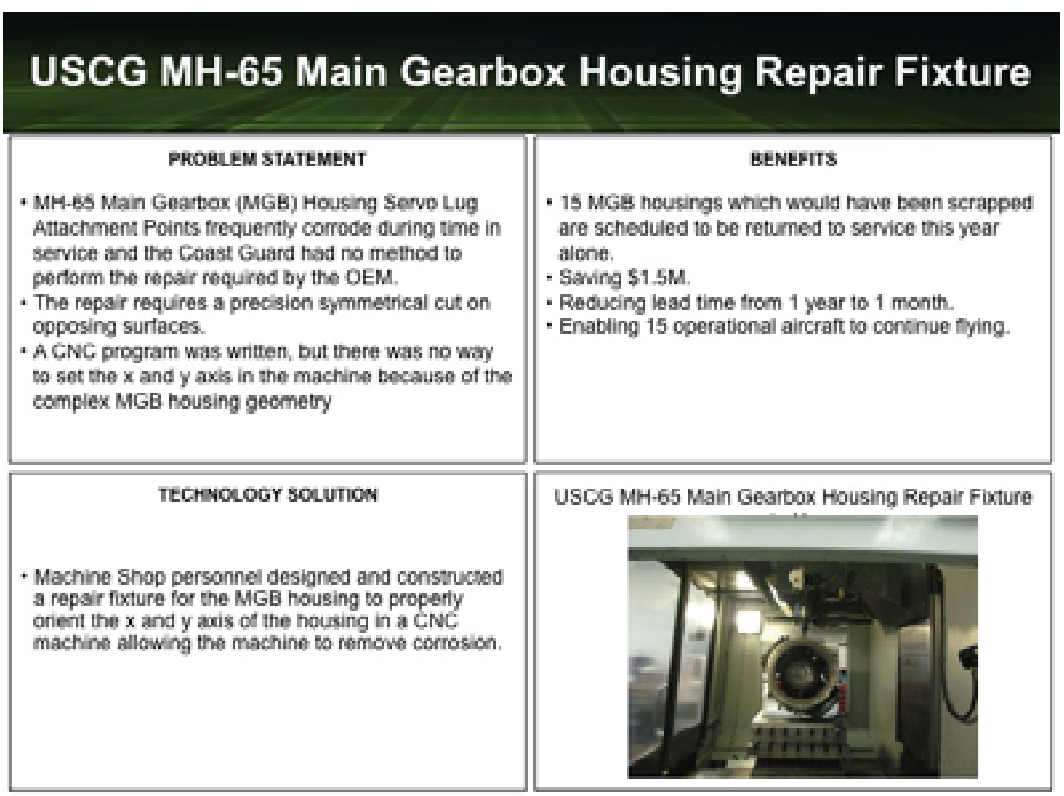
The MH65 Dolphin helicopter utilizes a magnesium main gearbox (MGB) housing. Due to the corrosive operating environment, the magnesium housing generally requires extensive corrosion repairs. Every scrapped gearbox requires the product line to purchase a new MGB housing at a cost of $86,000 with a lead time of over 1 year.

The Coast Guard previously did not have a method to repair corrosion to the MGB servo lug attachment points. As the attachment point between the MGB and the primary flight control servo, this part of the main gearbox is flight critical. The OEM repair for the attachment points requires a precise symmetrical removal of material on each side of the attachment point. The only way to perform this repair is utilizing a CNC machine. Due to the complex geometry of the MGB housing, there was no way to put the housing in the CNC machine and set the x and y axis.

To enable this repair, Shop 133 Tool Maker, Mr. Mark Midyette, designed and fabricated a fixture to perfectly set the x and y axis parallel to the floor. Mr. Midyette drew the fixture using the software Intelli-Max on the OMAX water jet. Material is 1" 6061-T6 aluminum and consists of four parts: base, mounting plate, and two braces for support. Once the fixture components were cut, they were then transferred to a Bridgeport Mill where a precise angle was cut on the base plate. This cut set the proper orientation for the MGB housing when mounted on the fixture. The assembly holes were then properly sized, corresponding holes tapped, and the fixture was then assembled.

With the fixture complete, MGB housings are mounted to the fixture and machined in the VF5 Haas CNC milling machine. The three servo lug attachment points are cut starting with the one with the most damage. There are two cuts available for the repair. After each cut, a Non Destructive Inspection is performed to inspect for defects. If no defects are found the housing is then rotated to the next lug where the repair is repeated. After all cuts are made, the attachment points are treated to protect the new surface. The MGB housing is then ready for issue and is built up to a completed main gearbox.

The OEM has approved the Coast Guard repair method including the fixture allowing MGB repair in house. This housing repair, made possible with the fixture, will save the Coast Guard approximately $1.5M this year alone. Additionally, the lead times on MGB housings are reduced from more than one year to just less than one month by repairing versus replacing. This directly supports the fleet of 88 operational MH-65D helicopters.



Develop Optimized Depot Flow Plan

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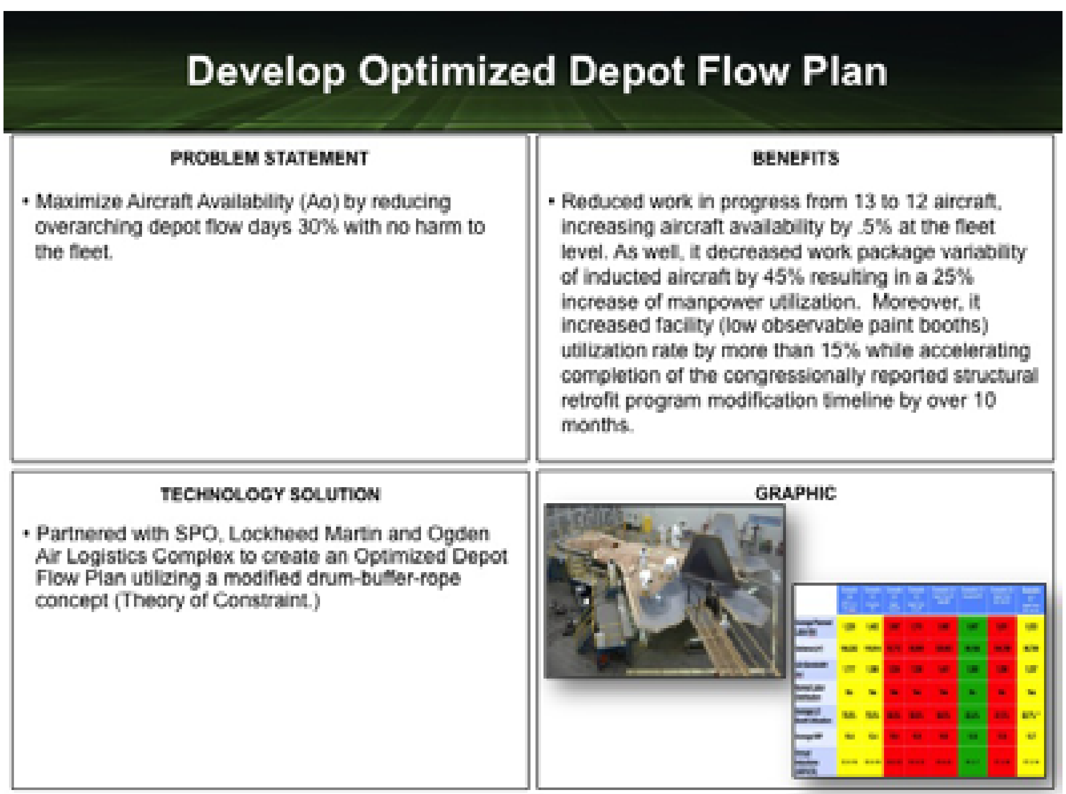
F-22 Depot maintenance and scheduling presents significant challenges over other weapons systems due to the small fleet size, multiple production configurations, and the time investment associated with a low observable platform of this complexity. Aircraft availability is currently more than 11% below the established standards with a bow wave of required Time Compliance Technical Orders coming in the near future. These challenges were intensified by the F-22 Enterprise goal to reduce depot spans by 30%. The F-22 team tackled this effort to improve aircraft availability (Ao) by reducing overarching depot flow days 30% with no harm to the fleet. It was quickly apparent neither the System Program Office nor Lockheed Martin as the Product Support Integrator could attack and conquer such a large fleet management level undertaking without bringing the entire enterprise team together. Subsequently, a team of F-22 SPO personnel, Lockheed Martin and OO-ALC depot/fleet planners were assembled and tackled the complex task to maximize both the depot facilities and manpower without causing any harm to aircraft availability or negatively impacting the time critical, congressionally reported Structural Retrofit Program (SRP). The team aggressively established governing principles and developed four Courses of Action (COAs). Over several months they gathered and analyzed data, meticulously working through the elements of each COA. Each non-viable COA drove short-notice decision briefs with senior leaders and stakeholders to garner approval of each disqualification. The fact finding period encompassed 75 days of fact based data analysis, producing one viable COA. The team drilled into this COA, retained the governing principles and applied "out-of-the-box" thinking to a modified drum-buffer-rope theory of constraint methodology to arrive at a new cornerstone for the F-22 Depot Flow Plan (DFP). The synergistic efforts of the team produced improved results; an immediate decrease from 13 to 12 depot docks, which singularly increased aircraft availability to the field by .5% at the fleet level. Furthermore, it decreased aircraft variability by 45% which increased manpower utilization by 25 %. As well, it increased the facility utilization rate more than 15% while accelerating completion of the major SRP mod timeline by over 10 months. Collectively, the diligent efforts of this team reshaped legacy depot planning methodologies and highlighted how public-private-partnerships can come together to improve long-established processes and reap benefits for the warfighter.



Centralized On-Demand Maintenance for Tactical Training Vehicles

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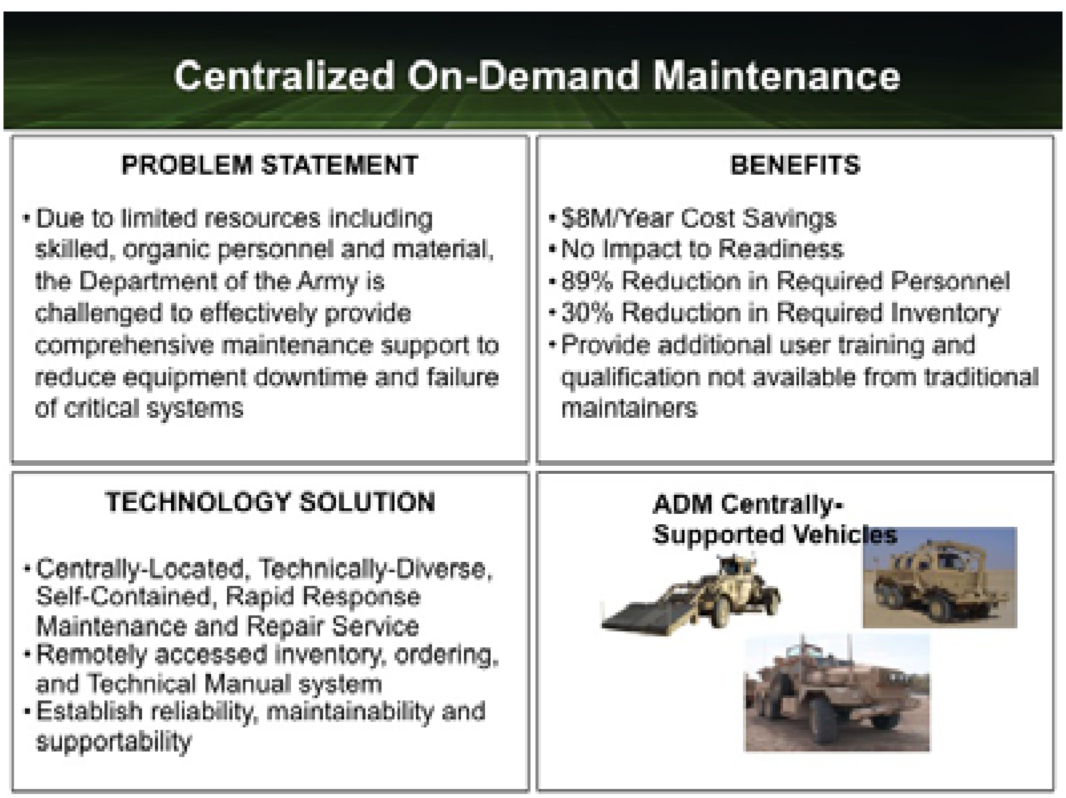
Tasked with providing a complete maintenance solution for approximately 171 tactical training systems in 47 locations for Joint Services throughout CONUS, Europe, Alaska, Japan, and Kuwait. Advanced Design and Manufacturing Division (ADM) developed and implemented a novel maintenance solution resulting in significant cost savings without impact to readiness.

The maintained systems allowed commanders to keep tactical assets in the combatant theater while providing adequate training to units preparing for deployment. The systems were also used in initial training facilities where reliability is critical to maintain rigid graduation schedules.

The traditional approach is an on-site Field Service Representative (FSR) with fixed infrastructure. While this approach appears to provide near instantaneous response, the cost of providing and maintaining this system is about $10.9M per year. Funding at this level is untenable for a short-term program.



The ADM approach was to build a contact team of technical experts which included traditional maintainers, fabricators, and electronics technicians as well as a logistician. The operation was centrally located with a warehouse and fabrication facility. When maintenance (planned or unplanned) was required, a 2-3 person team, with a mobile shop set and spares, was dispatched to the location. Unanticipated parts requirements were forwarded to the logistician and were provided to the team in an average of 1 day. The team could undergo all training without travel expense; indirect costs such as contracting for individual FSRs in 47 locations were completely eliminated. By eliminating 1/3 of the traditionally-required manpower and nearly all of the infrastructure, the ADM approach saved about $8M per year.

Building upon the organic piece can demonstrate the ability to instantaneously gain access to system data and ultimately organic on-demand support. The process was optimized with a parts-lookup system which contact teams used to find the part number and inventory status of a part and request it from the logistician from anywhere using a laptop. A mobile application, featuring the full capability of the parts look-up system, access to all parts and maintenance manuals, and the ability to send pictures, video, or live streaming images was under development when the overall program was discontinued. Further optimizations could be realized by creating the team as its own entity. As a subordinate element, the team was required to use higher headquarters for shipping and purchasing support and relied on commercial shipping and transportation. In FY2013, the team spent in excess of $500K on shipping and purchasing and $300K on air travel and rental cars. Making these functions organic would have saved in excess of $280K in shipping and purchasing and would have reduced variable travel costs by 28%.

This approach is easily scalable to any technically complex system which has limited active-duty maintenance. Any program which can accept a 1-2 delay in maintenance response will realize large savings, in-turn allowing more funds to directly impact warfighter readiness.

Cabin Pressure Leakage Testing in Hot Environments

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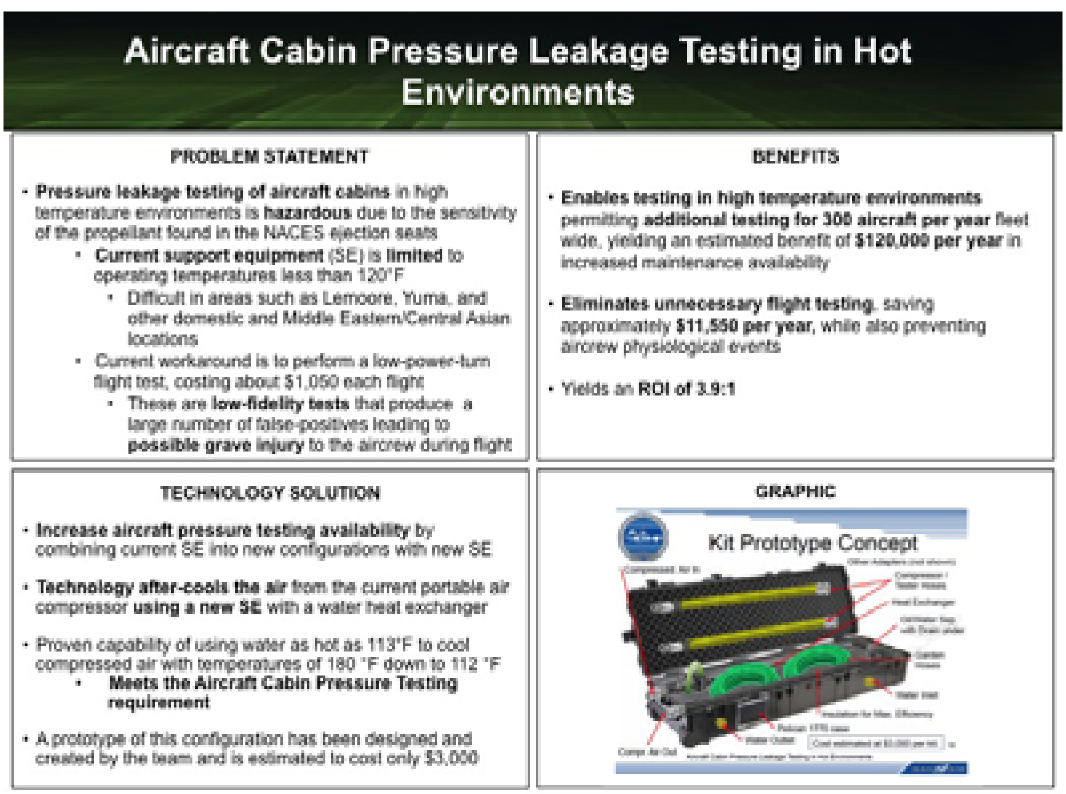
Testing the Aircraft Cabin Pressurization system in high temperature environments is hazardous due to the sensitivity of the propellant found in the NACES ejection seats. Current test equipment configurations cannot be used when the temperature is more than 120°F, which presents an issue at Lemoore, Yuma, and other domestic and Middle Eastern / Central Asian locations. If the air introduced into the cockpit exceeds 120°F, maintainers must wait for the temperature to decrease, which can be time-consuming. As a work around, pilots will test the Cabin Pressurization System by performing a low-power-turn during flight. Each flight costs $1,050 (based on labor rates of seven personnel and fuel cost for one hour), and data shows approximately 54 test flights conducted per year. Furthermore, these are low-fidelity tests, which often present false-positives causing rapid cabin de-pressurization. This can be very dangerous to the aircrew. In the last 12 months, flights conducted to accommodate cabin pressure testing have produced four documented cases of Environmental Control System (ECS) issues leading to aircrew physiological events.



In FY14 an effort to provide increased aircraft pressure testing availability to the fleet by combining current Support Equipment (SE) into new configurations with new SE was funded by AERMIP, a Science and Technology funding source. The project performed an analysis to determine the efficiency and reliability of two different cooling capabilities in five different configurations. The analysis determined that the most efficient and effective cooling capability was the use of a water heat exchanger to after-cool the air from the current portable air compressor. This process can use water as hot as 113°F to cool compressed air with temperatures of 180°F down to 112°F, meeting the Aircraft Cabin Pressure Testing requirement.

Enabling testing in high temperature environments will permit an estimated additional testing of 300 aircraft per year fleet wide, yielding an estimated benefit of $120,000 per year in increased maintenance availability (estimating 2 maintainers at 2 hours/test). This is based on a 20% increase of test reliability and aircraft maintainability fleet-wide. In addition, use of this new air cooling configuration will eliminate unnecessary flight testing, saving an additional $11,550 per year. In total, this yields an ROI of 3.9:1. This added capability of testing with temperatures of 120°F or more will increase the availability of testing, while preventing aircrew physiological events.

A prototype of this configuration has been designed and created by the team and is estimated to cost only $3,000. On-aircraft testing will be conducted at the end of FY15 to demonstrate the technology prototype in an operational environment, raising the Technology Readiness Level to 6. This allows fleet-wide fielding opportunities that are possible with funding from appropriate PMAs.

OTA Updates: Why Delta Technology is Better than Compression Techniques

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Many articles have been written re: the software revolution that is flowing through the automotive, defense industry, and "smart device" markets. Subject matter includes the exponential growth of software content to meet the growing functional requirements (e.g., ADAS, V2V, V2I, safety, security, etc.) as well as the increase in vehicle recalls to perform in-vehicle software updates to resolve performance and/or reliability issues.

Keeping the traditional methods for performing software updates, be it during the production process, at the service location, will continue the inefficiencies that exist today in the software update process, causing OEMs (or the Tier1s) hundreds of millions of dollars every year. This is the reason why the OEMs and Tier1 suppliers are looking for an optimized way to reduce the update time, and, by that, reducing the cost of recalls.

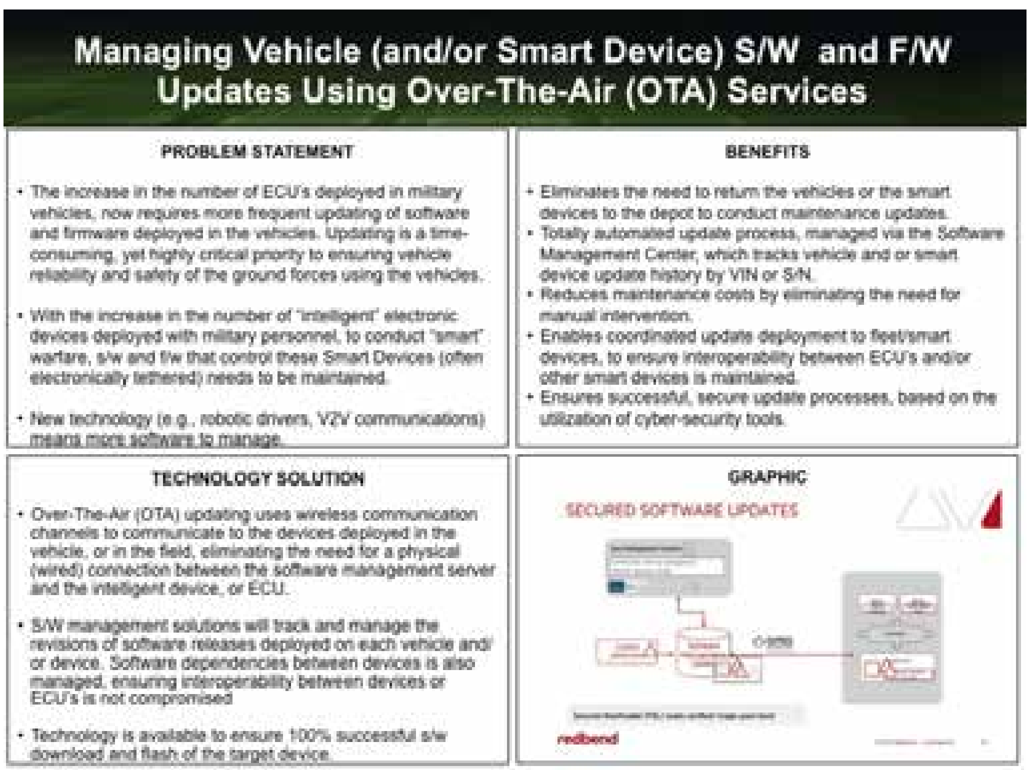
When doing a software update either over-the-air, or via a hardwired connection, the clear motivation is to reduce the size of the update package and reduce the update time. There are several methods to reduce the update file size, but the two most notable are compression and Delta update.

In both technologies the goal is to reduce the number of bytes that are going over the bearer (either cable or wireless) and by that achieving the following:

- Reduce the download time - the new software needs to get to the vehicle communication gateway in order to start the update process, in an efficient manner.

Description	File Size (Data to transmit)		Data Transfer Time on CAN			unit
			125	500	1000	kbit/s
Original file (complete)	32	MByte	4127.2	1031.8	515.9	s
Compression (-25%)	24	MByte	3095.4	773.8	386.9	s
2 Partitions	16	MByte	2063.6	515.9	257.9	s
Partitioning and Compression	12	MByte	1547.7	386.9	193.5	s
Differential File	1	kByte	0.1	0.031	0.016	s

- Cut the memory space – after the new version reaches the vehicle's gateway there is a need to store it before starting the update. Smaller footprints bring cost benefits in a number of ways.
- Decrease the transport time between the Gateway and the target ECU – in case of ECU update the new version needs to go through the CAN/LIN/MOST bus, which typically has bandwidth limitations. Large file sizes mean long transfer times.



- Reduce the update time – the update time typically is dependent on the amount of changes that exist in the new version of the software being updated.

Independent tests and research conducted by leading companies in the automotive space and scientists show in detail the comparison between compression and Delta update technologies.

Dr. Ralf Schmidgall in his thesis "Automotive embedded systems software reprogramming " analyzed the methods of reducing the size of the version when doing software updates. In the table that follows Dr. Schmidgall summarize the results of a theoretical case study to compare the various approaches.

Integrated Predictive Maintenance Solutions

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Equipment-intensive commercial industries like commercial aviation, power generation, oil and gas production, and mining have increasingly embraced remote monitoring and diagnostics (RM&D) in a quest to achieve greater operational availability and increase the effectiveness of their maintenance efforts. RM&D solutions gather real time data in the field and employ predictive analytic algorithms to produce advanced warnings of impending failures so that operators can avoid unplanned downtime and focus on the assets that most need attention. The result is increased readiness at lower cost.

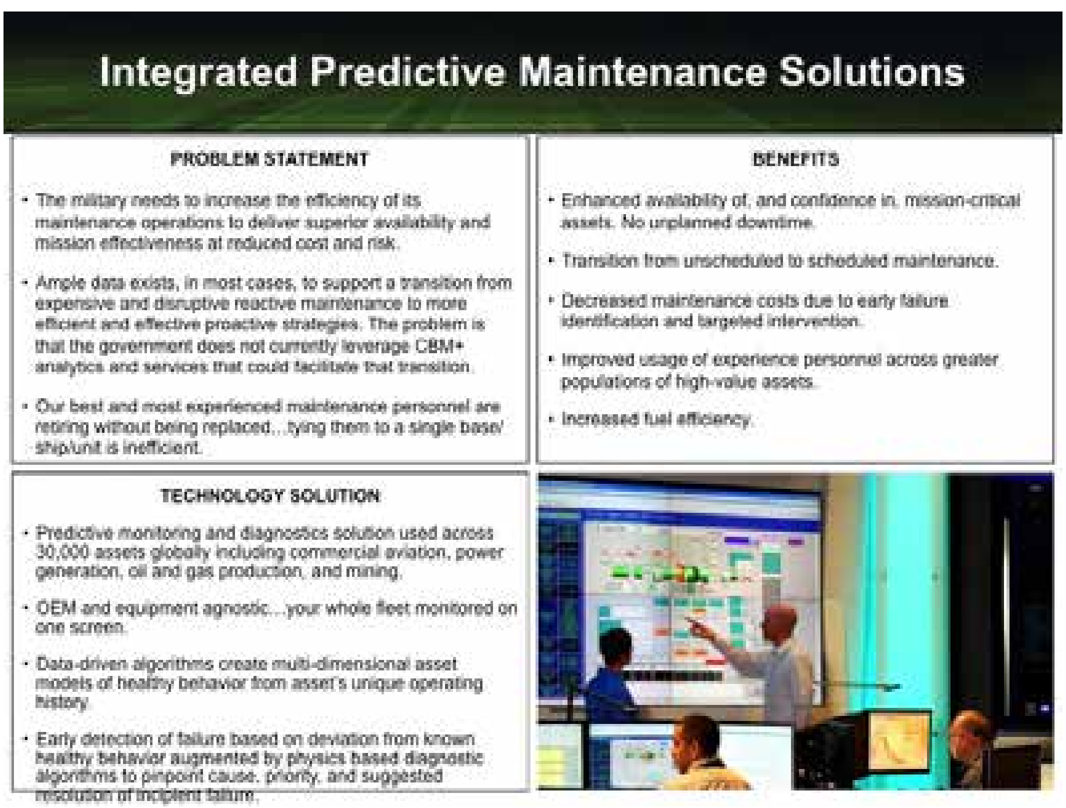
The military can adopt this innovative technology and configure existing, proven capabilities to meet defense-specific needs, rather than trying to develop custom solutions on a service-by-service or program-by-program basis. The result would be broader applicability of the solution, faster and more reliable implementation, and rapid scalability.

The most commonly used OEM and equipment agnostic RM&D solution used in industry today, and the innovation being proposed here, monitors more than 30,000 assets globally from a wide variety of customers and industries; it is a service and software integrated solution which consists of three key capabilities:

- **Anomaly Detection:** the patented predictive technology uses Similarity-Based Modeling (SBM) to provide very early warning of failure (generally 3-10 weeks ahead of time). The SBM methodology uses past operating data from a given asset to create a "digital twin" of that system which captures the way it's dozens or hundreds of available measurement parameters move in relation to one another under the complete range of operating environments and load conditions. This system can detect the very earliest warnings of failure by comparing current operating behavior to known healthy states.

- **Problem Diagnostics:** Once a potential anomaly has been detected using the SBM engine, diagnostic rule sets interrogate the warning and produce an estimate of the location, cause, time-based priority, and suggested resolution of the issue. The diagnosed anomaly is then reviewed and adjudicated by an experienced maintainer in a remote monitoring center; if it is judged to be valid it is written up as a "case" that delivers actionable intelligence usable by front-line maintainers.

- **Change Management:** Because SBM is able to provide advanced early warning, the actionable intelligence developed by the remote monitoring team can be communicated to front line maintainers via email/phone call on a weekly or other scheduled cadence. Actionable intelligence is communicated and work orders are developed as a result; outstanding issues from the previous meeting are closed out. This "coaching" relationship ensures that the predictive analytics create actual change on the ground rather than being ignored.



The military would do well to innovate by adopting best of breed commercial solutions like the one described above. In most cases, the data to support an RM&D approach is already being collected. What are missing are the tools to turn that data into insight and drive massively increased maintenance efficiency.

Ergonomic Assessment Using Inertial Motion Sensors

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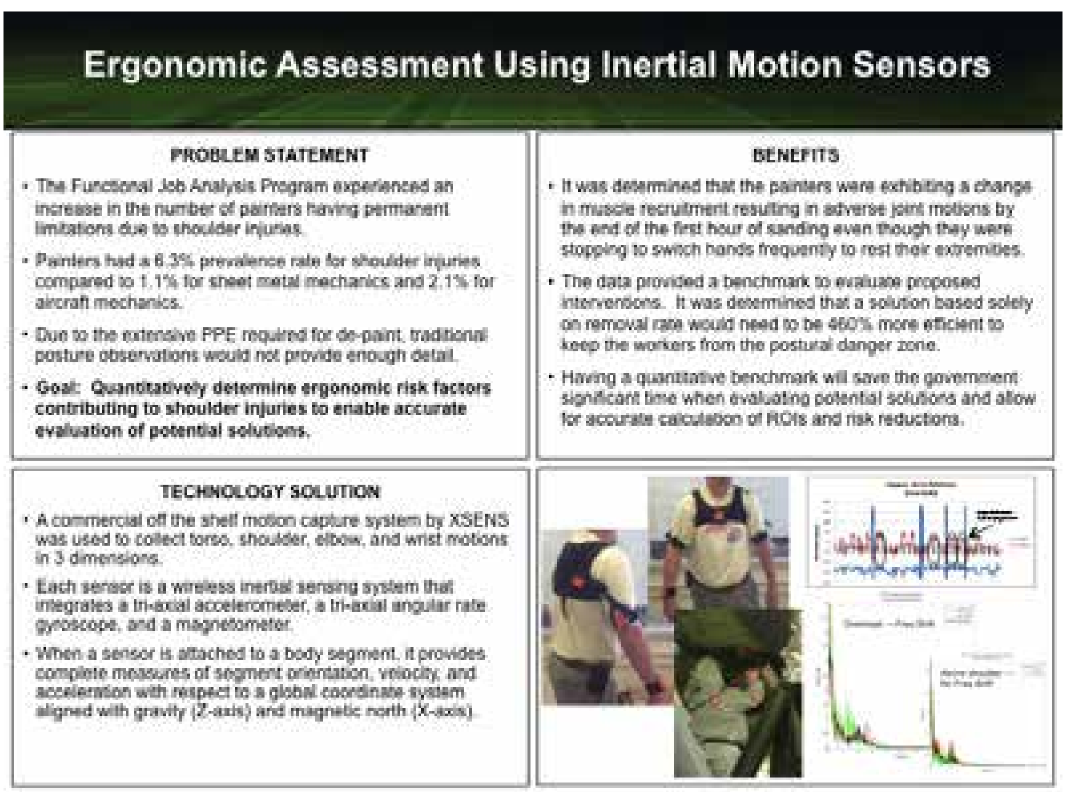
A dramatically increasing trend in the population of aircraft painters with permanent physical limitations was identified among participants in the Functional Job Analysis return-to-work program. Painters had a 6.3% prevalence rate for shoulder injuries compared to 1.1% for sheet metal mechanics and 2.1% for aircraft mechanics. The painter's job duties include paint and de-paint operations. Previous ergonomic assessments identified 50/50 and scuff sanding as tasks of concern that involve large numbers of employees. 50/50 sanding is the process of mechanically removing all layers of paint until at least 50% of the primer is visible. Due to the extensive personal protective equipment required for these de-paint tasks, traditional ergonomic posture observation methods would not provide enough detail to elicit accurate details of the range and types of risks faced by painters. Detailed quantitative information about the risks was needed to adequately evaluate potential solutions since several previous attempts at solutions tried by the area have not resulted in wide spread worker acceptance or injury rate reductions.

A commercial off the shelf motion capture system by XSENS was used to collect torso, shoulder, elbow, and wrist motions in 3 dimensions. Each sensor is a wireless inertial sensing system that integrates a tri-axial accelerometer, a tri-axial angular rate gyroscope, and a magnetometer. When a sensor is attached to a body segment, it provides complete measures of segment orientation, velocity, and acceleration with respect to a global coordinate system aligned with gravity (Z-axis) and magnetic north (X-axis).

Using the motion capture system it was determined that the painters were exhibiting changes in muscle usage resulting in adverse joint motions by the end of the first hour of sanding even though they were stopping to switch hands frequently to rest their extremities. The average continuous sanding time documented was less than 50 seconds while the expected endurance was 300 seconds based on published literature. This indicates a level of discomfort caused by the combination of muscular fatigue, postural impingement, and vibration.

Looking at the energy spectrum of the upper arm elevation there was a distinct shift in the energy from the beginning to the end of the data collection period when the painters were working overhead. This frequency shift provides further evidence that the muscles have become fatigued and the painter's muscle recruitment and joint kinematics have changed.



The small, repetitive motions of the shoulder required for sanding caused the use of adverse joint kinematics by the end of the first hour of sanding, even though the painters stop and switch hands frequently to rest their extremities. This data provides a benchmark to evaluate proposed interventions. It was determined that a solution based solely on removal rate would need to be 460% more efficient to keep the workers from the more dangerous postures.

Having a quantitative benchmark will save the government significant time when evaluating potential solutions and allow for accurate calculation of ROIs and risk reductions.

Electrical Wiring Interconnect System (EWIS) On-Wing Certification Test Protocol

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Aircraft and subsystems operate on ground or in-flight. Air crews observe abnormal equipment performance or associated Built-In-Test (BIT) detects a fault. Post- reporting, responding technicians Can Not Duplicate (CND) the symptom reported. Traditional and present practices include the following activities:

- Follow published Fault Isolation Procedures (FIPs) in technical manuals, wherein intermittent symptoms are typically not addressed.
- Perform a visual inspection of applicable Electrical Wiring Interface System (EWIS) with no discrepancies noted.
- Conduct a "ring out" of applicable EWIS paths using a Digital Multi-Meter (DMM), a Meg-Ohm Meter, or an Automatic Wire Test Set (AWTS), and include in their procedures the flexing of the suspect wire paths with no discrepancies noted.

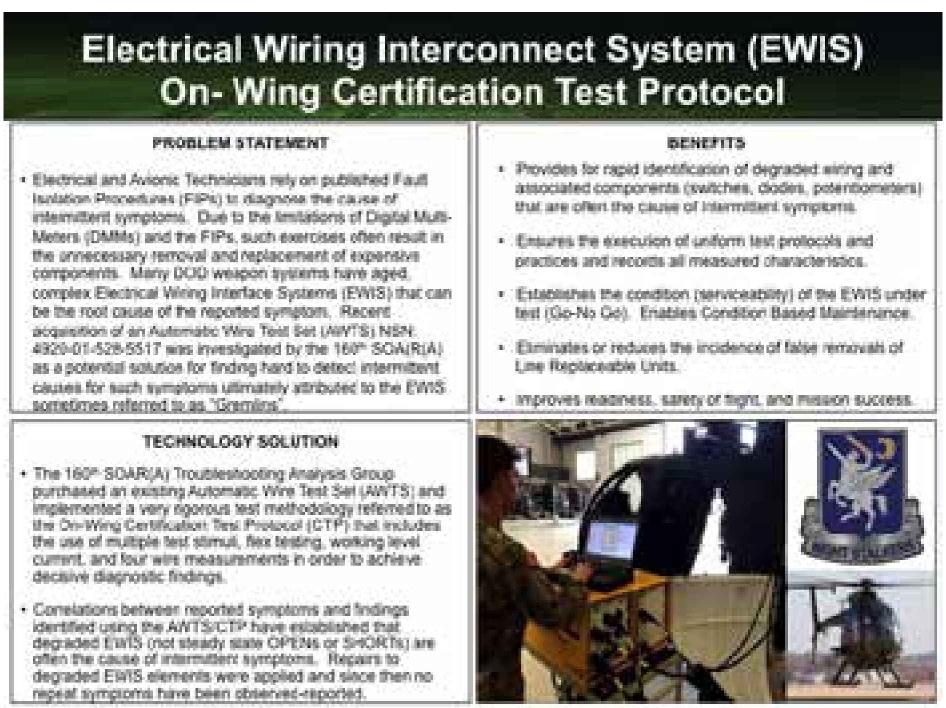
At this point, technicians are directed by the FIP, their supervisors, or their equipment operators (typically higher ranking Pilots) to replace either the sender or receiver Line Replaceable Unit (LRU), Weapon Replaceable Assembly (WRA), or major assembly and sign off the write-up. If the symptom recurs during a subsequent operating event the maintainers will repeat activities described above then replace the LRU or WRA at the other end of the EWIS that was evaluated and determined by test (often repeatedly) not to be causal.

To address this time consuming and expensive malpractice, the USASOAC AMSO decided to evaluate automated wire diagnostic equipment. After a preliminary internal selection process, inquiries to Eclypse International Inc. were conducted regarding the capabilities of the AWTS. With the assistance of OSD, NCMS, CTMA, two program managers subordinate to the Technology Applied Program Office (TAPO), and local commanders, we proceeded to evaluate the AWTS as a solution. The collaborative results achieved to date indicate that the "serviceability" of any given EWIS can be decisively established. This is a ground breaking capability.

To establish the condition of an on-wing EWIS, the maximum capabilities of the AWTS and the programmers at Eclypse were challenged to create a Test Protocol Set (TPS) for the MH-6M Full Authority Digital Engine Control System that included multiple test stimuli, flexing of the EWIS under test, four wire measurements, and the recording and analyses of all measured values.

During the one year evaluation, the AWTS and the TPS were used to troubleshoot intermittent symptoms and to establish the serviceability of the MH-6M FADEC System EWIS during scheduled maintenance. The findings include:

- 12 Unique Aircraft Tested
  - 3 Aircraft Tested for Unscheduled Maintenance
    - Data review triggered use of multi-stimulus testing
    - Found causal wire (intermittent fault)
    - Found causal switch (post event)
- Found 3 non-symptomatic wire harnesses that were replaced preventively
- Found 1 non-symptomatic failed diode
- Found 3 non-symptomatic open or high resistance shields
- Found 2 non-symptomatic thermocouples with high resistance to ground



No LRUs, WRAs, or mayor assemblies were replaced. Post-AWTS applications and associated corrective actions, none of the aircraft evaluated have manifested any associated symptoms.

Instead of the usual (futile) approach-response, this equipment and a rigorous TPS can decisively determine the condition on the installed EWIS. Applied more widely, such a capability will improve flight safety and mission effectiveness while addressing the diagnostic voids traditionally ignored during technician training and in published FIPs. They also enable-establish a means to implement EWIS Conditioned Based Maintenance (CBM).

Global Freeform Mapping using Laser Tracking and Active Target for Accurate and Efficient Machine Tool and Robotic Volumetric Error Compensation (VEC)

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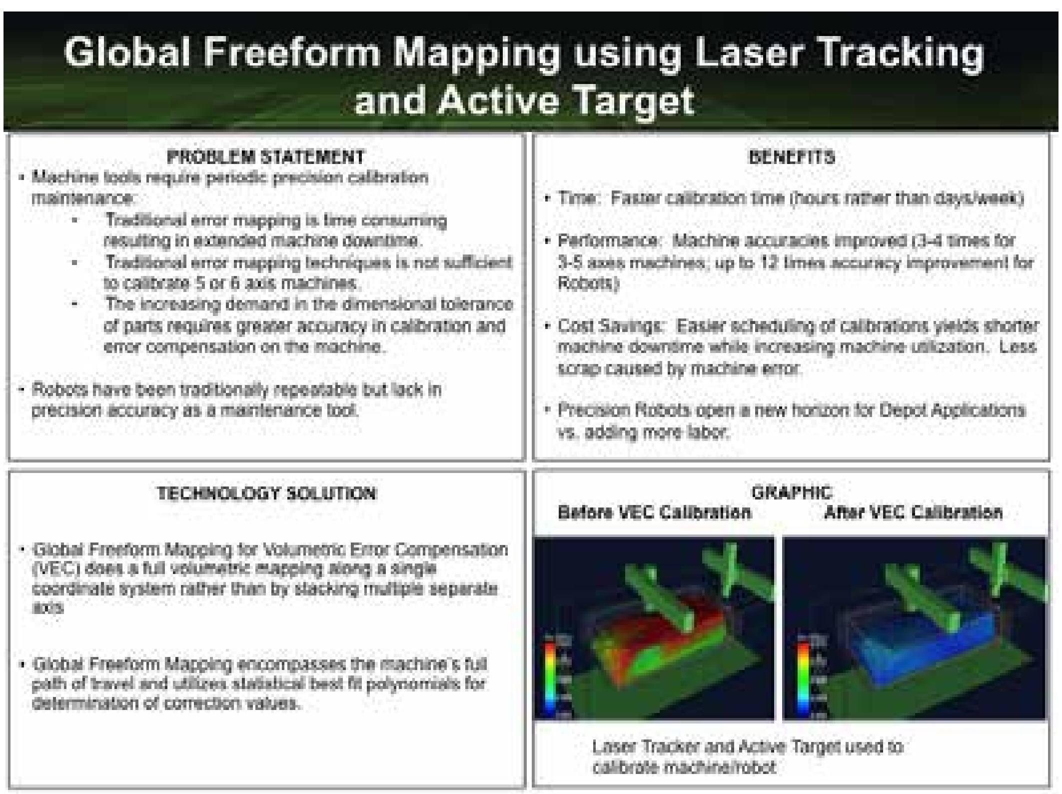
The ability to do highly accurate and time efficient volumetric calibration and correction is becoming increasing important to meet the demanding tolerances and schedules in both manufacturing and maintenance applications. Conventional 21 Error Parametric Mapping and Compensation requires a significant amount of time to perform multiple set-ups and repeat measurements to stack all 21 errors and account for final tool position. This can result in significant downtime to map and compensate for volumetric error, causing potential scheduling problems to calibrate the machine or robot on a regular basis. Furthermore, for more sophisticated five and six axis machines or robots, mapping and compensating for the typical 21 errors is not sufficient to calibrate the machine.

Global Freeform Mapping extends the efficiency and accuracy beyond conventional 21 error mapping techniques by providing a global, free-form error model. This is achieved by placing API's patented Active Target (AT) right at the tool tip of the machine or robot being calibrated. By monitoring the movement right at the tool tip, measurements are done in a single coordinate system rather than along three axes. This results in a full volumetric map of the machine tool's accuracy. The recorded data is compared to the true mathematical model to determine and compensate for error along its entire path of travel. By mapping the entire working volume at once, complex five- and six-axis machines can be compensated easily and quickly.

Global Freeform Mapping provides much faster volumetric error compensation with greater accuracy compared to conventional 21 Error Parametric Mapping. Full volume mapping of the machine or robot can be done in a few hours rather than days. By establishing the machine error measurements right at the tool tip, improvements of three to four times the accuracy can be achieved in machines and ten to twelve times can be achieved in sophisticated five and six axis robots. By providing higher accuracy measurements at much higher speeds, calibration and error compensation can be done more precisely and more often, resulting in higher accuracy machined parts with minimal downtime.

API has achieved R&D 100 Awards and a Certificate of Achievement from NCMS in Global Freeform Mapping for machine tools. This presentation will cover the details of Global Freeform Mapping and summarize the benefits obtained by its use for manufacturing and maintenance.



Enabling the Secure Networking of Automated Test Equipment

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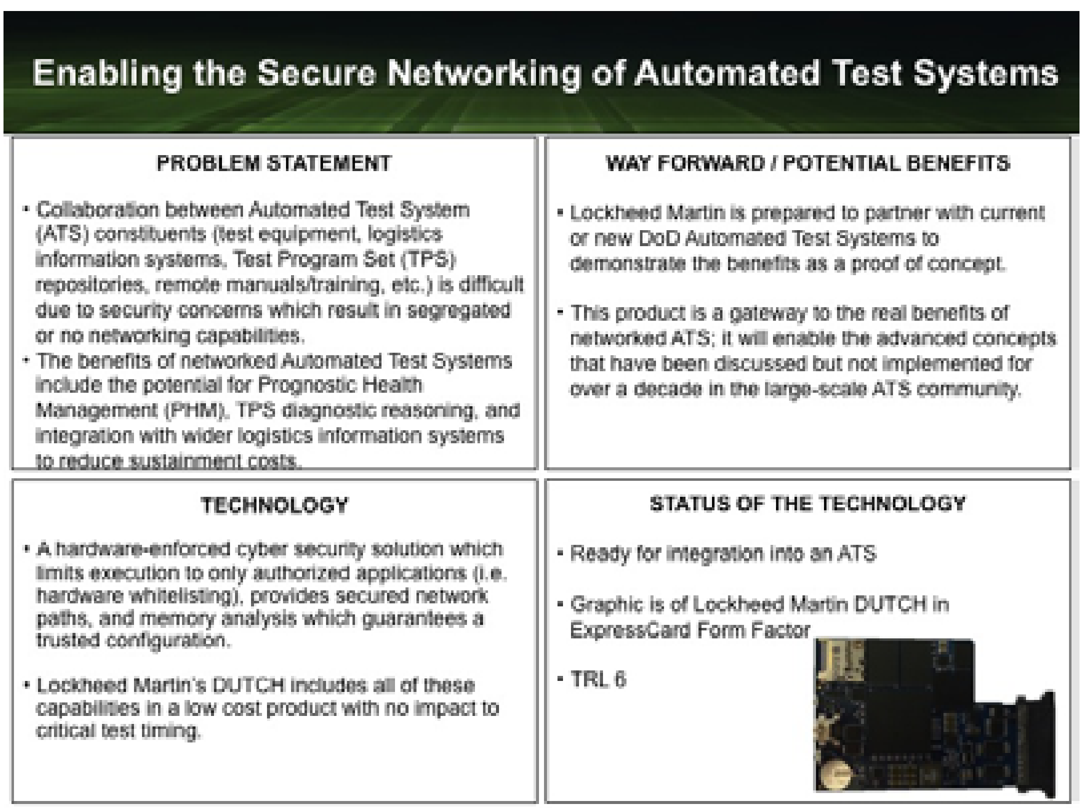
While standardization of automated test equipment and test program sets lends itself to cost-reduction and general efficiency improvements, these widely distributed systems often lack the networking capabilities to realize these benefits. Security concerns compound the difficulty of realizing a networked environment of test equipment. Lockheed Martin presents a hardware-enforced security solution capable of alleviating said security concerns. DUTCH (Defensive Unified Trusted Cyber Hardware) prevents unauthorized applications from executing. Software installations and updates are easy when a security administrator authorizes the changes but otherwise are impossible for attackers and rogue insiders. It also provides secured networking channels, limiting access to the test equipment through a secure gateway. The gateway ensures only approved communication paths are available and allowed. Finally, it provides run-time memory forensics capabilities to guarantee the test equipment always executes in a trusted configuration.

Lockheed Martin has performed various security penetration testing on the DUTCH product as well as integration testing with the LM-STAR automated test equipment and other platforms. Performance testing was conducted when integrated with LM-STAR to measure performance with and without the device. Data is available which proves the solution has minimal impact.



U-2S Dragonlady Snap-In Inflatable Seals

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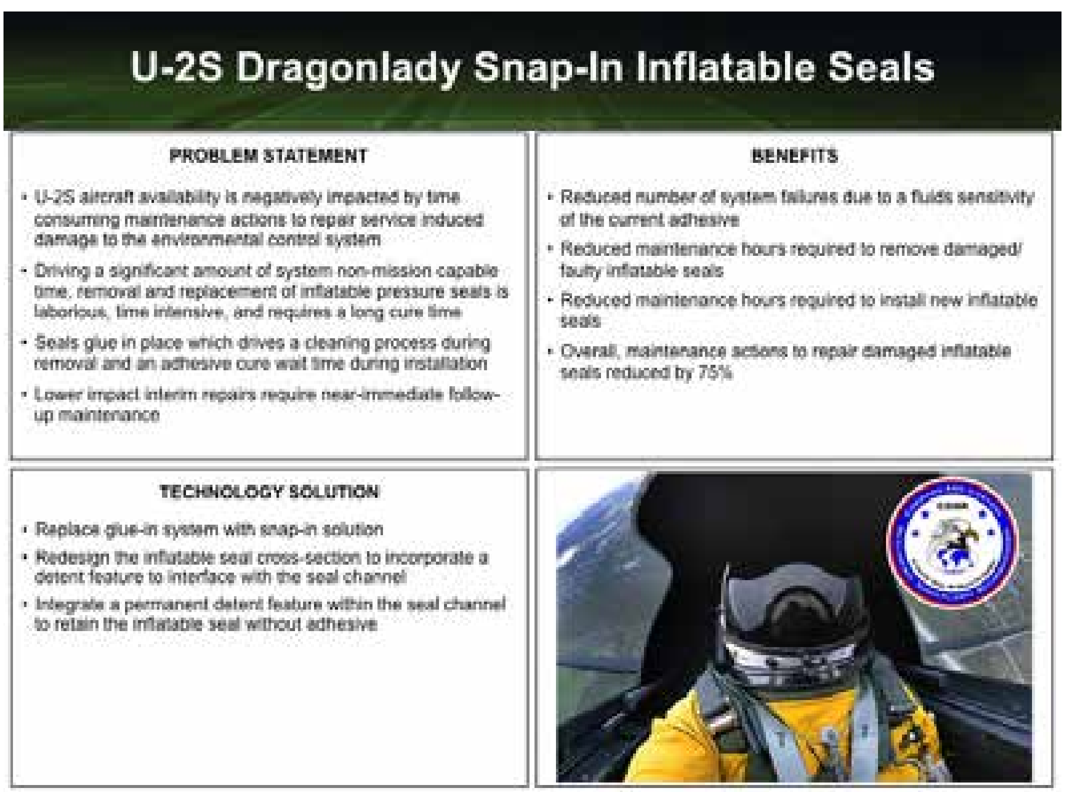
The U-2S aircraft operates at an altitude inhospitable to pilots and equipment. The first lines of defense in this environment are the pressurized areas of the cabin, nose, equipment bay, and electronics bay. These compartments are maintained at atmospheric conditions similar to 15,000 feet and 28,000 feet when cruising at altitudes over 70,000 feet. All of these pressurized areas utilize removable access panels or doors for routine servicing. These doors and panels present a unique maintenance challenge as their sealing systems are susceptible to wear and rupture causing a single point of failure for the pressurized area.

Lining the periphery of these removable access panels and doors are inflatable seals. They are installed within channels that are used to hold the seals in place and provide a recess for the seals to deflate into when not in use. To permanently install the seals within this channel, they are currently glued in place using a room temperature cure adhesive. Prior to flight, and once the panels are installed and doors shut, the system is pressurized to inflate the seals. Inflated seals are compliant enough to conform to the topology of the door and adjacent sealing surface to prevent pressurized compartment gases from escaping out into the ambient environment. The U-2S utilizes these inflatable seals on the Removable Nose, Cabin Canopy, Upper and Lower Q-Bay Hatch, Upper and Lower E-Bay Hatch and Aft Cavity Hatch.

Currently, the number-one U-2S maintenance degrader is a condition where either the Q-Bay or Cabin pressurized areas develop a leak in flight that does not allow them to maintain their pressure schedule. The number three maintenance degrader is a condition where the Lower E-Bay hatch seal tears during routine pre/post-flight operations. The impact of these two maintenance degraders contributes a significant number of non-mission capable (NMC) hours annually to U-2S operations fleet-wide.

Preventing these events from occurring and reducing the impact of these events on aircraft availability is an effort the U-2 System Program Office has undertaken.

On December 2014, the U-2 SPO held a configuration control board where a modification to the inflatable seal design, removal process, and installation method was proposed and approved for change. This new seal design departs from the glue-in paradigm, which can cause excessive aircraft NMC time due to the laborious effort required to scrape away the existing adhesive from the seal channel and wait the requisite time for the adhesive to again cure during installation. The improved design utilizes a snap-in feature which allows the inflatable seals to be removed or installed with little effort, no secondary processes, and no wait times for adhesive curing. It is anticipated that this improved design will reduce U-2S NMC time associated with maintenance actions against the inflatable seals by 75%.



A Strategy to Provide Alternatives and Remove Barriers to Cr6+-Free and Cd-Free Maintenance Technologies

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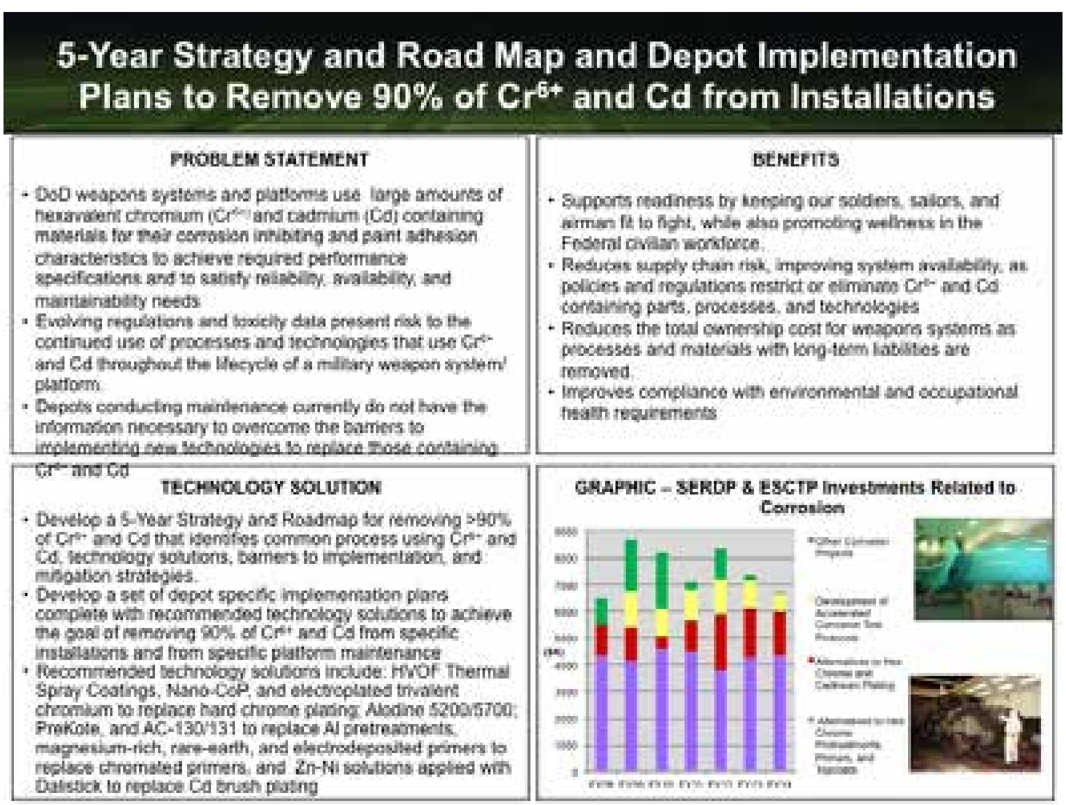
DoD weapons systems and platforms use a large amount of hexavalent chromium (Cr+6) and cadmium (Cd) containing materials because of their corrosion inhibiting and paint adhesion characteristics to achieve required performance specifications and to satisfy reliability, availability, and maintainability needs. Toxicity and evolving regulations present risk to the continued use of processes and technologies that continue to use Cr+6 and Cd. Depots conducting maintenance on weapons systems currently do not have the information necessary to implement alternative technologies. This includes identification of alternatives, specifications, demonstration/ validation test data, qualification information, and potential barriers and mitigation strategies.

The Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) Weapons Systems and Platforms Program Area has established the goal to eliminate >90% of hexavalent chromium (Cr+6) and cadmium (Cd) in use at Department of Defense (DoD) maintenance depots over the next 5 years.



This project created two types innovative products. The first is an overarching roadmap and the second is a series of depot-specific plans that will allow DoD to meet the goal of 90% reduction of Cr+6 and Cd.

The Five-Year Strategy and Roadmap establishes the framework for how this reduction can be achieved by identifying the current processes and technologies across DoD that drive the use rates of Cr6+ and Cd. Only by identifying the large sources of Cr and Cr and focusing on them can we reach the 90% goal. The Roadmap then identifies Cr6+-free and Cd-free alternatives that have been certified for use on specific systems.

The Depot-Specific Implementation Plans identify and describe the processes observed at a depot, documents the Cr6+ and Cd containing materials used in these processes, provides alternatives, identifies barriers and mitigation strategies and outlines a concrete plan to achieve >90% reduction over the next 5 years.

The first three Implementation Plans have been developed for Letterkenny Army Depot (LEAD), Fleet Readiness Center Southeast (FRCSE), Oklahoma City Air Logistics Complex (OC ALC). The sites were selected based on several factors including the desire to include representation from each the services, the need to cover the broad usage of Cr6+ and Cd processes, and senior leadership's desire for change and acceptance of alternative processes.

The installation visits were conducted in the spring of 2015. The Implementation Plans and Five-Year Road map scheduled for draft release in Q4FY15 and final in Q1FY16. Next steps include circulating the work performed to date and identifying new candidate locations for implementation plans.

Additive Manufacturing (AM) for Complex Maintenance Tooling and Training Systems

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BLUF: The use of Additive Manufacturing (AM) to produce complex tooling and fixturing will reduce the cost and schedules of Fleet maintenance operations. Similarly, the use of AM to produce complex replica training systems provides maintenance personnel a quality training environment for complex system- reducing maintenance costs and reducing errors during refurbishment operations.

Abstract:
Knowledge of AM benefits and versatility has grown within the Navy, prompting more Depots and Shipyards to seriously consider this technology for industrial/complex maintenance tooling and training systems. A primary mission area at NUWC Keyport is to couple advanced AM technologies with extensive mechanical/electrical design experience to produce time-saving, cost-effective tooling & training solutions. Since 2002, NUWC Keyport has leveraged industrial Additive Manufacturing (AM) technologies to rapidly develop functional prototypes, special tools, and custom-engineered automated maintenance systems to support a diverse range of applications. NUWC Keyport has used this technology to make tens of thousands of components with a very broad range of applications. Experience in multiple advanced manufacturing and repair technologies has developed a keen design intuition which leverages the best attributes of AM to produce the best solution.

Design freedom attributes of AM, such as the ability to 3D-print complex geometries and consolidated parts, can produce very cost-effective tooling & training systems. Additionally, some innovative hybrid designs incorporate COTS and conventionally-manufactured components in an assembly. For accelerated learning/maintenance training, Keyport has fabricated a large nuclear pump system and scaled catapult water brake system replicas, allowing maintainers to practice complex procedures in a shop training environment prior to implementing them shipboard. Repetitive personnel training has proven to reduce rework & errors, mitigates costly compliance issues (NNPI, HAZMAT, SUBSAFE, etc.), and allows for rapid emergency maintenance planning. Proliferating the use of AM thermoplastics to build hybrid, quick-turnaround, complex industrial tooling also serves as a low-risk proving grounds to collect data for AM Shipboard component implementation.

Industry is adapting their manufacturing, testing, and maintenance processes by integrating mature thermoplastic AM technologies. Additively manufactured shop tools, molds, test stands, and training systems (to list a few) will have an immediate and direct impact on the immense resourcing and workload challenges being experienced at Naval Shipyards and other Depots. NUWC Keyport's consistent effort to integrate new technologies into Navy Shipyards is reinforced by the FY15 "NAVSEA Warfare Center Innovation Support for Naval Shipyards" Initiative. Developing AM tooling & training systems is a key maintenance sustainability objective.

Portable Non Destructive Inspection Surface Contamination Sensor

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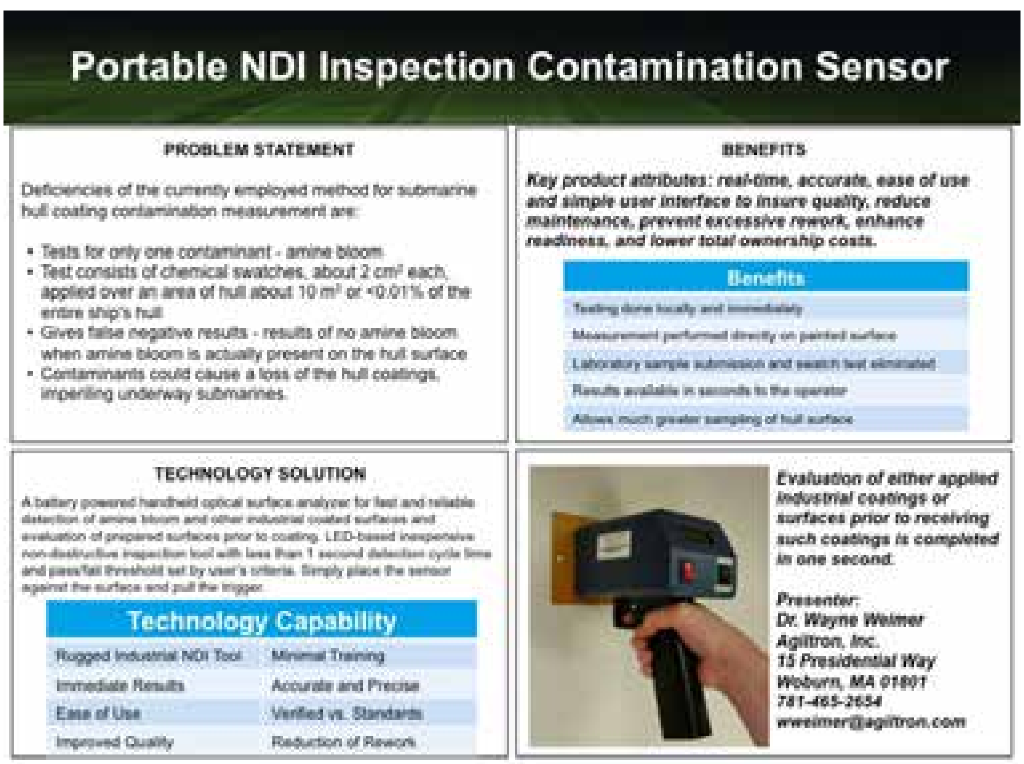
Agiltron is commercializing a Portable NDI Surface Contamination Sensor for instantaneous evaluation of both applied industrial coatings and surfaces prior to receiving such coatings. The innovative technology is optical detection of both the surface and sub-surface condition developed through correlation of complex chemical spectral analysis with a differentiated light scattering method, leading to a lightweight LED-based sensor that is simply placed in proximity to a surface and the analysis completed with the push of a button in one second. Developed to detect amine bloom, a well-known detrimental contaminant resulting from improper cure of two-part industrial epoxy paints, the device is demonstrated to reliably provide equivalent results to the sophisticated chemical spectroscopy technique from which is was derived, but at a small fraction of the cost and test time, yet with much greater accuracy, reproducibility and ease of use than existing test methods while operated by minimally trained personnel. Several validation trials have been conducted and the results show 100% accuracy in blind tests. A U.S. utility patent application has been filed.

As shown in Table I, 24 epoxy paint on steel samples were prepared by the US Navy and delivered to Agiltron as part of a blind test. The samples were prepared under conditions to produce either contamination free coatings or samples with amine bloom contamination to varying degrees. Agiltron's sensor correctly identified 5 samples to be contamination free and the others as contaminated. The Navy also provided test results using the current chemical-based color-change method of evaluation for these same samples that showed 7 incorrect (false negative) results, an error rate of 29%. In addition, the performance of product prototypes achieved Prime Contractor Naval shipbuilder validation by correctly identifying contamination in all blind test epoxy painted steel samples prepared by the Naval shipyards. Finally, in another blind test scenario, the prototype sensor also correctly identified the levels of pre-coating contamination in bare steel samples with 100% accuracy.

Sample	Contamination Present	Agiltron Test Method	Current Test Method
1	No	No	No
2	No	No	No
3	No	No	No
4	Yes	Yes	No
5	No	No	No
6	No	No	No
7	Yes	Yes	Yes
8	Yes	Yes	No
9	Yes	Yes	Yes
10	Yes	Yes	No
11	Yes	Yes	Yes
12	Yes	Yes	No
13	Yes	Yes	Yes
14	Yes	Yes	No
15	Yes	Yes	Yes
16	Yes	Yes	No
17	Yes	Yes	Yes
18	Yes	Yes	No
19	Yes	Yes	Yes
20	Yes	Yes	Yes
21	Yes	Yes	Yes
22	Yes	Yes	Yes
23	Yes	Yes	Yes
24	Yes	Yes	Yes



USCG C130J Hot Mock Up Test & Repair Benches

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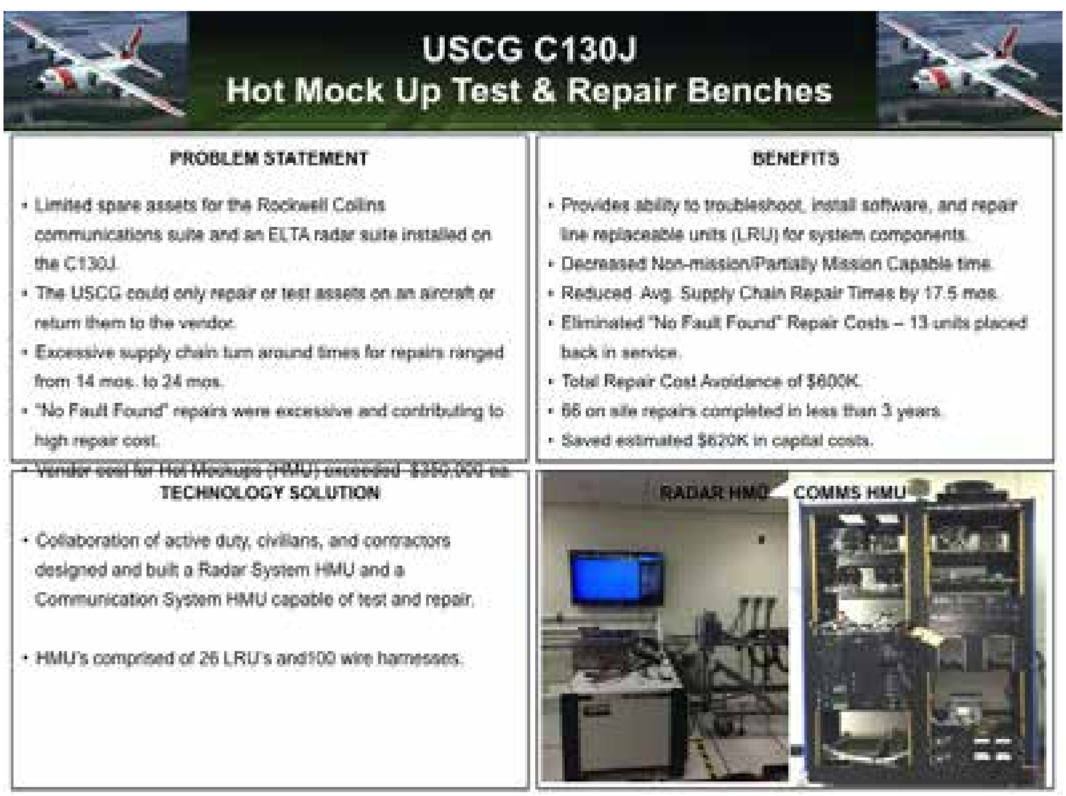
The HC-130J Super Hercules aircraft debuted for the USCG in 2008. The Long Range Surveillance (LRS) division at the USCG Aviation Logistics Center provides maintenance for the six aircraft in the USCG inventory which will expand to 22 by 2027. The aircraft supports counter-narcotics operations, long range search and rescue, logistics missions, and the International Ice Patrol among other missions. The aircraft has several mission system suites which include a surface search radar and various communication line replaceable units.

The OEMs were leveraged to provide the initial maintenance and service on the radar and communication components. The limited supply of spares, expense of "No Fault Founds", and supply chain repair times of up to 24 months for the radar prompted the USCG to investigate other options.

A working group consisting of active duty, civil service, and contractor personnel from two divisions was formed. Their vision was to obtain in house bench testing and maintenance capability for the radar and communication components.

Market research indicated that the OEMs could provide Hot Mock Ups (HMU), which would simulate the entire radar and communication systems, at a cost exceeding $350,000 for each HMU. The Industrial Operations Division and the C130 Product Line instead collaborated to design and construct a Hot Mock Up in house for each system. Radar HMU # 2094 was built for $3,600 and Communication HMU #2096 was built for $78,000. The cabinets, shelves, and LRU locations were all designed to easily connect and test components. Twenty-six components and over 100 wiring harnesses were manufactured from repurposed wire to provide the interconnectivity of RS-232, fill ports, and 1553 bus communications systems. The HMU's provide component interfacing for the radar and communications components with the ability to trouble shoot, install software, and repair line replaceable units (LRU). These assets allow the Industrial Operations Division to provide intermediate level repair, eliminate No Fault Found (NFF) repair charges, and allow assets to be repaired and returned to service immediately instead of waiting up to 24 months.

The Radar HMU has allowed 12 in house repairs and prevented 2 no fault found repair charges. The Communications HMU has allowed 54 repairs and prevented 11 no fault found repair charges. This equates to $13M in cost avoidance.



B-2 Additive Manufacturing Contamination Sensor

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The B-2 Sustainment Branch, Tinker AFB, has found an innovative approach to rapidly reverse engineer, design, and fabricate parts using additive manufacturing; a process we call B-2 Additive Manufacturing (BAM). For the past five years, the B-2 System Integration Lab (SIL) has utilized computer-aided design software and a plastic fused deposition modeling (FDM) 3D printer for rapid reverse engineering, design, improvement, and fabrication of legacy SIL equipment. In 2015, B-2 engineering expanded this capability to produce B-2 aircraft support equipment. In July, BAM reverse engineered and prototyped an actual B-2 aircraft part. The BAM ROI was predicted to be five years, but the program far exceeded expectations, reaching Return on Investment (ROI) in three years at a realized savings of $1.2M as of July 31, 2015.

As B-2 SIL equipment became obsolete, a quicker, cheaper way for fabricating and improving replacement parts was needed. In 2010, B-2 sustainment invested $470K in a FDM 3D printer and materials. Parts produced by BAM to date include over 400 rack equipment panels, ducting, and fixtures faster and with improved designs. The most common parts produced are rack equipment panels. The panels require frequent changes to the original labeling. Previous methods of procuring these panels involved producing aluminum panels with painted text manufactured offsite with a lead time of six months and cost of $10K per panel. Once panels are reverse engineered, the 3D printer technology allows onsite production at a cost of $200 per panel and lead time of two hours. Although the new panels are made of plastic, the FDM printing process allows the designer to tailor the structure of the panels to have maximum stiffness where needed at a minimum weight, yielding a part that is stiffer and lighter than its metal equivalent. Beyond simple direct part replacement, the 3D printer has been utilized to produce improved air ducting systems which resulted in improved equipment rack performance, providing more reliable equipment and layout flexibility.

BAM was also used in direct support of the B-2 aircraft. B-2 fuel lines from the manufacturer are quite complex and difficult to measure. A piece of complex support equipment was designed and printed to quickly check the dimensional accuracy of B-2 fuel lines prior to installation on aircraft. Utilizing the onsite 3D printer this project saved 22 months and $599K.

Most recently, a B-2 aircraft hydraulic fluid drainage bottle was reverse engineered and a prototype printed. The prototype design is undergoing qualification review to determine if the part is a suitable substitute. Early engineering analysis shows promising results. Engineering projects to qualify it for aircraft use in December 2015.

Looking ahead, B-2 is investigating procurement of a Selective Laser Melting (SLM) printer and a portable 3D laser scanner to add more rapid reverse engineering and flexibility to produce aircraft parts with minimum lead time and no compromise in part strength or weight. Additive manufacturing technology innovations are predicted to make a substantial improvement to B-2 aircraft supportability and availability now and into the future.

The Analysis of Resources with Visualization and Integrated Simulation Support (ARVISS) Decision Support Application Contamination Sensor

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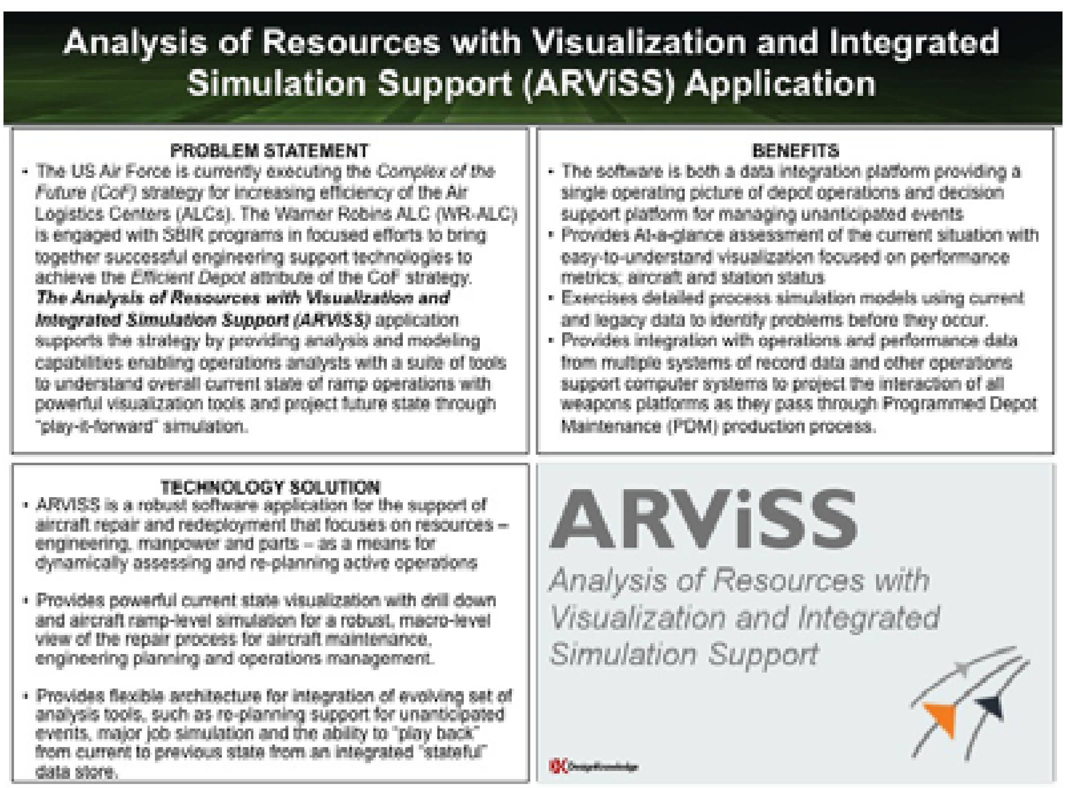
Warner Robins Air Logistics Complex (WR-ALC) is engaged with SBIR programs in focused efforts to bring together successful engineering support technologies to achieve the Efficient Depot attribute of the Air Force's Complex of the Future strategy. The Analysis of Resources with Visualization and Integrated Simulation Support (ARViSS) application supports the strategy by providing analysis and modeling capabilities enabling operations analysts with a suite of tools to understand overall current state of ramp operations and project future state through "play-it-forward" simulation.

Fundamentally, ARVISS is a robust software application for the support of aircraft repair and redeployment that focuses on resources – engineering, manpower and parts – as a means for dynamically assessing and re-planning active operations. ARViSS provides powerful current state visualization with drill down capabilities and aircraft ramp-level simulation for a robust, macro-level view of the WR-ALC process for aircraft maintenance, engineering planning and operations management. The software is both a data integration platform providing a single operating picture of complex depot operations and a decision support platform to assist with management of dynamic ramp operations.

Specific features of the application are at-a-glance assessment of the current situation with easy-to-understand visualization focused on performance metrics; aircraft and station status; detailed process simulation models that use updated current and legacy data to refine projections to help identify problems before they occur; and integration with operations and performance data from multiple systems of record data and other operations support computer systems to project the interaction of all weapons platforms as they pass through Programmed Depot Maintenance (PDM) production process.

As a decision support workbench, ARViSS serves as a platform for an evolving flexible set of analysis tools, such as re-planning support for unanticipated events, major job simulation and the ability to "play back" from current to previous state from an integrated "stateful" data store. The capability provides users with insight into the resource issues contributing to current state of the ramp from a past point in time.

Recently, the ARViSS application has been extended with the ability to maintain awareness of the operational availability of key support machinery, assess the need for proactive maintenance and understand the impact of machine downtime to depot throughput through integration of programmable logic controller data on instrumented machinery. ARViSS is listed on the AF Approved Software List and in active use in the Air Maintenance Group (AMXG) operations, SE (Safety) and QPQI (Quality) Groups at WR-ALC.



Data-Driven & Goal-Driven Condition-Based Predictive Maintenance (DCPM/GCPM)

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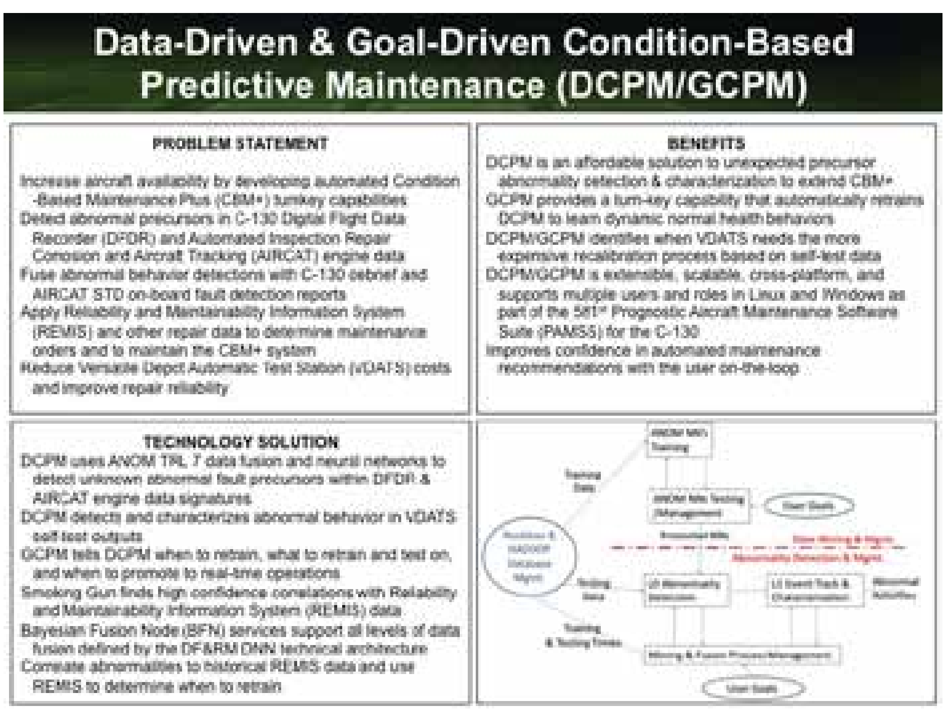
The DOD Maintenance Community needs being addressed include:

- 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

To affordably find activity patterns of interest in 'big maintenance data' we need turn-key intelligent data-driven and goal-driven systems. DF&NN has delivered a TRL 7 system to 3 sites that 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 over 10K measurands. These abnormality detections 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-unknowns'. 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 are computed to learn causes and recommended responses. The REMIS will also be used to define retraining criteria.

DCPM will be used to detect and characterize abnormal behavior in Versatile Depot Automatic Test Station (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. Then Reliability and Maintainability Information System (REMIS) data. The Bayesian Fusion Node (BFN) web services support all levels of data fusion defined by the DF&RM DNN technical architecture. The DF&NN Performance Assessment and Process Management (PAPM) capability computes the Probability of Detection (Pd), Probability of False Alarm (Pfa), accuracies, and other Measures of Performance (MOPS) for the abnormalities and responses provided by these tools for each application. These are used by the PM tools to improve the CBM+ parameterization.



The benefits of these capabilities include:

- 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

Expert Troubleshooting and Repair System (ETRS) Reduces "No Fault Found" Conditions in Testing Complex Aircraft Electronic Systems

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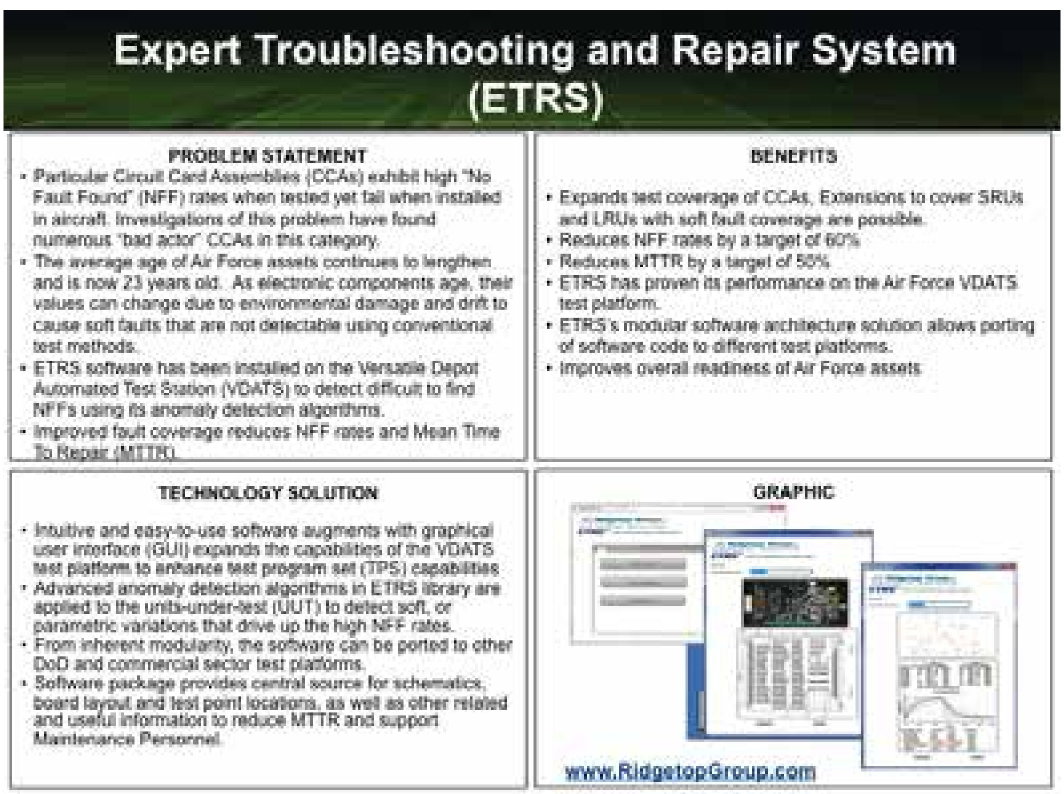
Over its life, military hardware is subject to environmental extremes such as temperature, lightning strikes, vibration and shock that can contribute to degradation from the design's nominal performance metrics. Often these variances result in No Fault Found / Could Not Duplicate, or NFF / CND, conditions that negatively impact the workflow and efficiency of the maintenance depots. Estimates have indicated as high as 50% NFF on legacy aircraft electronic modules. These NFFs stem from insufficient test coverage, and the Expert Troubleshooting and Repair System (ETRS) augments the existing test coverage with the addition of soft fault coverage. The algorithms included in ETRS are effective in detection of hard-to-find parametric variation (soft) faults. The resulting Test Program Set (TPS) test code achieves cost-avoidance by reducing NFF/CND occurrences. ETRS is a high performance, yet easy-to-use modular, software-based tool that operates on the Air Force's standard Versatile Depot Automatic Test Station (VDATS).

The potential cost-avoidance enabled by the Expert Troubleshooting Repair System (ETRS) 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 (3 CCA x $2M/year x 5 years). Extending the ETRS technology to other Air Force aircraft and subsystems assets will further enhance cost-avoidance.

The ETRS technology developed and funded by the Air Force exploits Lean Depot Management System (LDMS) historical data and CCA analysis to enhance the efficiency and efficacy of the VDATS system. Prioritized diagnostic and repair actions achieve cost-avoidance through reduced mean time to repair (MTTR), reduced frequency of no fault found (NFF) codes, 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. Examples of relevant beneficiaries include Electronic Warfare (EW), communications, and navigation systems where conventional diagnostic methods are not sufficient to ensure cost-effective operational readiness of the aircraft to perform its mission. With its modularity, ETRS can operate on additional test platforms being used in other DoD application areas, as well as the commercial sector. The paper will include an example test case of a circuit board with soft faults that are undetected using standard hardware, but quickly detected using ETRS.



WHERE ARE THEY NOW?

2008 WINNER: ELIMINATING UNCERTAINTY IN OIL CONDITION: FLUIDSCAN Q1000 PORTABLE FLUID CONDITION MONITOR
Commander Dave Scalf (Retired), Joint Oil Analysis Program Technical Support Center

The FluidScan® Q1000, Spectro Scientfic's handheld infrared analyzer, is the ideal tool to help the military asset maintainers determine when oil is no longer fit for use due to liquid contamination or degradation. This portable IR spectrometer has a built-in oil application library to deliver immediate, actionable quantitative results for critical properties such as water, TBN, glycol and soot. The extended library includes 12 use type categories with over 450 fluids, allowing immediate out-of-the-box operation.

Applications include mineral and synthetic oils used in machinery components: engines, transmissions, hydraulic sysembs, diesel engines, gear boxes, turbines.

2010 & 2011 WINNER: IFDIS
Ken Anderson, Universal Synaptics Corp

The "Great Ideas" Competition provided Universal Synaptics an opportunity to share our passion, knowledge of the intermittent / No Fault Found (NFF) testing void and our proven technology solution. Winning the "Great Ideas" Competition was the catalyst to a DoD wide recognition of the intermittent fault testing void and led to the formation of the Joint Intermittence Testing Working Integrated Product Team (JIT WIPT). It also provided us an introduction to some of the most dynamic, intelligent leaders within the Department of Defense. It is our opinion that this is the single most important platform the DoD maintenance enterprise provides to industry to share and promote innovative solutions to maintenance challenges.

2800 test point Intermittent Fault Detection & Isolation System™ (IFDIS™) testing an F/A-18 Generator Converter Unit (GCU)

The Ncompass-Voyager™ man portable Intermittent Fault Detector™ utilized for EWIS testing on the UH-60, CH-47, C-130, Eurofighter Typhoon, Tornado GR4, Trains, automobiles and consumer electronics.

8000 test point Intermittent Fault Detection & Isolation System™ (IFDIS™) testing an F-16 AN/APG-68 Radar System Programmable Signal Processor (PSP)

2011 WINNER: NO-MASK TOOLING FOR ELECTROPLATED PARTS
George Cushnie, Advanced Tooling Corporation

Electroplating is an essential process used at Department of Defense depots during overhaul of legacy aircraft, ships, tanks, small arms, and other weapons. It is primarily used for corrosion protection and resizing of worn parts. However, it is expensive to perform in terms of labor, materials and typically deals with hazardous materials. New, no-mask conforming anode tooling developed by Advanced Tooling Corporation through an NCMS-led CTMA project totally eliminates an expensive, time-consuming and potentially hazardous portion of the electroplating process saving millions of dollars at the depots where electroplating is performed. The tooling works for all types of electroplating including a new less toxic plating process under development to replace highly hazardous hexavalent chromium. In addition to the depots, no-mask tooling is now being used in commercial applications at Delta, American, and United Airlines and StandardAero. Warner Robins AFB recently integrated no-mask tooling in their new high tech plating facility launched last year.

2014 WINNER: LASTER TECHNOLOGY FOR AEROSPACE MAINTENANCE AND SUSTAINMENT APPLICATIONS
Deb Naguy, United States Air Force

The Air Force continues working toward full implementation of robotic laser depaint technology to replace current chemical and media blast methods. Process orders and training materials are being finalized and software updates are being developed to improve system safety, functionality, and surface coverage. Additionally, the Air Force is evaluating non-destructive testing technologies to incorporate into the system to further enhance system capabilities.

THE CHALLENGE IS ON!

Maintenance Innovation Challenge

2016 DOD Maintenance Symposium

December 5-8, 2016
Convention Center
Albuquerque, New Mexico, USA

Call for Innovations: Maintenance Innovation Challenge
Submit Your Innovation Today!

Deadline for Innovations: Wednesday, September 14, 2016

The 2016 DOD Maintenance Symposium is challenging you to summit your maintenance related innovations. An evaluation board comprised of maintenance subject matter experts will select six candidates to participate in the challenge during the 2016 DOD Maintenance Symposium, December 5-8, 2016.

Revolutionary or Evolutionary; showcase your maintenance innovation that offers a real solution and value to the DOD Maintenance Community to help them meet the needs and expectations for the future. Demonstrate how to keep maintenance ahead of the curve in processes, testing, validation, finance, methodology, products, services, and/or workflows to the Symposium audience on Monday, December 5, 2016 in Phoenix.

Presentations must be technical in nature -- focused on current or potential maintenance operations or management -- and strictly avoid commercialism. Each presenter will be allocated exactly 15 minutes, including audience Q&A. The winner will be selected through vote by the JGDM and MESC Senior Leaders and recognized at the Symposium Plenary Session.

Abstracts (300-500 words) for the 2016 Maintenance Innovation Challenge will be accepted through Wednesday, September 14, 2016. Don’t miss the opportunity to be part of the premier military and commercial maintenance event of this year!

Achieving Uncommon Results Through Innovation, Collaboration, and Leadership

ABSTRACTS MUST MEET THE FOLLOWING CRITERIA IN ORDER TO BE CONSIDERED FOR THE MAINTENANCE INNOVATION CHALLENGE:

- Must be an original contribution to the state of the art
- Technically accurate
- Must include test data or valid simulation support for all performance claims and conclusions
- Must be feasible or practical
- Abstract must be submitted in Word format using the template provided at http://www.sae.org/events/pdf/dod/2015_dod_cfp.pdf (See page 3 below) (abstract 300-500 words only)
- Include a PowerPoint Quad Chart using the template provided at http://www.sae.org/events/dod/cfp/quad_chart.pptx with the following information
- problem statement
- technology
- status of the technology
- way forward / potential benefits
- Must be received by Wednesday, September 14, 2016
- Include presenter's complete contact information
- Filename must be the presenter's last name (i.e., Jones.doc)
- One presenter per presentation

Submit via email to Kristie Saber, SAE International, at Kristie.Saber@sae.org. The email subject line should read, "Maintenance Innovation Challenge – Presenter's Last Name."

All abstracts that meet the minimum criteria listed above will be included in a Maintenance Innovation Challenge summary booklet that will be distributed to all symposium attendees onsite.

From eligible abstracts, an evaluation board comprised of maintenance subject matter experts will select up to six finalists to present at the 2016 DoD Maintenance Symposium. Presenters will be notified of acceptance by September 19, 2016.

The six finalists will have the opportunity to highlight their innovations via poster and static 3'x4' table top display. This display must be completely set up by noon on Sunday, December 4, 201.

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. Please call Kristie Saber at 724.772.4003 if you have any questions or need further information regarding the 2016 Maintenance Innovation Challenge.

MAINTENANCE INNOVATION CHALLENGE TEMPLATE

ABSTRACT TEMPLATE
Offer Number: (SAE To Provide)
Paper Title:
Author:
Organization:
Phone:
Email:

Abstract: (300-500 words)

www.sae.org/dod

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