MAINTENANCE INNOVATION CHALLENGE

Monday, December 5, 2016
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LOGISTICS AND
MATERIEL READINESS

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

October 21, 2016

MEMORANDUM FOR 2016 DOD MAINTENANCE SYMPOSIUM PARTICIPANTS

Innovation is the hallmark of America's Military. In an era requiring our forces to "do more with less" and rapidly adapt, maintenance process and technology ingenuity is more relevant now than any time in our history. In keeping with the theme "Engaging Tomorrow's Maintenance Enterprise Challenges, Today," we issued the 2016 Maintenance Innovation Challenge (MIC). 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 92 excellent submittals were received from DoD, industry and academia; an increase of 33 percent from submittals received for the 2015 MIC!

With assistance from the DoD Joint Technology Exchange Group, the 92 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 5, 2016 from 0800-1000 in the Albuquerque Convention Center, Room 115. 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 6, 2016. Additionally, I encourage you to please interact with these maintenance innovators throughout the Maintenance Symposium in their dedicated exhibition hall space.

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

Kristin K. French
Acting Assistant Secretary of Defense
for Logistics and Materiel Readiness

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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, 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.

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COMMERCIAL TECHNOLOGIES FOR MAINTENANCE ACTIVITIES

The Commercial Technologies for Maintenance Activities (CTMA) has a relentless focus on defense maintenance, sustainment and logistics. Created in 1998, CMTA is a joint effort between the Department of Defense and NCMS. 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. It provides technology development and insertion in support of the reliability and sustainment of ships, submarines, aircraft, land vehicles, non-traditional weapons systems and warfighter support systems. It must always benefit the U.S. military, industrial base and the public good.

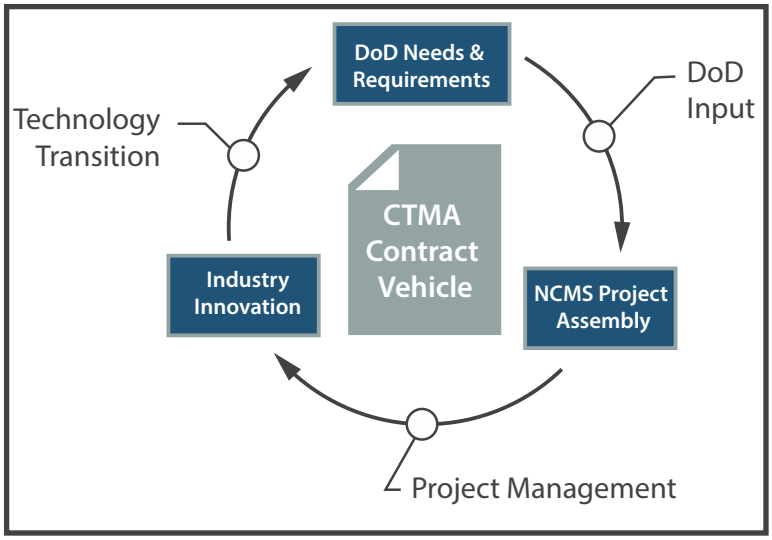
COLLABORATIVE AGREEMENT:

The CTMA Program offers a unique contracting vehicle for industry, academia and the DoD sustainment community to work in collaboration to find, develop and invent new and innovative technologies which enhance warfighter readiness at best cost. It functions through a Cooperative Agreement (CA), which is the legal agreement to conduct R&D that is mutually beneficial for all.

The CA offers significant, proven advantages for industry and DoD:

- Enables partners to provide and share personnel, services, facilities, equipment, and other resources in conducting R&D, reducing costs, optimizing resources
- Improves access to DoD facilities and equipment
- Streamlines contracting and cost accounting
- Reduces time between innovation and commercial production
- Opportunity to enhance D0D readiness while reaching corporate objectives
- Provides a means of sharing technical expertise, ideas, and information in a protected intellectual property environment, with non-government partners retaining IP rights

HOW CTMA WORKS:



- DoD maintenance activities have needs and requirements which are potentially solved by innovations created by industry.
- NCMS holds an unparalleled contracting vehicle to demonstrate commercial technologies prior to DoD acquisition.
- Companies with innovative solutions join NCMS and leverage CTMA to optimize their investment in technology. The CTMA team learns company goals, strategies, and capabilities. This collaboration guides companies and DoD to secure commercially available technology solutions.
- The CTMA team is experienced, respected, and connected to the DoD maintenance community and industry. This collaboration streamlines the validation and demonstration of requested technologies.
- NCMS quickly develops project teams connecting DoD with industry providers, integrators, and users.

MAINTENANCE FOCUS AREAS

- Cost Savings
- Environmental
- Cycle Time
- Safety
- Mx Avoidance & Reliability
- Mx Management
- Obsolescence Management
  Continued Mx Capacity
- Improved Readiness

Commercial Partners Benefit

- Access to DOD facilities and equipment
- Reduced cost of R& D through leveraging and sharing
- Reduced time between innovation and commercial production
- Opportunities to commercialize inventions
- Opportunities to enhance DoD preparedness while reaching corporate objectives
- Focused concentration of effort on specific industrial problems
- Profitable new product and process

DoD Benefits

- Supports Better Buying Power 3.0
- Streamlined contracting and cost accounting
- Focused on tech to improve capabilities
- Development and transfer of technologies
- Reduced cost of research & development
- Testing and evaluation before acquisition
- Ability to attract commercial entities which have technical expertise or technology of interest, yet have no government sector past performance
- Access to non-government expertise
- Able to build the industrial base through multiple uses of technologies
- Increased familiarity with market needs

Please direct questions to:
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MAINTENANCE INNOVATION CHALLENGE

Overview:

The Deputy Assistant Secretary of Defense for Maintenance challenaged individuals to submit their maintenance related innovations. An evaluation board comprised of maintenance subject matter experts selected six candidates to participate in the challenge during the 2016 DOD Maintenance Symposium.

Moderator:

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

Finalists:

Embedded Wireless Corrosion Detection
Jeffrey Banks, ARL at PSU

Expeditionary Fluid Analysis Capability
MGySgt Lance Baughman, HQMC, I&L, LPC-1

CBM+ to Enable Data Driven Fleet Mgt
Jason Duncan / Craig Hershey TACOM ILSC and AMSAA

Automated Large Standoff, Large Area Thermography (LASLAT) Inspection System
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DoD Depot Fielding of Cold Spray Technology
Alex Stonecipher, 429 SCMS/GUMB

Naval Undersea Warfare Center, Division Keyport X-Ray Reverse Engineering
Laura Watson

Embedded Wireless Corrosion Detection Technology

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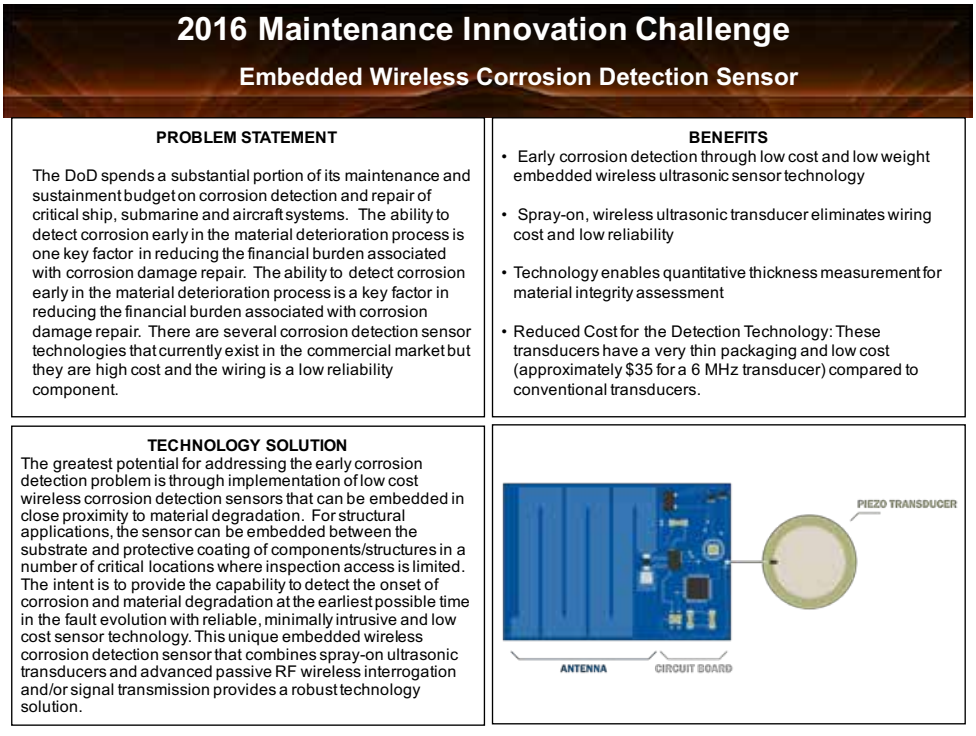
The DoD spends a substantial portion of its maintenance and sustainment budget on corrosion detection and repair of critical ship, submarine and aircraft systems. The ability to detect corrosion early in the material deterioration process is one key factor in reducing the financial burden associated with corrosion damage repair. The innovative technology that can impact this issue is a low cost and low weight wireless sensor for early corrosion detection. The attributes of this sensor include:

- Enhanced Military or DoD System Capability: The key capability enhancement is early detection through implementation of wireless corrosion detection ultrasonic (US) transducers that can be embedded between the substrate and protective coating of structures in a number of critical inspection areas. This provides the capability to detect/localize the on-set of corrosion and the material degradation severity at the earliest possible time in the fault evolution with minimally intrusive, low cost, and low weight sensor technology.
- Reduced Cost for the Detection Technology: This spray-on technique for ferroelectric materials is a relatively new approach to ultrasonic transducer fabrication. These transducers have a very thin packaging and low cost (approximately $35 for a 6 MHz transducer) compared to conventional transducers. The integration of advanced wireless technology for exciting the transducer and receiving data back from the sensor eliminates the cabling/wiring harness for the sensors that also reduces cost and increases sensor reliability (i.e. effective life), and means the inspection can take place without removing protective coatings or insulation.
- Improve the Thoroughness of Test and Evaluation Outcomes: The implementation of a wireless multi-transducer tomographic ultrasonic inspection capability will provide a fully quantitative thickness map of the entire area of interest for enhanced integrity assessment.

This unique embedded wireless corrosion detection sensor combines advanced wireless and spray-on ultrasonic transducer technology. The sensor operation includes the following steps: 1) the wireless ultrasonic sensor is installed in several distributed locations, typically corrosion critical or difficult to inspect, 2) a maintainer wirelessly interrogates individual or groups of sensors using a hand-held RF interrogator, 3) when the RF tag is energized from the interrogator, the ultrasonic transducer sends a high frequency signal (i.e. ~1-10 MHz) into the material, 4) the corrosion or material thickness reduction is detected through the time of travel of the reflected waveform, 5) the embedded signal processing electronics send the corrosion detection and severity indication to the RF tag, where it is sent back to the hand-held RF interrogator.

As DoD migrates to condition based maintenance (CBM) to convert from unscheduled to scheduled maintenance actions to reduce sustainment costs; sensors will be the critical technology to enable CBM to be effectively implemented. This low cost, embedded wireless corrosion detection technology provides a unique and innovative technology for addressing the corrosion challange that has the most significant impact of the DoD sustainment budget.



USMC Expeditionary Fluid Analysis Capability

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INTRODUCTION
In 2002, the Deputy Under Secretary of Defense (Logistics and Material Readiness) directed all service components to incorporate Condition Based Maintenance (CBM) practices.

APPROACH
The Marine Corps framed the following problem statement to NCMS: "Every year the Marine Corps spends a large portion of its operation and maintenance budget on changing oil and filters at pre-ordained, time-based PMCS intervals (semi-, annual, biennial, etc.), regardless, of the life of the fluid." NCMS, then partnered Marine Corps with Spectro Scientific, an industry leader that specializes in analytical tools and software for machine condition monitoring. Spectro Scientific provided a commercial-of-the-shelf (COTS) solution that allowed the Marine Corps to use current industry standards, to analyze a weapons systems fluid "health" within minutes of sampling, and use these analytics as a basis for decision-making at an organizational level.

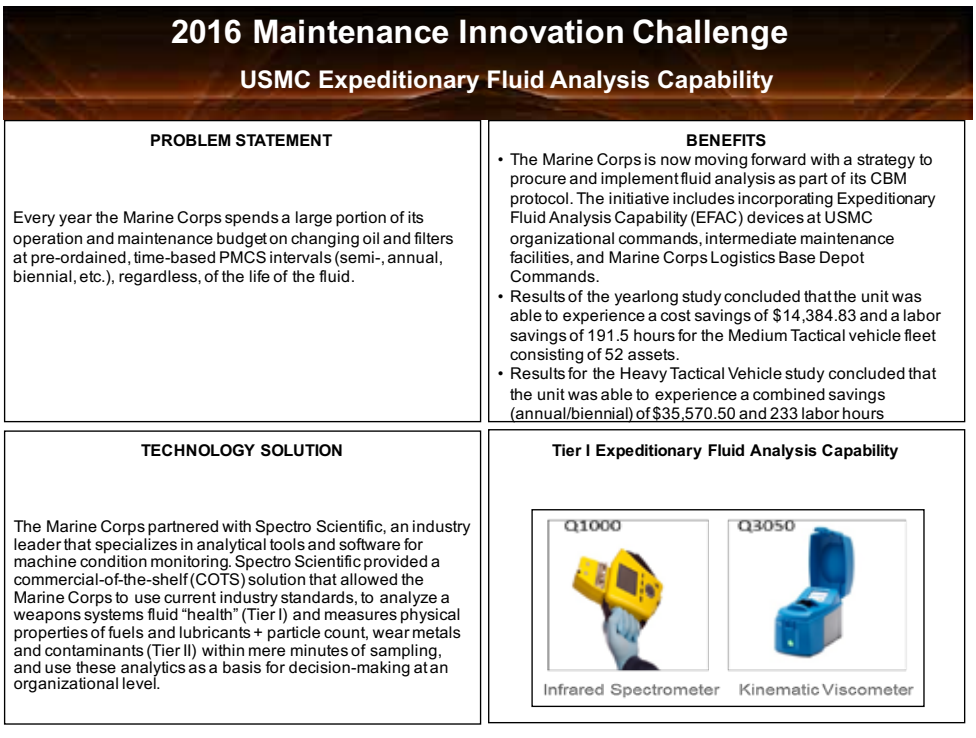
TIER I EXPEDITIONARY FLUID ANALYSIS CAPABILITY
In January 2015, the Marine Corps started a proof-of-principle study to demonstrate the feasibility of incorporating a device into the enterprise. The Marine Corps was provided with the hand-held FluidScan 1000 and the Q3000 Series Viscometer from Spectro. Together these devices, known as Tier I Expeditionary Fluid Analysis Capability, are capable of testing fluid physical properties and viscosity. The methodology of testing was focused on cost avoidance of oil wetted subcomponents prior to regularly-scheduled preventive maintenance periods. Subcomponents consisted of engines, transmissions, transfer cases, differentials, wheel hub, etc.

The results of the yearlong study concluded that the unit was able to experience a cost savings of $14,384.83 and a labor savings of 191.5 hours for the Medium Tactical vehicle fleet. A regression analysis was conducted using the data points from the study against the entire Marine Corps' Medium and Heavy Tactical Vehicle fleet. It was determined, if the Tier I EFAC device were incorporated, the Marine Corps could recoup $6.5 million and 60,809 labor hours.

TIER II EXPEDITIONARY FLUID ANALYSIS CAPABILITY
In addition to Tier I EFAC proof-of-principle study to identify a CBM solution, the Marine Corps is also undergoing an assessment of a Tier II EFAC, otherwise known as the Spectro Scientific, FieldLab 58. The test equipment weighs in at less than 35 pounds and provides the user with results in under 9 minutes. This equipment is beneficial for scheduled maintenance avoidance costs and component detriment identification (i.e., engine, transmission, transfer case, etc.).

The Tier II device has proven to be quite effective in the realm of cost avoidance. The device successfully identified a Heavy Tactical Wheeled vehicle transfer case with high metal concentration and extremely high particle counts. The $21,712.85 item was removed, replaced, and repaired before further damage took place. Preliminary data indicates a cost savings of $12,585 and 9 labor hours after three months of use.

As a result of the EFAC evaluation, the Marine Corps is moving forward with a strategy to procure, and implement fluid analysis as part of its CBM protocol. The initiative includes EFAC devices at USMC organizational and intermediate maintenance facilities, and the Marine Corps Depot.



Implementation of CBM+ to Enable Data Driven Fleet Management of TWVs & Strykers

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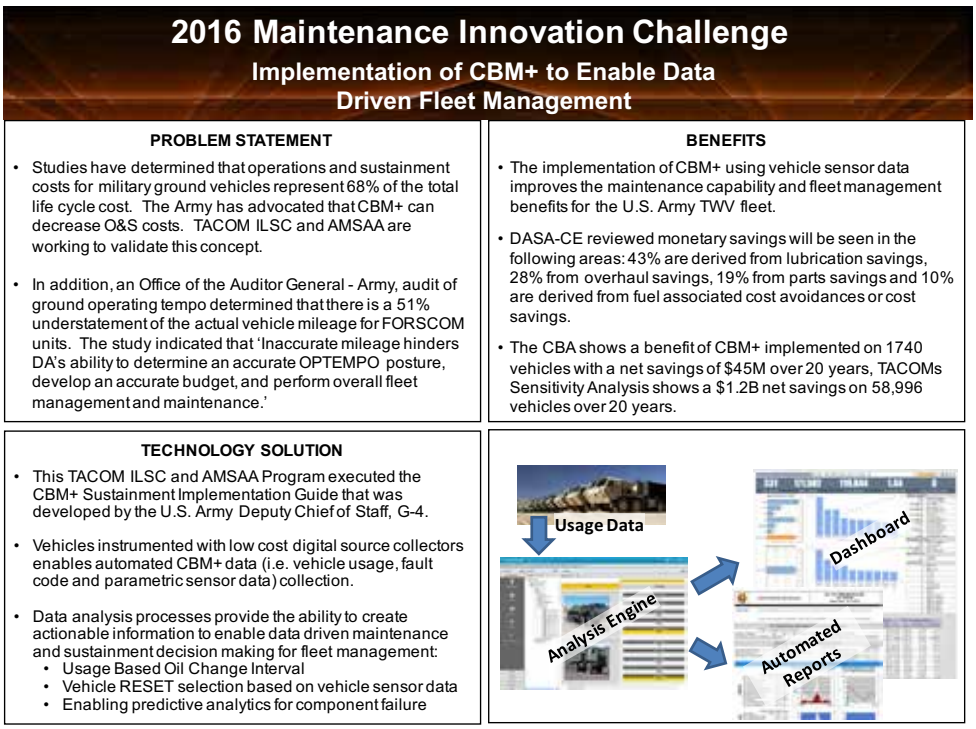
The TACOM Integrated Logistics Support Center (ILSC) Condition Based Maintenance Plus (CBM+) Tactical Wheeled Vehicles Pilot Program (TWV PP) was executed from 2012 to 2015. The purpose of the TWV PP was to demonstrate the value of equipping critical assets with CBM+ enabling technology by executing the CBM+ Sustainment Implementation Guide, developed by the U.S. Army Deputy Chief of Staff, G-4.

The scope of the TACOM TWV PP consisted of integrating hardware, software, and processes in order to instrument and collect parametric and performance data on a sample of 1,740 Army TWV at various Army locations around the world. The collected vehicle data summed to over 450,000 engine hours equating to over 2.5 million miles worth of OPTEMPO data. This data was collected for each active day of vehicle usage, comprising over 320,000 discrete days of vehicle operations. An automated analysis tool was employed to focus on providing insight into the condition of individual vehicles and enable more efficient at-platform maintenance and more effective enterprise level fleet management. The AMSAA-led analysis on the vehicle data resulted in the generation of over 300 Vehicle Health Alert (VHA) reports. VHA reports inform the Unit of maintenance faults and other unhealthy vehicle symptoms and suggest corrective actions; this information would not normally have been available without CBM+ data. With the VHA information and subsequent maintenance actions, vehicles experienced a reduction in parts ordered and diagnostic time. Additional analysis included looking at trends across the fleet of vehicles to identify systemic issues. Significant findings have resulted in ECPs, TM updates, and refinement of Engineering and Fleet Management tools.

After the conclusion of the TWV PP, AMSAA continued to collect data and further enhance its CBM capabilities. An analytical website, the Fleet Insight Toolkit, was deployed online to Soldiers to provide actionable information and directly influence maintenance decision making. CBM technicians were employed to assist Soldiers in utilizing CBM information, resulting in dramatic reductions in misdiagnoses (95% diagnostic day reduction) on major assemblies. This effort is the value realization of the cost benefit analysis (CBA), validated by the Deputy Assistant Secretary of the Army - Cost and Economics (DASA-CE) and disseminated to the PEGs, which estimated a $1.2B net savings on 58,996 vehicles over 20 years. Monetary savings will be seen in the following areas: 43% are derived from lubrication savings, 28% from overhaul savings, 19% from parts savings and 10% are derived from fuel associated cost avoidances or cost savings. As a direct result of the CBA validation, the Army is pursuing efforts to permanently equip their legacy platforms with CBM+ enabling technology and to include requirements for CBM+ in new systems.



FINALISTS

Automated Large Standoff, Large Area Thermography (LASLAT) Inspection System For Naval Aviation Structures

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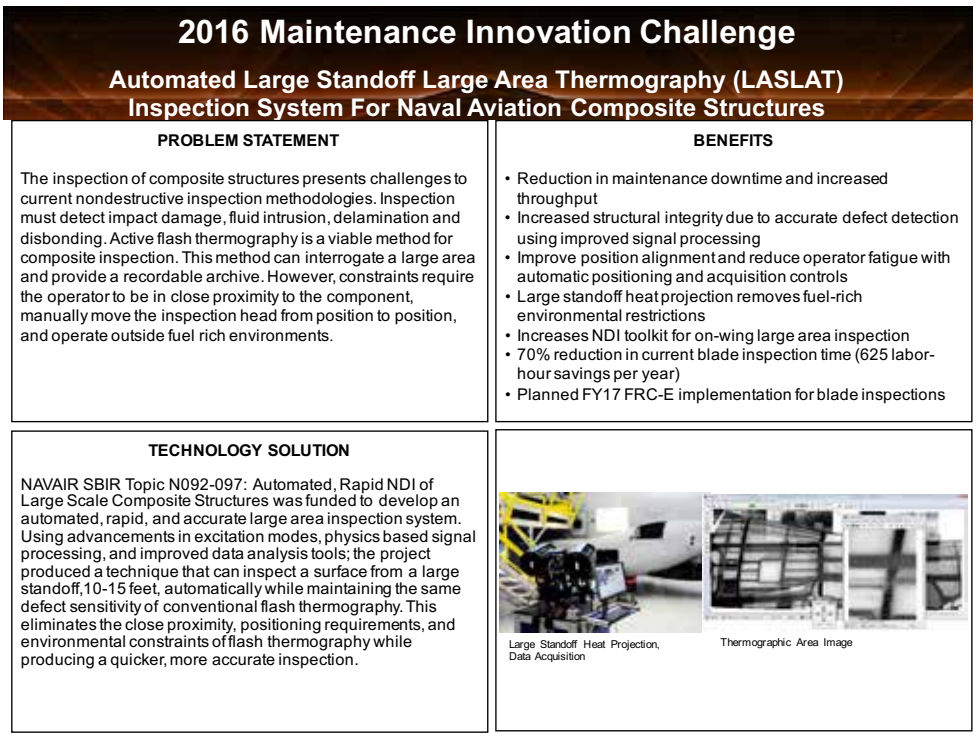
Background: The inspection of composite structures presents challenges to current nondestructive inspection (NDI) methodologies. Inspections are labor intensive, time consuming, and complex. The inspections must detect impact damage, fluid intrusion, delamination, and disbonding.

Issue: The most viable and widely used method is A-scan ultrasonics. However, inspection is a point area inspection and relies on experienced operators for signal interpretation. Another inspection technology used by Fleet Readiness Center East (FRC-E), Cherry Point is active thermography. Active thermography uses an external excitation, usually heat, to interrogate structures for subsurface damage. As the heat diffuses into the structure the surface cools. Any restriction of heat flow caused by a subsurface anomaly or defect creates a surface signature and is detected by an infrared camera. Thermography is an imaging technique giving it greater benefits than point sourced A-scan ultrasonics; however, constraints exist. The operator must be in close proximity to the component, manually move the inspection head from position to position, and is not allowed to operate in fuel-rich environments.

Solution: Naval Air Systems Command (NAVAIR) Small Business Innovation Research (SBIR) Topic N092-097: Automated, Rapid NDI of Large Scale Composite Structures was funded to develop an automated, rapid, and accurate large area inspection system. Using advancements in excitation modes, physics based signal processing, and improved data analysis tools; the project produced a technique that can inspect a surface from a large standoff, 10-15 feet, automatically while maintaining the same sensitivity and detection capability of conventional flash thermography. The development of the large standoff, large area thermography (LASLAT) system matured from a feasibility determination in Phase I (FY10), to a working prototype in Phase II (FY13), and into a Phase II.5 demonstrating the technology on a specific application in a hangar environment (FY16).

Benefits: Reduction in maintenance downtimes and increased throughput has become a reality by the reduction and elimination of the flash thermography constraints. The single image field of view (FOV) increased more than 50%, from 108 sq-in to 300 sq-in, which will decrease inspection times. The improved physics based signal process modeling and data acquisition using multi-thread capabilities will ensure accurate defect sensitivity. The improved data analysis tools will improve large area defect recognition. This technique will reduce the current FRC-E blade inspection times by 70%, savings an average of 625 labor hours annually, and will be implemented as a Phase III in FY17.



DoD Depot Fielding of Cold Spray Technology

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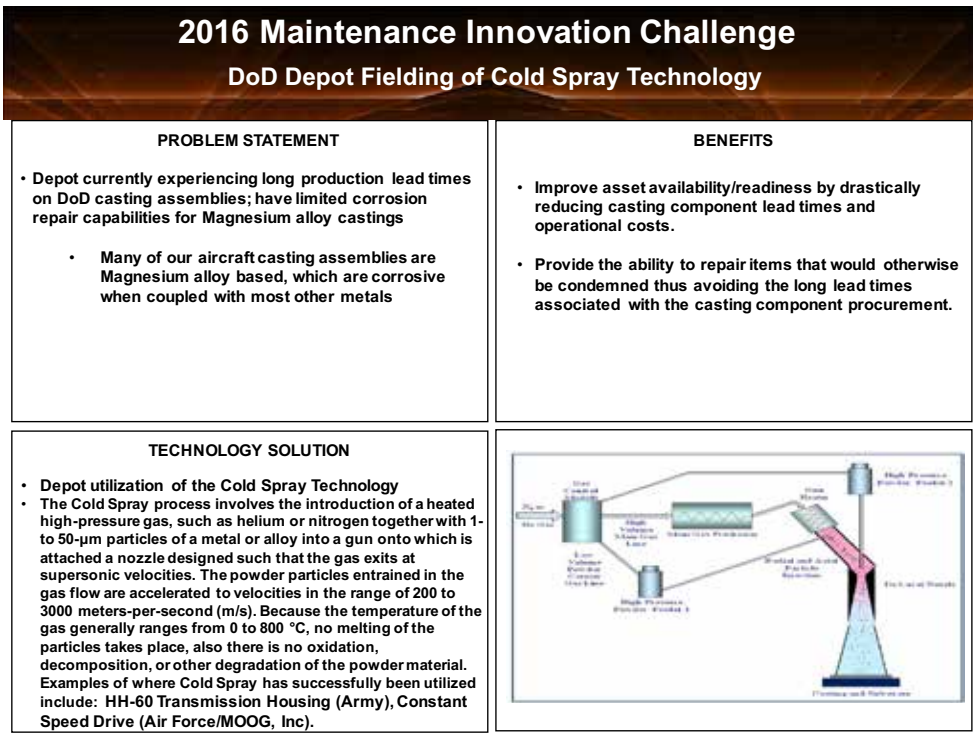
Air Force depots are currently experiencing long production lead times and/or high procurement costs as it relates to Department of Defense (DoD) casting assemblies. The Air Force has numerous cast items within their portfolio that are in need of repair. Cold Spray is an additive manufacturing process that involves the introduction of a heated high-pressure gas, such as helium or nitrogen together with 1- to 50-µm particles of a metal or alloy into a gun. It is then attached to a nozzle designed where the gas exits at supersonic velocities. The powder particles entrained in the gas flow are accelerated to velocities ranging from 200 to 3000 meters-per-second (m/s). Because the temperature of the gas generally ranges from 0 °C to 800 °C, no melting of the particles takes place. Also, there is no oxidation, decomposition, or other degradation of the powder material. The use of the Cold Spray process opens up opportunities for the Air Force to repair castings as opposed to condemning them. The use of this method of repair results in a fraction of the time and/or cost of procuring a new casting. The Cold Spray process has been successfully utilized within the DoD. Examples of these successes include: HH-60 Transmission Housing (Army) and the Constant Speed Drive (Air Force/MOOG, Inc.). Currently, the Enterprise Strategic Sourcing Flight has been working on identifying and pushing select items through the approval process utilizing the Cold Spray process. These items are being delivered to the Air Force Research Laboratory (AFRL) so that the Cold Spray process can be proven on these items. After the process is proven, a requirement will be developed to generate a contract to repair these assets. The team's goal is to eventually insert this technology in the depot maintenance back shops. This technology has the potential to dramatically reduce the Air Force's cost and logistical footprint.



FINALISTS

X-Ray Reverse Engineering Techniques

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A serious and growing challenge faced by the U.S. Navy is the obsolescence of and inability to replace electronic Circuit Card Assemblies (CCA). Smaller budgets have necessitated using equipment longer than its projected lifespan. Often the Original Equipment Manufacturers (OEM) cannot replace or repair these aging and obsolete assets. The Rapid Prototyping and Fabrication Technology Division, Naval Undersea Warfare Center Division Keyport has developed evolving processes for reverse engineering and redesigning of obsolete Printed Wiring Boards (PWB) since 2001. PWB's were analyzed using a two-step process. The first step was obtaining the net-list of a depopulated PWB using a cable analyzer connected to each point on the PWB. The second, and very destructive step, was to surface grind and photographically scan each layer using an industrial milling machine. The use of the X-Ray equipment for reverse engineering represents a technological leap forward and will eliminate previous costly, time consuming and destructive techniques.

Printed Wiring Boards are analyzed using X-Ray Computed Tomography (CT) and three-dimensional information is extracted with complex 3D capturing, image processing and segmentation algorithms. The 3D capturing process utilizes Computed Tomography to acquire 3-dimensional images of the PWB. Complex algorithms are performed which process the 3-D images into useful information. These algorithms accomplish edge detection, intensity and filtering, thresholding functions and can be used to isolate slices of interest. The segmentation process provides cylinder and VIA detection, and plane, trace and pad detection. The final step in X-Ray analysis is the conversion of raster images, such as bitmaps which are produced by the X-ray process, into vectorised images such as Drawing Exchange Format (dxf) images which can be used to manufacture the printed wiring boards. Specifically, the vectorised images must be converted to gerber file format in order to manufacture the reverse engineered products. The gerber files are vector 2-D file formats which contain all of the information required by Computer Aided Manufacturing software.

This process will greatly benefit the Navy by increasing the lifespan of otherwise obsolete and irreplaceable electronic assemblies. It will signitifcantly reduce the time required to reverse engineer a printed wiring board, increase production capability and greatly increase accuracy.

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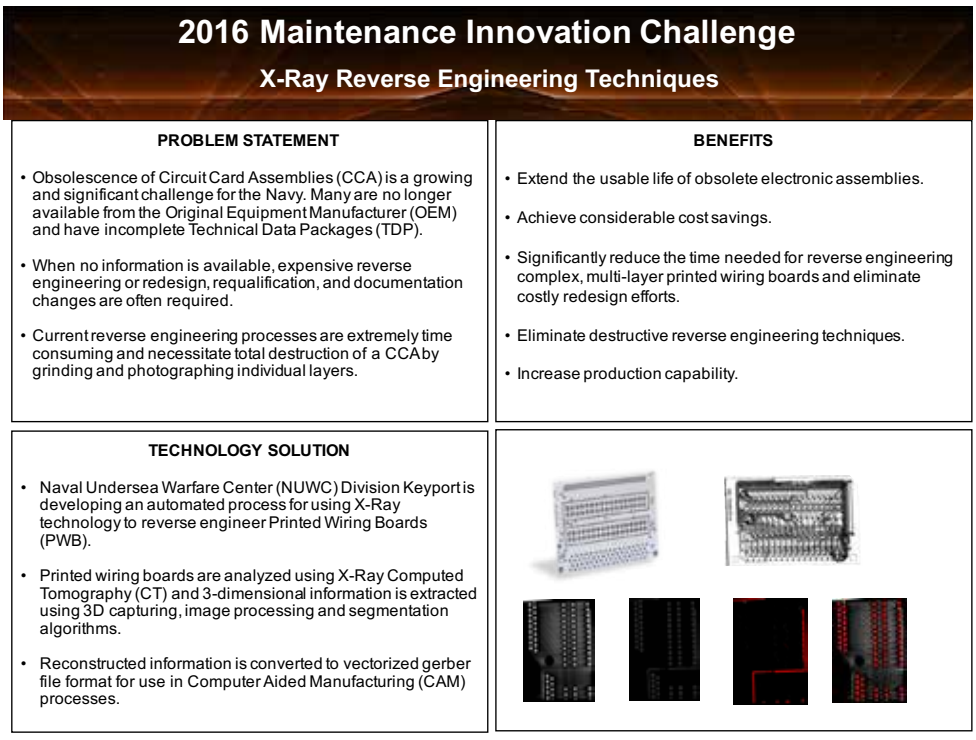

Prototyping Systems for Collaborative Design and Manufacturing of Replacement Parts

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Maintenance of antiquated and aging defense systems is becoming increasingly challenging due to hard or non-procurable items, particularly with forward deployed vessels or remote operating units. These situations pose extreme and exhausting logistic challenges, which in turn significantly impact the combat readiness of our forces.

A game changing approach to alleviating this problem is to facilitate the ability to reverse engineer required components (if design is not readily available) or safely redesign for temporary voyage repair utilizing rapid manufacturing technologies, including 3d printing. Through both access and education, this scenario was tested over the past year through a partnership between Applied Systems & Technology Transfer (AST2), USN and USMC. The main objective was to increase accessibility of design and manufacturing equipment to all defense personnel, and stimulate learning and problem solving skills for the next generation of warfighters.

Navy's maintenance command and AST2 developed compact mini Fabrication Labs; integrating design stations, INVENT3D printer and a CNC mill at a cost of <$10,000 ea. Two systems were deployed on forward operating vessels. Sailors with little to no manufacturing background quickly adopted and developed exceptional solutions. For example, sailors reverse engineered and small batch produced a frequently replaced Radio clip (TRUCLIP). In addition to cost avoidance of over $12,000 in two months, sailors proved effectiveness by allowing accessibility and peer to peer learning. Additionally, sailors reverse engineered and produced a mission critical nitrogen purge kit to replace corroded wrap around panel brackets on F/A-18 aircraft, a life-saving plastic adapter for anesthesiologists waste gas machine, and a fixture for the radar test bench set preventing a critical 10 day work stoppage.

Two spin-off initiatives were taken into further demonstration of the technology's potential. First, a Navy-wide Fleet design challenge was created. Eighteen exceptional concepts were received that could potentially improve efficiency, reduce cost and hazards. Second, USMC's 1st and 2nd Maintenance Battalions were trained and equipped in collaboration with SPAWAR and HQMC. Marines learned to assemble INVENT3D printers, and designed and manufactured a number of replacement parts. Examples include the Power Take Off Yok Shifter for the AAV that reduced total procurement/replacement time from 200 to one day and AN/VRC-110 Vehicle Amplifier Unit with a 79,400% ROI. The 1st Maintenance Battalion, working with SPAWAR, advanced the development of an Expeditionary Manufacturing Unit that recently won SPAWAR's Lighting Bolt Award. Similarly the TRUCLIP won the Fleet design challenge and was transmitted jointly by dignitaries including VADM Cullom and LG Dana for printing on the International Space Station.

The training programs and equipment also stimulated problem solving skills, and as VADM said, sailors and marines proved that the 'sky is no limit' when they are provided with both tools and training.

Further development and deployment of this approach is planned. USN and USMC are to deploy additional Fabrication Labs. AST2 is supporting ODU in developing Fleet Maker Workshops to train over 300 Navy personnel over the next few years. The program will also be extended to both Army and the Air Force.

2016 Maintenance Innovation Challenge

Prototyping Systems for Collaborative Design and Manufacturing of Replacement Parts

PROBLEM STATEMENT

- Maintenance of Legacy Systems is challenging
  - Hard to procure or non-procurable parts
  - Logistics for storage and distribution
  - Need to replace full system instead of a part
  - Procurement time 100 times replacement time
- Additional challenges for forward deployed forces
  - Places additional troops in harms way
  - Reduces operational readiness
  - High costs of transportation

BENEFITS

- Develops problem solving and critical thinking skills
- Accepted and appreciated by enlisted personnel and command officers
- Significant cost and time savings, and operational performance and readiness improvements
- Potential to create a library of designs for others to use and manufacture
- Promotes collaboration

TECHNOLOGY SOLUTION

- Reverse Engineering and Rapid Prototyping
  - Design using scanners and CAD programs
  - Collaborate with SMEs and experts virtually
  - Manufacture using additive/subtractive eqpt
- Compact and Easy-to-Use eqpt
  - Less than one week for sailors/marines to design and manufacture
  - Desktop eqpt
  - Suitable for forward deployment

Additive Manufacturing Traceability Assurances and Design Optimization S/W Tools

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Additive Manufacturing (AM) technologies are potential change agents redefining both producibility and operability space in many industries. Hence the need for increased reliability is of utmost importance in the AM environment for metal based low production rate materials development. As technological and regulatory advancements progress in the next decade there will be an ever increasing demand for reliable methods to replace OEM forged metal components with AM manufactured components with end-to-end lifecycle management built into components to provide reliable systems and avoid failures in both commercial and military aviation applications.

Given DoD indentified technology gaps optimizing AM designs to reduce time and expense associated with periodic inspections will be difficult unless there is an end-to-end method to compare data sets between "simulated designs", "as-built" and "in-operations". Intelligent Management Analysis System (IMAS) software developed by Analatom based on IBM Watson-Like technology but scalable is an affordable maintenance assessment tool with an "associative memory" indexing capability linking data from multiple sources. IMAS links end-to-end expertise knowledge and data associated with the AM technology domains: a) materials, b) engineering designs, c) design and materials standards that combine data from designs, d) simulated dynamics, e) 3D AM Statistical Process Control build parameters and f) environmental monitoring.

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

Analatom created IMAS AM prototype associative memory software that links and correlates all above listed expertise into an associative memory index that enables designers to ascertain that optimized inspection oriented designs retain their functional capabilities. Validation involved 1) building a multiple element heat exchanger design, 2) modification of design to optimize sensor placement or inspection probes, 3) data capture at materials and engineering modeling stages, design stages, 4) design aids inspections by being manufactured with different geometries to resonate at different frequencies via ultrasonic probes, 5) during build CT scan data collection, 6) after build Quantitative Percussive Diagnostics method validating number 4, 7) after build planned accelerated corrosion testing and data collection and 8) link observed data from computational tools. Supporting test data were obtained by capturing images during AM process for every fused build stage. Image-based associative memory linked data "as-built" parts could distinguish between "normal" and "seeded defects" regions.

2016 Maintenance Innovation Challenge

Additive Manufacturing Traceability Assurances and Design Optimization S/W Tools

PROBLEM STATEMENT

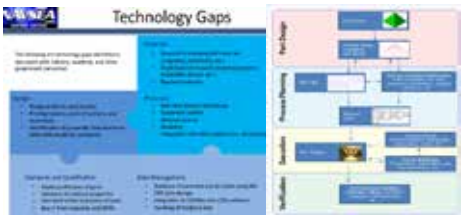
- Need for AM Driven Component Design Optimization, Process, and Configuration Management S/W Tools
- DoD Additive Manufacturing Study identified Technology Gaps in Design, Materials, Processes, Standards, Data Management.
- AM Design Optimization Tool to Ensure Component Life, Performance, Inspectability,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

BENEFITS

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

TECHNOLOGY SOLUTION

- To close technology gaps and provide sufficient part traceability and assurances, apply "big data" analytic methods that link and correlate disparate data sources.
- Analatom's IMAS,(IBM Watson-like) is an intelligent management assessment system that currently correlates disparate information
- IMAS can be adapted to link AM data sources that include in-process quality control "images" correlated with design, materials and build configurations.
- IMAS provides traceability assurance.
- Leverage SBIR, Fathom Studios, and other efforts to provide AM Component Design Optimization Tool sets.



Linking data across domains
(Watson-like associative index prototype)

Incorporating Additive Manufacturing into the Marine Corps

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Since March 2016, the Marines of 1st Maintenance Battalion have aggressively integrated a prototypical Additive Manufacturing (AM) experimental capability, referred to as the Expeditionary Manufacturing Mobile Test Bed (EXMAN TB-100), into their Intermediate Maintenance Activity. In cooperation with the Space and Naval Warfare Systems Command and the Marine Corps Deputy Commandant of Installations and Logistics, the Marines can now rapidly generate Computer Aided Designs and complete technical data packages, design digital concept models, and produce low-cost AM prototype solutions that directly sustain military equipment. The EXMAN TB-100 combines advanced control and information technologies with new production tools, methods, and materials. It augments existing traditional machining processes, while creating a hybrid supply chain of complimentary digital and physical components. This high visibility Fleet Marine Force focused effort was endorsed by the Commandant of the Marine Corps and is being used as an innovation case study by the White House Office of Science and Technology Policy, the Deputy Undersecretary of the Navy for Management and the Navy's Director for Material Readiness and Logistics.

The EXMAN compliments efforts such as the Navy Fabrication Laboratory and other maker-space oriented efforts in order to contribute to building requirements to establish the Department of the Navy's integrated digital manufacturing grid.

The Marines of 1st Maintenance Battalion have concentrated the efforts of the EXMAN to quickly meet critical requirements. Within weeks of accepting the EXMAN, the Marines were identifying, designing, and printing prototype replacement parts to repair degraded military equipment. What typically incurs lengthy delays to research, order, approve, ship, receive, and account for, the Marines were able to subtractively manufacture from locally stocked material or additively manufacture the parts from plastic utilizing their 3D printer in order to fulfill the requirement, avert substantial costs, and increase readiness.

The Marines targeted long lead-time parts such as the Assault Amphibious Vehicle's (AAV) Power-Take-Off (PTO) shift yoke. This item historically takes 270 days to be received from the source of supply. In this instance, the Marines created a digital model of this part, printed it in plastic, then checked it for fit, form and function. After a few refinements the design model, the part was manufactured in a machine shop. This entire process from concept to final production took mere days and was shared with another like maintenance activity within the Marine Corps.

With EXMAN, unprocurable parts are no longer an obstacle for the Marines either. An enterprising Corporal redesigned and produced several unprocurable plastic components for tactical radios. Producing these parts cost a few dollars to print, averting thousands of dollars of replacement costs, while improving materiel readiness.

When parts fail prematurely due to design flaws, Marines communicate the issue to the Marine Corps Logistics Command through a Product Quality Deficiency Report. This assists logisticians and engineers in the development or modification of materiel solutions. Through the EXMAN, Marines can better contribute to this process by submitting design recommendations while concurrently printing the modified part from the edge of the battlefield.

Additive Manufacturing for Agile Depot Operations

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Sustainment of aging aircraft presents a unique challenge due to lack of complete tech data, poor condition of legacy tooling, and rapid response required on unanticipated repair items. To meet the needs of the depot and return aircraft to service as soon as possible CMXG has leveraged 3D laser scanning, additive manufacturing, and castable materials to create solutions for maintenance problems where traditional manufacturing is either not possible or too slow. CMXG has had great success augmenting organic manufacturing by providing tech data packages for parts and equipment, prototype parts for aircraft, and end use dies and fixtures created either by 3D printing or resin casting into printed molds. Specific innovative solutions include printed Ultem weld fixtures containing internal flow cavities for argon cooling, allowing polymers to be used without melting. Fixtures like this save cost over traditional machining but more importantly allow greatly reduced turn- around times, typically 3- 6 months faster, including delivering parts currently unable to be sourced. CMXG has also helped the B1 maintenance save time and cost by scanning cracked sections and making prototype "bath tub" fittings using a binder jet printer. Creation of a section model allows for greatly reduced fitting design time and easy modification and prototyping has reduced time spent machining with an overall average time savings of 3 weeks per fitting. Printing or resin casting of sheet metal form blocks has also proven to be an extremely cost and time effective route to supporting organic manufacturing. CMXG has shown that fully dense printed ABS, PLA, and ASA form blocks can withstand 10,000 psi from the rubber and fluid cell presses with an average cost savings of $2500 for small to medium form blocks and elimination of nearly 2 months in lead time. Printing molds and casting form blocks from ceramic filled epoxy has also been demonstrated as a major cost and time saving technique with $3500 average cost savings per block and similar production time to printing, however these blocks are brittle and have more limitations than dense printed blocks. To date utilization of these techniques for die block manufacture have saved over $100,000 and a combined total of 284 flow days.

2016 Maintenance Innovation Challenge

76 CMXG Reverse Engineering And Critical Tooling

PROBLEM STATEMENT

- Sustainment of aging aircraft presents unique challenges due to the lack of complete technical data, aging legacy tooling, and the need to rapidly respond to unanticipated repairs to a wide variety of aircraft and exchangeable end items.

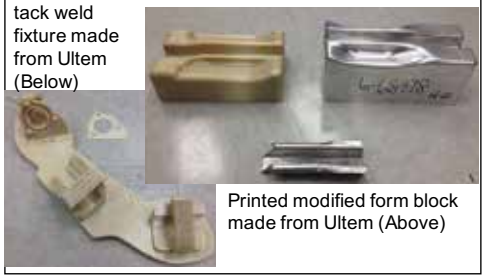
BENEFITS

- Rapidly prototype parts for fit checks and iterate design changes very quickly
  - Reduces material waste and machining time
- Print low production run tooling for sheet metal forming, welding, and drilling on demand
  - Reduces tool cost, lead time and storage footprint
- Create novel light weight and ergonomic solutions when standard fixtures or tooling doesn't exist
  - Improves employee safety and satisfaction

TECHNOLOGY SOLUTION

- Laser scanning and measurement to meet the needs of depot maintenance operations
  - Compare items to technical data
  - Create a model from a sample part
- Additive manufacturing to rapidly prototype solutions
  - Custom repairs
  - Innovative tooling
  - Validate/enhance technical data

Printed tube tack weld fixture made from Ultem (Below)



Printed modified form block made from Ultem (Above)

3D Metal Printing for the Factory Floor

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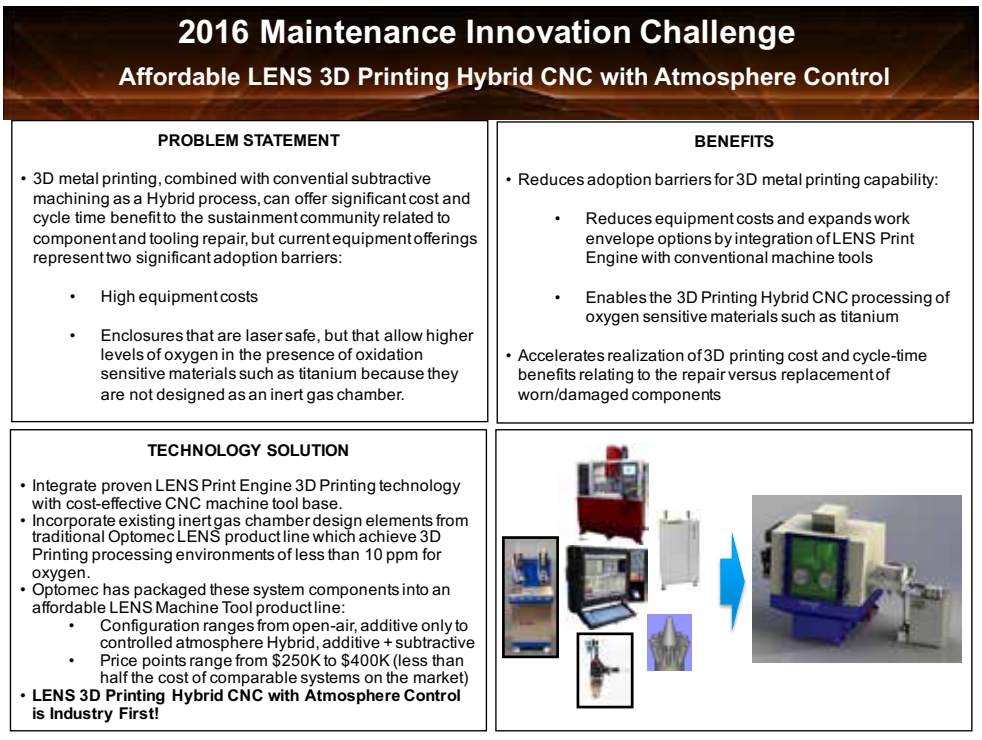
Additive manufacturing (AM) technologies have been utilized as rapid manufacturing techniques supporting the DoD maintenance and sustainment community for more than twenty years. More recently 3D metal printing has been integrated with conventional subtractive CNC capabilities in what has come to be known as Hybrid Metal 3D Printing (Hybrid). Hybrid capabilities have the opportunity to build on the fact that AM technologies have a well-documented potential for reducing sustainment/maintenance costs and cycle times. However, metal AM, and now Hybrid, capabilities have consistently been confronted by significant barriers to adoption.

Metal 3D printing is encountering many of the same adoption barriers that other 3D printing methods have experienced in the past. Cost of equipment has been a major obstacle to adoption and has been increased by Hybrid considerations. Additionally, most of the current Hybrid equipment offerings have come from established CNC machine builders offering metal 3D printing as an option. Most of these Hybrid offerings are approaching the $1,000,000 ($1MM) price point with many exceeding it. In addition, traditional CNC builders have in the past not dealt with the 3D Printing of oxygen sensitive metals and have relied basically on traditional welding practices providing local inert gas shielding to the immediate AM processing area of the part. Local inert gas shielding with these techniques is suitable for a wide range of materials, but for a small range high performance materials such as titanium alloys, an extremely low level of oxygen must be maintained. This has traditionally been achieved by processing these materials in a glove-box, not just an enclosure that can protect the user with lubricant and laser light containment.

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 R&D related to both discreet part fabrication and direct repairs. These systems are expensive since they are specialty machines built one at a time. In order to reduce costs for commercial grade production, Optomec has teamed with a cost-effective CNC manufacturer to produce AM and Hybrid machines that combine the best of both approaches – low-cost, robust CNC elements and proven LENS technology components, previously "packaged" LENS Print Engine for CNC upgrades and glovebox enclosure expertise. The result is a series of low price-point offerings for additive only open-air, Hybrid open-air and Hybrid with atmosphere control. The price-points for these offerings range from $250K to $400K **with the atmosphere controlled Hybrid system being the first of its kind as a commercial offering, enabling the Hybrid processing of high performance materials in a controlled atmosphere.** These types of systems can now be procured for less than half the cost of most systems on the market.

This new series of AM and Hybrid systems offerings significantly lowers the cost barriers for AM adoption and will accelerate the realization of benefits of cost and cycle-time reduction relating to AM and Hybrid fabrication and repair versus traditional fabrication and replacement practices for the DOD sustainment community.



76th CMXG Reverse Engineering And Critical Tooling (REACT)

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Sustainment of aging aircraft presents unique challenges due to the lack of complete technical data, aging legacy tooling, and the need to rapidly respond to unanticipated repairs to a wide variety of aircraft and exchangeable end items. To meet the needs of the Oklahoma City Air Logistics Complex (OC-ALC) depot customers, engineering must be responsive and leverage technology to expedite the return of aircraft and their components to service as quickly as possible. The 76th Commodities Maintenance Group (CMXG) has leveraged 3D laser scanning, additive manufacturing, and castable materials to create solutions for depot maintenance problems where traditional manufacturing is either not possible or too slow. CMXG has had great success augmenting contract and organic manufacturing by enhancing and creating technical data packages for maintaining equipment, prototyping aircraft parts, and manufacturing end-use tooling including dies, jigs, and fixtures created by direct printing or resin casting into printed molds. Specific innovative solutions include using fused deposition modeling to print weld fixtures containing internal flow cavities for argon cooling out of high temperature Ultem based polymer material to resist melting. Fixtures like this reduce costs over traditional machining but more importantly allow greatly reduced turn-around times, typically 3-6 months faster, including delivering components currently unable to be sourced. CMXG has also helped aircraft maintenance reduce flow day time and costs by modeling cracked structural members and making prototype "bath tub" fittings using a binder jet printer. These rapidly created fit check models allow for easy modification to optimize prototyping results and greatly reduced time spent machining with an overall average time savings of 3 weeks per custom repair fitting. Printing or resin casting of sheet metal form blocks has also proven to be an extremely cost and time effective route to support organic manufacturing. CMXG has shown that fully dense printed Acrylonitrile Butadiene Styrene (ABS), PolyLactic Acid (PLA), and Acrylic-Styrene-Acrylonitrile (ASA) polymer form blocks can withstand 10,000 psi from rubber and fluid cell presses with an average cost savings of $2500 for small to medium form blocks and elimination of nearly two months in lead time. Printing molds and casting form blocks from ceramic filled epoxy has also been demonstrated as a major cost and time saving technique with $3500 average cost savings per block and similar production time to printing, however these blocks are brittle and have more limitations than dense printed blocks. To date, utilization of these techniques for die block manufacture have cost avoidances totaling more than $100,000 and a combined total reduction of 284 flow days. CMXG is leveraging modern technology to deliver cost effective engineering solutions to the war fighter.

2016 Maintenance Innovation Challenge

76th CMXG Reverse Engineering And Critical Tooling (REACT)

PROBLEM STATEMENT

Sustainment of aging aircraft presents unique challenges due to the lack of complete technical data, aging legacy tooling, and the need to rapidly respond to unanticipated repairs to a wide variety of aircraft and exchangeable end items.

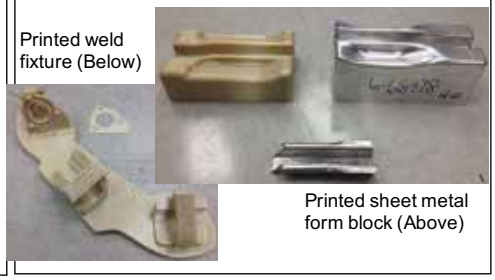
BENEFITS

- The ability to rapidly prototype parts for fit checks at very low costs and iterate design changes, this reduces material and machining time waste
- Print low production run sheet metal form blocks delivery needed manufacturing capability to the shop at lower cost and greatly reduced lead time by 8 weeks
- Create novel solutions when standard fixtures or tooling doesn't exist
- Laser scanning provides the ability to create drawings from exemplar parts or perform dimensional comparison on newly made parts to existing drawings

TECHNOLOGY SOLUTION

76th CMXG engineering has adapted rapid prototyping tools like additive manufacturing in combination with laser scanning to meet the evolving needs of depot maintenance operations.

Printed weld fixture (Below)



Printed sheet metal form block (Above)

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

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The Analysis of Resources with Visualization and Integrated Simulation Support (Jarvis) program has been instrumental in "changing the way WR-ALC does business" according to Brig. Gen. Lindsley (WR-ALC/CC) by providing an up-to-date view of depot operations by unifying data systems from financial status to engineering change data for throughput optimization. The (ARViSS) application supports a unified strategy for managing operations by providing analysis and modeling capabilities enabling analysts with a suite of tools to understand overall current state of ramp operations and project future state through "play-it-forward" simulation.

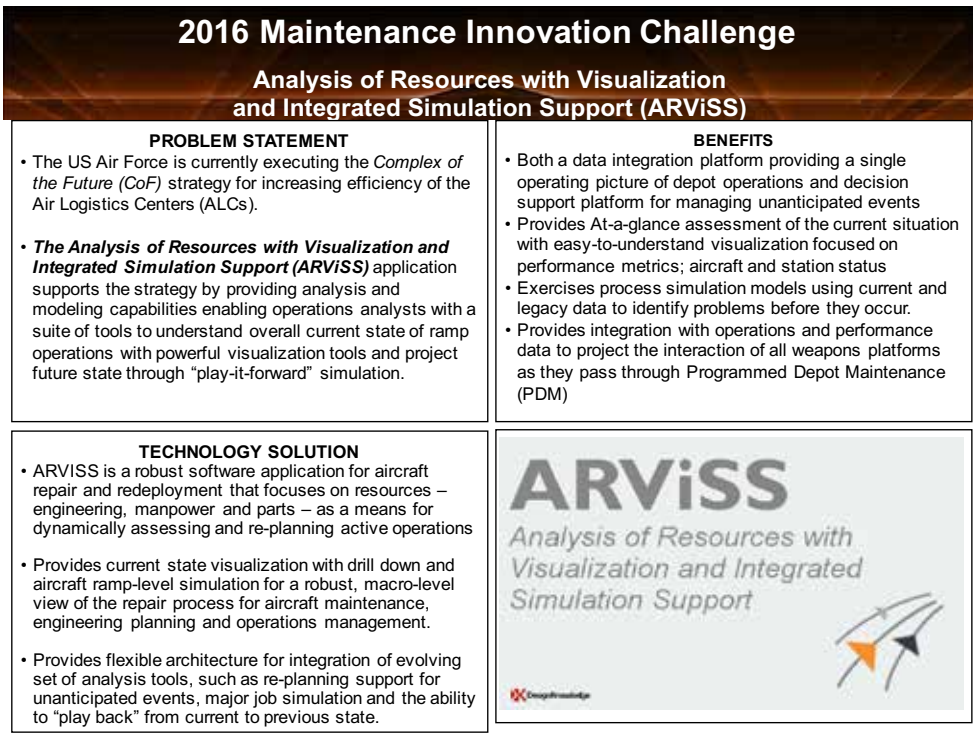
Fundamentally, ARVISS is a robust software application for the support of aircraft repair and redeployment that focuses on resources – engineering, manpower and parts – as a means for dynamically assessing and re-planning active operations. ARViSS provides powerful current state visualization with drill 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 an 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, ARVISS has been extended with the ability to maintain awareness of availability of key support machinery and assess the need for proactive maintenance through integration with condition-based maintenance hardware.

ARViSS is listed on the AF Approved Software List (ASL) and is in active use at WR-ALC.



AUTONOMIC LOGISTICS

Automated Maintenance Activity and Supply Ordering Process

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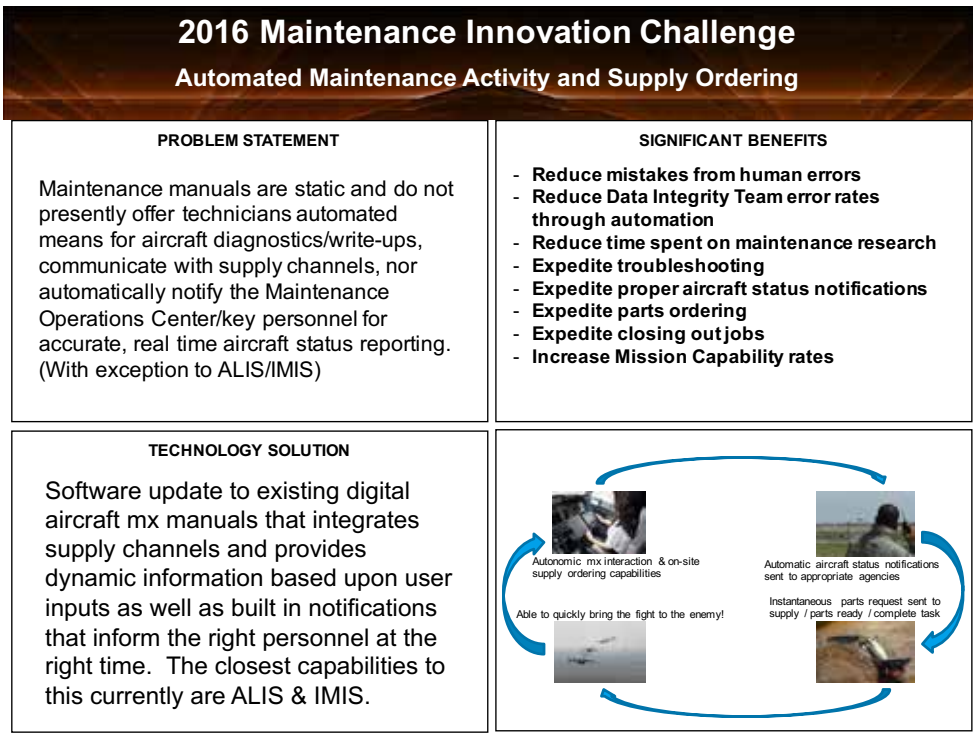
Current State: In the United States Air Force, it is known that our Aircraft Technicians spend the majority of their time preparing to perform a maintenance action. They are either in transit, logged into a computer, or inquiring about parts availability through their supply chain. The time spent accomplishing a maintenance action is only a small part of the process. Our plan listed below consolidates many of the redundancies that are inherent with manual operations while mitigating several human factors through automation. Currently, all 781 entries on the Boeing/ Gulfstream platforms at Joint Base Andrews, as well as many similarly equipped DoD bases, only use hard copy forms with a separate supply chain that isn't integrated within the same database(s) that are utilized to record these maintenance inputs.

Future State: In the future, technicians will work from a cellular or wifi enabled tablet in which the aircraft maintenance manual (AMM) and related software will be designed so that digital selections can be made from within the maintenance program itself that would create a digital write up based on minimal user inputs. Concurrently, while the technician is creating the write up, in-line troubleshooting suggestions are being presented based upon the symptoms the technician is inputting. Once the suspected faulty part or parts are identified, the technician could then be directed to a parts ordering screen that would interact with the supply chain. This cross-talk would be instantaneous, prompting notification to supply personnel, Production managers, and the Maintenance Operations Center (MOC) for status tracking purposes. Once the component(s) have been replaced, the software would interface with the MDS specific database allowing the technician to "take time" for the job from within the application. This maintenance implementation plan would increase productivity exponentially, eliminate millions of redundant wasted man hours, and ultimately producing more sorties. Our goal is to model the current Air Force and sister services maintenance culture(s) after the processes being implemented within the F22 and F35 maintenance communities.



Enterprise Service Bus

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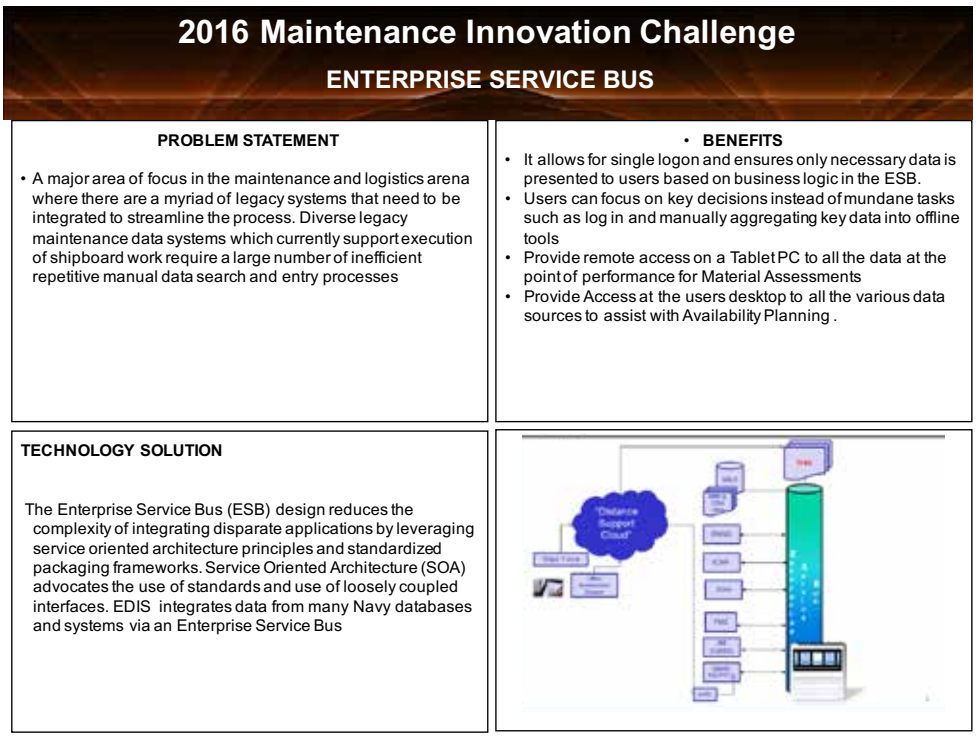
Currently, Navy, as well as Depart of defense, is moving through a period of transition impacting many facets of operations and maintenance. The Navy is facing the strain of expanding mission while dealing with diminishing resources. A major area of focus in the maintenance and logistics arena where there are a myriad of legacy systems that need to be integrated to streamline the process. Diverse legacy maintenance data systems which currently support execution of shipboard work require a large number of inefficient repetitive manual data search and entry processes. The Reliability Engineering Data Integration (REDI) System assists with automating the maintenance process. The REDI Project also provides portable tablets to modernize and reduce maintenance time on the deck plate. Naval Surface Warfare Center Philadelphia (NSWC PD) has developed an open interface modern architecture to automate interactions among the diverse Navy logistics legacy systems, called the Reliability Engineering Data Integration (REDI) System, to assist with automating the maintenance process for the assessor, planner, and maintainer. Assessments are currently completed using physical paper. Manuals often required by the sailor to understand which parts are required and outline maintenance procedures, are only available in physical form and require the assessors/sailor to leave the ship to obtain them. The ultimate goal of Readiness Engineering Data Integration (REDI) concept is to simplify, standardize and unify ship assessment and maintenance processes. REDI integrates data from many Navy databases and systems and provides remote access on a Tablet PC. Inspection is always considered to be a non-value added process. Why? If everything were done right in the first place there would be no need to inspect. If you have a Six Sigma process, you could also do away with inspection. Chances are you will miss a good amount of the defects anyway, making the inspection process pointless. Significant savings have been realized both in time and cost. Previously, it took a month trying to transcribe handwritten inputs that could be hard to read, and usually lacked information and clarity. The new assessment system using Tablets loaded with REDI saves the material assessments team hours of processing after each assessment. SERMC indicated they were able to assess 15% more systems with the same number of personnel. For INSURV REDI improved the “how Goes it’, discrepancy and 2kilo report into a Single on step process on the Tablet. REDI can help with the waste items onboard our ships! Maintenance is a multi-step process. The waste is so simple but is overlooked most of the time. If you are part of a multi-step process (PMS and other system process steps) and you cannot do your work because you are waiting for a previous step to finish their work, this also leads to the waste of waiting. Having PMS schedules and procedures, made available by REDI, will expedite workers to start working faster vice waiting for assignment from the WCS and printing of PMS procedures.



Dynamic Test Requirement-Code Architecture

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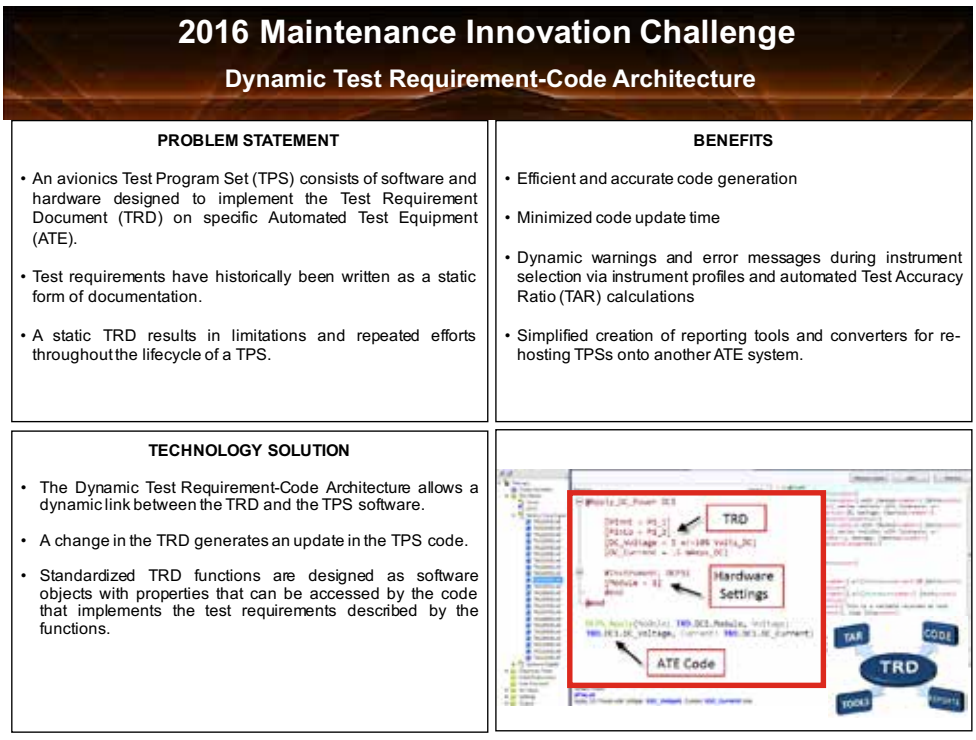
Test Program Sets (TPS) are the software, hardware and documentation used to test, diagnose, repair, and certify complex avionic systems. The development of Test Program Sets (TPS) has traditionally been divided into three main efforts: defining the test requirements, writing software, and designing hardware to implement the test requirements on specific Automatic Test Equipment (ATE). Historically, test requirements have been written as a static form of documentation, known as a Test Requirements Document (TRD). Unfortunately, a static TRD results in limitations and repeated efforts throughout the development life-cycle of a TPS. However, a dynamic TRD, using the Standard Generalized Markup Language (SGML) architecture, can improve development efficiency and end-product consistency, reduce limitations and cost, improve maintainability, and simplify creation of automation and reporting tools.

In avionics testing, a Unit Under Test (UUT) can be a single circuit card or an assembly of electronics. For each UUT, a TRD is developed to describe the stimuli, loads, and measurements required to verify UUT functionality and provide failure diagnostics to repair the UUT. The goal of a TRD is to describe the test requirements of a UUT without requiring specific test equipment. Once developed, an avionics TPS consists of software and hardware designed to implement the TRD on specific Automated Test Equipment (ATE). During the life-cycle of a UUT, TPSs are often converted (known as re-hosting) from one ATE to another due to maintainability of an aging ATE system. As a result, considerable time and cost is associated with translating the information in the TRD to the actual code in the TPS required for the specific ATE. Although it is necessary to design a TRD in an ATE-independent manner, there is no reason to completely disconnect the code from the TRD.

The Dynamic Test Requirement-Code Architecture allows a dynamic link between the TRD and the TPS software. A change in the TRD generates an update in the TPS code. The TRD content is created from a set of standardized functions that describe the stimuli, loads, and measurement requirements. These standardized TRD functions are actually software objects with properties that can be accessed by the code that implements the test requirements described by the functions. This dynamic system resulted in several benefits: efficient and accurate code generation, minimized code update time, dynamic warnings and error messages during instrument selection via instrument profiles and automated Test Accuracy Ratio (TAR) calculations, and simplified creation of reporting tools and converters for re-hosting TPSs onto another ATE system. Furthermore, an industry standard TRD can be generated from the dynamic TRD.

The Dynamic Test Requirement-Code Architecture has been in use for over a year and has resulted in an 18% reduction in TRD development time and a cost savings of 14%. More importantly there has been a 36% reduction in hardware design time and a cost savings of 42%. Additionally, the quality and consistency of the TRDs have improved due to the benefits of the new architecture.



From Manual to Semi-Automated Repair of Composite Aircraft Parts Utilizing ProvenTechnologies

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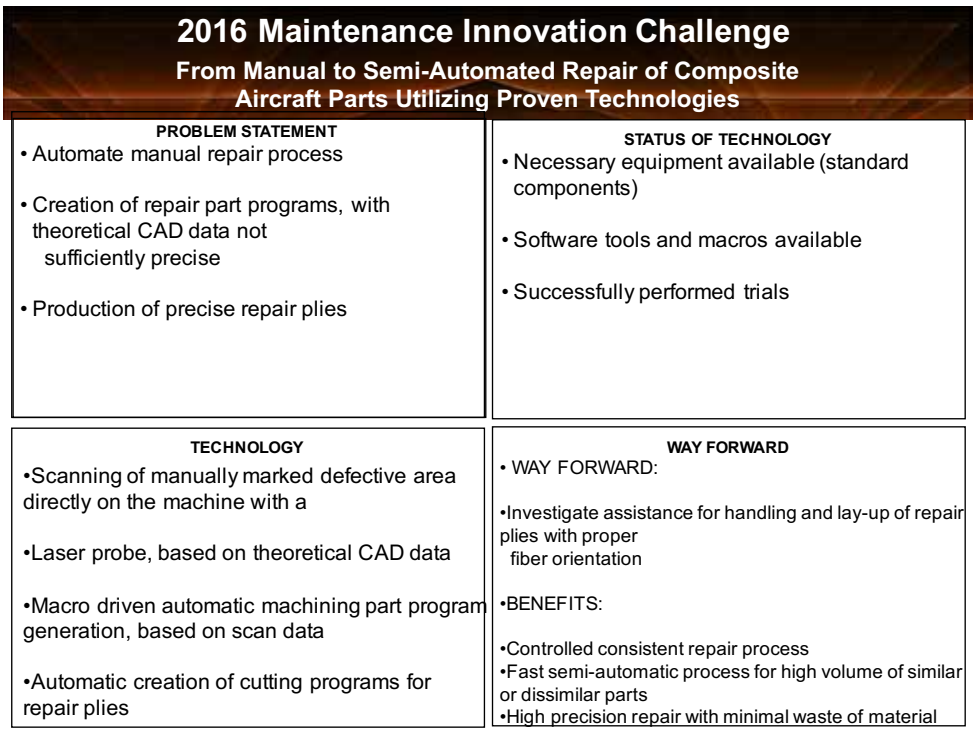
Traditional approaches to the repair of composite aircraft parts typically starts with manual NDI, or in some cases, simply a tap test, with the locations and boundaries of defects/damage marked on the part surface; then manual scarfing or step machining , to remove the defective material. Subsequently, the plies needed to replace the defective material, are typically either (A) cut by hand oversized, placed on the surface of the part over the defective area, and then trimmed to the correct size/shape, or (B) a compliant clear plastic cover foil material is placed over the defective area and the boundaries of each required replacement ply are traced onto the cover foil. The individual shapes traced on the cover foil are used as templates from which the shapes of the replacement plies are then individually traced onto the replacement ply material, and the individual replacement plies are each cut by hand.

The above replacement processes are very laborious and time consuming, and result in a considerable amount of material waste, with no way to determine/track the actual percent of material utilization, and often requires several attempts to create a complete, accurate replacement ply stack required in order to repair a single defect … and often there will be several areas on a single part which require repair.

Inherent in the above described approach involved in manual composites repair "culture" is the fact that no digital data is created during this entire repair scenario, thus there is no definitive digital data that can be reviewed relative to the location or boundary of the defect(s), nor relative to the results or to the specific processes employed for the repair … nor to tracking or reducing cost.

This paper describes the differences between manual composites repair "culture" and our now-available automation-assisted-composites-repair "culture," plus the "culture changes" that are required in order to achieve the many benefits of automation-assisted-composites-repair "culture", including consistency of process cycle times savings, and the superior results and reliable digital data, that this new proven and demonstrated approach offers to DoD depots.



Easy-to-Use Portable Vibration Data Logger

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Specialized equipment is needed to perform vibration testing on military structures, systems, and aircraft. This equipment is difficult to setup and therefore there are limited testing opportunities for engineers in the field; they often have to wait to perform testing in a laboratory or simulated environment. This poses a logistical, time, and cost burden for the military. For example, NAVAIR uses specially instrumented aircraft which costs them around $100K per test flight and can takes several months to become available for testing. The military is in need of a simpler solution to gather data in the real operational environment, in the field, cost effectively and with a much shorter lead time.

Midé Technology developed a compact, lightweight, and easy-to-use yet powerful vibration recording system as part of a RIF BAA development program with the Navy. Since this product was commercialized in 2014 the Navy has utilized 200 units to simplify and reduce the costs associated with vibration testing. Over 500 units have also helped commercial companies test and advance new technologies and systems. This testing tool reduces costs for the military while accelerating the development and qualification testing on new and enabling technologies.

The Slam Stick vibration recording system is already significantly impacting maintenance and sustainment of DoD weapon systems and equipment. They are ideal for a diverse range of testing applications with their portability, ease-of-use, selectable 3-axis measurement ranges (up to 2,000g), and powerful electronics (20 kHz per channel). They cost around $1,000 each compared to similar traditional systems that require many heavy and bulky components costing greater than $10,000. The Slam Stick vibration data logger is expected to save NAVAIR alone $3-5M in the next four years. The Department of Defense has the opportunity to save a substantial amount of money in testing by utilizing this system across other military organizations.

2016 Maintenance Innovation Challenge

Easy to Use Portable Vibration Data Logger

PROBLEM STATEMENT

- Vibration characterization of all mechanical systems is needed to provide:
  - Environmental specifications to enable design of new technology and systems for our military
  - Operational data for engineers to determine how, why, and when components fail
  - Qualify new systems
- Currently a significant labor and material investment is needed to outfit aircraft with required equipment and instrumentation
  - Costs approach $100K per test flight
- Limited number of outfitted aircraft results in long lead times for engineers

BENEFITS

- Cost effective
  - Ranges from $1,000 to $2,500 per unit
- Wide measurement range
  - ±25g, 100g, 500g, and 2,000g options
- Time stamped data to correlate vibrations to known events
- High sample rate (20,000 Hz per channel)
- Long rechargeable battery life (>12 hours)
- Lightweight (40 grams for plastic, 65 for aluminum enclosure)
- Shock, vibration, and EMI qualified
- Over 4 billion data points of onboard memory
- Micro-USB for set-up and download
- Expected NAVAIR savings of $3-5M in four years
- Commercially available

TECHNOLOGY SOLUTION

- Developed in a Navy RIF BAA program
- Handheld unit embedded with:
  - Two triaxial accelerometers (one for high frequency shock and vibration, another for lower frequency)
  - Temperature and pressure sensors
  - CPU for data processing, triggering recordings, and time stamping
  - Analog filters
  - Battery for power in remote locations
  - >2GB of memory for large recordings
- Easy to use and free software for data processing and analysis

Cost-wise Cyber Risk Management Using Static RAM Drives

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As a result of the increase in cyber threats and attacks upon military and civilian systems, the Department of Defense (DoD) has issued policy aimed at modernizing the security posture of Weapons Systems. At Naval Air Systems Command (NAVAIR), support equipment is connected directly to avionics systems and used to overwrite software which operates avionics equipment. That avionics equipment is critical to safe, effective execution of the aircraft mission. Insertion of malicious software to compromise a tactical mission will have a real impact on physical systems. Effective cyber-attacks seek to impact physical systems. This paper describes a low-cost technical solution to reduce cyber risk across all DoD Information Technology (IT) enabled systems.

Fleet Readiness Center South East (FRCSE) has over 750 unique IT-enabled industrial systems. Those systems include all manner of Depot maintenance equipment, but two critical systems include Programmable Read-Only Memory (PROM) programmers and Computer Numerical Control (CNC) machines. These systems are critical because PROM programmers load the final software onto circuit card chips that fly in Weapon Systems and CNCs produce flight critical mechanical parts. A cyber-attack to compromise either D-level system will produce compromised repair parts flying on an aircraft and ultimately impact the kill chain. In an effort to ensure the Depot produces parts that are "Cybersafe," FRCSE is developing a Static Image Random-Access Memory (RAM) Drive (SIRD). The SIRD stores the computer Operating System (OS) in a known-good state, on a read-only drive. Upon boot, that drive is loaded into RAM so the OS can function transparently as it would with any other read/write hard drive. Any malicious code or compromised software loaded during operation is contained in the volatile RAM memory and destroyed during power-down. FRCSE implements a power-down cycle as part of the process to produce a "Cybersafe" certified part. This ensures the industrial equipment is returned to a known-good state prior to creating each new part. Because this is a hardware solution to ensure configuration control, it is software agnostic and will work with any Operating System or installed applications. The process is to simply clone the existing computer hard drive onto the SIRD, apply security controls to lock down the software image, and then replace the old physical drive with the SIRD. A method is under development to update the read-only image as required from a digitally-signed, encrypted, update source. A method also exists for persistent data storage that survives reboot if necessary.

FRCSE is piloting a limited capability Commercial-off-the-shelf (COTS) solution today that costs roughly $500 per system. Conversely, the cyber approach to-date has been to upgrade each system from Windows XP to Windows 7, then again to Windows 10, and then again and again as future software becomes obsolete. That approach is expensive, unsustainable, and is not an effective way for the DoD to spend scarce dollars. The SIRD technology development will greatly reduce cyber risk from these maintenance systems in a cost-wise manner. FRCSE has a provisional patent on the technology.

2016 Maintenance Innovation Challenge

Cost-wise Cyber Risk Management Using Static RAM Drives

PROBLEM STATEMENT

Depot avionics and mechanical parts are repaired using cyber-vulnerable industrial systems. Examples include programmable chips installed on circuit cards and machines that fabricate flight critical mechanical parts. The cost to modernize legacy Operating Systems and software is expensive, recurring, and won't yield the desired risk reduction. How can DoD Depot repair facilities ensure they are producing "Cybersafe" parts?

BENEFITS

1. This disruptive technology will reduce cyber-risk to nearly all DoD Information Technology (IT) enabled systems at low cost.
2. Hardware solution is software agnostic. i.e. will work for all Operating Systems and software.
3. Breaks the cycle of updating legacy systems to the latest software and patching.
4. Provides a technical solution for risk reduction of legacy systems that are too expensive or impossible to upgrade.

TECHNOLOGY SOLUTION

Develop a Static Image Random Access Memory (RAM) Drive (SIRD) as a form-fit-function replacement for a standard hard drive. Booting is only allowed from an encrypted, authenticated, validated, static image of any Operating System and software. Only files on the RAM drive are executable at boot. Any malicious software encountered during operation remains in volatile memory and will be destroyed by cycling power.

Managing Software Obsolescence through Virtual Applications

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Managing software obsolescence for Department of Defense (DoD) systems has always posted a particularly difficult challenge for programs with limited support and sustainment dollars. The DoD must balance the need for cutting edge technology development during the early program lifecycle with the need for sustainability 20, 30, even 40+ years into the life of the Weapon System. Programs spend thousands of hours and millions of dollars thoroughly testing systems prior to fielding. Once the Weapon System is out of production, test and evaluation of software changes becomes increasingly costly and less likely. The result is increased risk to operational efficacy of DoD systems. Cyber security concerns drive updates that are otherwise unnecessary and do not add value to Weapon System capability. This paper describes a technical solution to package legacy software as "Virtual Applications" and execute that software on modern Operating Systems (OS).

The DoD spent millions of dollars migrating away from Windows XP to Windows 7 when Microsoft dropped support for the Operating System on 30 April, 2014. Many applications had to be re-written and re-tested, driving hardware changes, process changes, and unnecessary cost. That process is repeating again as programs try to transition from Windows 7 to Windows 10 Secure Host Baseline per DoD CIO Policy Guidance released on 25 February, 2016. Instead of re-writing a program to run natively on the new host OS, software programs can be deployed as Virtual Applications. Virtual Applications allow a program to execute in a virtual bubble running on a Just Enough Operating System (JeOS). The JeOS only contains pieces of the original OS necessary to run the virtual application. This differs greatly from Virtual Machines that recreate an entire operating system in a virtual environment. A virtual application does not allow the user to logon or access the virtual OS. NAVAIR Fleet Readiness Center South East (FRCSE) has tested several tools and packaged many traditional applications as virtual applications. VMWare's ThinApp tool is the best in class tool. Here's how it works. First, install a clean operating system in a virtual environment. ThinApp takes a snapshot of system settings after the clean install. Second, install the application and all dependencies. ThinApp takes a snapshot post-install and determines what settings, files, and components are required for the application to run. The needed components are bundled with the application and packaged into a single executable. That executable is self-contained with everything needed to run the software. The virtual application is then transportable to another OS. No license fees are required for each virtual application instance.

2016 Maintenance Innovation Challenge

Managing Software Obsolescence through Virtual Applications

PROBLEM STATEMENT

Managing software obsolescence for Department of Defense (DoD) systems has always posted a particularly difficult challenge for programs with limited support and sustainment dollars. Cyber security concerns push applications to be re-written and re-tested, driving hardware changes, process changes, and unnecessary cost. How can the DoD minimize cyber-risk, without continually updating all software when Operating Systems reach end-of-life?

BENEFITS

1. This disruptive technology will reduce cost to maintain obsolescent software across nearly all DoD systems.
2. Programs that have been thoroughly tested through fleet operation do not have to be re-written, thus reducing risk to operational efficacy.
3. Multiple applications with conflicting software dependencies can operate cohesively on a single machine.
4. Breaks the cycle of OS-driven software updates.

TECHNOLOGY SOLUTION

Software programs can be deployed as Virtual Applications instead of being re-written to run natively on the new host Operating System (OS). Virtual Applications allow a program to execute in a virtual bubble running on a Just Enough Operating System (JeOS). The JeOS only contains pieces of the original OS necessary to run the virtual application. That executable is self-contained with everything needed to run the software. It is then transportable to run on any updated host OS.

GRAPHIC

FRCSE has packaged applications in a virtual Windows XP 32-bit OS and run them on a Windows 7 64-bit host OS. FRCSE has also packaged systems with conflicting dependencies, i.e. one application requires Java 7, another requires Java 8, and both must run on the same physical machine. That was previously impossible, but when packaged as virtual applications, both run seamlessly side-by-side. This disruptive technology will revolutionize support and sustainment of obsolescent software across the DoD.

Munitions Integrated Tablet

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Logistics functions throughout the Air Force use a variety of IT systems. Technology has reached the point where tablet-based solutions can integrate multiple systems and revolutionize Air Force logistics.

The current IT landscape in the USAF munitions community presents numerous operational constraints. To complete a single task our technicians must utilize at least 3 separate CAC enabled devices: a desktop PC located away from the worksite for hazard classification data and work order processing, a laptop PC for technical manuals, and a Hand Held Terminal for asset movement and inventory management input. Each task requires processing at the worksite and back in the office which adds, on average, 30 minutes to each task.

Each of these systems require capital investment. The purchase price alone for these systems are in excess of $7000, considering the cost of a desktop is ($500), rugged laptop is ($3400) and hand held terminal are ($3000) (AFWAY USAF, 2016).

The MIT solution is centered on a Windows-based tablet which consolidates all IT resources into a single DoD network compliant tablet PC at the current cost of $3200 each. This single IT gateway currently consolidates applications and productivity capabilities of standard desktops and provides a true mobile computing solution. In our current configuration the MIT delivers all desktop productivity, Technical Orders, and Combat Ammunition System Automation Information Technology, (CAS-AIT) in one CAC enabled device.

In addition, the MIT is delivered on a MIL-STD 810G rugged platform and delivers true mobility through perpetual connection to AFNET and the internet. This connection is ensured through a triad of connectivity capability: wired, 802.11 Wi-Fi, and cellular. The MIT is Hazards of Electromagnetic Radiation to Ordnance (HERO) certified and approved for use in both conventional and nuclear munitions operations.

All certifications and network authorizations have been obtained and the MIT is fully mission capable. Since the inception of the project 24 months ago, the MIT project team has installed 1178 MIT's at 31 locations across the AF enterprise.

We believe the MIT to be the premier IT platform that delivers a ground-breaking standard of mobile connectivity to the DoD munitions community. It puts all of an enterprise's IT power in an individual's hands at the work site.

2016 Maintenance Innovation Challenge

Munitions Integrated Tablet

PROBLEM STATEMENT

- Deliver Auto data entry and all IT resources/ Maintenance Information systems (MIS) to Munitions Storage Area/Flight-Line maintainers on a single fully connected device.

BENEFITS

- The MIT consolidates all IT resources into one DoD network compliant tablet PC, $3200 per device.
- Delivers productivity, standard desktop all Technical Orders, (TOs), and Combat Ammunition System, Automation Information Technology, (CAS-AIT) in one CAC enabled device.
- 45% IT capitol investment reduction over current state (3 systems $7K, MIT $3K).

TECHNOLOGY SOLUTION

- Munitions Integrated Tablet (MIT)
  -- Getac F110 Tablet
- Mobile barcode printers
- Combat Ammunition System
- Enhanced Technical Information System
- Automated Identification Technology
- Global Combat Support System
- Enterprise Data Collection Layer
- Connectivity, AFENT, Wi-Fi and Cellular

Deploying an Internet of Things for Automatic Test Equipment

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The trend in high capital asset businesses is towards implementing an Internet of Things (IoT); a network of physical devices, with embedded electronics, software, sensors, and network connectivity, which enable these devices to collect and exchange data. In the case of the DoD electronic maintenance enterprise, the value of an IoT approach is the source of data - smart devices such as Automatic Test Equipment (ATE), which generate data about test activities, maintenance events and the ATE asset itself. This data provides visibility into performance and decision processes across the maintenance enterprise. ATE systems produce volumes of test results, self-test, calibration and other parametric data, as a natural by-product of the diagnostic and/or acceptance testing process. The value that can be derived from all this information is often not recognized or effectively utilized. Whether the data is analyzed to reveal additional insights about specific ATE systems or the end items they test, Units Under Test (UUTs), or whether the data is used to generate predictive insights into the degradation of equipment performance to predict failures before they occur, an ATE IoT provides the foundation necessary for deriving the value from the insights that analysis of the data can provide.

In order to attain the economic and operational benefits from the data in an ATE IoT (and potentially other data sources), one must begin by establishing connectivity to the ATE. Then, automatically and regularly, begin collecting the data from the ATE, transforming, integrating and storing the data in a common open standard format. This ATE IoT enables the Data Acquisition (DA) and Data Manipulation (DM) layers of the ISO 13374/OSA-CBM functional model, as well as data exchange and interoperability of data and information across O, I and D-levels of maintenance organizations, program-specific Automated Logistics Environment (ALE) and other enterprise systems. This first step also enables a progressive implementation of the other OSA-CBM layers; State Detection, Health Assessment, Prognostics Assessment and Advisory Generation. Hence, in order to unlock the potential of an ATE IoT, a solution must address connectivity to the ATE, integrate ATE/UUT test results and maintenance action information with health monitoring data produced by the system itself, to the troubleshooting, test and repair data produced throughout the maintenance process , and provide for data storage, exchange and interoperability using open standards.

The System Health Record (SHR) technology is an IoT-based application that provides a solution for ATE data connectivity, data capture and transformation, data management and exchange. Through automated, user-friendly machine learning engines, relevant predictive insights information can be generated on a routine basis to monitor both the health of the ATE and effectiveness of the test applications and provide insight into the overall maintenance operations, usage and probable life expectancy of weapon systems and subsystems. The SHR integrates IEEE STD 1636.1 Test Results and 1636.2 Maintenance Action compliant Information for data exchange. The SHR enables the ability to achieve cost reductions by improving maintenance effectiveness and ATE/Test Program Set sustainment. The SHR is a CBM+ enabling technology.

2016 Maintenance Innovation Challenge

Deploying an Internet of Things for Automatic Test Equipment

PROBLEM STATEMENT

There is an need for DOD maintenance organizations to leverage **Big Data** technology **using** data from Automatic Test Equipment and other related data sources to:

- Enhance both the **efficiency** and effectiveness of the **ATE applications,**
- **Monitor the health of the ATE assets,**
- **Improve** maintenance operations
- Provide **predictive** insight into the health condition, trends and probable life expectancy of weapon systems and subsystems

BENEFITS

- Immediate, actionable insights for the maintenance organizations at the point of maintenance
- Ability to conduct analysis of the data and develop predictive insights
- Maintenance cost reductions
- Improved platform readiness
- Improved maintenance turnaround
- Improved maintenance effectiveness and efficiency
- Improved maintenance business process
- Faster and better decisions
- Robust, open, modular, flexible, lower cost technology infrastructure

TECHNOLOGY SOLUTION

- **The System Health Record (SHR) is an IoT-based application that provides a solution for ATE data connectivity, data capture and transformation, data management and exchange**
- An infrastructure to enable Big Data analytics
- A means to facilitate availability of relevant test and repair data across all levels of maintenance (O/I/D/OEM)
- An open standards-based architecture (ISO 13374, OSA-CBM, IEEE 1636.x, IEEE 1671.x, etc.) to facilitate interoperability and exchange of health status, test and maintenance data with other systems

Automated Data Cleanser for Just-In-Time Maintenance Risk Discovery

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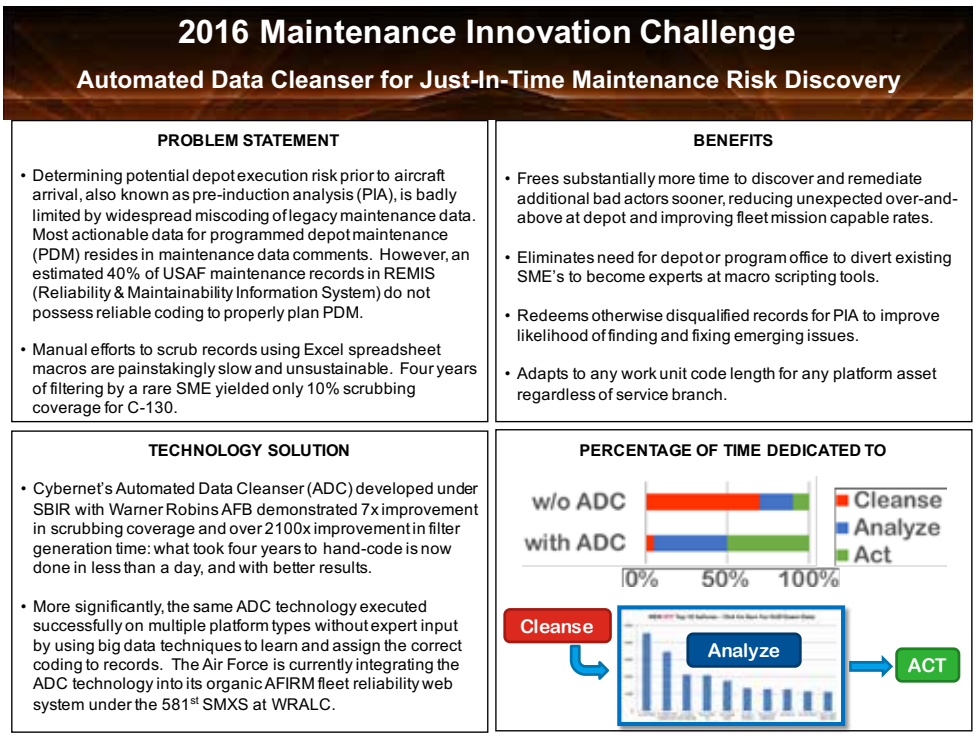
Determining potential depot execution risk prior to aircraft arrival, also known as pre-induction analysis (PIA), is badly limited by widespread miscoding of legacy maintenance data. Most actionable data for programmed depot maintenance (PDM) resides in maintenance data comments. However, an estimated 40% of all USAF maintenance records in REMIS (Reliability & Maintainability Information System) do not possess reliable coding for PDM. Manual efforts to scrub records are painstakingly slow and unsustainable: four years of filtering by a rare SME yielded only 10% scrubbing coverage for C-130.

Cybernet's Automated Data Cleanser (ADC) developed under SBIR with Warner Robins AFB demonstrated 7x improvement in scrubbing coverage* and over 2100x improvement in filter generation time**: what took four years to hand-code is now done in less than a day, and with better results. More significantly, the same ADC technology executed successfully on multiple platform types without expert input by using big data techniques to learn and assign the correct coding to records. The C-130 Hercules Division Structures and Integrity Engineering Section Chief at AFLCMC/WLNEB described the ADC technology as "revolutionary for managing legacy USAF maintenance data." The Air Force is currently integrating the ADC technology into its organic AFIRM fleet reliability web system under the 581st SMXS at WRALC.

The ADC uses the discrepancy and corrective narrative text entered by pilots and maintainers to train itself without a priori knowledge. The ADC then applies a multi-stage cleansing process to correct the alphanumeric maintenance work unit codes (WUC) that identify the system, sub-system, and component worked on. For example, a poorly coded record with WUC "11000 Airframe" may be corrected to "1128B Nose Landing Gear Hydraulic Door Support." The ADC successfully tested on four platforms (C-130, F-15, C-5, E-8C) with three to five years of data consisting of hundreds of thousands of records each, and executed in less than a day.

The ADC module is plug-and-play: coded in Java it takes a database file as input and outputs the corrected work unit code into the same database. The ADC only requires each maintenance record to include a WUC and a descriptive text. The module will adapt to any work unit code length for any platform asset regardless of service branch, enabling its potential impact to extend across the DoD maintenance community. The ADC redeems otherwise disqualified records for PIA to improve the likelihood of finding and fixing emerging issues. Most importantly, it frees substantially more time to discover and remediate additional bad actors sooner, reducing unexpected over-and-above findings at depot and improving fleet mission capable rates.



*Based on 1500 random samples of C-130 records: 115 evaluated by manually developed Excel macros vs. 780 evaluated by ADC for 7x more coverage.

**Based on 3200 filters (C-130) hand-coded over four years (2.2 filters/day) vs. 7420 generated by ADC in 1 day (7420 filters/day) for 3385x speedup; and 740 filters (F-15) hand-coded in 6 months (4.1 filters/day) vs. 3860 generated by ADC in 1 day (3860 filters/day) for 939x speedup, resulting in over 2100x average speedup.

Enhancing Maintenance with Augmented and Mixed Reality Technologies

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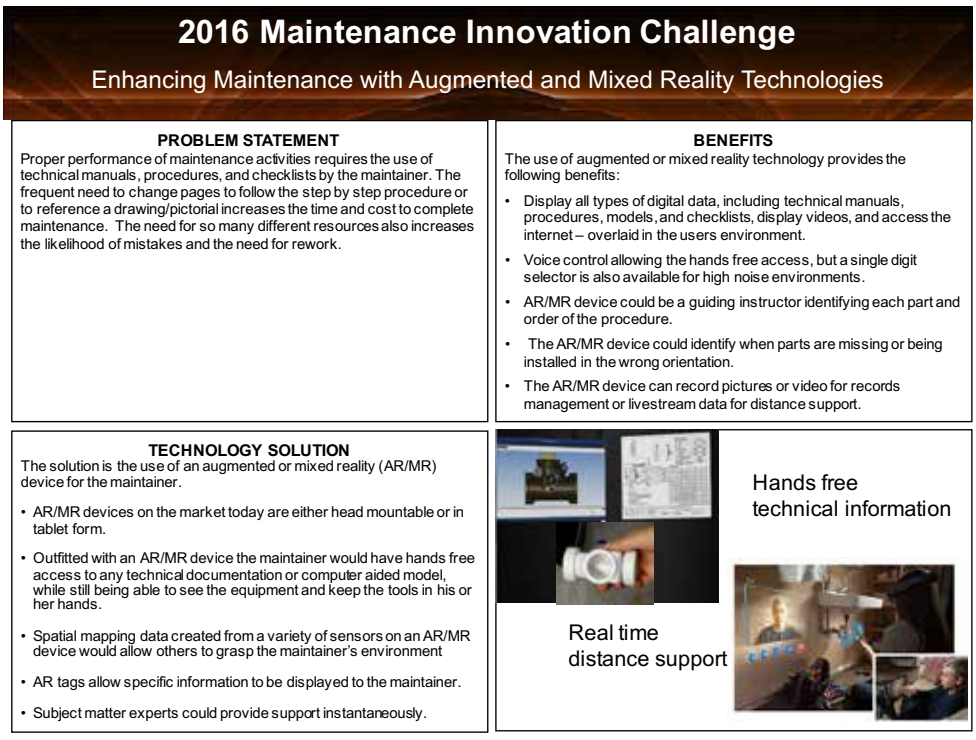
Proper performance of maintenance activities requires the use of technical manuals, procedures and checklists by the maintainer. The frequent need to change pages to follow the step by step procedure or to reference a drawing/pictorial increases the time and cost to complete maintenance. The need for so many different resources also increases the likelihood of mistakes and the need for rework.

The solution is the use of augmented or mixed reality (AR/MR) technologies for the maintainer. AR/MR technologies on the market today are either head mountable devices, allowing hands free access, or in tablet devices, which could be positioned for hands free accessibility. Both types of devices are able to display digital data, including the above mentioned technical manuals, procedures and checklists, but they also display videos and access the Internet. Some devices are wired, while others are wireless. Voice control is also a common feature, allowing the hands free access, but a single digit selector is also available for high noise environments.

Outfitted with an AR/MR device the maintainer would have hands free access to any technical documentation while still being able to see the equipment and keep the tools in his/her hands. However, the use of the AR/MR device can be more than just a digital assistant holding a digital document in front of one's eyes. The AR/MR device could be a guiding instructor identifying each part and their order in the procedure through AR tags that display information when viewed. The AR/MR device could also identify when parts are missing or being installed in the wrong orientation. An AR/MR device would also allow the maintainer to wirelessly control certain devices. Finally, the AR/MR device would be able to record videos or still pictures to be sent to a subject matter expert (SME) for assistance. If the need for assistance is immediate, the SME can communicate with the user in real time through a live feed. For a more detailed analysis of the environment, the AR/MR device would allow the maintainer to scan their surroundings and create a three-dimensional image of the space so that the SME would be able to see exactly what the maintainer is seeing without having to travel to their location, reducing maintenance time and cost.

The use of this technology is currently being explored by manufactures and independent developers. NSWC Philadelphia has procured or is in the process of procuring Microsoft's HoloLens, Epson's Moverio BT-200 and BT-300, ODG's R-7 Smartglasses, and Meta's Meta 2 Development kits to explore use cases in the Navy. Testing has been initiated regarding the ability for distance support. Communication between two Hololens has been successful in testing. This allowed the users to see what the other is seeing, as well as having the ability to share annotations among the users. The application of this technology to enhance the maintainer's ability to accurately and quickly perform maintenance activities requires an evaluation of the technology in a realistic environment. NSWC Philadelphia's Land Based Engineering Station, which has a working DDG51 Main Machinery space onsite, would be an ideal environment to evaluate these AR/MR devices.

The business case for this application still needs to be developed. However, since technical manuals and procedures are already digitalized, and AR/MR devices only cost around $500-$3000 per device, the ROI of this application should be exceptional.



Asset Life-Cycle Information Management (ALCIM) Program

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

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

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

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

This combination of the LifeMeter and ARViSS programs combined with intelligent machine condition monitoring provides for a complete machine asset assessment reporting and decision aiding system that can be extended AF-wide for critical machine asset maintenance and troubleshooting solution.

2016 Maintenance Innovation Challenge

Asset Life-Cycle Information Management (ALCIM)

PROBLEM STATEMENT

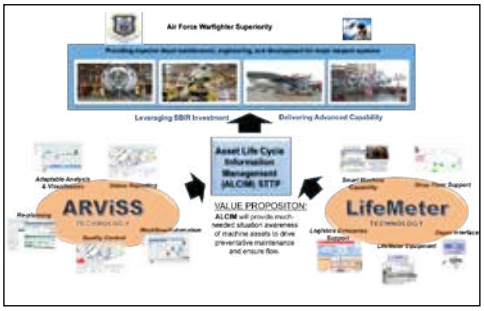
- The Air Force has a ***need to reduce the impact of machine asset downtime on AF Support Squadron*** activities to achieve the *Air Force Complex of the Future: Efficient Depot (Attribute #4) and Intelligent Sustainment Network (Attribute #7)* goals.
- Providing continuous operations support for *Efficient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

BENEFITS

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

TECHNOLOGY SOLUTION

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



Replicating Tyndall AFB's Innovation Flight

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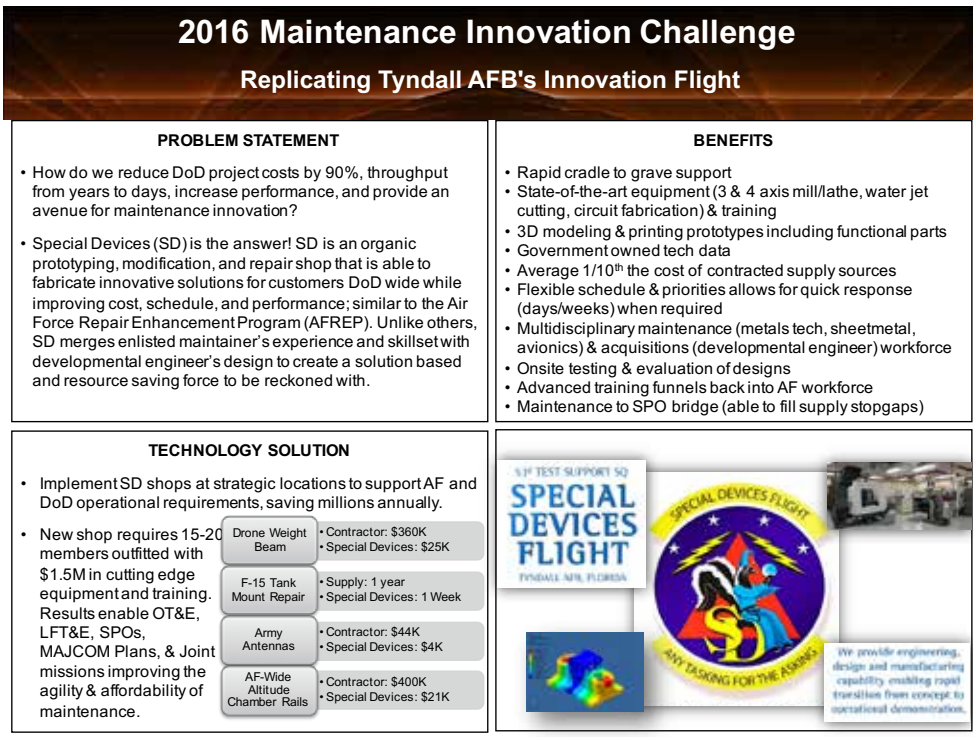
Maintenance and acquisition communities provide ample opportunities for creative solutions to everyday obstacles faced throughout our Air Force and DoD. The issue, however, is their capabilities are disconnected preventing ideas from becoming realized. Maintenance personnel often identify shortcomings and have the manufacturing skill-set, but fall short on design and resources. Acquisitions often knows key players, can wrangle the resources, and design the solution, but do not have access to manufacturing without contracts. So the question becomes: How do we provide DoD maintenance and acquisitions with professional engineering, design, and manufacture capabilities enabling its solutions rapid transition from concept to certified operational demonstration?

Enter Special Devices Flight, a small test support flight at Tyndall AFB that does just what the question above asks. The flight is comprised of 15-20 enlisted maintainers and acquisitions officers utilizing $1.5M in specialized equipment and training who are able to complete over 110 unique projects annually. Divided up into three sections, Avionics, Fabrication, and Engineering, the Flight's solutions are regularly a tenth of the cost of contracted work and exceed its customer's time and performance expectations. The projects support a variety of initiatives including Operational Test & Evaluation, Live Fire Test & Evaluation, System Program Offices (SPO), MAJCOM Plans, and sister service requirements. It enables rapid solutions to fill supply gaps, increase efficiency, and empower Airmen.

The proposed solution for the Maintenance Innovation Challenge is to implement additional regionally based Special Devices shops globally where they can best serve the maintenance and acquisition communities. For example a shop at Nellis AFB could serve the western US test community, space operations, and depot at Hill AFB. Two other shops, one each in EUCOM and PACOM would provide access for 422,000 military and civilian personnel working in the region. These locations would enable a flexible outlet where innovations are realized quickly and at a substantial cost savings to the government. Maintainers can implement process improvement; Program Offices can overcome supply hurdles and modifications. An illustrative example occurred when OSHA deemed the Air Force out of compliance after finding no safety rails on any of its 12 altitude chambers. Contractors bid the job for $400K, but Special Devices was able to solve this Air Force wide dilemma for just $21K. Another example comes from a broken F-15 conformal fuel tank (CFT) bracket at Seymour Johnson AFB. The situation quickly escalated as there were no spare CFTs and supply had no brackets in inventory. Special Devices was contacted and began coordination with the SPO. The part was shipped, repaired, and installed back on the tank rendering aircraft fully mission capable within a week.



This concept of organic repair shops and embedded engineers within maintenance is not new and has been paying huge dividends for more than a decade. The Air Force Repair Enhancement Program (AFREP) for electronics and the Depot Liaison Engineer positions in the AOR are on the ground assisting maintainers daily. Additional Special Devices Flights would provide needed outlets for maintenance and acquisition innovations which would improve DoD maintenance agility while reducing overall costs drastically.

Maintenance Benefits From ESPC At Rock Island Arsenal JMTC

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The Rock Island Arsenal Joint Manufacturing and Technology Center (RIA-JMTC) is the only multi-purpose and vertically integrated manufacturing center in the Department of Army and possesses the unique technical expertise and equipment necessary to the war-fighter while maintaining unsurpassed capability and quality. The RIA-JMTC's 16 critical manufacturing capabilities span the entire range of manufacturing capabilities from foundry and forging operations continuing through final assembly operations and shipping. The RIA-JMTC is a major tenant of the Rock Island Arsenal managed by the Rock Island Garrison.

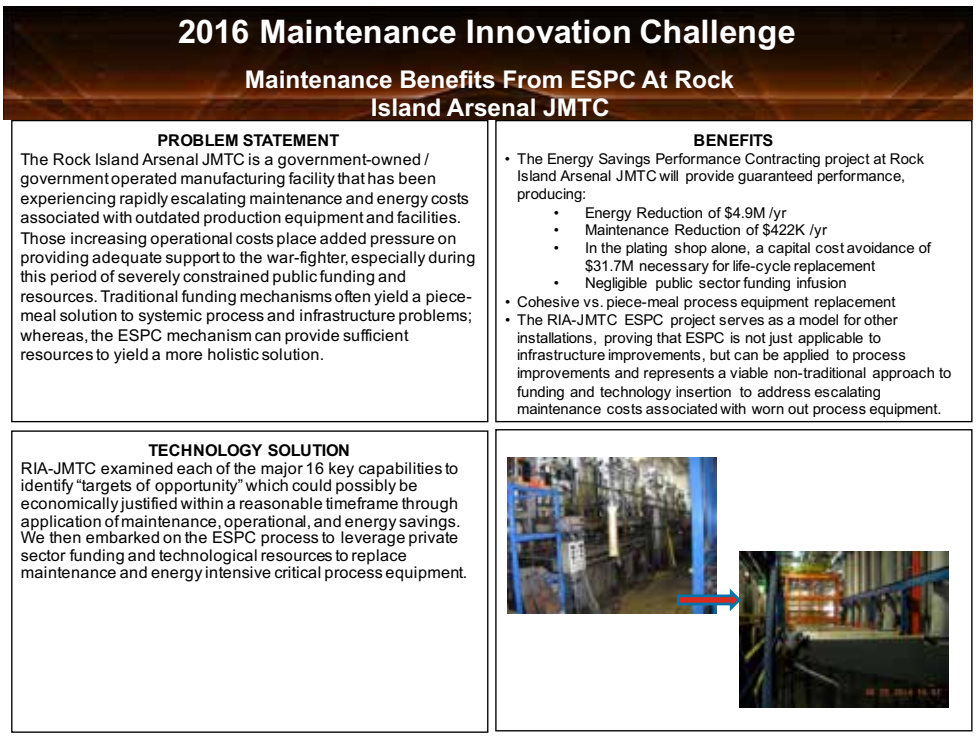
Faced with an aging infrastructure, critical process equipment at the end of its projected useful life, spiraling maintenance costs, regulatory environmental and energy compliance requirements, and fiscal uncertainties, RIA-JMTC embarked on a multi-year Energy Savings Performance Contract (ESPC) project. In addition to eliminating reliance on public sector funding by utilizing private sector funding, the project is highly innovative as it deviates from the traditional infrastructure-focused approach in favor of a process-centric examination of energy, maintenance, and operational improvements. RIA-JMTC was able to leverage that project to tackle not only energy savings and environmental compliance issues, critical process upgrades, while achieving dramatic reductions in both preventative and corrective maintenance intensity, but also obtain safety and operational improvements.

While ESPC must be economically justified by recurring energy savings, the process is generally focused on infrastructure alone. As RIA-JMTC has demonstrated, energy intensive manufacturing processes, combined with significantly reduced maintenance requirements can provide sufficient justification to refocus on critical process improvements.

The cornerstone of the RIA-JMTC project was the renovation of the Metal Finishing Plant (electroplating and conversion coatings). The renovation involved switching from brick-lined open-top plating tanks with massive air scrubbing and air make-up requirements to engineered material closed-top tanks, dramatically reducing air handling requirements and associated maintenance of make-up air units and wet scrubbers, all while providing greater flexibility for plating bath recipes and processes.

The RIA-JMTC ESPC Project enabled the transition from a centralized coal fired boiler plant to decentralized packaged natural gas boilers, gas-fired infra-red radiant heat in the production areas, and variable refrigerant flow heat pumps; thereby greatly reducing the inefficiencies and maintenance related to long-run steam distribution systems while eliminating 63 million pounds per year of carbon dioxide emissions. HVAC improvements included the adoption of a locally managed Energy Management Control System (EMCS) for improved control and predictive maintenance.

The efficiency improvements enjoyed by RIA-JMTC have been actively socialized and have served as a catalyst for ESPC projects at the Rock Island Garrison and attracted the interest of Letterkenny Army Depot, Corpus Christi Army Depot, and other installations.



Optimizing Aircraft Availability: Enabling Maintenance to Deliver Cost Effective Readiness (CER)

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In order to achieve and/or extend its service life, aircraft require maintenance. An effective maintenance program is paramount to successfully managing aircraft. This is especially true for the USAF and DoD, given the longer-than-commercial life cycles of DoD aircraft. While in maintenance, however, aircraft are not available for missions. In order to ensure a given fleet has enough aircraft to "fly, fight, and win", Aircraft Availability (AA) targets are established, as well as targets for all five non available categories:

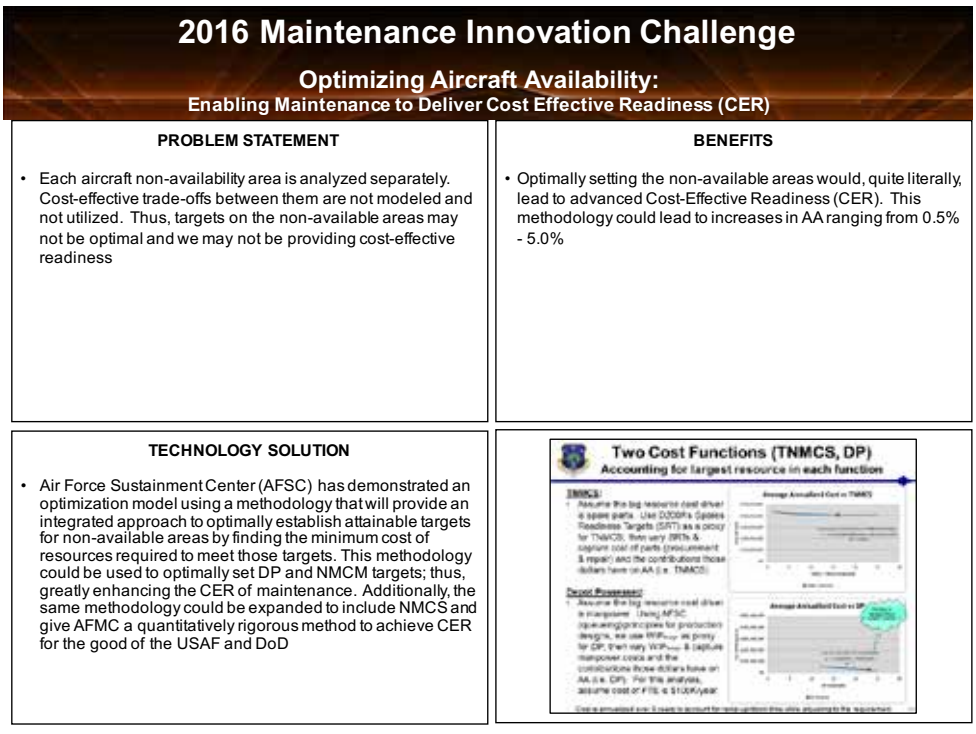
1. Depot Possessed (DP)
2. Non Mission Capable Maintenance (NMCM)
3. Non Mission Capable Supply (NMCS)
4. Non Mission Capable Both (NMCB)
5. Unit Possessed Not Reported (UPNR)

The Air Force Sustainment Center (AFSC) has advanced Cost Effective Readiness (CER) on the B1 by using techniques from nonlinear programming. These techniques could be used to 'right size' DP and NMCM; thus, improve the maintenance environment on a fleet by fleet bases. The paragraph below was taken from an AFSC document. It is included because it provides insights into the underlying general (optimization) methodology and highlights that the methodology could be exported to other fleets in AFMC in a reasonable amount of time.

"The AFSC is the majority owner of three reasons an aircraft could be unavailable for its mission, called non-availability areas: Depot Possessed (DP), Non Mission Capable Supply (NMCS), and Non Mission Capable Both (NMCB). Attainable targets are set for non-availability areas under the premise that meeting them will improve aircraft availability. However, each non-availability area is assessed and analyzed separately so the targets are established in isolation of each other. As such, the underlying premise does not necessarily hold at the enterprise level, and therefore, AFSC may not be executing the most cost-beneficial use of resources. The proposed methodology will provide AFSC with an integrated approach to optimally establish attainable targets for non-available areas by finding the minimum cost of resources required to meet those targets. This is a first step toward the goal of operationalizing CER in AFSC, and it has implications beyond AFSC."

The methodology above was applied to a case study on the B1 and the new, yet-to-be-validated optimization model showed that adding the 'next dollar' to spare parts (i.e.. NMCS) would lead to higher AA than depot possessed (DP) aircraft. While the model has not been officially validated, its conclusion was consistent with an IPT that ultimately led to the 448 SCMW changing the S-rate target (i.e.. more spare parts to improve NMCS) in our (D200A) inventory model.

This methodology could be used to optimally set DP and NMCM targets; thus, greatly enhancing the CER of maintenance. Additionally, the same methodology could be expanded to include NMCS and give AFMC a quantitatively rigorous method to achieve CER for the good of the USAF and DoD.



Naval Maintenance Ecosystem

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The Naval Shipyards are responsible for the depot maintenance of various Navy vessels and are in the early stages of forming an increased functionality to create a long-term, modular environment that enables rapid growth and adaptation to support future technologies. These efforts are necessary to maintain pace with the increasing demands for maintenance and modernization. This environment is termed an "Ecosystem" in that it will allow various solutions to co-exist with each other, growing, maturing and being replaced as necessary.

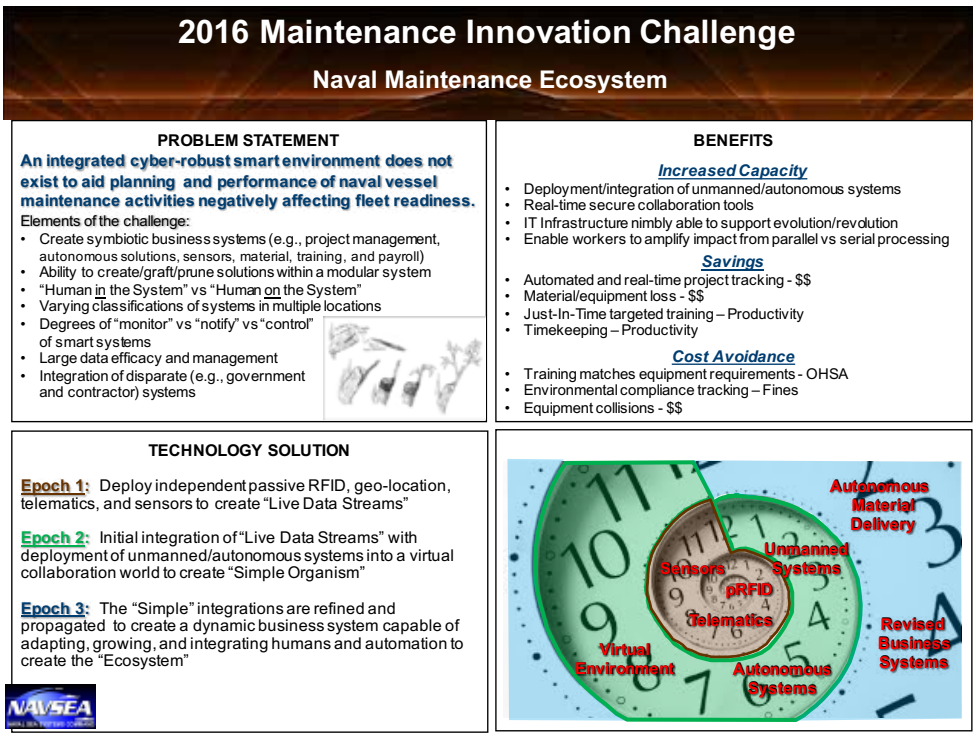
The creation of this ecosystem is envisioned in three stages termed "epochs":

- Epoch 1: Creation of "Live Data Streams" – A number of real-time data feeds will be created through unconnected technology deployments. Epoch 1 will include the continued deployment of passive Radio Frequency Identification (pRFID), geo-location devices, telematics, and a suite of installed sensors on industrial equipment.
- Epoch 2: Integration to Create the "Simple Organism" – The original data feeds will combine with streams from unmanned and autonomous systems into a virtual environment. Epoch 2 will begin to leverage unified data sets and improved collaboration tools to accelerate productivity.
- Epoch 3: Smart Integration will Create the "Ecosystem" – More integration will be achieved to field an autonomous material delivery system and revise the business systems to optimize productivity.

The ecosystem is expected to yield increased worker efficiencies through concurrent, augmented, and autonomous systems; allow for faster identification of work stoppages; and create real-time data for project, property, and material management. Properly constructed and deployed, the ecosystem will integrate data streams that are currently disjoint into a unified solution to enable more rapid delivery of ships back to the fleets. Interlocks on equipment for safety and proficiency coupled with environmental compliance tracking are additional benefits that are expected.

Many of the elements for this ecosystem (e.g., pRFID, telematics, cellular systems, virtual environments, contractor available data) exist but their on-going deployment has not yet benefited from deliberate data and information integration. As existing bio-medical unmanned and autonomous solutions are adapted and fielded for industrial applications, these systems will become part of the expanding ecosystem. The solution is being designed to transcend locations and organizations (e.g., DOD entities). It will also be constructed with the discernment as to which processes to "monitor" versus which processes to "control" via automation. The industry analogies include Epoch 1 - airport luggage tracking; Epoch 2 - global UPS package tracking; Epoch 3 - Amazon integrated inventory management, customer ordering, delivery, and customer relations.

The Naval Maintenance Ecosystem will weave the various facets of naval maintenance into a system to allow for faster maintenance and modernization of naval vessels. Applicability beyond Navy ship repair is expected for other DOD agencies performing industrial fabrication and/or repair operations. The Navy must construct this agile system in order to accommodate the creation, grafting, and removal of varying technologies in an ever-increasing complex maintenance environment.



ADR Center of Excellence - Enables "Freedom of Movement in Europe" without the Red Tape

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The AER (Army in Europe Regulation) 55-4 requires any US Army owned conveyance intended for the transport of Dangerous Goods of certain quantities by surface must meet the prescribed technical construction and engineering safety standard technology by design IAW the European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR 2015). US Army Military equipment is predominantly designed and manufactured tested IAW MILSTRIP & DOT standards which are not the same as European requirements. USAREUR has delegated the ADR executive authority to the 21st Theater Sustainment Command which in turn has tasked to TLSC-E maintenance activities to become the new ADR Center of Excellence (ADR COE) in 2016 that facilitates the entire vehicular ADR process; to include ADR compliant prototype development, vehicle modifications, component engineering, component fabrication, parts acquisition, vehicle testing, vehicle certification and sustaining a fleet of 2000+ various models operating in the European theater.

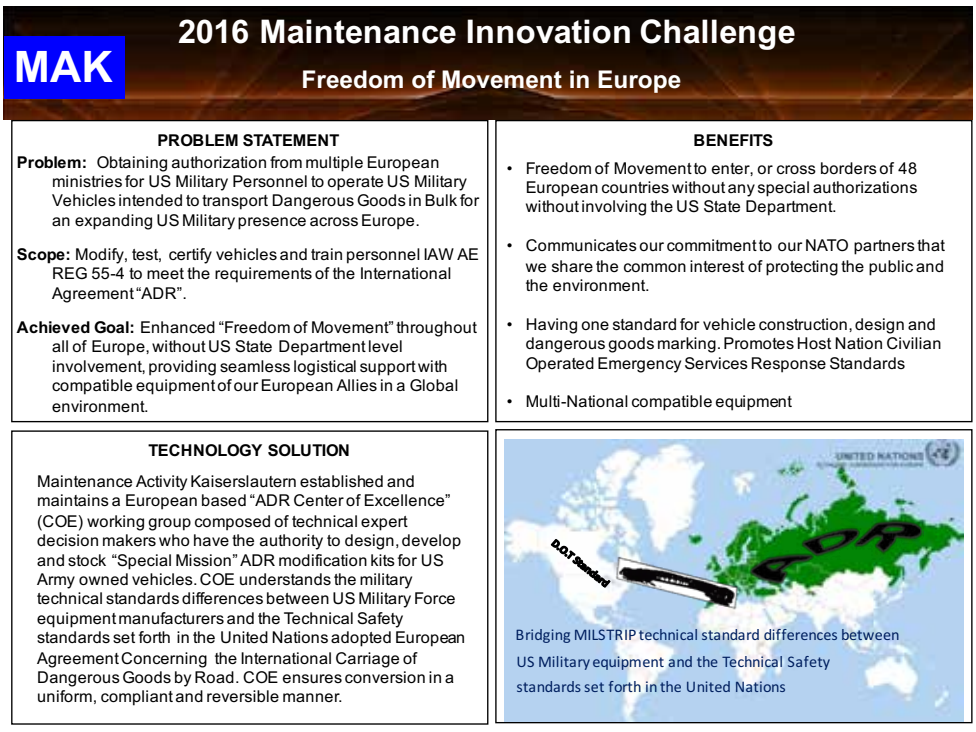
The COE is responsible for material development, acquisition and sustainment supply support without having TACOM or DLA provisional support. ADR modification work orders (MWO) of vehicles are not following the prescribed normal "Red Tape" MWO processing of having to get engineered packeted and approvals from the Material Developer (MATDEV). The modifications are officially approved from TACOM's PM engineering staff and appointed European Ministry of Transportation/Defense officials.

ADR COE mission is to promote the international movement of US Army persons and goods by inland transport modes on a Global scale. It aims to improve the effectiveness of US manufactured military vehicle competitiveness with improvements, safety, energy efficiency and security of the US Army transport conveyance sector while operating in Europe. At the same time it focuses on reducing the adverse effects of transport activities on the environment and contributing effectively to sustainable logistical development.

TLSC-E ADR COE is a:

- Center for multi-national manufactured transport platforms for initial ADR certification, prototype development & design, vehicular modification, periodic testing and ADR compliance recertification standard enforcers as in agreement with numerous Ministries of Defense from our NATO allies-Europe and beyond MILSTRIP & DOT regulations for dangerous goods transport and road vehicle construction at the global level.
- OCONUS Gateway for technical assistance and exchange of best practices
- Promoter of multi-country material compatibility diplomatic clearance and border crossing authorization
- Substantive partner for transport and trade facilitation initiatives
- Historic center for transport statistics.

For more than a decade, the maintenance activities (ADR COE) have provided a platform for US Army Europe Leadership, Soldiers serving in Europe, TACOM representatives, vehicle manufacturers the technical expertise feedback, training knowledge and intergovernmental cooperation to facilitate the ADR process and develop safe international transport while improving its safety and environmental performance. The main results of this persevering and important work are reflected in an incident free decade of more than 3000+ ADR certified vehicles logging endless miles across all of Europe. This COE process is a game changing innovative effort that will earn the respect European NATO Allies our US military deserves.



OO-ALC/TEAD - Cross-Service Partnership

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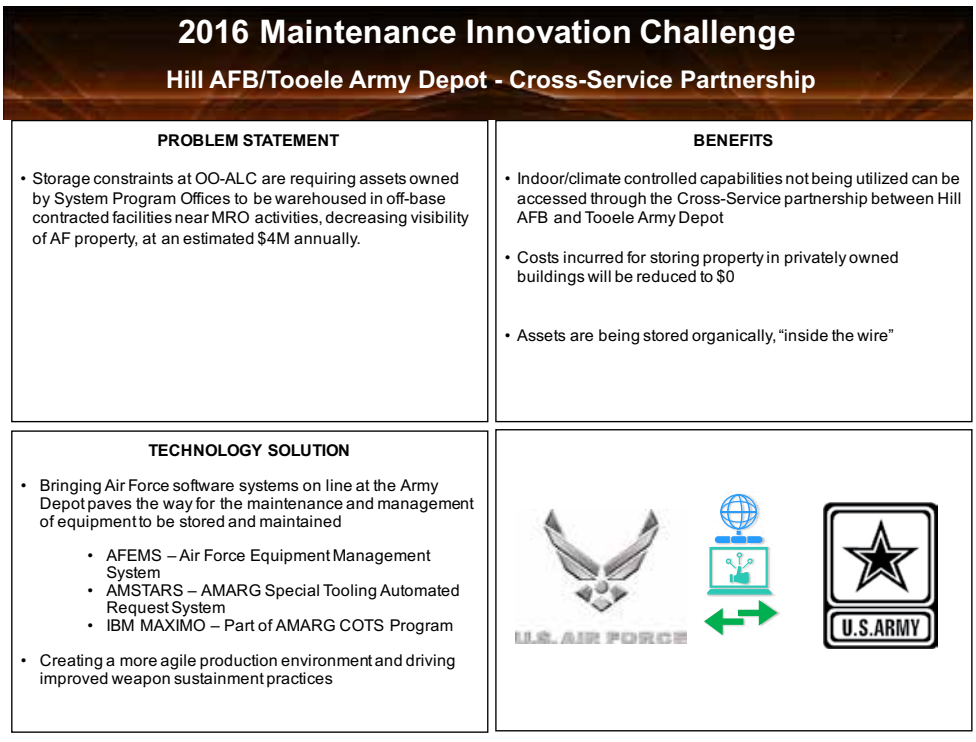
In an effort to increase available facilities while leveraging existing standard aerospace asset management processes, a strategic cross-service statewide partnership was created between the Ogden Air Logistics Complex (OO-ALC) and Tooele Army Depot (TEAD). This agreement helps solve the increasing need for climate controlled indoor storage to preserve sensitive assets belonging to advanced weapon systems which will be utilized to ensure readiness to the war fighter when requirements arise. Before this agreement was in place, the standard process of excess equipment/tooling being stored at Aerospace Maintenance and Regeneration Group (AMARG), in Tucson, AZ, was not possible for additional assets that have indoor or climate controlled requirements. A Memorandum of Agreement (MOA) now allows TEAD to function as an AMARG forward Operating Location (OL) which solves the storage issue for multiple System Program Offices (SPOs) who are using Centralized Asset Management (CAM) funding to pay contracted companies to store and manage assets. Bringing Air Force software systems (AFEMS, IBM MAXIMO, AMSTARS) on line at the Army depot facilitates the logistics of asset management between Department of Defense entities. Items being warehoused by contracted companies and in privately owned facilities for C-17, B-2, and ICBM systems have a current cost of over $4M per year in contracted funds, and additional resources being spent by employing warehouse staff and maintaining equipment such as trucks, trailers, forklifts, etc. Moving to an organic storage location will drop those contracted costs to $0, resulting in a $4M per year cost savings in warehouse contracts alone. Charges for actions performed on stored assets will be expensed on actual hours worked at standard shop rates, utilizing personnel and equipment already in place. By utilizing existing facilities located at Tooele, Army personnel increase utilization rates and reduce cost per square foot for storage capability. Another tremendous benefit to the storage partnership lies in the relative closeness in geographical location to the Hill AFB maintenance complex, as opposed to the bone yard in Tucson, AZ. This will decrease response time for repairs needed to keep up with customer demands and war fighter needs. It is imperative that these assets remain on-hand for engineer reach-back for the life of a program.



Coast Guard 87: Patrol Boat Programmed Depot Maintenance – "Bow-to-Stern"

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The 87' Patrol Boat "Bow-to-Stern" (BTS) Drydock program is a depot maintenance initiative that aims to boost operational availability, reduce days-away-from-home for PB crews, cut costs and improve results of programmed depot availability projects for patrol boats. Started in November 2014, BTS centralizes the planned drydock (DD) program for 48 Atlantic Area 87' Patrol Boats (PBs) at the CG YARD in Baltimore. Under BTS, each PB undergoes a 67-day DD every 4 years with a standardized work package completed at the same depot facility.

BTS returned benefits in FY15-16 for PB crews in reliability of operational schedule, quality of life, and recurring cost savings. BTS DDs are more robust than typical commercial DDs, nearly the same duration, and average 2 days less in schedule delays. In commercial DDs, PB crews had to accompany the cutter, increasing time away from home, and incurring temporary lodging costs. Under BTS, DD preservation work has increased and the duration has remained the same at about 9 weeks. More importantly, schedule delays were driven down to about 2 days. Tight schedule reliability has enabled crews to sail their PB to drydock at the CG Yard, drop off their cutter and cross-deck to another PB fresh off the production line. Crews' days-away-from-home for drydockings dropped from about 1200 days per year to 360 days (the time for 12 cutters to transit to the CG Yard and cross-deck to another PB). Beginning in FY15, BTS eliminated personnel expenses for two PB crews, saving $2.2M per year. Additionally, as crews no longer remain aboard PBs during DD, $480K in per diem expenses are avoided annually with funds being redirected to maintenance. BTS has also returned 30 days to the PB operational schedule, despite the reduction of two crews.

BTS also resulted in optimizing depot processes. To enable tight production schedules, two environmentally-controlled paint enclosures were built to permit preservation year-round. Standardized BTS work packages afforded stable work flow for the Yard work-force and predictable demands for depot supply. BTS also enables a more robust scope for DD work, providing the key benefits to fleet service life:

- 100% Exterior & Lazarette Preservation;
- Extensive Engine Room Bilge Preservation;
- 100% Renewal of Props, Shafts, Rudders and U/W Seals;
- Full 3-D hull benchmarking; and
- Repairing all hull problems identified by scanning.

The continuous, repetitive work stream provides the opportunity to implement uninterrupted improvement based on lessons learned in BTS production and efficient completion of standard engineering changes, executed with high quality control fleet-wide.

Many positive operational benefits of BTS have been realized in the Atlantic Area, in terms of reliable operations scheduling, cost savings and better depot maintenance. The program has been so positively received; managers in the Pacific Area requested a business case analysis to determine if this model is the best solution for the 154WPC Fast Response Cutter.

As BTS continues to improve and grow, there is little doubt that long-term benefit of better depot maintenance and higher operational availability rates will result.

PMXG Rework Reduction

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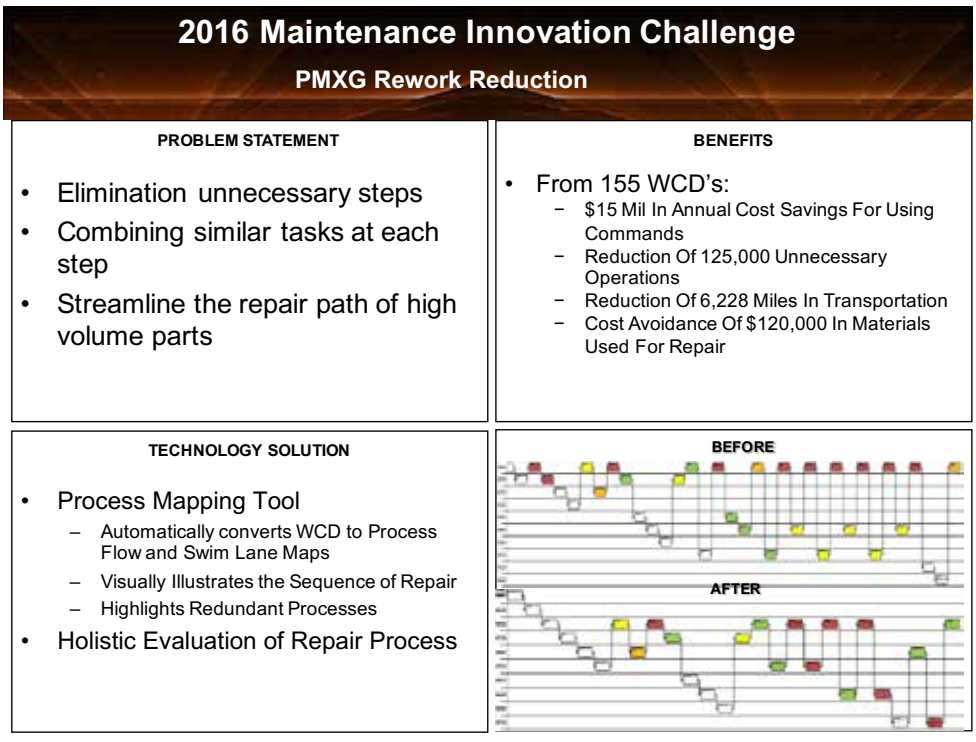
As part of the depot level maintenance of a jet engine, individual parts are routed for repair using work control documents (WCD's). The WCD reflects the potential inspection and repair steps required for each part. The WCD's are living documents that reflect the path of the part from process to process, and the routing can change as new requirements develop. Over time, small incremental changes to the routing/sequence unintentionally created inefficiencies in the whole process, penalizing our customers with higher costs and longer lead times. There was no review process in place to holistically provide a check of the WCD's to prevent these inefficient steps from accumulating.

The Propulsion Maintenance Group has approximately 14,000 WCD's. The Rework Reduction team used a Pareto analysis to determine the highest frequency of part induction with the highest number of operations in each WCD. The team initially identified 155 WCD's as having the best opportunities to cut potential waste. An innovative process mapping tool was developed to visually illustrate the sequence of repair and highlight where redundant processes were occurring. The tool automatically converted the WCD to color-coded Process Flow and Swim Lane Maps to show routing/sequence inefficiencies to the WCD reviewer. This tool allowed the team to holistically evaluate the full repair path of each part, resulting in the consolidation of similar repair actions and elimination of unnecessary operations to streamline the flow and reduce transportation waste. During the investigation of the repeated routes, the team also improved the execution of some existing processes and in some cases, identified alternative repairs that were more efficient.

As a result of this effort, approximately 125,000 unnecessary operations were removed from the repair process. This translated to $15 million in annual cost savings for the using commands. The effort avoided annual costs of $120,000 in materials used for repair. The throughput of our cleaning, blasting and FPI operations increased by 10-20% each, reducing the impact to production from these traditionally bottlenecked processes.

PMXG is a learning organization and with the insights gained during this rework reduction project, we believe additional WCD evaluations are justified. As such, PMXG continues to use the process mapping tool to evaluate WCD's when new repairs or routing steps are added.



A4 Innovation Challenge Multi-Junction Probe Abstract

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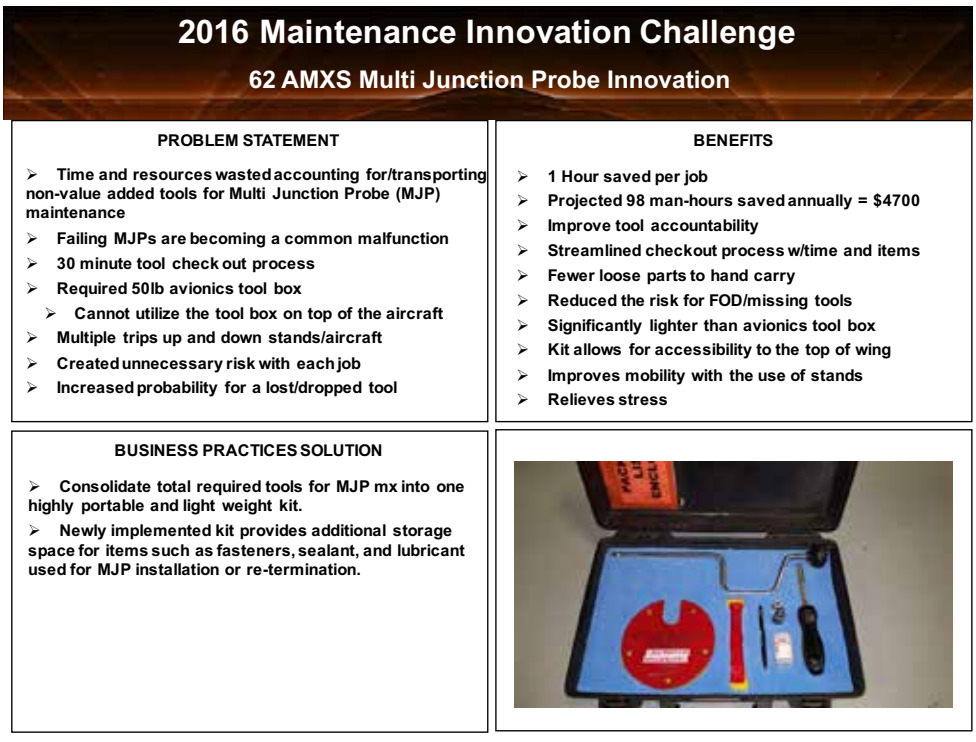
The 62d Maintenance Group has experienced an increased trend of failing Multi-Junction probes (MJP) on C-17s over the past year. Prior to 2015 the average MJP maintenance was twelve jobs per year. McChord experienced 106 MJP related jobs in 2015 and 67 in the first 6 months of 2016. Based upon the recommendations from the 62 Aircraft Maintenance Squadron, Integrated Flight Control System (IFCS) technicians, the support section consolidated the total amount of tools required for MJP maintenance into one highly portable and light weight kit. While being much smaller in size, this kit provides additional storage for items such as fasteners, sealant, and lubricant used in the MJP installation or re-termination process. Prior to the implementation of the MJP kit, time and resources were wasted accounting for and transporting non-value added tools for MJP maintenance. Historically, personnel spent up to 30 minutes in support checking out six separate items in order to have all the necessary tools to complete the task. This included a 50lb avionics tool box consisting of 138 individual tools which had to be accounted for and inspected at check out. Additionally, due to the tool box's size and weight, technicians were not able to utilize the tool box on top of the aircraft, where the maintenance is performed. This resulted in technicians hand carrying the tools required from the avionics tool box, making multiple trips up and down stands. This inefficient process thereby created unnecessary risk while performing the task and potential injury to personnel and/or damage to equipment. Moreover, due to the number of unnecessary tools being checked out with the need to hand carry; the risk for a lost/dropped tool was unreasonably high. The MJP consolidated tool kit was made available for check out in February 2016. Based on interviews with IFCS technicians, it has cut approximately one hour off the total time to accomplish the task through the streamlined checkout process and transportation. Analysts project the MJP will save 98 man-hours annually which equates to approximately $4700 per year. The overall reaction towards the MJP kit is unquestionably positive. IFCS troops were excited to see the kit and believe it not only saved time, resulted in zero lost tools, but also relieved stress involved with the task. The MJP kit conclusively provides a far more efficient approach to fuel maintenance while also improving safety and resource management practices. Finally, the MJP kit has decreased aircraft down time and improved work flow utilizing Air Force Lean principles.



C-17 HSC Initiative

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The C-17 Home Station Check (HSC) Initiative has the ability to improve maintenance agility and affordability by incorporating a new process into how scheduled maintenance is performed. Through this initiative, maintenance personnel and resources are more efficiently utilized while still completing current inspection intervals as required.

The C-17 HSC Inspection Cycle is broken down into six 120-day aircraft inspections over a 720-day HSC cycle. The inspection work cards are divided among HSC #1, 2, 3, 4, 5, and 6. The organization of the Legacy HSC inspection work cards result in APG-heavy (2A5X1) or Propulsion-heavy (2A6X1) 120-day periods. Additionally, each of these six Legacy HSC inspections require approximately the same number of man hours and calendar days to accomplish (approx 3 days).

The 860th AMXS at Travis Air Force Base (AFB) was granted approval to re-organize the required HSC work cards. In doing so, the unit more evenly divided the work load between different AFSCs which made for a more efficient use of available manpower. This was accomplished by grouping work-cards by the type of mechanic needed. Ultimately, this resulted in a more evenly distributed workload every 120 days throughout a two-year cycle and the ability to schedule four "small" HSCs, one "medium" HSC, and one "large" HSC inspection over the 720-day cycle.

As a result, under Travis' modified HSC Initiative, the four "small" inspections (#'s 1,2,4 and 5) require 1-day to complete; the "medium" inspection (#3) requires 3-days to complete and the "large" inspection (#6) requires 5-days to complete. Through this process, an average of only 13.2 down-days is utilized for each aircraft over the 720-day HSC cycle. Note: Over 6-days downtime are saved per aircraft when compared to the Legacy HSC. As currently organized, the Legacy HSC work cards require 19.3 down-days to complete over the 720-day cycle.

Since the 860th AMXS began utilizing the modified HSC work cards, the C-17 fleet at Travis AFB has proved this process is both feasible and practical. As a result of the decreased downtime for scheduled maintenance Aircraft Availability has increased and overall fleet health has improved. Over a two-year period (July 2013-July 2015), the Travis C-17 fleet has recapitalized 71.7 days of Aircraft Availability (5.5 days per aircraft). Additionally, through maintenance consolidation Time Change Items (TCIs) are aligned with the closest HSC date, Time Compliance Technical Orders (TCTOs) are scheduled and accomplished more effectively with specialists and the Boeing Recovery and Modification Services (RAMS) team, and Delayed Discrepancies (DDs) are scheduled/completed within the HSCs.

2016 Maintenance Innovation Challenge

C-17 HSC Initiative

CONCEPT

- **Legacy requirement**: 720 day cycle (Six 120-day inspection intervals)
  - #'s 1, 3 & 5 Propulsion Heavy
  - #'s 2, 4 & 6 APG Heavy
  - Total acft downtime = 19.3 days per 720-day cycle
- **Modified concept**: 720 day cycle (Six 120-day inspection intervals)
  - Balanced workflow across Propulsion & APG
  - Four small (1 day) inspections
  - One medium (3 day) inspection
  - One large (5 day) inspection
  - Total acft downtime = 13.2 days per 720-day cycle

BENEFITS

- C-17 Modified HSC Initiative potentially adds over 1350 days of Aircraft Availability fleet wide
  - Over $88M TWCF *saved?* within 24 months of implementation
    - Equates to nearly two addl C-17 per day available for tasking (fleet-wide)
- Reduced scheduled maintenance down time
- Increased Aircraft Availability (AA)
- Improved fleet health through maintenance consolidation
  - TCTO/TCI/DD during HSC

TIMELINE

- August 2012:Concept Development and Finalization
- July 2013: Began C-17 WSM Authorized Test
- July 2014: C-17 Authorized Extension

COSTS

- No addl manpower utilized for Travis AFB tests
- Suggest independent audit of Travis procedures/results
- Suggest fleet-wide implementation

The Travis HSC initiative, if implemented fleet-wide, could yield over 1,350 days of Aircraft Availability and result in an additional 1.88 taskable aircraft daily with no additional manpower or infrastructure requirements. Using the Minimum Activity Rate of $65,516, the 1,350 days additional Aircraft Availability represent potential Transportation Working Capital Fund earnings of more than $88 Million.

Cyber-Physical Manufacturing for Logistics

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The Air Force Air Logistics Complex (ALC) has established the Logistics & Sustainment Enterprise 2040 (LSE 2040) Plan. This plan looks to realize the Art of the Possible in many areas; striving to reach the full potential of the depot and supply chain enterprise. The need for rapidly available parts and components are vital to the speed of returning aircraft from the maintenance depot to the field. Reconfigurable Manufacturing Systems (RMS) are viewed as an engineering technology to address changes in manufactured products via rapid reconfiguration and improved flexibility of manufacturing systems-machines, controllers, design methods, software modules, etc. The next step in the process of reaching toward the supply chain potential is to move from the strictly physical to the Cyber-Physical realm. Deployment of Cyber-Physical Systems (CPS) creates a pathway to monitor and synchronize information between the physical factory floor and the cyber computational space. CPS will do for RMS what condition based maintenance (CBM) does for the upkeep of machines. CPS, or network enabled systems, are becoming more and more prevalent. However, very little standardization exists to quantify exactly how to construct a CPS environment, or even qualify what makes a CPS environment. Advancements in network management, intelligence, security, analytics, and computational capability will drive CPS into fruition at the ALCs.

An NSF funded center for Intelligent Maintenance Systems (IMS) has developed a 5-level approach, arranged in a hierarchical model, to assist in standardizing and defining CPS. The Smart Connection level is the lowest with the broadest reach. It consists of the sensors and actuators interface to the physical world, along with the communication networks. The Data-to-Information Conversion level does just as the name implies, it aggregates and fuses data to create information that may be analyzed. The Cyber level acts as central information hub. Information is being pushed to it from every connected machine to form the machine's network. Having massive information gathered, specific analytics have to be used to extract additional information that provides better insight over the status of individual processes. The fourth level is the Cognitive level which is where human interaction occurs. It provides the simulation capability as well as support for decision making. The highest level is the Configuration level. This is a self-diagnostic level that monitors everything occurring in the network and provides alerts and adaptive correction.

Our team has constructed the base architecture of a CPS, allowing for planning of manufacturing processes, sequencing of the processes, virtual simulation of the processes, activating the processes, and monitoring and evaluating all aspects of the processes to ensure they are running as planned. Future research will require the incorporation of powerful mathematical and algorithmic tools such as Data mining and fusion to identify the critical information needed to make intelligent decisions. Information reasoning will be needed to predict future bottlenecks and dynamically react to them. Simulation tools and human interface technologies are all requirements for CPS.

2016 Maintenance Innovation Challenge

Cyber-Physical Manufacturing for Logistics

PROBLEM STATEMENT

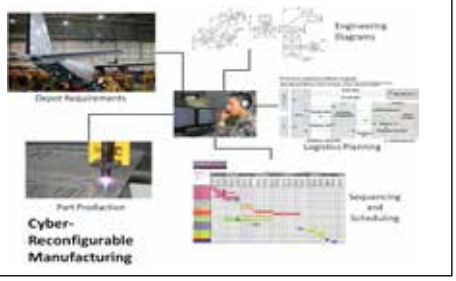
- Delays in the maintenance schedule at Air Force ALC's lead to aircraft being returned late to active duty
- Unforeseen damage to parts can delay the maintenance work due to the lack of replacement parts
- Parts for aging aircraft sometimes require retooling of manufacturing lines
- There is a need to quickly manufacture these parts so that the depot can complete its work
- Since the need for the part may not be known until the aircraft is already being processed, there is a need to be able to get the part manufacture initiated at the depot

BENEFITS

- Reconfigurable manufacturing allows the production of parts with little to no retooling needed
- Cyber-Reconfigurable Manufacturing allows the depot to request, identify the gathering of raw materials, sequence the part development, and schedule the part all from the depot
- Diagnostic and simulation tools allow the depot to see where and when the part can be produced, the status of the part, and the estimated delivery date
- The faster return of replacement parts means that the aircraft will be returned to active duty as soon as possible

TECHNOLOGY SOLUTION

- 5-Layer Hierarchical Model
  - Smart Connection
  - Data-to-Information Conversion
  - Cyber information hub
  - Cognitive
  - Configuration
- Information Security via Intelligent Observer. Continuously compares expected results with actual to identify network faults or deliberate intrusion
- Cyber enabled (distributed) planning and scheduling tools. Multiple job owners are assigned task execution times based on advanced heuristics



Implementing a Modular Software Sustainment Process

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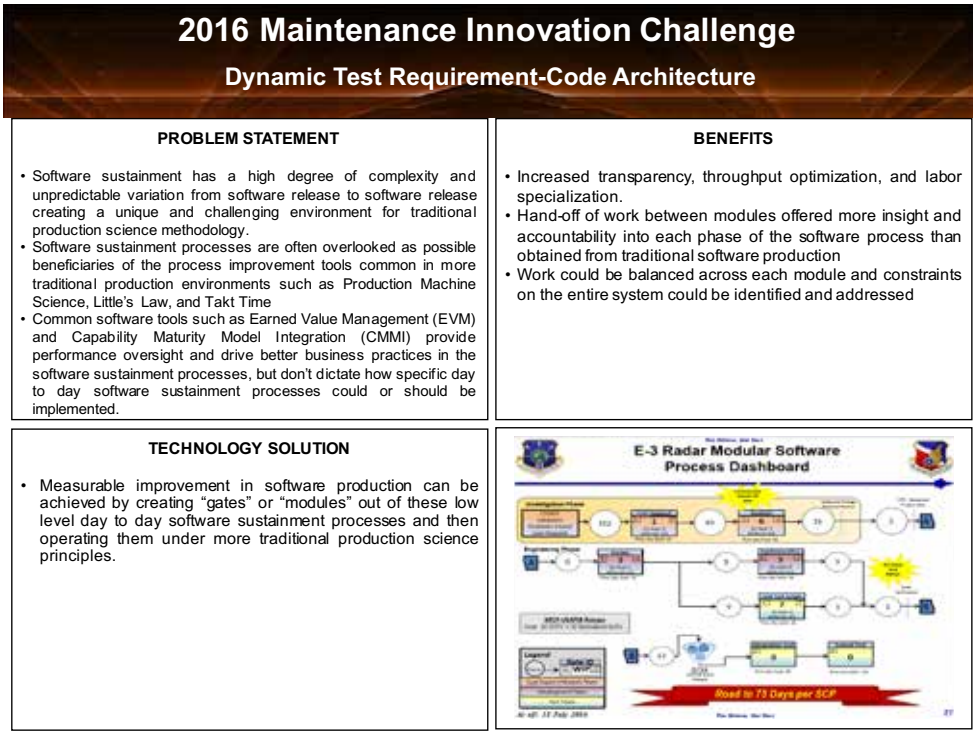
Software sustainment has a high degree of complexity and unpredictable variation from software release to software release creating a unique and challenging environment for traditional production science methodology. Software sustainment processes are often overlooked as possible beneficiaries of the process improvement tools common in more traditional production environments such as Production Machine Science, Little's Law, and Takt Time. Common software tools such as Earned Value Management (EVM) and Capability Maturity Model Integration (CMMI) provide performance oversight and drive better business practices in the software sustainment processes, but don't dictate how specific day to day software sustainment processes could or should be implemented. Measurable improvement in software production can be achieved by creating "gates" or "modules" out of these low level day to day software sustainment processes and then operating them under more traditional production science principles. Benefits include increased transparency, throughput optimization, and labor specialization. All which outweigh the additional overhead cost of operating a more modular software process. Analysis of using such a process found that handing off work between modules offered more insight and accountability into each phase of the software process than obtained from traditional software production. It also found that when work entering this system of software modules was well defined, work could be balanced across each module and constraints on the entire system could be identified and addressed. Lastly, using this process found that team expertise developed in their respective software modules and that communication increase crossed the entire effort. This communication was originally seen as an inefficiency, but resulted in a workforce more educated in the entire effort. Over all, organizing software sustainment processes into modules or gates provided additional work product metrics when moving between modules, enabled better workload management across the entire system, and forced greater communication and collaboration between module teams. Our senior software engineers will discuss the successes and challenges of adapting traditional gated production science methodology to software sustainment processes.



EBM tool as a foundation for CBM+

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BACKGROUND

The Marine Corps faces many challenges in maintaining diverse and aging fleets of equipment across a dynamic global operational environment. An additional challenge was intentionally self-inflicted in 2014 by directing a transition to Condition Based Maintenance (CBM+) in the release of the Ground Equipment Maintenance Program (GEMP) Marine Corps Order. The Marine Corps knows that it does not have the financial or personnel resources to maintain readiness in a post-war, but not post-conflict world without structural improvements to the way equipment is managed. The Marine Corps assessed what the Joint community and commercial industry were using to establish a CBM+ capability balancing suitability for a Marine Corps ground environment with low risk and investment. Selecting the NAVAIR-developed and Government-Owned (GOTS) Maintenance Planning, Scheduling and Execution (MPS&E) suite provided a common set of tools across Marine aviation and ground equipment, but also provided a robust set of tools to facilitate integration of data across acquisition, sustainment and maintenance domains in a closed-loop.

A pilot was established, using the LVSR platform to migrate the maintenance tasks from the legacy format, and introduce recommendations from recent RCM analysis. The Event-Based Maintenance (EBM) tool is the MPSE component used by maintainers and provided to a unit at Camp Lejeune, NC for use in scheduling maintenance and providing a mobile, tailored technical manual that was optimized for specific maintenance tasks to be performed that day. Introduction of EBM at the field-level is the start of the "fleet-side" introduction of a CBM+ capability that through MPS&E and other system interfaces will enable the feedback and Continuous Process Improvement (CPI) between Field and Enterprise stakeholders.

BUILDING THE ECOSYSTEM

The introduction of EBM directly demonstrated cost avoidance of $280k in parts, plus over 6,000 man hours for 18 months of LVSR PMCS maintenance in one unit. The Marine Corps demonstrated how EBM can linked to GCSS-Marine Corps linking maintenance task data with supply chain management systems. The system integration with MPSE is key to enabling an "Ecosystem" to support fleet management, decision support, serialized item management, and financial reporting in addition to core RCM/CBM+ analyses.

The Marine Corps plans to integrate EBM with operational planning tools such as the Transportation Capacity Planning Tool (TCPT) allowing operations and maintenance personnel to plan missions and maintenance for equipment through sharing data about maintenance schedules, planned and current usage. Capture and re-use of the data is useful outside of the unit, extensible to "condition-based" lifecycle and fleet management decisions such as Depot-level maintenance, in-service engineering, modification planning, SLEP and retiring or replacing equipment.

Headquarters, Marine Corps (HQMC) intends to transition CBM+ into a program of record in order to build upon the EBM model and provide resources and for Joint Capabilities Integration Development System (JCIDS). HQMC performed a CBM+ Capability-Based Assessment and has identified the logical Materiel and Non-materiel solutions needed to identify the correct entry into the acquisition domain. This is being pursued in parallel to the expansion of the EBM pilot to new platforms and interfaces.

2016 Maintenance Innovation Challenge

USMC Event Based Maintenance (EBM)

CONCEPT

- Deliberate approach to Condition Based Maintenance (CBM+) starting with EBM
- Leverage NAVAIR investment in CBM+ tools and processes
- Maximize interoperability of IT systems to provide collaborative environment across operations, maintenance, and acquisition/lifecycle management
- Formalize requirements within JCIDS process for acquisition rigor and sustainment resources

BENEFITS

- Minimizes upfront investment and risk
- Reduces USMC development lead time to Zero
- Maximizes commonality of tools and processes across Marine Air and Ground Forces, plus Naval Aviation
- Enables Ecosystem of data sharing for Continuous Process Improvement (CPI) of maintenance plans, fleet management, and equipment scheduling

TIMELINE

- FY 2014: Release MCO 4790.25 with CBM+ requirements; Demonstrate EBM integration with GCSS-MC; Initiate EBM pilot for preventive maintenance with LVSR
- FY 2015: Perform CBM+ Capabilities Based Assessment (CBA) to document gaps and risks
- FY 2016: Expand pilot to additional platforms and to corrective maintenance
- FY2017: Pilot EBM integrated with TCPT and wireless environment
- FY2018-2020: Pilot integration with TCPT and GCSS-MC; Complete JCIDS and transition to POR

COST

- Total investment FY2014-16 is $977k
- Projected cost through 2020 is $1,600k
- Pilot analysis of 18 month period from Oct 2013 on 2nd TSB LVSR Preventive Maintenance:
  - $280k in documented parts avoidance
  - 6,000 maintenance manhours avoidance

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 Virtual Diagnostics Automated 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

2016 Maintenance Innovation Challenge

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

PROBLEM STATEMENT

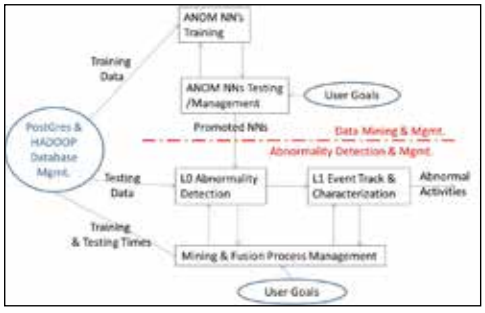
Increase aircraft availability by developing automated Condition -Based Maintenance Plus (CBM+) turnkey capabilities
Detect abnormal precursors in C-130 Digital Flight Data Recorder (DFDR) and Automated Inspection Repair Corrosion and Aircraft Tracking (AIRCAT) engine data
Fuse abnormal behavior detections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

BENEFITS

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

TECHNOLOGY SOLUTION

DCPM uses ANOM TRL 7 data fusion and neural networks to detect unknown abnormal fault precursors within DFDR & AIRCAT engine data signatures
DCPM detects and characterizes abnormal behavior in VDATS self-test outputs
GCPM tells DCPM when to retrain, what to retrain and test on, and when to promote to real-time operations
Smoking Gun finds high confidence correlations with Reliability and Maintainability Information System (REMIS) data
Bayesian Fusion Node (BFN) services support all levels of data fusion defined by the DF&RM DNN technical architecture
Correlate abnormalities to historical REMIS data and use REMIS to determine when to retrain



Leveraging KC-46 CASS' Predictive Analytics for Other Fleetss

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Consciousness enables individuals to survey and process information, enabling individuals to make sound decisions for the good of the whole individual. The KC-46 "Pegasus" Program Office plans to stand up a Continuing Analysis and Surveillance System (CASS) to be the 'consciousness' of the AF's newest fleet of tankers. FAA Advisory Circular (AC) 120-79A summarizes, "A CASS is a system that air carriers and commercial operators use to monitor, analyze, and optimize the performance and effectiveness of their maintenance programs." Simply put, an effective maintenance program is paramount to successfully managing aircraft. This is especially true for AFMC, given the longer-than-commercial life cycles of USAF aircraft.

The ultimate goal of CASS is to find issues and protectively address. To accomplish the CASS goal(s), the KC-46 PO has procured a government-owned, Fleet Management Tool (FMT) to include both an architectural design to house "big data" – AND – predictive analytics capability to mine the data and find patterns previously assumed to be random "noise".

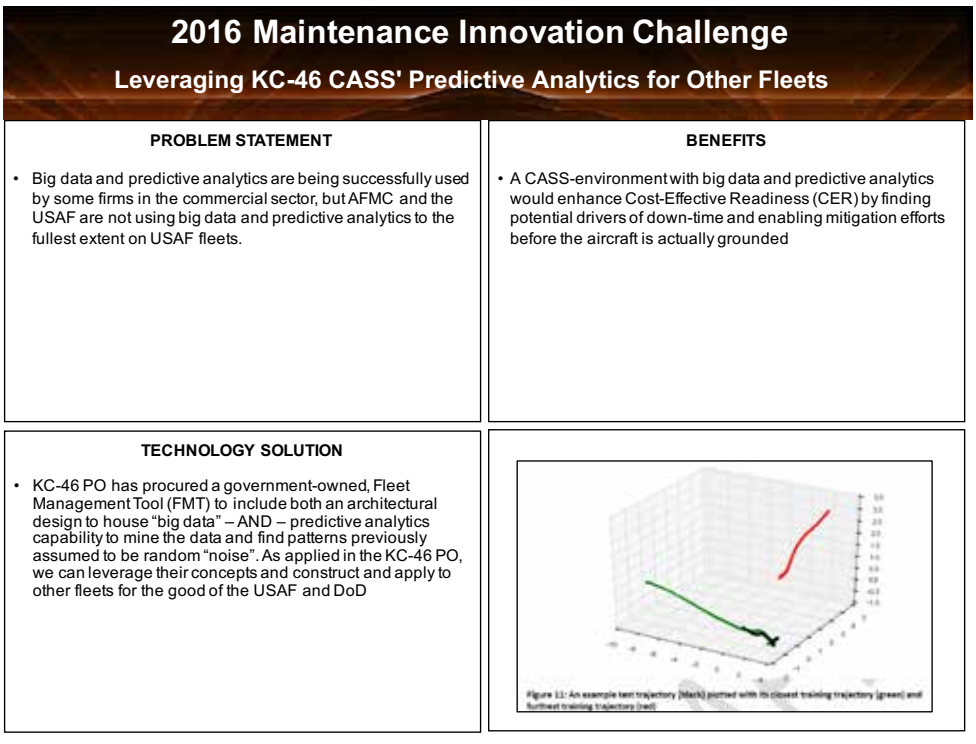
Now is the time for AFMC to establish big data and predictive analytics capabilities to enhance the maintenance environment. The following examples illustrate the current environment and capability; thus, they show that big data and predictive analytics capabilities that are in the KC-46 PO, could be exported to other fleets in AFMC in a reasonable amount of time.

1. The Global Combat Support System - Air Force, (GCSS-AF), with vision of big data, created the "Data Warehouse" to promote the use of vast amounts of data from a multitude of IT systems, including maintenance-centric systems: CAMS/G081, Standard Base Supply System (SBSS), REMIS, ETIMS, JDRS, etc.
2. The KC-46 PO has procured the FMT and has accessed many data fields across multiple IT systems via the "Data Warehouse"
3. The KC-46 a/c has 217 sensors collecting data on each flight and the KC-46 PO will be collecting the sensor data for each flight
4. The KC-46 PO will also be collecting a multitude of maintenance data such as deficiency reports, man-hours of depot maintenance, man hours of schedule and unscheduled field maintenance

The big data is 'housed' in the FMT via DISA. A small sample of the KC-46 PO planned predictive analytics:

1. Correlations of data elements with other data elements
2. Correlation of data elements with fleet performance (i.e.. Aircraft Availability)
3. Predictions: such as time in depot maintenance, level of unscheduled maintenance remaining useful life of engines, aircraft availability, etc.

These capabilities will be used by the KC-46 PO to help manage the fleet. The same capabilities could/should be leveraged by all of our fleets. A successful CASS-like environment that includes big data and predictive analytics capabilities would greatly enhance AFMC's ability to advance Cost-Effective Readiness for the USAF and DoD.



Wireless Vibration/Temp/Pressure Data Logger

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NAVAIR sustainment engineers are in need of data loggers capable of measuring vibration, temperature and pressure to troubleshoot the platforms and systems they support.

This problem became readily evident in late 1995 when an Airborne Self-Protection Jammer (ASPJ) system installed in an F/A-18 aircraft departed the avionics bay during flight. It took two years and hundreds of thousands of dollars to properly instrument a test aircraft to discover that 68 G's were traveling up the keel during catapult stroke, causing failure of the ASPJ rack system. Forward deployed F/A-18 aircraft sustained millions of dollars worth of damage to their keels before the issue was identified and the ASPJ was grounded for carrier use. During that time-frame, the idea of a portable, lightweight, wireless, cost effective data logger was born in the mind of a young engineer.

Fast forward to the 2011 Navy SBIR forum, Fleet Readiness Center South-West (FRCSW) Advanced Aircraft Technology (AAT) Team member, Brett Gardner, came across a device that could solve this problem. Utilizing 2014 Rapid Innovation Funding, the AAT partnered with Midé Technology to further develop the device. The result, SlamStick-X, a data logger capable of accurately measuring vibration (DC to >2KHz at sample rates up to 20KHz), temperature, and atmospheric pressure. A device that can be installed in minutes on any fleet aircraft located anywhere on the globe for $1,200 a copy.

In the current NAVAIR environment, sustainment engineers rely on Flight Test Engineers to perform instrumentation testing on specific flight test aircraft. This testing is expensive, $5K-100K per flight, and often times either the flight test aircraft and/or the flight test engineers are not readily available to perform testing due to prior aircraft scheduling commitments. With the appropriate flight clearance, SlamStick-X allows for cost effective and timely testing of fleet aircraft by the sustainment engineers charged with their support.

In July of 2016 SlamStick-X was used at VFA-37 by F/A-18 environmental control systems (ECS) sustainment engineers to test and troubleshoot fleet aircraft experiencing cockpit pressure scheduling anomalies. During SlamStick-X testing, specific ECS anomalies were identified allowing sustainment engineers to provide specific maintenance repair disposition for each aircraft. After repair of all VFA-37 aircraft, grounding restriction was lifted.

SlamStick-X was also used to troubleshoot a C-2 aircraft at FRCSW. Conventional troubleshooting was not able to detect the cause of a vibration anomaly detected in the flight yoke. Delivery of the aircraft back to the Fleet had been delayed by 80 days as the ground crews worked to resolve the issue. Nine SlamStick-X units were used to instrument the aircraft allowing sustainment engineers to quickly identify the issue as a damaged flight control dampener.

SlamStick-X was developed for approximately $450,000. Savings realized by using SlamStick-X is over $1.5 million (302 flights) and climbing when compared to the cost of conventional flight test instrumentation (based of $5,000 saved per flight test).

SlamStick-X can be used anywhere in the world by DoD and industry sustainment engineers to quickly understand, analyze, and resolve issues with vibration, temperature or pressure on equipment such as; aircraft, tanks, submarines, avionics, and depot/industry machinery.

2016 Maintenance Innovation Challenge

Wireless Vibration/Temp/Pressure Data Logger

PROBLEM STATEMENT

- **NAVAIR sustainment engineers need wireless, lightweight, cost effective data loggers capable of measuring vibration, temperature, and pressure to aid in engineering investigations**
  - *Example* – Avionics WRA chassis cracking
  - Instrumentation of a flight test aircraft by flight test engineers is currently the only option sustainment engineers have to collect aircraft data
    - Can take months or longer to complete due to aircraft scheduling and funding conflicts
    - Is costly - typically $5-100K per test flight
    - May not highlight squadron's specific jet issues
    - For non safety of flight issues – typically not instrumented

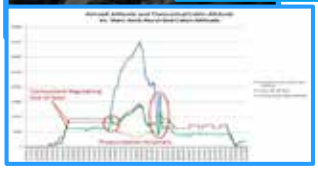
BENEFITS

- Places highly accurate data loggers in the hands of thousands of DoD sustainment engineers
- Enhances current flight test capabilities
- **Time Critical** – Reduces troubleshooting time from months to days
  - Installs in minutes
- **Cost Effective** –Saves $5K and up per use over conventional instrumentation testing methods
- **Sustainment Engineering Success Stories:**
  - Used to support F18 physiological event testing at VMFA-232 VFA-37, VFA-11 and VFC-12 (over 302 flights recorded)
  - Resolved C-2 vibration issue at FRCSW flight line
  - Used byt; F/A-18 VX-23, NASA, Boeing, Northrop Grumman, Lockheed Martin, and many other Industry partners
  - Over $1.5 million in instrumentation savings realized to date

TECHNOLOGY SOLUTION

- **Navy SBIR and 2012 RIF funded (PMA-265 sponsored) Wireless 8 Channel Data Logger- Midé SlamStick-X**
  - 3 axis vibration sensor (National Institute of Standards and Technology (NIST) calibrated) - six channels!
  - Temperature and pressure sensor- two channels
  - Records up to 4 hours of vibration data sampled at 20KHz, 10 hours at 5Khz (2 GB data card)
  - Frequency response DC to >2KHz
  - Programmable with analysis software installed on SlamStick-X
- Allows for timely wireless instrumentation of fleet aircraft by sustainment engineers (flight clearance required)
- **Time Critical** - Test results in hours
- **Cost Effective** - $1,200 per device

Two of nine SlamStick-X Installations on C-2



Analysis: F/A-18 cockpit pressure chart showing pressure anomalies

Condition Based Maintenance for Combat System Elements

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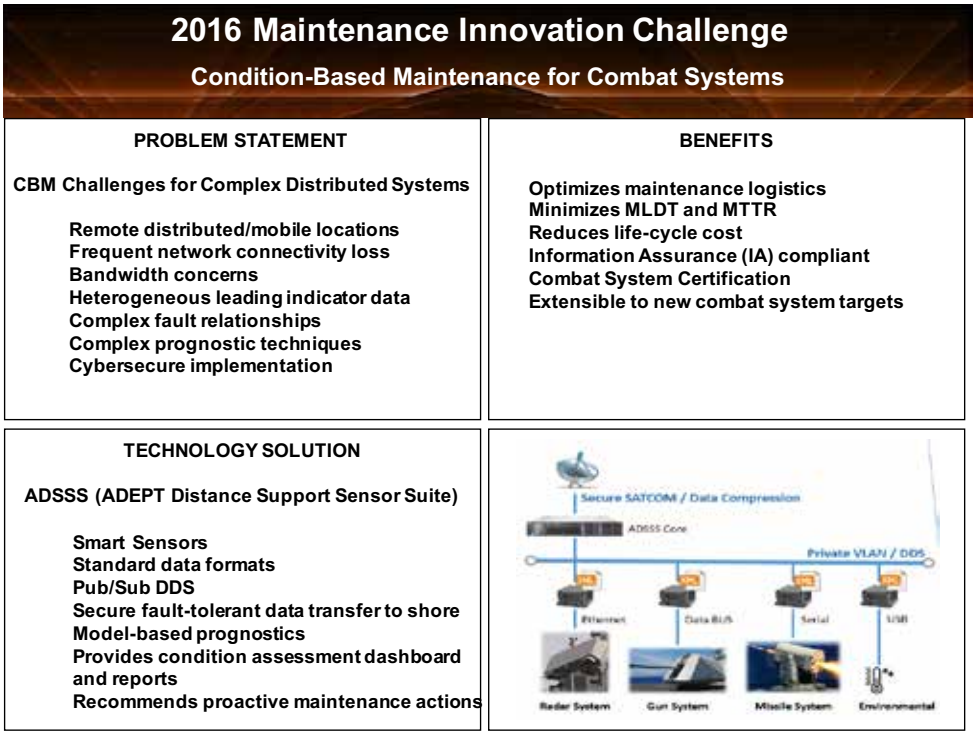
Reliability Centered Maintenance (RCM) and Remote Maintenance Monitoring (RMM) are increasingly recognized as essential techniques for minimizing the life-cycle cost of maintaining complex distributed systems, such as those used in defense systems, Air Traffic Control, power utilities, shipping and remote plant installations. We present an architectural framework for implementation of RMM and RCM for such systems, and an application using this approach for radar and other complex combat system components used worldwide by the U.S. Navy.

The systems to be monitored are at remote locations, and require a secure, robust and scalable network infrastructure for data collection and distribution. The data collected may include leading indicators such as system states and modes, parametric data from dedicated sensors; and manually collected data. We have found that an RCM solution for complex distributed systems must be based on three core pillars: smart sensors for heterogeneous data collection, scalable and generically applicable predictive analysis methodologies, and a secure network infrastructure.

Model-based prognostics offers an algorithm-agnostic methodology for RCM of complex distributed systems. It can use heterogeneous data from disparate sensors and sources, and is scalable using hierarchical models. The analysis transforms RMM data into actionable information by predicting specific failures tied to maintenance actions.

Mikros Systems is currently deploying a "Condition Based Maintenance Plus" (CBM+) solution for combat systems on the U.S. Navy's Littoral Combat Ship (LCS). In this application, a custom smart sensor is used to collect maintenance data from combat system equipment. The data collected is transferred securely from ships deployed around the world to a central server for analysis, and the Prognostics Framework (PF), a model-based prognostics reasoning engine, is used to analyze all data. PF outputs include prognostic alarms, maintenance action needs, and Remaining Useful Life (RUL) estimates for key components, providing a comprehensive health management capability for the LCS fleet.



Interrogative Diagnostics Solution (IDS)

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THE PROBLEM

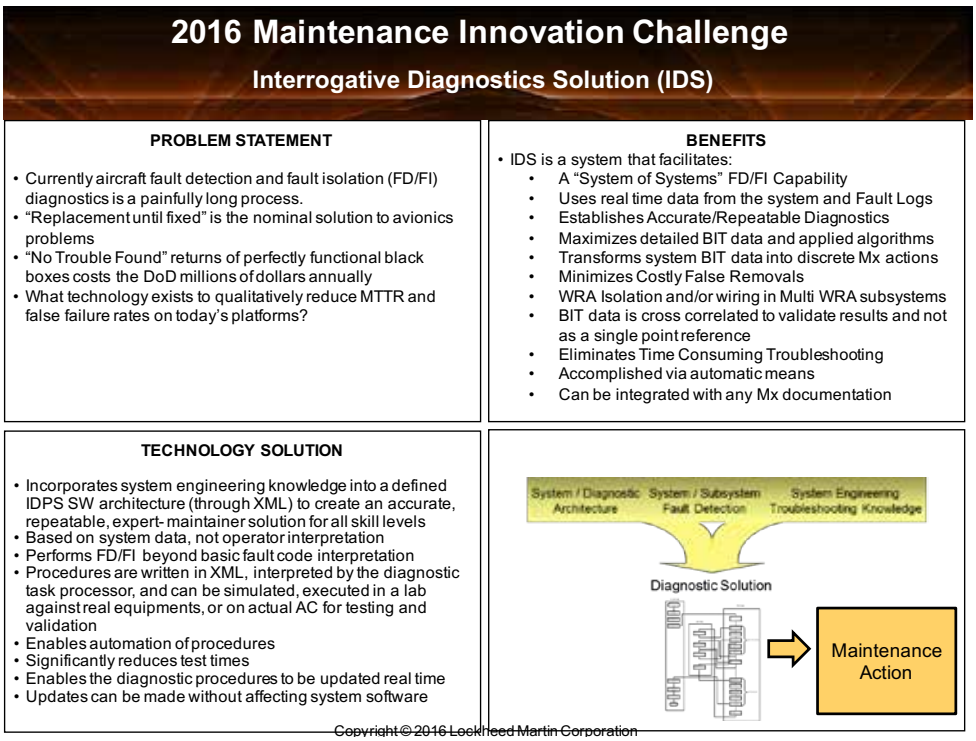
Any technician will tell you that diagnosing and repairing Weapons platforms and vehicles is not as simple as reading a code and replacing a part. State of the art systems are complex and are highly integrated. The integration and functional interdependences increase ambiguity groups and greatly complicate 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.

EXECUTIVE SUMMARY

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.

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.



INTERROGATIVE DIAGNOSTICS

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.

CONCLUSION

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

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Drying Biodiesel Fuel During Transport and Storage by Injected Dry Compressed Air

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Biodiesel has become an important fuel, both for commercial and military diesel engine operators. As its use has become increasingly popular, however, a number of issues have been recognized. Biodiesel is hygroscopic (attractive to water) due to the chemistry of the primary fuel molecule. Left alone, it will absorb up to approximately 1500 parts per million of water and will support moisture puddling in the bottom of tanks. When the fuel is stored, transported and used, exposure to moist air is inevitable since fuel tanks are vented.

Water content, in and of itself, poses only minor difficulties. Unfortunately, the interface of fuel and puddled water at the bottom of the tank is an excellent growth site for various microbes. This growth proceeds at such a rate as to produce large amounts of biological mass sufficient to cause fouling of filters (in tank and vehicle fuel pumps) and accretes in tanks forming corrosion sites. Distribution tanks that once had cleaning intervals measured in decades now require it after only a couple of years.

Water intrusion can be prevented. The fuel cannot be sequestered, but the air that comes in contact with the fuel can be so extremely dry that contamination is prevented and even reversed (where necessary). Garrett Engineering Services is developing a group of products that prevent moisture intrusion from the air, remove entrained water from the fuel itself and eliminate any puddled water. These systems may be added easily to existing railroad fuel cars, delivery truck tanks, distribution and storage vessels and individual vehicle fuel systems.

Storage and transport tanks receive a kit, consisting of a compressor (unless compressed air is provided already), dryer and controller, mounted either in the vessel manway or remotely. These kits maintain the air in the tank at desert-dry dewpoints or attack the puddled and entrained moisture directly via mixing in a fluid pump. Moisture could be removed by bubbling dry air or nitrogen through the fuel (the method used during production), but that foams the fuel, rendering it unusable for a time. By air-drying or sequestered mixing, foaming is avoided or limited to a thin layer at the top surface of the fuel and doesn't interfere with pumping.

To protect vehicles, a kit is added to the parking location and dry air is supplied to each vehicle's fuel tanks via a distribution network and tubes connecting to special fuel tank caps. When vehicles are parked, the operator need only remove the regular filler cap and replace it with the one attached to the drying network. During periods of non-usage, the air in the fuel tanks would be dried and moisture that is absorbed during operation (as the tank emptied and air was vented in) would be removed.

As in other Garrett systems, these kits are small, simple and inexpensive. Although the application is new, the hardware is off the shelf and proven. We can keep your fuel dry, just the way you like it.

Reducing Aircraft Structural Corrosion with Injected Dry Compressed Air

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Intruded atmospheric moisture in aircraft structures is a critical component of corrosion. Most current efforts to remove this moisture are limited to localized venting. Reducing the effects of moisture-induced corrosion requires metallurgical processes (corrosion resistant alloys), physical processes (such as shot-peening), a myriad of surface treatments (from electroplating to painting) and great care in the matching of electro-compatible materials in aircraft functional areas. The counter-corrosion success associated with storing aircraft in a moisture-reduced (perhaps even moisture-free) environment (such as the aircraft storage facilities in Tucson, Arizona) is well-established. Logically, then, if such a desert environment helps restrain corrosion, extending that environment into the operating regime would be valuable, if practical.

Garrett Engineering Services offers just such an approach. We are currently developing a system which supplies and distributes extremely dry air (considerably dryer than the Arizona desert) to the interior regions of an aircraft, monitors and reports the performance of that system in real time and possesses a much smaller "footprint" within the structure of the aircraft. Bulky items required for the system (compressor, dryer, plumbing and controls) are external and independent of the aircraft, ensuring against performance degradation. There is no interface with aircraft power or controls, vastly simplifying aircraft modification, which is limited to the interior mounting of thin-walled stainless steel tubing (typically 3/8" O.D.), an array of microchip humidity sensors and a small interface junction box. Air for the tube and power/data for the sensors are supplied to the system after the aircraft lands. Since even extremely busy aircraft typically spend more time on land (or on ship) than in the air, those equipped with our system would experience the operational equivalent of being deployed to the Nevada desert, rather than at sea or on the sea coast.

Our system is small, simple and inexpensive. Although the application is new, the hardware is off the shelf, proven and milspec. It's time to banish moisture from your list of concerns; let us show you how.

Data-Driven & Goal-Driven Condition-Based Predictive Corrosion Maintenance

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

Proposed system will incorporate in situ corrosion micro-sensors, providing data for advanced modeling assessment and prediction of protective coating/CPC system condition. Assessing/predicting coating degradation and corrosion onset through sensor data management, analytics, and hybrid coating condition/corrosion modeling establishes the framework for real-time corrosion assessment of in-service platforms to substantially enhance Condition Based Maintenance (CBM+) programs. Benefits: Heightened Military Capability by ensuring maintenance is performed based on condition, resulting in shortened procedures and reduced depot times; Accelerated Military Development when domain experts/engineers can identify areas frequently maintained to improve structural and material designs; Reduced Costs and Increased ROI by identifying failure modalities in critical components and reducing life cycle costs associated with unnecessary maintenance, particularly for inaccessible critical components.

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

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

2016 Maintenance Innovation Challenge

Data-Driven & Goal-Driven Condition-Based Predictive Corrosion Maintenance

PROBLEM STATEMENT

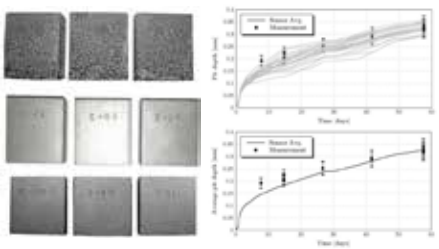
- Annual corrosion related costs for DoD facilities, infrastructure, and equipment are $20 billion. Approximately 25% ($5 billion) occurs at depot-level maintenance for Air Force aircraft and missiles.
- Navy and Marine Corps aviation annual corrosion cost is $2.6 billion; 26.1% of total maintenance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

BENEFITS

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

TECHNOLOGY SOLUTION

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



Comparison of Coupon Measured &Sensor Data Computed Pit Depths.

Environmental Severity Monitoring for Increased Aircraft Maintenance Efficiency

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Exposure to corrosive environments during operations and on the ground can degrade aircraft structures and systems. The U.S. DoD spends $4.7 billion annually on preventative corrosion maintenance, driving the high total life cycle costs of aircraft. Additionally, a finite pool of maintenance man-hours (MMH) exists that, without accurate corrosion assessments, may not be scheduled effectively. Currently, there is no way to track, assess, or project corrosion within an airframe to prioritize individual aircraft inspection and fleet maintenance for more efficient allocation of maintenance man-hours (MMH), assessing the impact of deferred actions, or early detection of corrosive conditions requiring attention.

To manage costs and labor associated with aircraft corrosion maintenance, Luna has developed the LS2A sensor suite for aircraft corrosion monitoring. The system has been evaluated as a means to improve the testing and inspection for corrosion. Aircraft test and inspection alone is estimated to cost the U.S. Armed Forces $2.8 billion annually. Use of the LS2A sensor suite enables the inclusion of corrosion related issues in reliability centered maintenance (RCM) practices within CBM+. By using the LS2A to track corrosion severity within an airframe, more effective use of finite labor resources can be accomplished. Unnecessary corrosion inspection and testing can be avoided and identification of aircraft at high corrosion risk can be achieved. The LS2A system is being used to establish corrosion management models in Army and Navy programs, including Army Capability-Based Operations and Sustainment Aviation (COST-A), Navy Integrated Hybrid Structural Management System (IHSMS), and Navy Sea-Based Aviation. The system has also been successfully deployed to detect corrosive conditions in HH-60 search and rescue rotorcraft, NH90 rotorcraft performing anti-piracy missions in the Gulf of Aden, and to characterize performance of aircraft covers and dehumidification systems. The small-size, lightweight packaging provides is ideal for retrofit of existing assets, and can provide benefits from both a cost and MMH standpoint.

Environmental conditions (temperature and relative humidity) as well as contaminants contribute to corrosion and degradation of aerospace structures. To provide in situ measurements of environmental severity and corrosion, the LS2A monitoring system continuously measures, records, and analyzes multiple environmental parameters and corrosivity. LS2A sensor nodes can be distributed as a wired or wireless network throughout an airframe or at critical corrosion "hotspots" to evaluate the extent of corrosion, determine whether maintenance activities are required, and reduce unnecessary manual inspections. Luna has developed data analysis techniques to track and visualize environmental severity within airframes for clear, intuitive, and informative presentation of long-term environmental exposure. Corrosivity classification models are embedded within the system so maintainers can assess environmental severity without the need for post-processing or expert analysis. In addition to the on-board processing that calculates an ISO standard environmental classification, a complete time-history of measurements recorded is maintained in LS2A memory. Engineers and scientists interested in evaluating historical daily and seasonal trends for an area or component can access the entire sensor node time-history.

2016 Maintenance Innovation Challenge

Environmental Severity Monitoring for Increased Aircraft Maintenance Efficiency

PROBLEM STATEMENT

- The DoD spends in excess of *$2.8 billion* per year on corrosion test and inspection for aircraft
- Maintenance man hours (MMH) for corrosion test and inspection are applied on a schedule basis
- Application of MMH to corrosion test and inspection on a schedule basis reduces aircraft availability and reduces overall maintenance enterprise capacity
- Deferring corrosion test and inspection without knowledge of corrosive conditions increases risk of corrosion damage and increases future repair costs
- The DoD does not have a means for monitoring aircraft corrosive condition to prioritize inspections and airframe corrosion maintenance

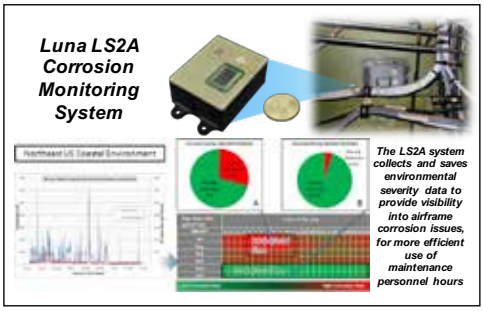
BENEFITS

- Reduced MMH devoted to corrosion test and inspection
- Prioritization based on corrosion usage severity of individual aircraft for inspection
- Improved aircraft availability based on proactive condition based inspection and maintenance
- Reduced maintenance costs through early detection of high severity conditions (contaminants, poor drainage, etc.) on individual aircraft
- Improved fleet level lifecycle sustainment planning by relating operational and deployment profiles to corrosion severity, inspection requirements, and preventative maintenance schedules

TECHNOLOGY SOLUTION

- The Luna sensor suite for aircraft corrosion monitoring (LS2A) is a small, robust system that monitors, records, and reports environmental parameters related to corrosion severity within an airframe
- By monitoring temperature, relative humidity, solution conductance, and alloy corrosion rate, the severity of aircraft environmental exposure can be quantified
- Autonomous data analysis techniques provide a clear, intuitive presentation of individual aircraft and fleet-wide corrosivity as well as environmental severity
- The system has a flexible configuration and is easily integrated on new aircraft or retrofit to legacy airframes

Luna LS2A Corrosion Monitoring System



The LS2A system collects and saves environmental severity data to provide visibility into airframe corrosion issues, for more efficient use of maintenance personnel hours

Bioinspired Proactive Self-Cleaning Coating

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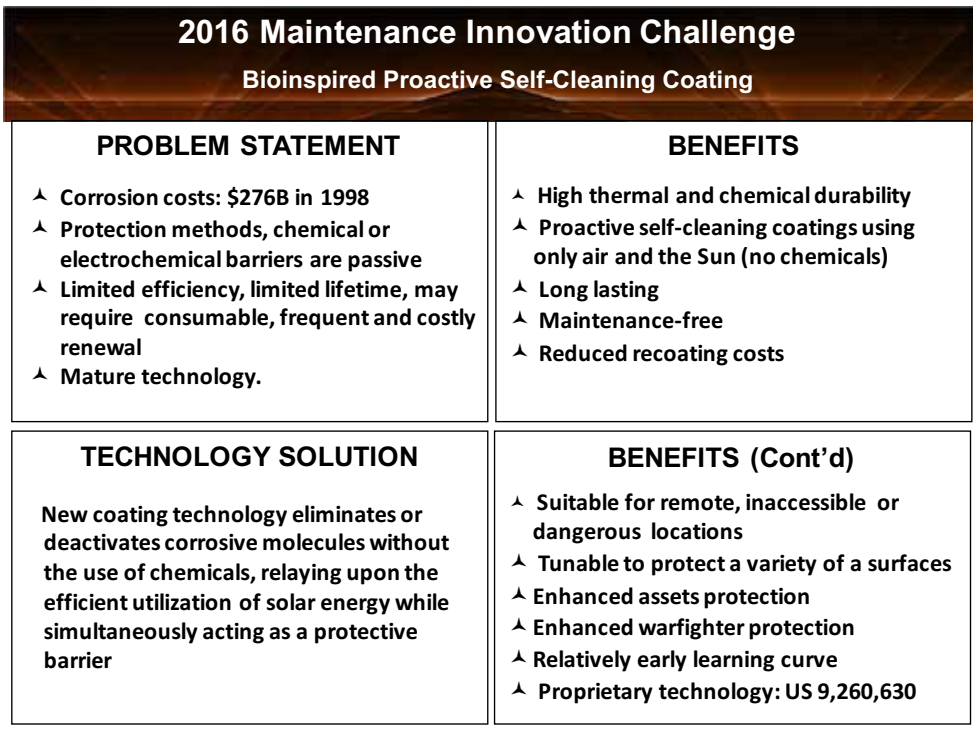
A landmark study by NACE estimated the direct corrosion costs at $276B in 1998, a figure that may reach $1.1T in 2016 when indirect costs and inflation are considered, an enormous drain of resources.

We present a new approach to corrosion mitigation based on a self-cleaning polymer matrix that generates aerobically reactive species that deactivate organic pollutants while also providing an anti-corrosion barrier.



Advanced Metal Finishing Facility

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The Advanced Metal Finishing Facility (AMFF) was designed and built to improve the plating process by reducing worker exposure to health hazards, reducing energy consumption and environmental pollutants, and improving plating quality. The AMFF significantly reduces worker exposure to hazardous plating chemicals by separating the preparation area from the wet process area. The AMFF is equipped with nine automated process lines controlled by individual Programmable Logic Controllers (PLCs), which allow the operators to operate the plating process from the unexposed preparation area. Removal of the operator from the hazardous environment reduces their exposure to dangerous chemicals such as caustics, acids, cyanide, heavy metals, and other carcinogens. The PLCs contain saved process recipes that require the operator to load the parts on racks and select the appropriate recipes for production. These recipes improve quality of the plating by removing the potential for operator error and deviation. The PLCs also allow for easier modification and troubleshooting of processes since all recipes and parts scheduled are documented, reviewed, and edited electronically. As part of the automated process lines, the AMFF is equipped with an adaptable overhead crane structure and an automated process tank chemical addition system. This technology reduces the manual labor required by the plater to improve ergonomic efficiency, and further removes the plater from the hazardous environment by making the chemical additions remotely. The facility minimizes maintenance worker exposure in the wet process area by strategic location of mechanical systems away from hazardous areas, inclusion of process tank safety shields, and separation of plater and maintenance work aisles.

The AMFF also has systems in place to reduce hazards to the natural environment. Designed with an internal waste water treatment facility and rinse water recycle system, the AMFF mitigates pollutants and wastes released to the surrounding environment. The installation of high capacity ventilation systems and upgraded air scrubbers reduces air emissions and improves the quality of air in the facility for the platers. The recycle systems and reduction of chemical evaporation at the source help improve efficiency and contributes to the facility's LEED (Leadership in Energy and Environmental Design) Certification. Efficiency is also improved by upgraded quality assurance measures such as the relocation of the quality lab to within the AMFF to eliminate delay time for tests. Capacity is further increased by the scale of the AMFF. The facility has 155 process tanks, ranging in size from 500 to 10,000 gallons with additional space for expansion. The increased size of process tanks allows for processing of larger parts which enables AMFF to support a larger workload. Overall, the AMFF has increased the ability of the plating process to keep the worker and environment safe, ensure quality, improve efficiency and provide the DOD with a state of the art plating facility for all foreseeable future workload demands.

2016 Maintenance Innovation Challenge

Advanced Metal Finishing Facility to improve electroplating

PROBLEM STATEMENT

- Electroplating exposes workers to chemicals hazardous to their health such as caustic acids, cyanide, heavy metals and other carcinogens.
- Chemical additions to tanks and hoisting parts are done manually, exposing the worker to physical strain.
- Electroplating processes produce air emissions which are hazardous to the environment.
- Evaporation of waste water and chemicals reduce efficiency
- Quality and consistency of plating is difficult to control due to human error/deviations.
- Need for increased capacity for C-17 and C-5 parts.

BENEFITS

- The layout and automation of electroplating process lines will significantly limit worker exposure to hazardous materials.
- Automated system for chemical additions and adaptable overhead crane system will reduce physical strain and chemical exposure.
- Improved air scrubbers will reduce air emissions. Improved ventilation will enhance air quality for workers.
- Chemical evaporation and drag-out will be reduced at the source to improve efficiency.
- Automated processes and testing will improve quality and consistency of finishing.
- Increased size will allow processing of bigger parts.

TECHNOLOGY SOLUTION

- Prep area is separated from wet process area, removing the worker from the hazardous environment.
- 9 Automated process lines controlled by programmable logic controllers (PLC) allow operators to run the process from the prep area.
- Approved process recipes are saved to the PLC to improve quality and consistency of plating.
- Relocation of quality lab to AMFF and automated tank testing allows for more efficient testing and analysis.
- Automated chemical additions and tank shields provide further protection to the worker.
- Installation of large tanks to have capacity for larger parts.

GRAPHICS

Automated process line

Isolated prep area with hoist

Process lines with tank shields

Programmable logic controller

Protective Covers for Critical Asset Corrosion Prevention

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The maintenance community is charged with maintenance reduction, increasing life cycle and improving mission readiness of critical assets. Innovative protective covers were developed to meet these critical objectives. As the community knows, legacy covers do not perform to expectations and in some cases cause maintenance issues. This includes the trapping of moisture, absorbing of water, creating static charge and in some cases the use of Vapor Corrosion Inhibitors (VCI) which can be a health hazard and create a coating on optics.

The AMCOM Corrosion Program Office supported by the 160th SOAR(A) researched what material makes an effective protective cover. During this 4 year study, they concluded that a protective cover should have the following characteristics to ensure success and a technical textile was created:

- Air Permeable: Eliminate "greenhouse" effect to mitigate corrosion and mold. (ASTM D737)
- Waterproof: Inherently waterproof even in driving rain storms. (ISO 811)
- Hydrophobic: Will not absorb water – wet weight equals to dry weight. (ASTM D3776)
- Freeze Proof: Will not retain water so will not freeze. (ASTM F392-93, 2000 Cycle Gelbo flex at room temperature and -40 degrees C)
- Sand Proof: Filters out 1 micron of sand. (ASHRAE 52.2)
- UV Resistant: UV Durable (ASTM G154)
- Scratch Protection: Protects windscreens, lenses or coatings. (ASTM D4966)
- Washable: Able to be cleaned with standard detergents. (ASTM D2960-05)
- Lightweight: Less than 12oz / sq yard for easy handling and stowage. (ASTM D3776)
- Anti-Static: Inherently ESD for use on ordinance, electronics and canopies (Fed. Std. 191A, T.M. 5931)
- Durability: Be durable for 100's of on/off uses in ever climate. (ASTM D5035, ASTM D2261)

The revolutionary technical textile offers a significant reduction of maintenance, improves mission readiness and life cycle extension to the DOD maintenance community.

Cleanforce and MegaWash Solution

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Cleanforce equipment combined with Mega Wash solution is an environmentally safe, effective, economical system for cleaning, reclaiming and re-using parts of all sizes and media. Cleaning means the system will de-rust, de-grease, de-debris parts processed through the system while using the appropriately noted cleaning agent.

Cleanforce is an industrial wash system consisting of a minimum of 1 pre-dip tank/vat, 1 washing chamber, 1 continuous feed conveyor belt, Mega Wash chemical cleaning solution and a rust protectant. It is a water based system that uses an EPA approved chemical solution to clean (de-rust, de-grease, de-debris). It is powered by existing facility electricity or natural gas plus facility water.

Parts are soaked in tanks containing the specially formulated, EPA approved, water based, non-caustic Mega Wash solution. They are then placed onto a continuous feed conveyor belt that moves parts and assemblies through zoned chambers containing jets that rinse the solution off while simultaneously removing the residual rust, grease and other debris within. The like-new part or assembly emerges from the chamber for inspection or follow on processing, handling, or storage.

Cleanforce cleans any known media from plastic to alloys to hardened metal without changing the physical or chemical properties of the part. Thus, any part that meets specification going in, will still meet specification coming out. It will clean parts, sub-assemblies, assemblies and kits in almost any stage of oxidization, corrosion or any part or assembly less than 3' wide x 4' high.

Time in the soaking tank can be as little as 15 minutes followed by 10 minutes through the wash and rinse chambers. On average, heavily rusted parts are cleaned of corrosion in less than 1 hour by one technician and can be re-used immediately.

The parts processed per hour rate is a function of three variables - the number of parts that will fit in the soak tank at one time, the number of parts that will fit on the conveyor belt without overloading it and the time it takes the operator process the parts to go onto and off of the conveyor belt by hand or hoist.

The system can be operated with no special equipment, training, storage, disposal, environmental inspections or finishing operations like re-grinding or machining. Added functional processes are engineered with limited touch points to reduce processing costs when and where appropriate. The system's installation and implementation does not require major construction and can be operated in a space as small as 60' L x 12' W x 12' H. The system works effectively and efficiently with as few as two personnel – one at the front of the line and one at the end of the line.

The primary benefits of Cleanforce and Mega Wash are increased reclaim/salvage/re-use rate of DoD parts while reducing depot discharge rates. Secondary benefits are reduced cost of corrosion control and correction and improved depot operations, both of which contribute to lower, more competitive rates.

Examples of military parts processed through Cleanforce and returned to the production line are:

- D7 bulldozer engines. The block, cylinders, veins, and capillaries were de-rusted, enabling a scrapped engine to be restored to production line ready.
- MRAP wheel hubs, which were de-rusted without damaging the gasket
- MRAP bearings. Rusted to the point of being seized, these were de-rusted as an assembly and were again fully operational

2016 Maintenance Innovation Challenge

Precision Global Systems' Cleanforce and Megawash Solution

PROBLEM STATEMENT

- DoD corrosion related maintenance costs exceed $20B per year as of 2015
- DoD missions increasingly require operations of equipment in highly corrosive environments for extended periods
- Current DoD corrosion correction practices and equipment are costly, marginally effective and environmentally unsound
- Current Army and Marine Corps corrosion correction equipment contributes significantly to the rate structure of depot operations
- Reclaim and re-use rates of corroded parts at Army ground vehicle depots is less than 40% using existing technologies and equipment

BENEFITS

- Cleanforce and Megawash Solutions provides an EPA approved, water based system that de-rusts, de-greases and de-debris' any known DoD part, sub-assembly or assembly
- Cleanforce operates using existing depot or arsenal power (electricity or natural gas)
- MegaWash Solutions requires no special storage, handling, or disposal of residue for most parts
- Cleanforce removes of rust, grease and debris from media ranging from plastic to alloys to hardened steel
- Cleanforce and MegaWash require no special clothing, training, hazmat controls, or medical evaluations
- Cleanforce and Megawash equipment costs less than salt and acid baths and large blasting machines

TECHNOLOGY SOLUTION

• Cleanforce consists of pre-soak vats and a rinse chamber containing a continuous feed conveyor belt
• MegaWash is a chemical solution that attacks corrosion without pressure, temperature or acidity as the catalyst
• The Cleanforce equipment and MegaWash solution have de-rusted and de-greased every DoD part ever processed
• Normal processing time is less than 2 hours
• The quantity of parts processed per hour is a function of the quantity that fit in a pre-soak vat at one time
• The system is currently capable of processing parts up to D-7 bulldozer engines
• Cleanforce equipment fits in any 60' L x 12' W space

GRAPHIC

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High Performance Ceramic Coatings to Address Wear and Corrosion Problems

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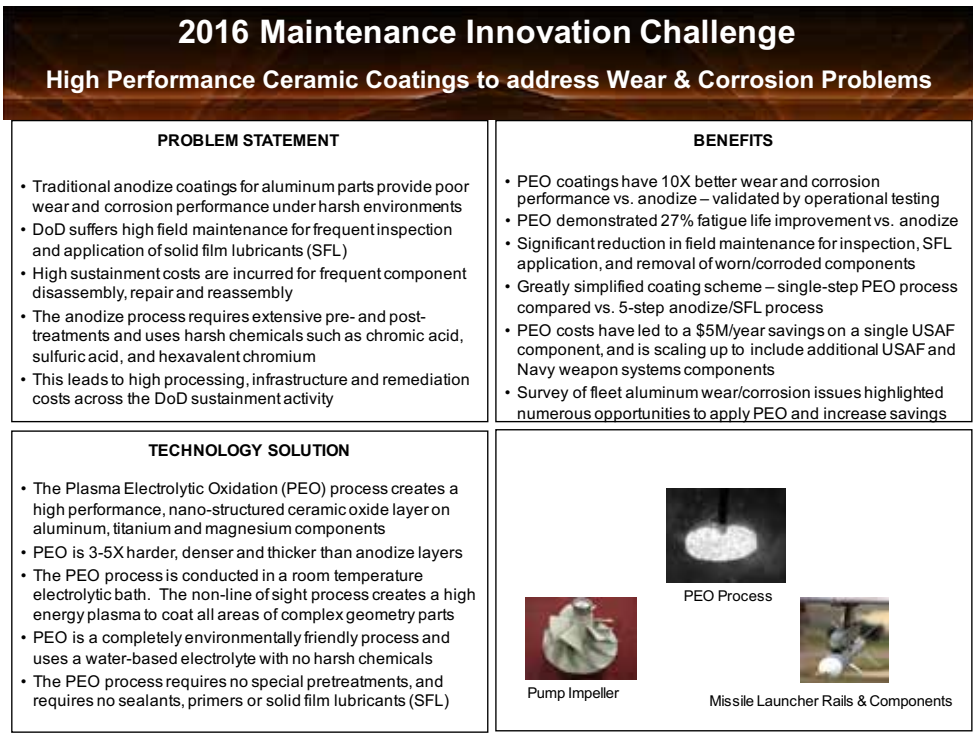
Missile Rail Launchers (MRLs) are loaded on current US Air Force fighter aircraft. These aircraft fly every training sortie with either a missile or a POD up-loaded onto wing station MRLs. The flight regimes on these training sorties create vibrations and impact loads between the MRL and loaded asset, erosion on leading edges due to aerodynamic loading, and corrosion due to thermal cycling between ground and elevated altitudes. Maintenance is performed on the MRLs every 90 days, then 18 and 36 months. Procedures usually carried out at these maintenance intervals are measuring wear, inspection for corrosion and erosion, and the reapplication of Solid Film Lubricant (SFL) as well as top-coat paint.

Wear is the largest maintenance issue on the MRL and occurs on the Rail Structure of the MRL. This structure is in physical contact with a loaded missile or POD and it is the loaded asset that drives the wear. The Rail Structure is replaced when .016 in of wear has occurred with typical average wear values of .008 in exist. The maximum wear value has been reached in some cases in as little as 6 months of flying.

A joint venture between the Missile and Launcher Group (AFLCMC/EBREM) and IBC Materials and Technology, Inc., has developed a revolutionary new coating for lightweight metals that, will replace the four current coatings on the Air Force's MRLs: anodization, primer, paint, and SFL. The bonus with this new coating, Plasma Electrolytic Oxidation (PEO), is that it is also green. It neither contains nor produces any hazardous elements or compounds in its application. PEO offers 27% increased fatigue life, better corrosion performance, and 10X more wear resistance compared to Type III anodization.

Six Rail Structures have been coated with PEO and then assembled into LAU-128 MRLs and loaded onto F-15 aircraft. These six LAU-128s have been flying for over 24 months loaded with a missile or POD. Physical measurements of the Rail Structure, at the missile/POD contact points, have been conducted every 6 months. These detailed measurements show .000 in of actual wear during this 24 month period. The coating appears as it did when it was first applied. War Fighters have not had to apply SFL/paint and not had to replace any of the six Rail Structures for being worn out. The estimated cost savings of replacing the Rail Structure for both the F-15 and F-16 MRLs is $5.4M per year.



Testing in Support of Cyber Hardened Avionics

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As cyber threats continue to evolve in today's unstable environment, Strategic Agility in dealing with new and emerging threats must be diligently employed. DragoonITCN's maintenance innovation is the reuse of our flagship BCIT test tool in a configuration that simulates cyber intrusion on a 1553 or Ethernet bus interface. The normal application for BCIT is to continually monitor the health of the bus, but with firmware modifications and the Bus Controller - the BCIT may be converted into a surrogate cyber intrusion tool that resides on the data bus and tests the hardening of avionics to attack. Additionally, the BCIT's inherent ability to determine cable discontinuities may be used effectively as a indicator of federated modules being attached to the bus structure that could serve as an entry point for cyber intrusion. The key to the success of this concept is the dynamic nature of the disruption of normal bus activity. The most likely sequence for a cyber attack on a 1553-controlled system is to take control of the bus and produce harmful commands to the R/Ts. Gaps of non-activity would be a potential indication of intrusion. Similarly with Ethernet, the activity on the LAN is readily monitored for bus health and the innovative modification is to insert command words and false data in the stream to simulate an attack. By realizing the capability to stimulate the bus in this manner, significant progress may be made in hardening the avionics and weapon systems to cyber intrusion as is described in the 2016 AFRL TPP.

DragoonITCN presents this concept to the 2016 MIC for consideration having been a contributor to the AF engineers and maintainers for over 12 years in sustainment. BCIT can become a test tool to verify trustworthiness of critical avionics, embedded software and hardware and identify methods to mitigate vulnerabilities to ensure mission success. This modified BCIT will be an independent Line Replaceable Unit attached to the 1553 or Ethernet bus to monitor, alert, and/or take an active response to adversarial activity within the aircraft systems.

2016 Maintenance Innovation Challenge

Testing in Support of Cyber Hardened Avionics

PROBLEM STATEMENT

- 2016 AFRL TPP Chapter 14 Sub CTC 3.2 (RYW) describes the near-term Avionics Hardening initiative
- Intrusion monitoring key to the "DETECT" principal
- Legacy weapon systems are often augmented with federated LRUs that attach to the bus interface
- Emerging need to TEST the system for cyber intrusion responses and contingencies

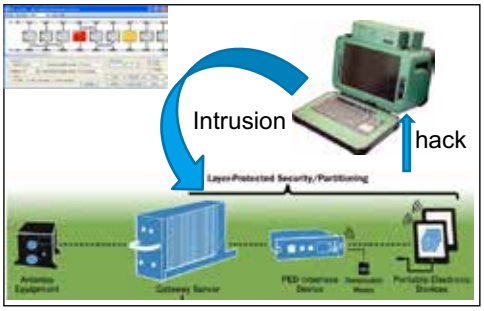
BENEFITS

- Graphical representation of bus data for rapid intrusion detect
- Dynamic and intelligent capabilities for surrogate intrusions
- Portable, ruggedized test tool placed on-board platform
- Rapidly generate "DETER" modifications based on test

TECHNOLOGY SOLUTION

Leverage BCIT – AFRL's Phase III SBIR as stimulus

- Modify 1553 Bus Controller SW to act as intruder
- Capture real-time Bus data and health status
- Graphical representation of data "river"
- Ethernet LAN expansion with same tool
- Cable integrity test to show inclusion of federated equipment



ENHANCED INSPECTION

E&E Backshop AWTS Integration

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PROBLEM STATEMENT:
E&E Backshop at Dover AFB is experiencing a lack of capability to fix many of the components and test various systems on the C-5M Super Galaxy. This is largely due to most of the test equipment being developed for the C-5A, dating some pieces back to 1969. Here at E&E Backshop we test various systems and parts on the C-5M at the Isochronal Dock. If we had a tester that we could use on and off the aircraft, we could test the aircraft further than we ever thought possible.

TECHNOLOGY SOLUTION:
The Automatic Wire Test Set (AWTS) is automated test equipment that aids wiring diagnostics of electrical and electronic devices that is 100% portable. This equipment uses resistance measurements, capacitance measurements, and AC/DC voltage measurements to perform continuity, insulation, and isolation tests on 1024 test points. This test equipment can be used to test any system or part; the only requirement is a Test Program Set (TPS) designed specifically for the aircraft/system/part that connects the equipment to the Unit Under Test (UUT).

BENEFITS:
The benefit of this equipment is limitless. We currently have the AWTS in the backshop but require more TPSs to replace our outdated test equipment and to test the various systems on the aircraft. This would also boost our capability to test different systems, both at ISO and on the flight line. Additionally, the time spent troubleshooting complex problems can be drastically reduced with the ability to plug in a tester and check the entire system. Also, our repair capability in the shop would return to its original ability. Lastly, the guidance a technician would need to hook up the equipment to the UUT would be displayed directly on the screen, with pictures, step by step. This would reduce human error and fast track our training of personnel due to every test starting on the same piece of equipment.

2016 Maintenance Innovation Challenge
E&E Backshop AWTS Integration

PROBLEM STATEMENT

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BENEFITS

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GRAPHIC

Rapid, Precision Measurement and Non-Destructive Inspection (NDI)

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Rapid, Precision Measurement and NDI: Based on the Cross Cutting Mx Study, inspection is the #1 cost and readiness driver in DoD maintenance. A new optical NDI and measurement capability has been developed which can rapidly assess the integrity of areas up to 1 square meter and see defects as small as 1 micron (1 one millionth of an inch). This fidelity is orders of magnitude more precise than current NDI methods and much faster. This technology will lay the foundation for a new era of faster, more precise NDI.

Proposing a new optical NDI instrument (SS-TSMI, 'Swept-source Time-to-spectrum Mapping Interferometer) providing measurement volume up to 1 meter square, while measuring defects as small as 1 micron.

Range: flexibly designed for measurements up to 1.5 meters.

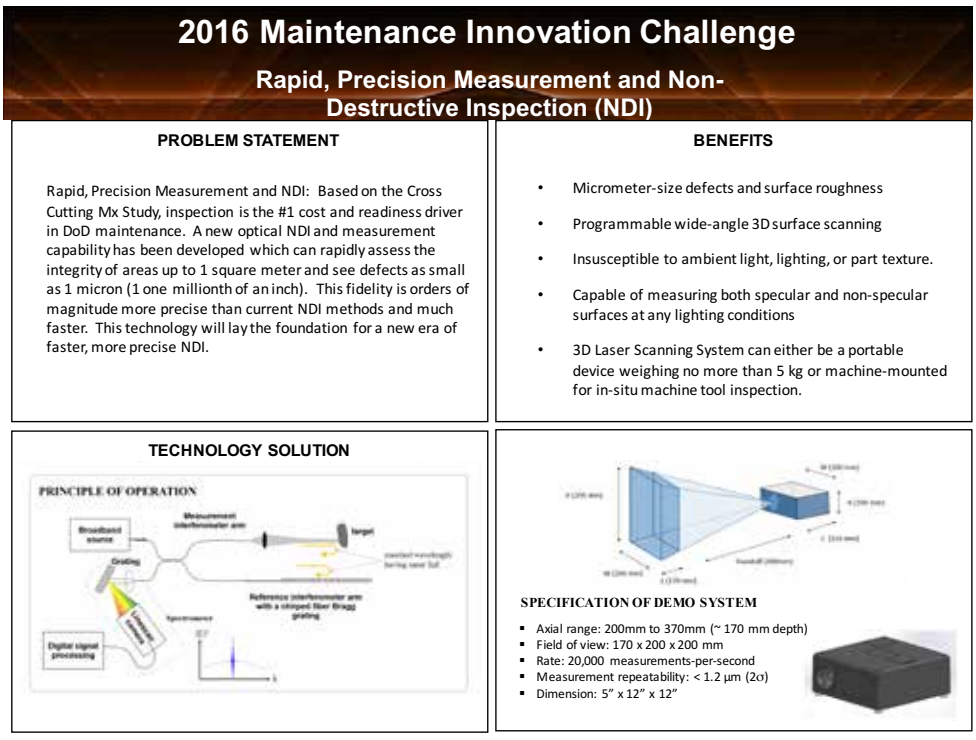
Speed: faster than 50kHz.

Accuracy: 1 micron/meter for specular and non-specular surface.

Sensitivity: non susceptive to background light, surface textures.

Inspection process: surface geometry inspection of machined and welded parts (as an in-Situ measurement on machines or as a compact, agile instrument providing precision measurement of molds, welds or general dimensional requirements).

Careful conceptual system design and component selection will be made in order to make the system very affordable and feasible for commercialization.



PC4 Depot Organic Replacement Solution to OEM Vibration Monitoring System

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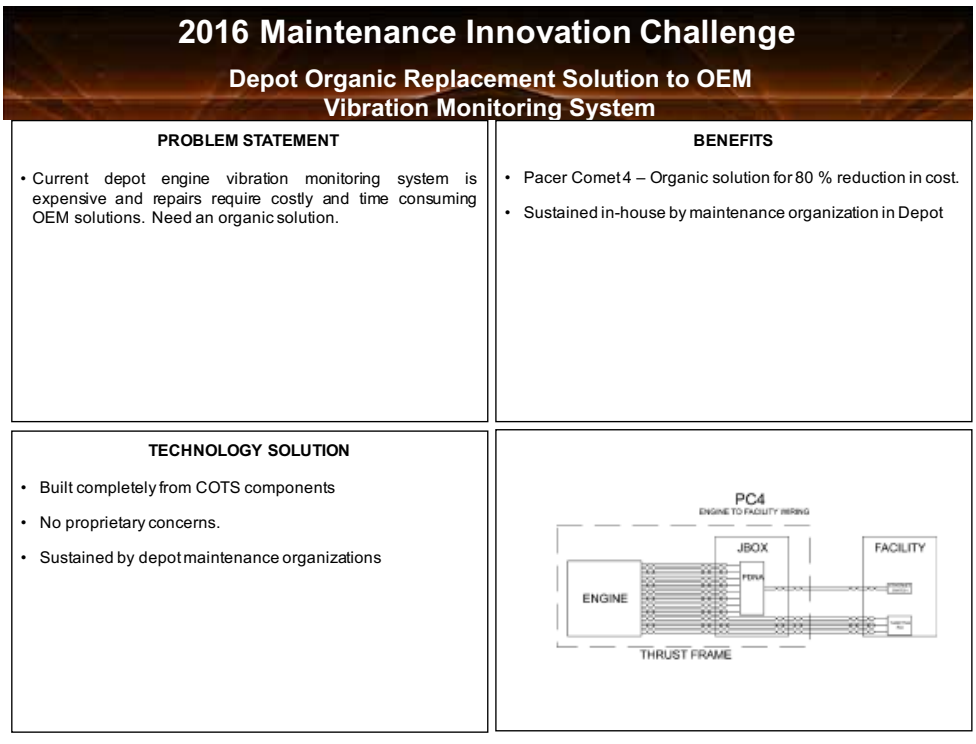
The current vibration monitoring standard utilized at multiple facilities across the Air Force is the MTI PBS-4100R. This system provides a solution to vibration monitoring and trim balancing for many different types of gas turbine engines. Although it does provide a necessary capability, there are several pitfalls to using this system. First, the cost of each individual unit is over $50,000. Given that there are currently 12 test cells active at Tinker alone, with additional test cells planned for the future, the cost adds up quickly. Second is the issue of sustainment. Whenever the PBS has a problem, it must be sent to the OEM, MTI, to be repaired. This is expensive and results in downtime unless a spare unit is available. Additionally, the system has recently experienced end of life issues making some of the older units unrepairable. This ultimately requires procurement of new units. Third, the PBS experiences frequent communication problems. These problems cause a great deal of production downtime. The OEM has not provided a solution for this problem.

The Pacer Comet 4 development team is developing an organic solution to replace the PBS-4100R. This system is designed to be used with the Pacer Comet 4 jet engine test system. It addresses all of the issues that are currently being encountered with the PBS. The biggest area of improvement is the cost. The target cost of this new vibration monitoring system is $10,000. Given the PBS-4100's end of life concerns, number of active test cells, and plans for future test cells, the cost savings are considerable. The sustainment issue has also been solved by this new system in several different ways. There are inherent cost savings and reduced down time associated with the organically developed and locally maintained system. . This system is also built completely from COTS components. The use of COTS components, coupled with no proprietary concerns, has streamlined the procurement process throughout the system's life cycle.

Although the organic solution is not currently in use, it has already proven to be a viable replacement. Recently the Pacer Comet 4 development team experienced vibration problems during initial testing of the F137. To solve this issue, a great deal of signal analysis was necessary. The team was able to use the organic vibration system to look at the problematic signal in ways that the PBS would not allow. This helped to reduce the time in solving an extremely difficult problem while simultaneously providing a proof of concept.

When complete, this system could replace both the vibration monitoring and trim balance functions of the PBS. It is currently being developed specifically for use with Pacer Comet 4, but that is only the beginning. Many organizations across the Air Force are using the PBS in a variety of different settings. Several of them are experiencing the same problems we have experienced at the Complex. After being proven as a test cell solution, this system could easily be adapted for use on the flight line or any other setting where the PBS is currently used.



Innovative Low Observable Sustainment and Maintenance

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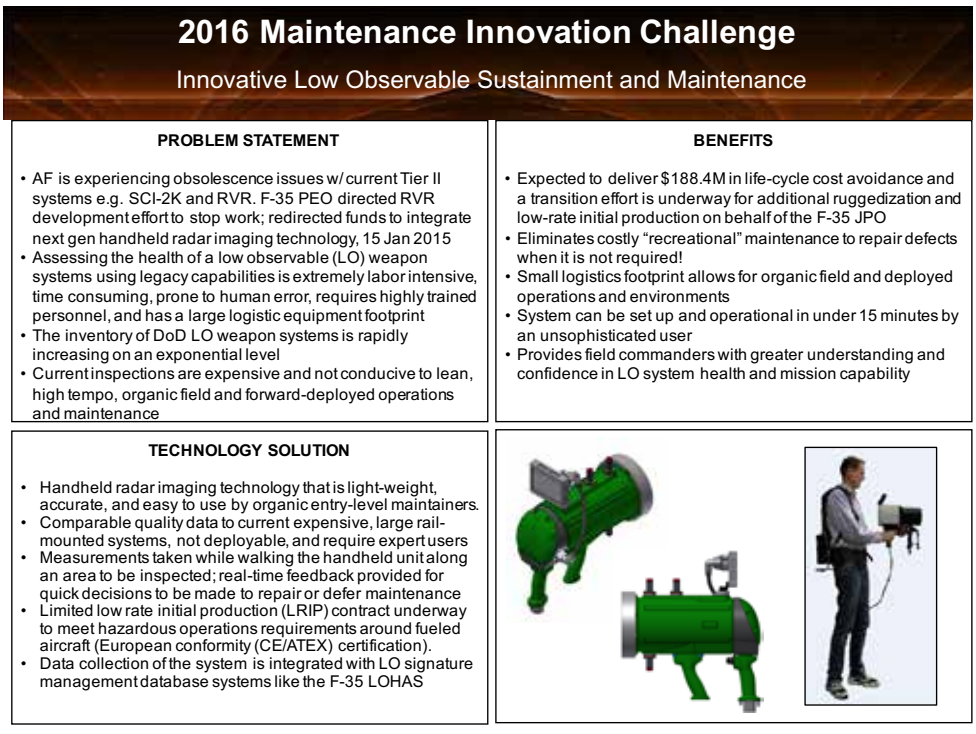
Handheld radar imaging technology is being developed by the Air Force Research Laboratory Materials and Manufacturing Directorate to revolutionize sustainment of weapon system low observable (LO) treatments with cross-cutting maintenance tools and practices. The rapidly increasing inventory of DoD weapon systems incorporating advanced LO technology is driving an urgent need to improve LO sustainment approaches. Common maintenance practices are very labor intensive, time consuming, prone to human error, and require highly trained personnel, special contractor logistic support, and large logistics footprint for inspection equipment. These practices are prohibitively expensive and not conducive to lean, high tempo, organic field and forward-deployed operations and maintenance. Handheld imaging technology enables LO systems to be more available and affordable! Specifically, AFRL/RX is producing a handheld radar imaging system that is light-weight, easy to use by entry-level organic maintenance personnel, with a small logistics footprint that is designed for organic field and deployed operations and environment. The handheld imaging system has been proven to be very accurate, repeatable and simple to use. It provides similar quality data to current, large rail-mounted systems that are expensive, not deployable, and require expert users. The handheld imager is innovative because the system can be set-up and operational in less than 15 minutes by a single maintainer! The handheld system architecture facilitates integration with LO signature management database systems like F-35 LOHAS. The imaging technology has been demonstrated to a high technology/manufacturing readiness level, with Joint Service maintainers successfully inspecting and collecting radar cross-section images to determine the health of LO systems. Operation is performed by calibrating and aligning the unit to the weapon system and walking the handheld unit along an area to be inspected. Real-time feedback is provided so that quick decisions can be made to repair or defer maintenance. The inspection technology eliminates costly "recreational" maintenance to repair defects when it is not required! Handheld imaging will assist commanders in the field to better understand the health of LO systems and provide confidence in weapon system mission capability. Additional investment in hardware miniaturization and robustness, as well as software tools for advanced data processing will support technology advancements to meet the needs for future LO weapon systems. The handheld imaging system has commonality across multiple weapon systems and Services through design for Air Force flight lines, Navy aircraft carriers, and austere forward operating locations. The technology program has a limited low rate initial production (LRIP) contract underway to meet hazardous operations requirements around fueled aircraft including European conformity (CE/ATEX) certification. The handheld imaging program is part of the F-35 LO maintenance tool set and will continued to be matured to advance capabilities for more DoD stakeholders.



ENHANCED INSPECTION

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 normal 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.

After successful bench scale oil dewatering testing in 2013, the United States Coast Guard (USCG) procured two portable membrane dehydrators, Phoenix C-4 units, for two Great Lakes icebreakers as existing onboard centrifugal purifier and conventional filter cart are unable to remove dissolved water in the Controlled Pitch Propeller (CPP) system EAL.

Last July, the USCGC Hollyhock experienced leaking blade seals that introduced heavy concentration of dissolved water in the CPP EAL to 3.75%. Underwater replacement of blade seals were performed and after 50 hours of sump dehydration using the portable membrane dehydrator, dissolved water is reduced to 2.04%. Cutter has confirmed that the source of leak is isolated and will continue dehydration efforts until dissolved water is reduced below 0.5% which is recommended limit for normal operation. Cost savings in avoidance of EAL replacement and disposal amount to about $20,000.

2016 Maintenance Innovation Challenge

Membrane Dehydrator

PROBLEM STATEMENT

Dissolved water pose an engineering and asset risk of damaged mechanical components, as well as the additional costs from downtime, maintenance, and replacement. Managing dissolved water is an emerging concern where water soluble polyalkylene glycol (PAG) environmentally acceptable lubricants (EALs) are now used in Controlled Pitch Propeller (CPP) system of two USCG cutters. Existing centrifugal purifiers onboard and conventional filter carts are not able to remove dissolved water in the CPP oil.

Recently, one of the cutters experienced leaking blade seals that the dissolved water increase to 3.75% in the CPP oil. After replacing the blade seals, dissolved water needs to be reduced to normal levels to allow continued use of the CPP oil for normal operation.

WAY FORWARD / POTENTIAL BENEFITS

- Avoid costly replacement of water soluble EALs due to excessive water contamination
- Dehydrators are available in portable and fixed units
- Unit runs with a filter cart so it is much simpler, less expensive and compact compared to standard oil dehydrators or centrifuges
- Minimal moving parts, requires less maintenance
- Total automatic operation, suitable for remote applications
- Unlike vacuum purifiers, no complicated floats or drive
- Water is discharged into the atmosphere as water vapor – no contaminated water to deal with

TECHNOLOGY SOLUTION

The dehydrator is based on an amorphous fluoropolymer hollow fiber membrane module that is configured similarly to a shell-and-tube heat exchanger. Water-laden liquid lubricant follows across outside of the hollow fiber membrane while a vacuum is applied on the inside. The membrane dehydrator uses a vacuum to force water to permeate from the oil through the membrane. Technology functions by separating components in lubricating oil based on their size. As a small molecule, water permeates through the membrane at a much faster rate than the other species in the lubricant. Higher alkanes such as those formulated into lubricating oil, their large size and low vapor pressure makes it very difficult for them to go through the membrane. The permeated water is then discharged into the atmosphere as water vapor.

STATUS OF TECHNOLOGY

USCG procured two portable membrane dehydrators for the two cutters with PAG EAL in the CPP system. USCGC Hollyhock currently using the unit to remove high dissolved water due to leaking blade seals. Blade seals were replaced and after 50 hours of sump dehydration, dissolved water is reduced to 2.04% and will continue dehydration until dissolved water is reduced below 0.5%.

eTool Sync Check and Management Utilities

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Problem: Management of digital technical order program and eTool network is excessively time consuming and inefficient. Processes, applications, and infrastructure used to manage Aviano AB's 500 eTools are inefficient and fraught with synchronization/communication deficiencies, limited data collection/reporting utilities, and inept network controls.

Old Process: TODO and eTool managers ensure that Technical Orders (TO) on eTools are synchronized/updated with the AF Master Digital TO library, at minimum, every 7 days. Currently, the only resources available to manage digital TOs are the Enhanced Technical Information Management System (ETIMS), TO account custodians, and manually checking "sync" status. The ETIMS website, is good for an overall view, but has some usability issues. The site is sometimes unavailable due to technical issues and updates. Additionally, ETIMS depends on the eTool Reporter service on the Master eTools. When there are power or network issues, the data for master and slave eTools and are not updated. Moreover, changes to eTool network names and removal of eTools from service causes orphaned eTool slave records that have to be found and deleted. Furthermore, ETIMS data must be converted into a useable format by manually copying the HTML tables into Excel. This process can take a lot of time and may not be accurate if the eTool Reporters are down or not running properly.

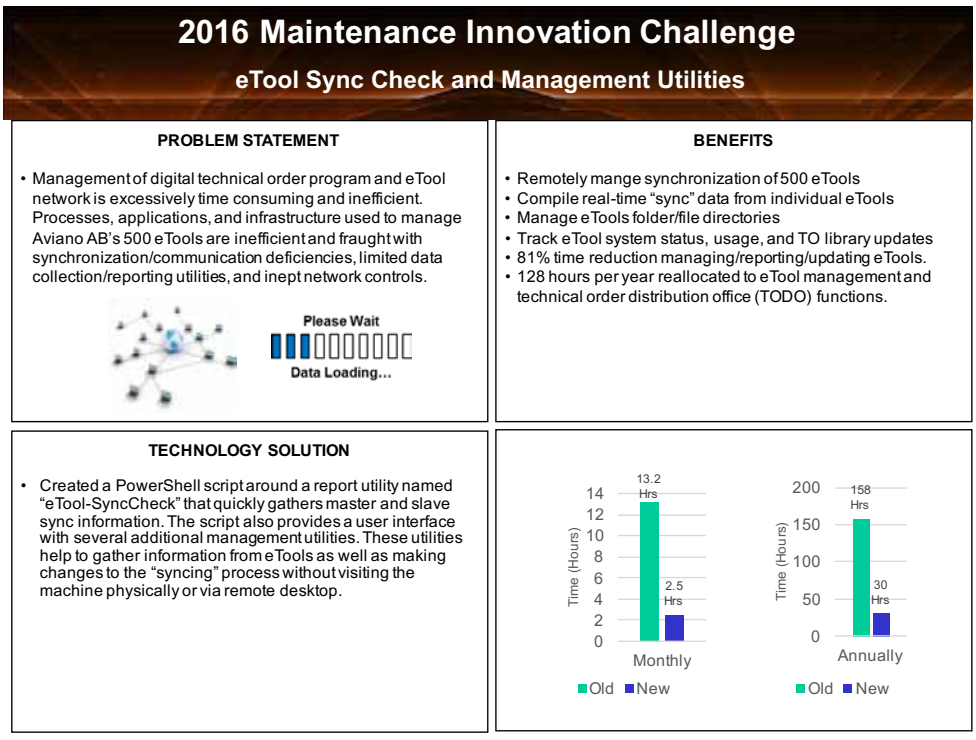
Results: Created a PowerShell script around a report utility named "eTool-SyncCheck" that quickly gathers master and slave sync information. The script also provides a user interface with several additional management utilities. These utilities help to gather information from eTools as well as making changes to the "syncing" process without visiting the machine physically or via remote desktop. The eTool-SyncCheck uses the information from the Master eTools and two additional configuration files. When the eTools "sync", they create an ETOOLS$ share folder on the master. The slave also copies the log from the "sync" process (robocopy) to the share folder. This information along with the master's sync information contains the same information available on ETIMS. However, this data can be compiled in a couple minutes and provides "real-time" information. The script also utilizes PowerShell Active Directory modules to gather extra information from each eTool, such as: last login date, days since last login, system status for both Master and Slave eTools, verify eTool network accounts, and can be run remotely and as often as needed. Moreover, "eTool-SyncCheck" utilities reduced eTool management from 158 to 30 hours per year for a net savings of 128 hours annually.

Additional "eTool-SyncCheck" Utilities:

eTool folder clean up: This tool enables eTool "sync" folder directory. From here managers can identify orphaned folders for deletion, and manage "sync" data.

Enable/Disable computer account: This option can be used for computer accounts that have become disabled because of lack of use/updates, troubleshoot "sync" issues, force updates, and enable/disable accounts remotely.

System Information Viewer: This tool queries eTools directly to get the make, model, serial number, date of last Windows update, date created, security group membership, 'location', Master and LogFileHost settings, and TO date.



Automatic Test Sequence Generator (ATSG)

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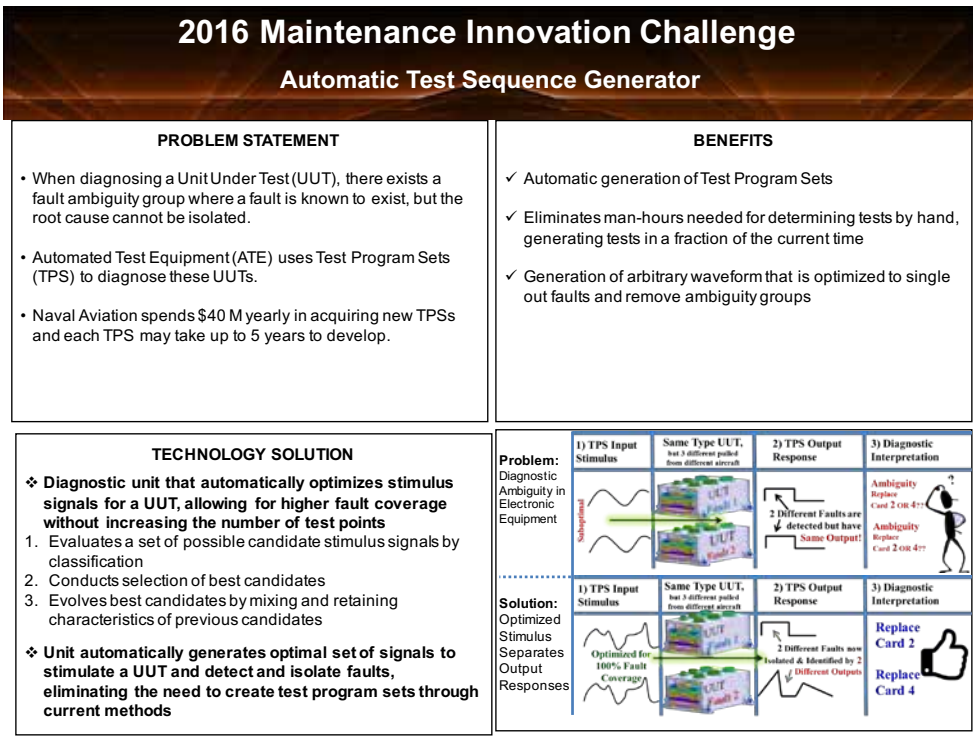
When creating a test program set for a Unit Under Test (UUT), a sweep of signals is used to stimulate a circuit board, while probing several test points on that board. The specific board responses for each of those signals are captured, creating an understanding of what a faulty output signal will be. This is done repetitively until a test program set is created that best highlights all known faults for that specific board. The process of stimulating the board to capture these fault profiles and create a test program set for a specific UUT can take to 5 years to develop.

The Automatic Test Sequence Generator allows for these test program sets to be created automatically, creating a large impact on schedule, budget, and accurate fault coverage. This diagnostic tool automatically generates an optimal set of stimulus signal specific to a UUT, which singles out faults and removes ambiguity groups. The system creates a candidate set of stimulus signals that are run through a classification process, where the UUT is simulated utilizing its fault models. From this classification process, best candidate signals are chosen and evolved by mixing and retaining characteristics of previous candidate signals. This process is continuously repeated until a set of optimal stimulus signals are created that best detects and isolates faults for that specific UUT.

The Automatic Test Sequence Generator has reached a Technology Readiness Level (TRL) of 4, after being validated in a laboratory environment. An analog circuit board, with ten fault options, was modeled, created and tested on. A system comprising of an NI compact RIO (reconfigurable inputs and outputs) system was used to output the set of optimal stimulus signals generated from ATSG, in place of what would normally be a TPS controlling ATE assets (such as IO pins, tolerances, limits, timing, delays, signal generators, etc). The compact RIO then reads in the response from the UUT and used its diagnostic algorithms to detect and isolate each of the faults within the analog board. Moving forward, the team plans to prove whether the technique will scale on highly-integrated, real-world circuit cards.



AGM-65 Video Generator/Tester

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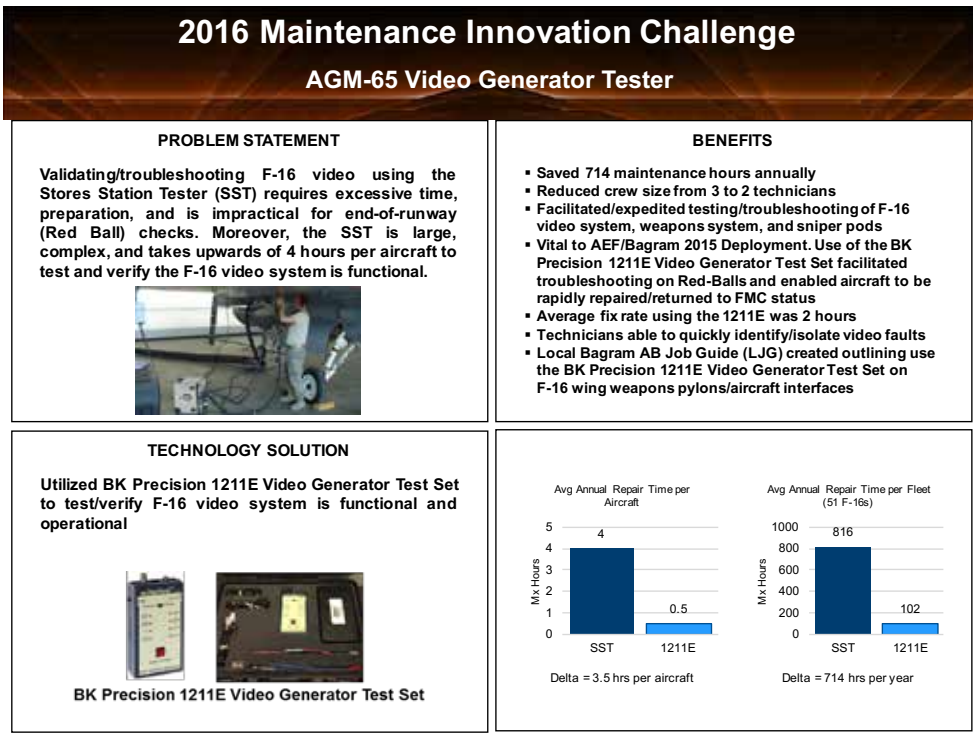
Problem: Validating/troubleshooting F-16 video requires excessive time, preparation, and is impractical for end-of-runway (Red Ball) checks. Moreover, test equipment being used is large, complex, and takes 4+ hours per aircraft test to verify F-16 video system is functional.

Old Process: Each F-16's video system is functionally tested biannually and whenever a fault is detected. It is also tested prior to AEF and training deployments. On average each aircraft's video system is tested at least 4 times per year. Aviano AB has 51 aircraft which equates to an estimated 204 video system functional checks performed per year. The old process uses the Stores Station Tester (SST) to test for the presence of video on the F-16 and verify weapon systems are operational. The SST is excellent for identifying/isolating faults but it does not have a direct test to verify video processing. During pre-flight or end-of-runway checks, technicians are required to verify the video system can process weapons video. Using the SST, diagnostic checks take approximately four hours and require three technicians. Due to its size the SST is not routinely carried by avionics technicians. When one is needed, a technician must return to the unit support section, sign out an SST, and return to the aircraft. This process adds an additional 30 to 60 minutes to testing. The combination of size, complexity, and testing time make the SST impractical for verifying operation of the video system during normal sortie generation.

Results: In an effort to reduce testing-time/complexity, the BK PRECISION 1211E VIDEO GENERATOR TEST SET (1211E) was chosen to verify/test the F-16 video system. The 1211E is a hand-held, battery operated test set that can generate a variety of video test signals/patterns which can be viewed/verified on the aircraft. The unit is connected via F-16 suspension equipment or aircraft interface using locally manufactured adapter cables. This enables technicians to verify video signals are sent via aircraft wiring to ensure the system is operational and facilitates video system/Sniper Pod fault isolation. Testing can be done by two technicians and takes <30 minutes per aircraft. If a fault is detected using the 1211E, the aircraft can be removed from flying status for more in-depth analysis. The 1211E was vital to 555th AMU success at Bagram AB in 2015. The normal Standard Configuration Load (SCL) included an AGM-65L "Maverick" missile which had never been flown in combat by the 555th, and led to many challenges. Use of the 1211E facilitated troubleshooting on Red-Balls and enabled aircraft to be repaired and returned to FMC status in minimum time. Technicians authored a Local Job Guide (LJG) outlining use of the 1211E to test the F-16 video system and were able to quickly identify/isolate video faults. The average fix rate for Maverick video issues was 2 hours. Overall, use of the 1211E reallocated approximately 714 man-hours, annually, and permanently reduced crew-size by 33%.



ENHANCED INSPECTION

F-16 BRU-46 Inspection Requirements

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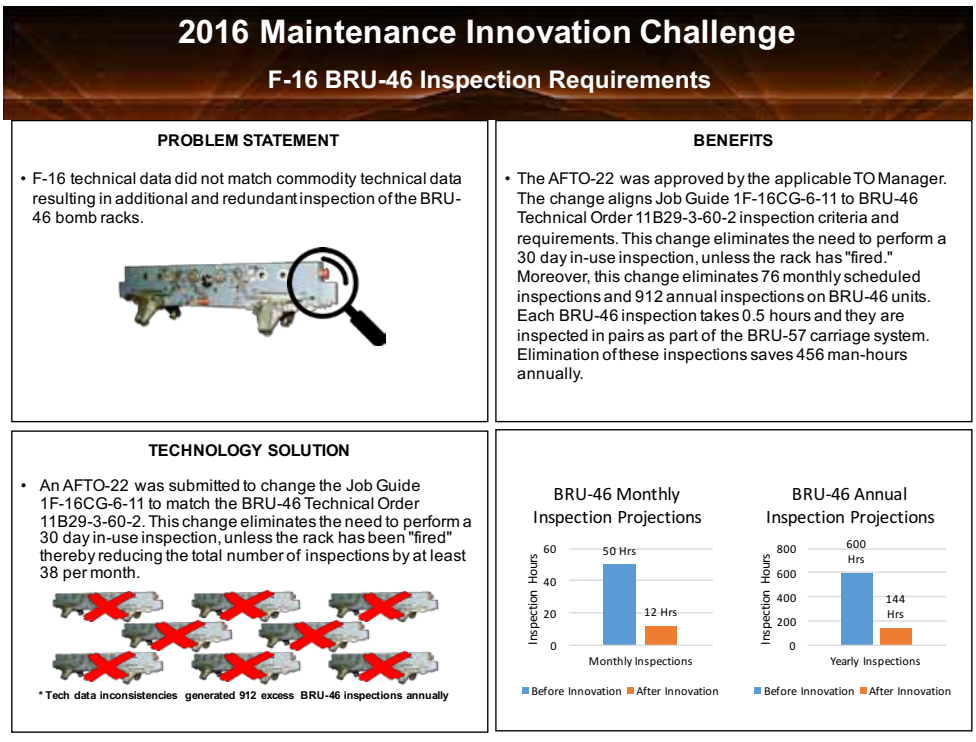
Problem: F-16 technical data did not match commodity technical data resulting in additional and redundant inspection of the BRU-46 bomb racks.

Old Process: Technical Order/Job Guide 1F-16CG-6-11 required personnel to accomplish 30 day in-use inspections on BRU-46 bomb racks (bomb racks used in the BRU-57 carriage system) regardless if it had been "fired" (bombs dropped). However, BRU-46 technical order 11B29-3-60-2 only requires the 30 day inspection to be accomplished if the rack has been "fired" (dropped bombs). The inconsistencies between technical data sources drove an additional 38 redundant 30-Day scheduled maintenance inspections in addition to inspections required when the BRU-46 is "fired." Aviano AB has 38 BRU-57s and each unit contains 2 BRU-46s (72 units in total). The BRU-46s are inspected together as part of the BRU-57 unit. Each inspection takes approximately 1 hour to complete; totaling 38 hours of inspections per month and 456 man-hours per year. However, these inspections could be eliminated by standardizing the F-16 Job Guide 1F-16CG-6-11 to the BRU-46 Technical Order 11B29-3-60-2 which requires the bomb rack to be inspected when it has been "fired."

Results: An AFTO-22 was submitted to change the Job Guide 1F-16CG-6-11 to match the BRU-46 Technical Order 11B29-3-60-2. This change eliminates the need to perform a 30 day in-use inspection, unless the rack has been "fired" thereby reducing the total number of inspections by at least 38 per month. The AFTO-22 was approved by the applicable TO Manager. The change aligns Job Guide 1F-16CG-6-11 to BRU-46 Technical Order 11B29-3-60-2 inspection criteria/requirements. This change eliminates the need to perform a 30 day in-use inspection, unless the rack has "fired." Moreover, this change eliminates 76 monthly scheduled inspections and 912 annual inspections on BRU-46 units. Each BRU-46 inspection takes 0.5 hours and they are inspected in pairs as part of the BRU-57 carriage system. Elimination of these inspections saves 456 man-hours annually.



Automated Inspections and RANDE

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A prototype 6 degree-of-freedom robotic arm to aid in inspections of remote or difficult to access structural areas has been in development over the past several years at the Air Force Research Laboratory Materials & Manufacturing Directorate. The robotic arm positions cameras and nondestructive sensors inside of structural cavities to facilitate inspection and situational awareness. The sensor package is designed to use existing nondestructive sensor technology, or incorporate newly developed probes with better detection capabilities. The system follows specific pre-programmed paths to be able to autonomously enter a structure through small ports without breaking it open for human access and accumulating maintenance-induced damage from disassembly. Robotic arm-assisted inspections can be completed using small access holes in the structure, accelerating inspection times and cuing high-value human inspectors to structural hotspots needing critical attention. Maintenance induced damage is a major concern as most disassembly results in some form of damage, adding associated repair cost and reassembly time to Depot flow. The automated nature of the inspection also provides more reliable and repeatable inspection of parts. The high stress and effort for maintainers to enter these structural cavities and fatigue while performing the inspection has the potential to affect the accuracy and validity of the results. The robotic inspection arm is designed to be deployable, as recently demonstrated by the AF/Industry team in an austere field environment at Davis-Monthan AFB storage area on B-52 and A-10 wing assemblies, with the system unpacked and ready for inspection within a half-hour. The system will soon be sent to the Ogden depot maintenance facility at Hill Air Force Base for initial trials, incorporating lessons-learned from the Davis-Monthan demonstration. Robotic-assisted inspection will support commanders to better understand the health of structural aircraft systems and provide confidence in weapon system mission capability.

2016 Maintenance Innovation Challenge
Automated Inspections and RANDE

PROBLEM STATEMENT

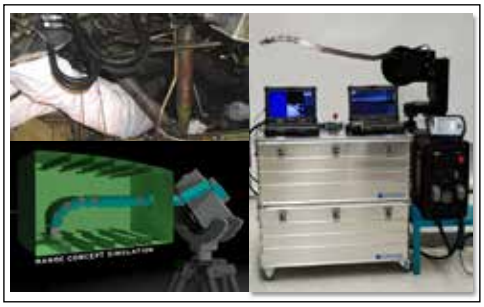
- Remote, difficult to access, or hazardous areas require teardowns prior to inspection
- Man power intensive & highly stressful
- Reduced inspection accuracy
- Teardown damage must be repaired.

BENEFITS

- More reliable, repeatable, and accurate inspections for difficult to access areas
- Eliminate expensive teardowns
- Reduced maintenance induced damage
- Reduced stress on human inspectors

TECHNOLOGY SOLUTION

- 6 degree of freedom modular and transportable robotic arm
- Integrated control module and leader-follower path programming
- Use advanced eddy current sensors
- Utilize designed in structural access points



Using Voice Directed Technology for Transforming 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 Vocollect 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.

NightHawk™ No Fault Found Reduction Platform: The Software Platform to Close the Age and Performance Gap

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NightHawk™ ETRS (Contract Number FA8501-15-C, SBIR Phase II) is an interactive test development platform system that can find, reduce, or eliminate No Fault Founds (NFFs) on critical systems by determining the cause of the problem at the circuit level. NightHawk provides enhancements to test program set (TPS) code to detect soft faults on 'Bad Actor' Circuit Card Assemblies (CCAs), which remain difficult to isolate and detect using conventional TPS methods. NightHawk has been tested on Electronic Warfare (EW) circuit cards at Warner Robins Air Logistics Complex where Ridgetop was able to demonstrate its VCO test board which found numerous "soft faults" that conventional ATE could not find. These soft faults contribute to the high NFF rates on these CCAs, and as a tool, the NightHawk objective is to reduce the incidence of NFF to 50% along with reducing MTTR by 60%.

As sources of NFF are difficult to isolate and detect using current TPS methods, these problems are exacerbated with aging avionic components and other electronic subsystems that are subjected to harsh environments, resulting in parameter drift and degradation in the form of 'soft faults' that contribute to NFF instances.

Approximately 18,000 CCAs are utilized within the Air Force, with a significant number suffering from NFF indications, and as conventional ATE TPS programs are still being used without the ability to accurately pinpoint mission critical problems; both testing costs are increased while operational readiness is reduced. NFF conditions result directly into increased labor hours, overhead, needless downtime, and recurring shop-replacement unit maintenance, concluding into wasted millions of dollars spent each year for substandard system readiness.

NightHawk provides algorithmic methods that root out 'Bad Actor' CCAs and electronic modules through a software-based, troubleshooting and repair system (ETRS) that is designed to work with Hardware Instrument Test Platforms, including the Air Force's VDATS.

NFFs are also caused by lack of design margins in the original design, causing these 'bad actors' to be re-hosted. When 'bad actors' need to be re-hosted, Ridgetop can add a Built-in-test option to the platform to provide full wraparound of the waveform outputs to verify the correct amplitude, offset; frequency and distortion are as expected. The CCA will detect a failure condition and the details of the failure will be stored in a digital field programmable gate array as a flag. These failure flags will be read out during depot testing to determine the failed IC.

A prototype re-host of a "Bad Actor" Electronic Warfare prototype CCA has been developed, providing an original topology using the existing form factor. Built-in-Test features have been added to the CCA, and the new design cost is only a fraction of the present production cost, requires no calibration, eliminates marginal design issues – including many obsolescence issues – and provides Built-in-Test to simplify testing at the depot, unit, and aircraft level.

Diagnosis time will be reduced by at least 60% and MTTR reduction by more than 40% with NightHawk implementation. Ridgetop's NightHawk is an innovative prognostic and diagnostic tool that saves money and time.

2016 Maintenance Innovation Challenge

NightHawk™ No Fault Found Reduction Platform: The Software Platform to Close the Age and Performance Gap

PROBLEM STATEMENT

- "No Fault Found" (NFF) readings of CCAs found in depot testing, yet fail when installed in aircraft, contribute up to $2 Million per year/per 'bad actor' while also lengthening Mean-time-to-Repair (MTTR).
- The average age of Air Force assets continue to grow, already 23 years old, and as electronic components age, parameter drift and component degradation occur that is not properly accounted for in conventional TPS.
- Dynamic environmental conditions, such as humidity and G-Force, along with aging are just a few of the factors effecting the parametric margin of circuits attributed to component drift.
- ETRS software, like NightHawk, has already been installed on VDATS and is a proven innovation to detecting difficult to find NFFs through its anomaly detection algorithms.

BENEFITS

- Test coverage provided by NightHawk™ of CCAs, SRUs and LRUs, with soft fault coverage possible provides and estimated $2M per year/per 'bad actor' in direct maintenance costs on depot-level test systems.
- Reductions in Re-spins and obsolescence from built in diagnostics to the board under test provide higher costs savings and significantly reduces inventory at the depot level.
- Predicable warranties possible, allowing for maximum value of NPV dollars spent. Condition-based Maintenance (CBM) is facilitated by up to 50% cost savings.
- Reduces NFF rates by a target of 60% and reduces MTTR by a target of 50%, increasing safety margins of the systems.
- Modular software architecture solution that allows porting of software code to different test platforms, including VDATS.

TECHNOLOGY SOLUTION

- NightHawk is an intuitive and easy-to-use software tool augmented with a graphical user interface (GUI) that expands the capabilities of the VDATS test platform, enhancing TPS capabilities.
- Ridgetop provides algorithmic methods and testing techniques as run time executables to root out difficult to find faults with high predictability in minimum run time.
- NightHawk utilizes these advanced anomaly detection algorithms to determine what us failing on the circuit level, thereby highlighting design margin instances.
- The package provides schematics, board layout, and test point locations to reduce MTTR and support maintenance personnel for baseline measurements and database tracking.

Stem Centerline Measuring (SCM) Fixture

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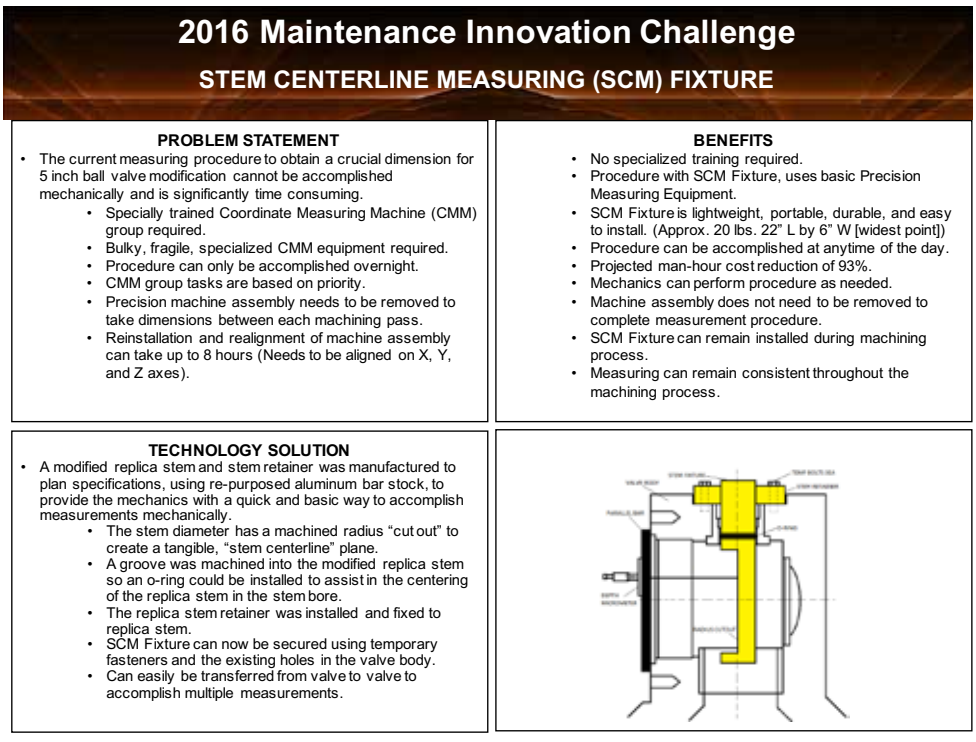
The Stem Centerline Measuring (SCM) fixture was conceived during the inaugural precision machining modification of a 5 inch ball valve. Mechanics were unable to accomplish measurements mechanically during the machining process which therefore, required assistance from a specialized group. The SCM fixture consists of a modified replica stem and stem retainer manufactured separately, to plan specifications. The modified replica stem has a machined radius cut-out approximately 9" long which creates a tangible stem centerline plane (previously imaginary) and provides a flat, firm surface for a depth micrometer to bear against, so that mechanics can accomplish the crucial "flange face-to-stem centerline" measurements for the modification of the ball valve. The replica stem retainer is fixed to the modified replica stem, after the validation process, to allow the assembly to be secured using the existing retainer holes on the top of the valve body. This prevents the SCM fixture from inadvertent movement during the measuring procedure and allows it to remain installed throughout the precision machining process. The fixture was manufactured using re-purposed aluminum bar stock, which provides mechanics with a lightweight, portable tool (approximately 20 lbs. 22" L by 6" W [widest point]) that is easily transported shipboard and from valve to valve. The SCM fixture eliminates the need for a priority categorized, highly specialized Coordinate Measuring Machine (CMM) group. This creates the ability to accomplish dimensions as often as desired during the precision machining process without removing the machine, which routinely takes up to 8 hours to align on all 3 axes (X, Y, and Z). During the validation process, a groove for an o-ring was machined into the modified replica stem to ensure that when installed into the valve body, the stem was centered within the valve stem bore. While working with the CMM group, measurements were constantly taken with the CMM, as well as a depth micrometer, and adjustments were made until both measurements were close to identical (0.001" – 0.002" tolerance for mechanic's feel and thermal expansion). The replica stem retainer was then affixed to the replica stem to lock in the fixture. The SCM Fixture was then transferred to another identical valve and the validation procedure was completed again with both the CMM, as well as a depth micrometer to confirm repeatability of the fixture. Finally, the dimensions of the SCM Fixture itself were taken with the CMM to ensure that the SCM fixture was manufactured to the correct specifications and that the valve measurement data that was recorded using the fixture was accurate. Based on the job data gathered during both occasions the measuring procedure was completed, there is a projected average man-hour cost reduction of 93%. The SCM Fixture saves time, money, and ultimately accomplishes the goal of providing mechanics with a quick and basic way to accomplish measurements that previously could not be accomplished mechanically.



Large Scale Large Area Thermographic (LASLAT) Nondestructive Inspection of Composite Structures

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Effective Non-Destructive Inspection (NDI) of composite aircraft requires inspection of large areas of the aircraft, subject to the constraints of equipment and labor costs, operational requirements for minimum down-time and training requirements. However, many of these requirements are contradictory, as the least expensive NDI equipment is often quite time and labor intensive, often based on inspection of a point or small area, while large area systems involve expensive scanning apparatus, and frequently, disassembly of the aircraft. In either case, the ultimate criteria for an NDI method must be its ability to detect critical flaws that may compromise the structural integrity and performance of the aircraft. Our program is focused on addressing these issues, and providing the required inspection sensitivity and large area coverage in a versatile multipurpose system that can be deployed economically for use at the depot level. Such a development should enhance the readiness of military aircraft by minimizing the time a vehicle spends in the depot and by reducing the possibility that the aircraft will suffer an unexpected failure during operation by ensuring the structural integrity of critical components.

To meet the need for an automated, large-scale NDI capability, Thermal Wave Imaging developed the Large Standoff/Large Area Thermography (LASLAT) automated NDI system, capable of rapid and accurate inspection of the composite structures of aircraft (e.g. trailing edges, flight control surfaces, and fuselage), detecting flaws such as voids, delaminations, and disbonds during depot maintenance. From a stationary position, the 4-axis LASLAT system can pivot (3-axis for camera and two novel optical projectors) and tilt to inspect an area 20 feet by 15 feet from a distance of 10 to 15 feet at a rate of approximately 4.4 square feet per min through an automated inspection routine, without the need of a gantry, creeper or track. The intelligent defect identification tool allows the user to pinpoint the exact location and nature of defects found.

The LASLAT system was used to perform two depot-level inspections. Inspection of a V-22 rotor blade, which previously took approximately 12 hours per blade for data capture and analysis, was reduced to approximately 12 minutes capture time and allowed for physics-based data analysis using a modified version of our proprietary Thermographic Signal Reconstruction (TSR) method during the capture sequence. Inspection of a V-22 Fuselage area of approximately 10 feet by 8 feet was performed in approximately 15 minutes. Previously, this inspection was done using two-sided UT, which took considerably longer.

This technology will result in decreased maintenance downtime, increased throughput, cost savings, and increased structural integrity of aircraft.

2016 Maintenance Innovation Challenge

Large Scale Large Area Thermographic (LASLAT) Nondestructive Inspection of Composite Structures

PROBLEM STATEMENT

Effective Non-Destructive Inspection (NDI) of composite aircraft requires inspection of large areas of the aircraft, subject to the constraints of equipment and labor costs, operational requirements for minimum down-time and training requirements. However, many of these requirements are contradictory, as the least expensive NDI equipment is often quite time and labor intensive, often based on inspection of a point or small area, while large area systems involve expensive scanning apparatus, and frequently, disassembly of the aircraft. In either case, the ultimate criteria for an NDI method must be its ability to detect critical flaws that may compromise the structural integrity and performance of the aircraft. Our program is focused on addressing these issues, and providing the required inspection sensitivity and large area coverage in a versatile multipurpose system that can be deployed economically for use at the depot level.

BENEFITS

- Reduced cost
  - Faster inspection = fewer man hours
  - No gantry infrastructure required
  - Single system can be used for multiple platforms
- Improved inspection capability
  - TSR signal processing extends depth and sensitivity
  - Built-in validation with secondary method
  - Quantitative output for lifetime tracking
  - Assists operator with automated flaw detection
  - Result is subsurface image of entire part
- Configured specifically for maintenance
  - Large standoff distance for use in fuel vapor areas
  - Inspection programmed for repeatability

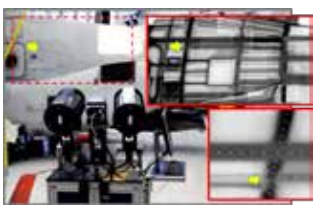
TECHNOLOGY SOLUTION

The Large Scale Large Area Thermography (LASLAT) system provides the precision and sensitivity that has been achieved with close-proximity flash thermography in a system that can inspect a large area while operating at a large standoff distance. There are three primary components to the technology:

- Remote excitation of the aircraft using a novel optical projector developed in Phase II SBIR
- Physics-based processing of the IR signal using a modified version of our proprietary Thermographic Signal Reconstruction (TSR) method.
- Combining scanned inspection results into a single data set representing the entire structure.

The net result is a subsurface map of the inspection area that highlights likely indications of impact damage, trapped fluid, delamination or disbanding from the underlying structure.

LASLAT Inspection of a V-22 Fuselage



LASLAT inspects an 8' x 10' V-22 fuselage section in under 15 minutes. Insets show the subsurface image and an adhesive disbond.

ENHANCED INSPECTION

MJ-1C Bomb Loader Hydraulic System Manufacturer Defect

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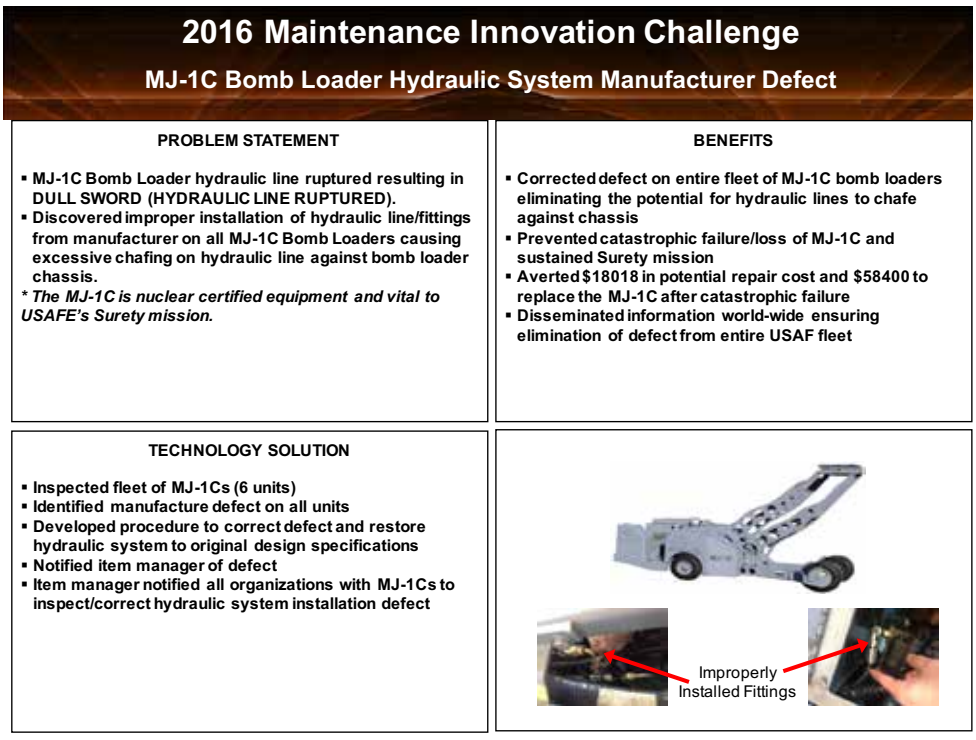
Problem: MJ-1C Bomb Loader hydraulic line ruptured resulting in DULL SWORD (HYDRAULIC LINE RUPTURED). Led to discovery of improper installation of hydraulic line/fittings from manufacturer.

Old Process: MJ-1C transports, lifts and attaches bombs, fuel tanks, pylons and aerial stores weighing up to 3,000 pounds to wing or fuselage stations of military aircraft. Additionally, the MJ-1C is nuclear certified equipment (NCE) and therefore a critical component of the 31 FW's Surety mission. Aviano received 6 units in 2009 and put them into operation. In September of 2015 one of these units experienced a hydraulic system failure when a hydraulic line ruptured while the bomb loader was in operation. The operator realized the failure and was able to power down the unit before catastrophic failure of the hydraulic system. The incident was reported as a DULL Sword (Dull Sword is the term that describes reports of minor incidents involving nuclear weapons, components or systems, or which could impair their deployment.) During the investigation/repair of the unit it was discovered that the failure was caused by excessive chaffing of the hydraulic line against the units chassis. Upon further examination, it was identified that the fittings on the rupture hydraulic line, from the pump to a manifold, were installed backwards from by the manufacture. Researching the part number and hydraulic plumbing diagram in the unit T.O., identified that the 90 degree fitting should be installed on the pump side and the straight on the manifold side. However, on this unit is had been install in reverse. The remaining 5 MJ-1C Bomb Loaders were inspected and they all had the same manufacturer's defect.

Results: Immediately after discovery of the improper installation of hydraulic line/fittings all MJ-1C models (6 units) were removed from service for inspection. All six units were identified with the same manufacture defect. All units were corrected using the existing hardware by disconnecting the hydraulic line and installing it IAW T.O. 35D3-2-25-11 and design specifications. The hydraulic line when installed IAW technical data provides adequate spacing from the chassis bulkhead. This action mitigates chaffing/rupture of the line and subsequent catastrophic failure of the unit's hydraulic system. Moreover, if the hydraulic system were to fail it would cost approximately $3000 to repair each unit. Execution of this repair abated catastrophic fail of Aviano AB's six MJ-1C Bomb Loaders, $18000 in repair costs, and 324 maintenance hours. This action was routed up to the USAFE A4/A4MA as the AF's entire fleet of MJ-1Cs is potentially affects. In-turn, USAFE A4/A4MA office disseminated this innovation/corrective action to entire AF for correction.



F-16 External Fuel Tank Inspection Process

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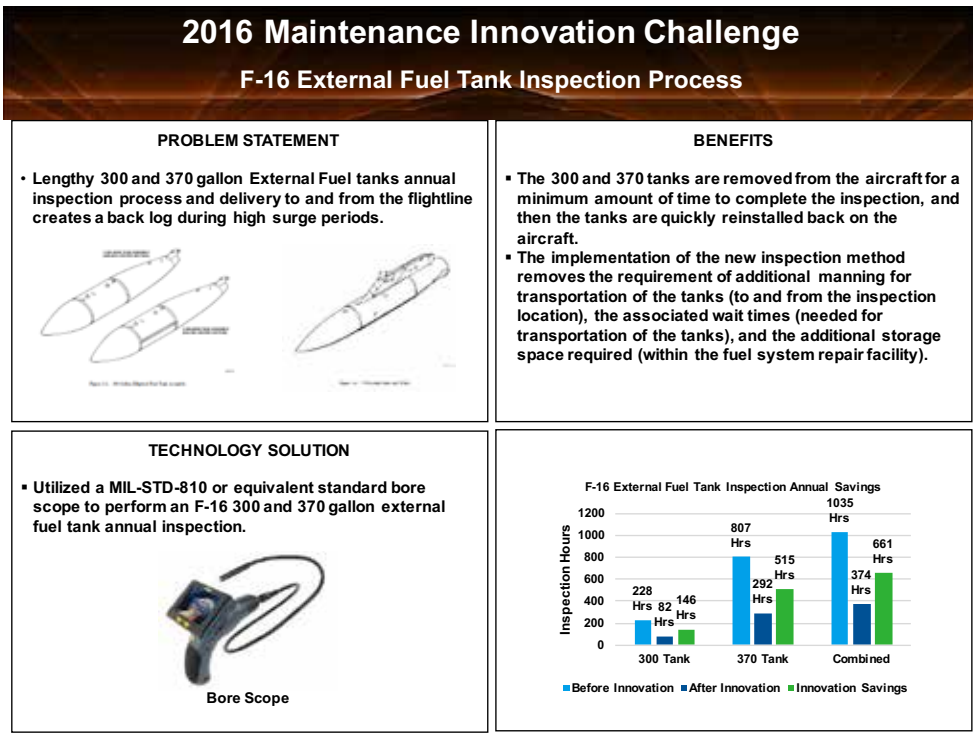
Problem: Lengthy annual inspection process and transportation 300 and 370 gallon external fuel tanks creates a backlog during high surge periods.

Root Cause: Current process requires external fuels tanks to be removed from aircraft and sent to fuel shop for inspection. The inspection entailed: removal of 370 gallon center access panel and/or the 300 gallon nose cone to facilitate visual inspection of the interior/exterior of the tank. After which the access panel was reinstalled. The tank was then tested on the tank certifier to verify pressurization and seal. This additional step is required anytime the access panel or nose cone are removed/installed. The entire inspection took approximately 3 hours to complete. However, the need to de-fuel/remove the tank, transport to and from the fuel shop, and then reinstall it on an aircraft generated additional delays. Moreover, tanks were stored awaiting maintenance (AWM) until operational priorities allowed for or drove their inspection added more delays. Combined these delays added up to an additional 3 hours to several days (per tank) and created a backlog.

New Process: Utilizing a MIL-STD-810 or equivalent bore scope the annual inspection can be preformed on the aircraft without the need to drop or transport the tank. The bore scope is inserted through the fuel filler neck allowing inspection of the tank's interior. This process eliminates the need to remove the access panel or nose cone which in-turn eliminates the need use the tank certifier to test pressurization and tank seals. The entire inspection can be performed on the aircraft in approximately 15 minutes. Additionally, this new process eliminates the need to transport and store tanks. The overall result is that annual external fuel tank inspections can be accomplished quickly, in place, reduce down-time and back-log, and eliminate approximately 661 man-hours, per year, in non-value added maintenance activities.



Resilient Integrated Power Heating and Cooling System

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This abstract presents a Resilient Integrated Power, Heating, And Cooling system (RIPHAC, pronounced "Rip-Pack"), which was developed under the U.S. Air Force Small Business Innovative Research (SBIR) grant contract FA8501-14-C-0004. The purpose of the system is to demonstrate an integrated cooling, heating, and power generation system that operates from multiple energy sources and that can be easily incorporated onto a building similar to a standard air conditioning system. The single system provides the same capabilities to a building as the combination of a conventional heat and cooling system, an uninterruptable power supply (UPS), and back-up generator, but with the added benefit of lower initial cost, reduced maintenance, and significant energy savings. The system can operate on energy provided from any combination of solar thermal collectors, photo-voltaic systems, natural gas, propane, or traditional grid power. Installation and maintenance is similar to a traditional air conditioning system, allowing affordable back-up power to be available for numerous locations that were not previously cost affective, and enhancing the energy resilience of any traditional building.

The prototype system provides 15-tons of heating and cooling with 7 kW of back-up power. The unit will be available for installation in mid-2017 to demonstrate significant reduction in building energy costs (75% reduction expected) for heating and cooling, plus the ability to provide back-up power. These dramatic reductions will be demonstrated through primarily 4 system operating modes: 1) Direct solar-thermal driven air conditioning, 2) The ability to put electric power back onto the grid, if excess solar energy is available, 3) Operation in a co-generation heating mode, which produces electricity as a by-product from heating the building, and 4) the ability of the system to operate autonomously and provide back-up power to the building in the event of an electrical grid failure.

Maintenance savings are realized by eliminating the monthly maintenance required to assure availability and reliability of traditional stand-by generators. The air conditioning and heating system that is used every day is also the back-up power system. 90% of the system has been built and is undergoing testing of the sub-systems and system modes.

The RIPHAC has broad application for both military and commercial installations, which can benefit from the availability of back-up power. As commercialization progresses and production costs decrease, the RIPHAC will seek to challenge conventional heating and cooling systems in traditional installations.

2016 Maintenance Innovation Challenge

Resilient Integrated Power, Heating, and Cooling System

PROBLEM STATEMENT

- ❑ Make resilient power, heating and cooling affordable for every building.
- ❑ Lower installation, maintenance, and 75% lower operating cost than conventional approach.
- ❑ Maintenance schedules, service procedures and operation similar to conventional HVAC systems

BENEFITS

- ■ Energy security provided in single package
- ■ Without solar field:
  - ❑ Immediate payback
  - ❑ Lower initial cost than heat pump + back-up generator + uninterruptable power supply.
  - ❑ 40% lower energy cost than conventional heat pump
- ■ With solar field:
  - ❑ 75% energy cost reduction
  - ❑ 6 year payback (without Federal tax credits)

TECHNOLOGY SOLUTION

- ❑ Combined cooling, heating, and back-up power
- ❑ Runs on solar thermal, photovoltaic, natural gas, or grid power
- ❑ Switches to lowest cost energy source.
- ❑ Heating from natural gas provides co-generated electricity at 2.5 ¢/kw-hr.
- ❑ Prototype unit provides 15 tons cooling/heating, 7 kWe back-up power.
- ❑ Hermetically sealed, dual-cycle system.

OPERATING COSTS BENEFITS

❑ Savings By Region – Solar Option (From DOE BLCC Program)

With Federal Tax Credits	Newark Fixed	Atlanta TOU	Atlanta Fixed	Phoenix TOU	Phoenix Fixed	Chicago Fixed
% Reduction In Energy Costs	102%	70%	78%	100%	98%	77%
Annual Op Cost Savings	3816	2734	2708	4921	4145	2590
Gas/Elec Ratio, ($/Therm)/($/kw-hr), summer	5.1	7.0	11.2	2.3	2.9	8.8
Gas/Elec Ratio, ($/Therm)/($/kw-hr), winter	5.1	14.3	10.4	9.2	8.0	8.8
Payback, simple, years	0	0	0	0	0	0
Net NPV, $k	41	29	31	52	42	31

❑ Example Operational Cost Savings Newark, NJ

AnnualConsumption	Conventional HVAC	EQ CHP w/ Solar
Electricity Cost	$1,624	$0
Natural Gas Cost	$2,125	$1,840
Electricity Production	0	($1908)
Total	$3,749	($68)

102% reduction in energy cost

KC-135 Fuel Leak Elimination and Life-Cycle Cost Enhancements

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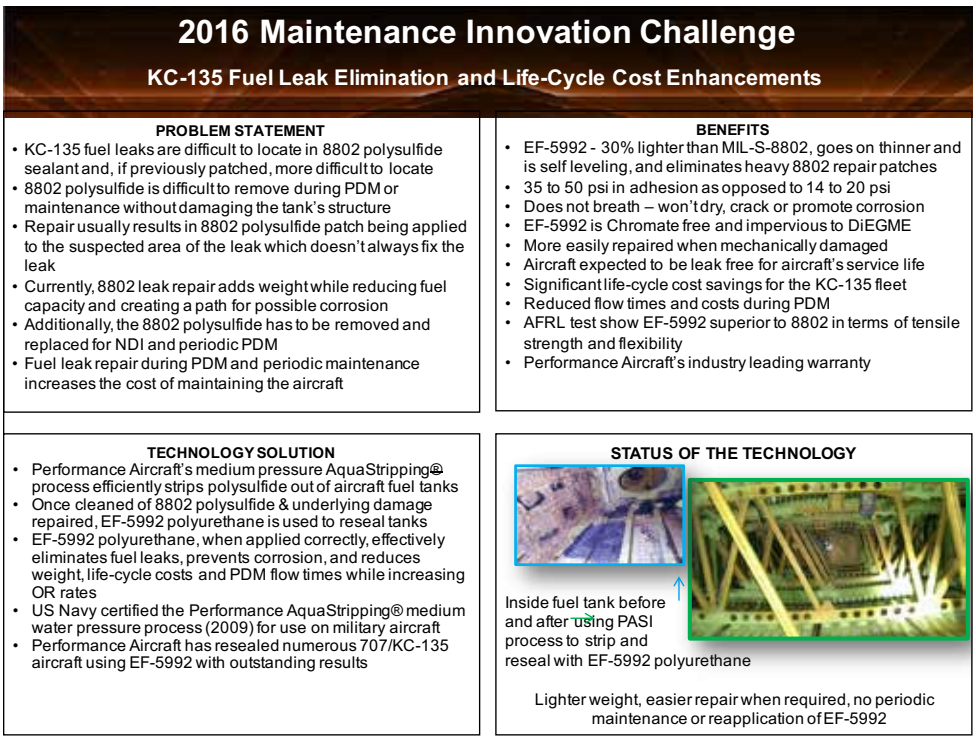
Performance Aircraft Services, Inc. (PASI), a Woman Owned Small Business, is the only company certified to perform the application of the Meggitt EF-5992 polyurethane sealant on aircraft. PASI is an FAA part 145 repair station specializing in the repair of fuel systems, with an emphasis on refurbishing integral fuel tanks. Our highly successful repair model, performed on hundreds of commercial and military aircraft, is based on a proven process using a US Navy certified medium water pressure aquamisier to strip the Mil-S-8802 polysulfide out of the KC-135 fuel tanks and reseal them with EF-5992 polyurethane sealant. EF-5992 was developed and refined over many years of collaboration with Meggitt Polymers and Composites, an industry leader. In addition, PASI develops a work deck for each type of aircraft worked on that ensures that all personnel follow a step by step operating instruction. To aid in surface preparation, our Venturi system ensures removal of the water as the stripping progresses. Following stripping, our quality control personnel perform a three-part check to ensure the surface is absolutely dry and ready to receive the Meggitt EF-5992 polyurethane sealant. The EF-5992 is brushed on in four layers with a uniform thickness and density. The EF-5992 provides numerous benefits to the KC-135 aircraft over the 8802 that is currently used in aircraft fuel tanks.

- It is lighter by 30%, is self-leveling, goes on thinner and is easier to repair when the tank suffers mechanical damage. Also, elimination of Mil-S-8802 repair patches dramatically increases achieved weight savings and increases engine fuel savings.
- It has 35 to 50 lb/sq in adhesion as opposed to 14 to 20 lb/sq in for Mil-S-8802.
- Does not breath; so it won't dry, crack, or promote corrosion.
- Requires virtually no maintenance and dramatically drives down life cycle cost.
- Is more easily repaired than other products when mechanically damaged.
- Is impervious to DiEGME and most other chemicals.
- Is far superior in terms of tensile strength and flexibility. In tests run by the AFRL in 2015 in 2015, MIL-S-8802 failed after 200,000 cycles, while the test on EF-5992 was discontinued after 1.3 million cycles.

Life-cycle cost savings to the KC-135 Program will result from using the Performance Aircraft medium water pressure aquamisier to efficiently strip the 8802 polysulfide out and reseal with EF-5992 polyurethane. The cost savings will result from reduced/no work on the KC-135 fuel system during PDM, reduced operational fuel system maintenance, increased Operational Readiness rates and reduced fuel used during operational missions.

Lockheed Martin Corporation recently released new LM Process Bulletin C-475-M to define the application requirements for EF-5992 and revised LM Process Bulletin C-331-M to allow the use of EF-5992 polyurethane as an alternative to 8802 polysulfide.

EF-5992 polyurethane will significantly reduce the life-cycle cost of operating legacy aircraft while at the same time greatly reducing the MICAP rates for fuel system issues.



V-Tail Mount Guards and Bolt Extraction Tool

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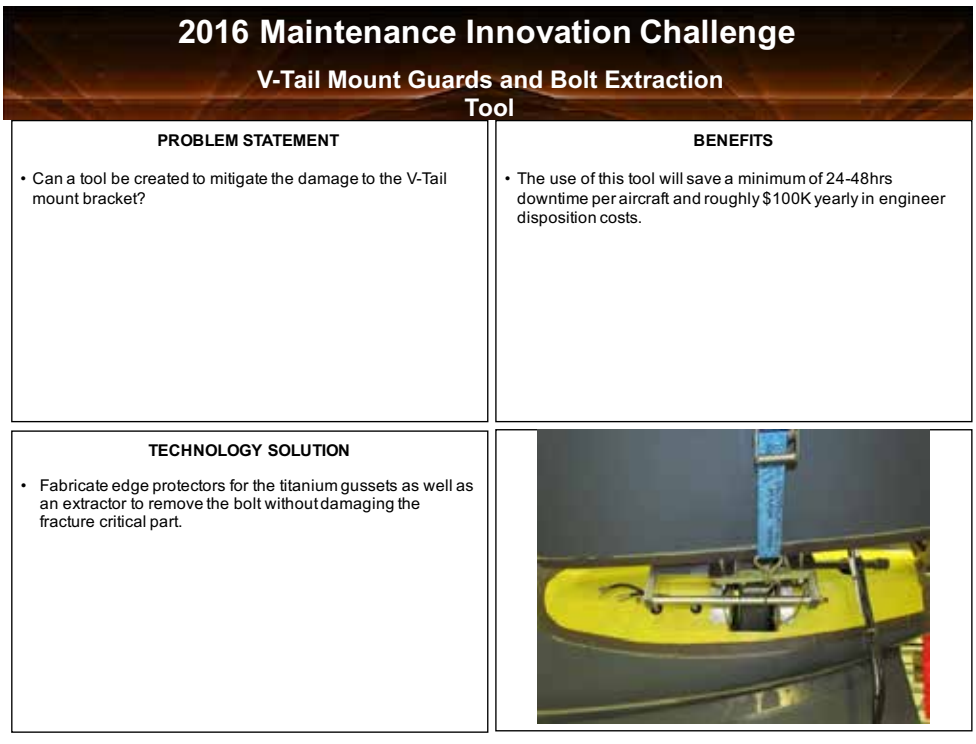
After every 50/200/350/500/650 flights the RQ-4B Global Hawks requires a Non-destructive inspection to pinpoint possible delaminations and other defects in the carbon-fiber material. In order to conduct this inspection both V-Tails must be removed. During every removal process, the fracture critical mount brackets are damaged thus prompting a engineer repair disposition. To alleviate this problem, the Aircraft Metals Technology shop at Grand Forks Air Force Base designed and fabricated a solution to prevent damage to these brackets by engineering the V-Tail mount guards and bolt extraction tool. The first step during the bolt removal process is to insert the mount guards on the four gussets to prevent damage from the ratchet's vertical alternating motion as the nut is being removed. The second step is to remove the V-Tail mount bolt. The technical data states that once the nut is removed use a hammer and a brass punch to push out the 7 3/4" bolt. Although this method works, it has been proven that with a minor slip-up the bracket is guaranteed to get damaged and in some cases beyond repair. To counter this problem a bolt extractor tool was designed. This tool mounts onto the V-Tail mount bracket and uses an acme thread rod to push the bolt effortlessly through both mounts avoiding catastrophic damage to the aircraft structure. A normal V-Tail removal procedure consists of 2-3hrs of maintenance however, damage of the mount brackets requires an engineer disposition adding a minimum of 24-48hrs turn-around time per aircraft and additional 1-2hrs of repair time. Grand Forks AFB submitted seven engineer dispositions costing roughly $10K each. Implementation of these tools into standard V-Tail removal procedures would save the Air Force approximately $100K yearly in engineer disposition costs alone.



M978A4 Emergency Battery Disconnect Switch

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The AER (Army in Europe Regulation) 55-4 IAW ADR 2016 require any transporting equipment of flammable liquids to be equipped with an emergency shut off switch for all electrical power, installed within the drivers cab and easily reachable for the driver at any time.

Purpose for switch is to disconnect electrical power (as close as possible to the batteries) from all energized circuits in case of an emergency. An "Electronically Controlled Switch" must be installed inside the Operators Compartment; Highly Visible and Protected from accidental engagement with two levels of activation. This configuration meets the ADR Technical Specification compliance standards.

To meet ADR FL compliance:An empty control panel cover is removed from the instrumental control panel and modified to mount Toggle Switch NSN:5930-00-683-1633 & Guard, Switch NSN: 5930-00-615-7952 into the dash (see quad chart picture 1).

An ADR compliant 24VDC wiring harness circuit is fabricated and installed from the back of the Toggle Switch in the dash panel, routed through the floor of the Armor Cab using an existing hole and secured to frame rail back until it reaches the vehicles battery box. A 10 Amp fuse link Fuse, Enclosed Link NSN: 5920-01-149-6952 is integrated within fabricated circuit (see quad chart picture 2).

Relay part is mounted to the inside wall of the battery box. Wiring harness for battery disconnect switch is routed and secured along the main wiring harness into the Cab! All electrical Connections and Cables are covered with convoluted Tube, RTV & Electrical Tape. Blank Spot's will be painted GREEN CARC (see quad chart picture 3).

The implementation of this standard by OEM parts results in costs of approx. $ 3,400 vs. $ 1,400 with OEM compliant parts after a local market survey and involvement of our ADR specialists. All certifying authorities (ADR Certifiers, Logistics Agency Representative - TACOM, USAREUR Dangerous Goods Advisor) accepted the cost preventing method, while its ADR compliant and OEM conform.

Note: A few M978A4 models arrive OCONUS without an OEM Battery Disconnect switch installed, this modification is an exception, not the norm!

2016 Maintenance Innovation Challenge

M978A4 Emergency Battery Disconnect Switch

PROBLEM STATEMENT

Problem: ADR 2016 (Hazardous Cargo Transportation Law in Europe) require a disconnect of any electrical power in case of an emergency, e.g. accident.

Scope: The project focuses on the disconnect of all electrical power on a M978A4 by the driver, in case of an emergency

Goal: Ease disconnect of all electrical power in a M978A4 to reduce the hazards during an accident to a minimum and comply with European laws.

BENEFITS

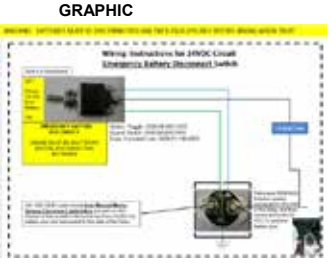
In compliance with European laws allowing US Fuel Tankers to cross borders of 48 European countries without any special authorizations

Return on Investment (ROI):
Primarily intangible, while preventing any diplomatic clearances and special approvals while crossing borders in Europe, e.g. ANAKONDA participation.
Furthermore considerable are the reduced safety risk in case of an accident with such a Heavy truck filled with explosive flammables.

TECHNOLOGY SOLUTION

Purpose for switch is to disconnect electrical power (as close as possible to the batteries) from all energized circuits in case of an emergency. An "Electronically Controlled Switch" must be installed inside the Operators Compartment; Highly Visible and Protected from accidental engagement with two levels of activation. This configuration meets the ADR Technical Specification compliance standards applicable for 48 countries in Europe. The implementation of this standard by OEM parts results in costs of approx. $ 3,400 vs. $ 1,400 with OEM compliant parts after a local market survey and involvement of our ADR specialists. All certifying authorities accepted the cost preventing method, while its ADR compliant and OEM conform.

GRAPHIC



Mast Boom Lift for wash rack operations

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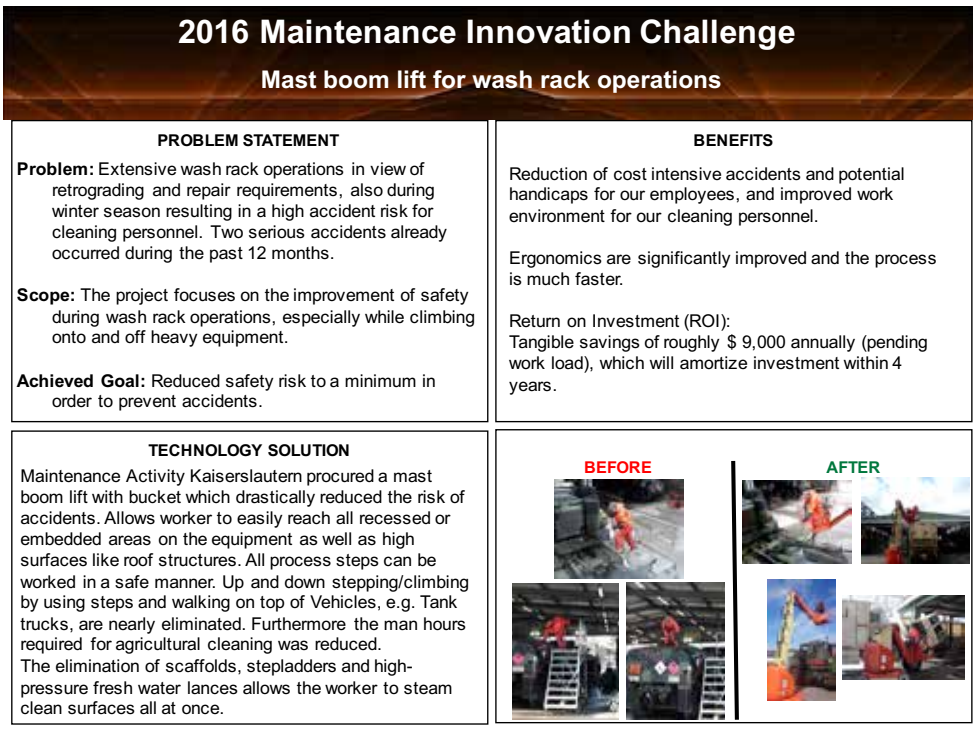
The Maintenance Activity Kaiserslautern (MAK) is supporting the AG (Agricultural) cleaning mission and is the largest US Army owned FM (Field Maintenance), limited SM (Sustainment Maintenance) repair facility in USAREUR.

a. In accordance with The Federal Plant Protection Act 2000 (Title IV of Public Law 106-224) the DOD is required to process equipment prior entering or being returned to U.S. Items must be free of prohibited and restricted plants, animals, and plant and animal products when returned (Agricultural cleaning is required). All vehicles shall be cleaned with high-pressure fresh water or steam. Special attention is paid for removing mud from a vehicle's recessed areas as well as undercarriage, fender wells, axles, springs, bumpers, and wheels. To satisfactory complete this process; workers are required to reach all recessed areas with high-pressure fresh water lances regardless of the vehicles dimensions. At large size wheeled equipment all cleaning procedures are challenging the worker regarding reachability of all areas to be cleaned. Partially stepping/climbing is required.

In addition MAK has a pretty large FM repair and paint mission requiring dozens of pieces to be steam cleaned every week. consisting of

b. In the recent past the Maintenance Activity experienced two accidents with more or less serious personal injuries during the process of vehicles at our wash rack. Both accidents happened during climbing down of vehicles. Personal slipped off and fell down. Both accidents were going along with "lost time".

c. After a extensive investigation of the accidents and a local market research it was decided to procure a mast boom lift with bucket, which did significantly reduced the risk of such accidents. The worker will easy reach all recessed or embedded areas at the vehicles as well as high surfaces like roof structures. All process steps are worked in a safe manner. Up and down stepping/climbing by using steps and walking on top of Vehicles, e.g. Tank trucks are nearly eliminated. All process steps are worked in a safe manner. Furthermore, while eliminating the accident risk and utilizing procured equipment the man hours required for wash rack operations were reduced as well (cost avoidance).



Instead of walking down/up and relocating scaffolds, stepladders and high-pressure fresh water lances, the worker is able to steam clean surfaces all at once and without interruptions, while lifting or turning the boom to whatever spot required. Accordingly process time is reduced.

d. The costs of a mast boom lift was $ 45,000 with tangible savings of $ 9,000 each year, not even considering the sick accident costs in this calculation. Furthermore it significantly improved the ergonomics of such wash rack operation duties for the cleaning personnel.

Single Common Powertrain Lubricant

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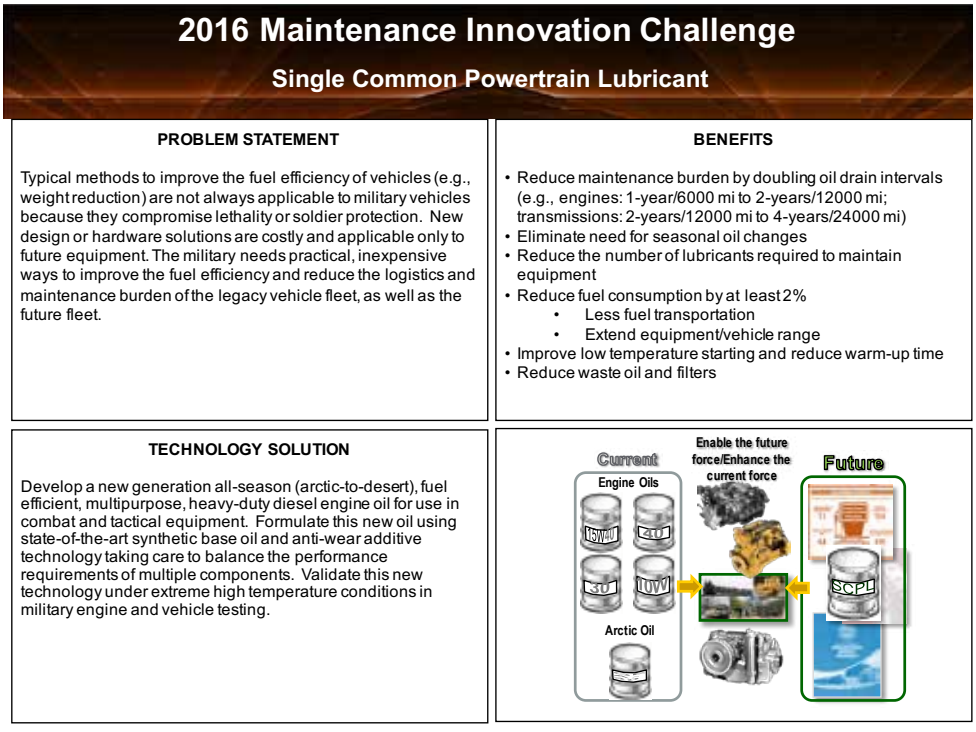
The U.S. Army Tank Automotive Research Development and Engineering Center (TARDEC) has develop a new all season (arctic-to-desert), multipurpose, fuel efficient heavy-duty diesel engine oil called the Single Common Powertrain Lubricant (SCPL). The SCPL enables significant reductions in logistical burden and improved capability compared to existing qualified military engine oils.

Fuel is a major logistical burden for the military. According to a 2001 report published by the Defense Science Board, more than 70% of the total tonnage required to position ground forces into battle is fuel. It doesn't end there, fuel transportation burdens continue as forward operating bases need a constant supply of energy to sustain the fight. Supplying this energy is costly. Reducing energy demand at the source, without the need for expensive hardware changes and retrofits is a main goal of the SCPL. Conducting oil and filter changes are also a significant burden to the war fighter. SCPL will reduce this burden by enabling the current oil drain interval to be doubled.

With the cooperation of industry partners, lubricant candidates were developed, tested, and iteratively improved. The final SCPL candidates have achieved fuel consumption improvements of greater than 2%, as determined by vehicle and dynamometer testing. Engine oil drain intervals twice the current recommendations have been validated (i.e.., 6000 miles or 1-year increased to 12,000 miles and 2-years) in engine and vehicle tests. Finally, the SCPL was tested in a variety of military engines ranging from 170 HP to 1050 HP at desert-like conditions and has been shown to maintain the wear and deposit protection of current military lubricants.

Adoption of the SCPL for military tactical and combat equipment will reduce the number of military qualified lubricant grades from 5 to 3, double the current oil drain intervals, and reduce vehicle fuel consumption by 2% or greater. A 2015 economic analysis found that implementing SCPL will result in an estimated annual savings for the Army of more than $8 million. This analysis didn't include logistical savings from eliminating the administrative, storage and handling costs associated with the removal of several oil grades made unnecessary by SCPL. The analysis also didn't account for the potential to reduce soldier risk or the reduction in fuel resupply and waste removal. Additional benefits of the SCPL include reduced risk of misapplications, easier equipment starting and less warm-up, improved hydraulic response over a larger range of ambient temperatures, and greater tolerance to extreme high oil temperature excursions.



Drying Biodiesel Fuel During Transport and Storage by Injected Dry Compressed Air

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Biodiesel has become an important fuel, both for commercial and military diesel engine operators. As its use has become increasingly popular, however, a number of issues have been recognized. Biodiesel is hygroscopic (attractive to water) due to the chemistry of the primary fuel molecule. Left alone, it will absorb up to approximately 1500 parts per million of water and will support moisture puddling in the bottom of tanks. When the fuel is stored, transported and used, exposure to moist air is inevitable since fuel tanks are vented.

Water content, in and of itself, poses only minor difficulties. Unfortunately, the interface of fuel and puddled water at the bottom of the tank is an excellent growth site for various microbes. This growth proceeds at such a rate as to produce large amounts of biological mass sufficient to cause fouling of filters (in tank and vehicle fuel pumps) and accretes in tanks forming corrosion sites. Distribution tanks that once had cleaning intervals measured in decades now require it after only a couple of years.

Water intrusion can be prevented. The fuel cannot be sequestered, but the air that comes in contact with the fuel can be so extremely dry that contamination is prevented and even reversed (where necessary). Garrett Engineering Services is developing a group of products that prevent moisture intrusion from the air, remove entrained water from the fuel itself and eliminate any puddled water. These systems may be added easily to existing railroad fuel cars, delivery truck tanks, distribution and storage vessels and individual vehicle fuel systems.

Storage and transport tanks receive a kit, consisting of a compressor (unless compressed air is provided already), dryer and controller, mounted either in the vessel manway or remotely. These kits maintain the air in the tank at desert-dry dewpoints or attack the puddled and entrained moisture directly via mixing in a fluid pump. Moisture could be removed by bubbling dry air or nitrogen through the fuel (the method used during production), but that foams the fuel, rendering it unusable for a time. By air-drying or sequestered mixing, foaming is avoided or limited to a thin layer at the top surface of the fuel and doesn't interfere with pumping.

To protect vehicles, a kit is added to the parking location and dry air is supplied to each vehicle's fuel tanks via a distribution network and tubes connecting to special fuel tank caps. When vehicles are parked, the operator need only remove the regular filler cap and replace it with the one attached to the drying network. During periods of non-usage, the air in the fuel tanks would be dried and moisture that is absorbed during operation (as the tank emptied and air was vented in) would be removed.

As in other Garrett systems, these kits are small, simple and inexpensive. Although the application is new, the hardware is off the shelf and proven. We can keep your fuel dry, just the way you like it.

Reducing Aircraft Structural Corrosion with Injected Dry Compressed Air

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Intruded atmospheric moisture in aircraft structures is a critical component of corrosion. Most current efforts to remove this moisture are limited to localized venting. Reducing the effects of moisture-induced corrosion requires metallurgical processes (corrosion resistant alloys), physical processes (such as shot-peening), a myriad of surface treatments (from electroplating to painting) and great care in the matching of electro-compatible materials in aircraft functional areas. The counter-corrosion success associated with storing aircraft in a moisture-reduced (perhaps even moisture-free) environment (such as the aircraft storage facilities in Tucson, Arizona) is well-established. Logically, then, if such a desert environment helps restrain corrosion, extending that environment into the operating regime would be valuable, if practical.

Garrett Engineering Services offers just such an approach. We are currently developing a system which supplies and distributes extremely dry air (considerably dryer than the Arizona desert) to the interior regions of an aircraft, monitors and reports the performance of that system in real time and possesses a much smaller "footprint" within the structure of the aircraft. Bulky items required for the system (compressor, dryer, plumbing and controls) are external and independent of the aircraft, ensuring against performance degradation. There is no interface with aircraft power or controls, vastly simplifying aircraft modification, which is limited to the interior mounting of thin-walled stainless steel tubing (typically 3/8" O.D.), an array of microchip humidity sensors and a small interface junction box. Air for the tube and power/data for the sensors are supplied to the system after the aircraft lands. Since even extremely busy aircraft typically spend more time on land (or on ship) than in the air, those equipped with our system would experience the operational equivalent of being deployed to the Nevada desert, rather than at sea or on the sea coast.

Our system is small, simple and inexpensive. Although the application is new, the hardware is off the shelf, proven and milspec. It's time to banish moisture from your list of concerns; let us show you how.

B-2 Cooling Cart Units Due and Obsolescence

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1. Currently B-2 Rotary Launcher Assemblies (RLA) are cooled by Cooling Cart Units (CCU) using facility air that is pushing to the RLA. The RLA is an open loop system; air ventilates to the atmosphere through the electronics boxes. The CCU PN DAA729F707-005 was developed for the testing of RLA with munitions that require cooling while under test. RLA is only tested in an empty configuration. The CCUs are only used on the B-2 fleet at Whiteman AFB, and Edwards AFB may choose to utilize the same equipment.
2. Propose that CCU fleet is reduced to 1 or eliminated and placed in long term storage for future weapon system development ie; future weapon systems utilizing Air Force long term storage facility. Instead use a high volume commercially available box fan box fan (similar to UB20xx UL RamFan Class I- Group C,D and UL Class II-Group E,F,G Intrinsically Safe rated). This is a better alternative than a Big Easy which provides too much air volume when cooling and to warm air when in idle. The fan can be hooked up to the RLA using the already existing Common Operator Level Tester (COLT) RLA test equipment. For Electronic System Test Set (ESTS) test a sensor similar to the one already located in the RLA for COLT should be developed to actively monitor the airflow on the RLA or a local manufacture a dummy plug to bypass the legacy circuit. The only limitation is the ambient temp shall be less than 110 degrees F. Initial communication has been accomplished w/ RLA Equipment Specialist.
3. Currently the CCUs parts are difficult to procure due to low fleet volume. Placing the CCUs into long term storage will eliminate the section from maintaining them. The maintenance cycle on the 4 CCUs are 150 manhours per year which include a calibration, replacement of pressure gauges and temp gauges. Temp gauges are no longer procurable and are breaking at an average of 1 per year. The air filters located inside the CCU are not procurable. The pre fitted pressure lines are unprocurable, causing technicians to bend, flare and install tubing with Engineering Technical Assistance Requests (ETAR). By eliminating completely or reducing the fleet of CCUs it technicians will be able to concentrate on other maintenance areas and shop functions.
4. Cost to implement is minimal. The purchase of two fans at $2,132 each. Dummy plugs may be made locally at the cost of $200. Recommend manufacture of 3 to add as part of existing Empty Launcher Test equipment. Total cost for implementation is aprox$5K.

2016 Maintenance Innovation Challenge

B-2 Cooling Cart Units (CCU) Obsolescence

PROBLEM STATEMENT

- B-2 Cooling Cart Units PN DAA729F707-005 are difficult to maintain and difficult to procure parts for due to low fleet numbers. This model CCU is only used at Whiteman AFB for B-2 launcher and Line Replaceable Unit checkout.

BENEFITS

- Reduce mx hours by 150 manhours per year.
- Reduce ETAR submissions for CCU Mx
- Expand RLA testing capabilities

TECHNOLOGY SOLUTION

Implement COTS UB20xx UL RamFan (Class I, Div I and Intrinsically safe)

Build 3 electrical dummy plugs for circuit bypass. Explore option of sensor similar to COLT RLA TPS air movement sensor. (possibility of plug and play into correct cannon plug style electrical adapter)

In-Situ Robotics for Fleet Maintenance

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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 Computer Numerical Control (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.

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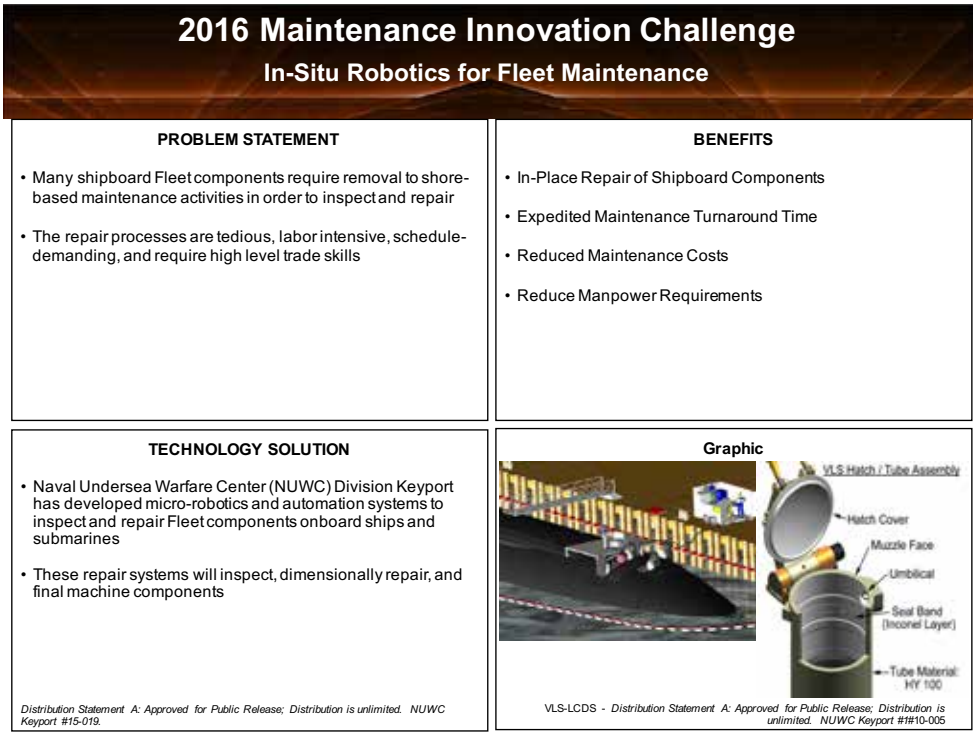

Laser-forming

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Weld distortion is an issue that can occur when using high temperature additive manufacturing practices, such as laser cladding and welding, to perform maintenance operations on metal parts. In projects that involved extensive use of laser cladding and/or welding, slight elastic deformation can occur during repair and these deformations can lead to part distortions. In many situations these issues can be fixed during the follow-up machining processes, but sometimes even the refurbished parts are out of tolerance. One particular project that contended with this issue was the Los Angeles/Ohio Class Shaft Seal and Mating Ring Refurbishment Capability Project. With some solicited help from experts at ARL Penn State, one solution to this problem we researched was the use of the existing laser cladding system to perform thermal forming of the shaft seal rings.

Thermal forming is the process of local surface yielding via localized heating to reduce dimensional distortion resulting from high temperature operations. As a small area of a part is heated, it expands in accordance with the material's volumetric coefficient of thermal expansion. This element is constrained by the remainder of the material surrounding it which results in a compressive stress in the element. Simultaneously the yield strength of the element is reduced as temperature is increased and the result is the element undergoes plastic (compressive) yielding. As the entire part cools to ambient temperature, the yielded element contracts again in accordance with the coefficient of thermal expansion. But since it has been compressively yielded, it returns to the ambient temperature physically smaller, resulting in a residual compressive stress in the part and a tensile stress in the element.

This process was applied to the inner diameter, or the bore, of the shaft seal ring using a laser beam to locally heat a small area (analogous to the element previously mentioned) while the rest of the ring half remained at approximately room temp. The beam was directed along several continuous passes on the inner diameter bore resulting in large area of surface stress created through localized heating as explained above. As a result, the ring deformed inward to a smaller diameter, and was brought back towards its pre-weld process dimensions to within a very precise dimensional tolerance.

After preliminary tests were performed on the half-rings that make up the seal ring, a simple engineering mechanics model was created from the analysis performed on the thermodynamics and mechanics of weld stresses and how they are formed. Using this model, we were able to predict the distortion of the ring halves as they underwent both cladding and thermal forming. With this information, we were able to effectively remove more than 90% of the welding distortion in several of the developmental rings.

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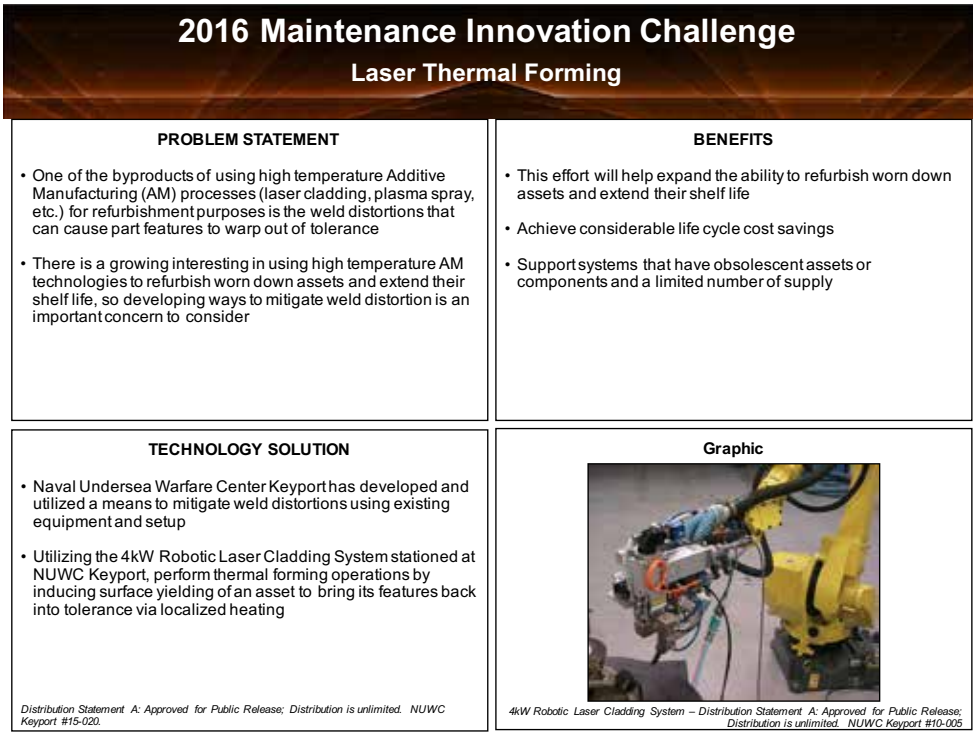

M109 Series Howitzer Gun Tube Wrench

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Maintenance Activity Vilseck (MAV) provides field maintenance support for Army units in the USAREUR footprint. In conjunction with internal quality procedures and organizational processes MAV contentiously strives to implement innovative maintenance initiatives. During a mission to replace several M109A6 Gun Tubes the standard gun tube wrench as prescribed in the technical manual used by maintenance personnel was seen as an opportunity where the current wrench could be modified to improve control. Upon installation and removal of the M109 series howitzer cannon tubes the mechanics must be able to precisely rotate the cannon tube in both directions as well as be able to maintain horizontal and linear control guiding the tube into the gun cradle. The current gun tube wrench works only for movement in one direction, only has one handle and does not secure adequately to the gun tube often damaging and scratching paint/metal where the wrench is applied.

While the gun tube is out of the cradle the new design allows mechanics to easily grip and guide the barrel while attached to the chain sling and overhead crane during movement. The newly developed gun tube wrench has two handles allowing for superior directional control of the gun tube in both removal and installation with moderate effort, when necessary with two mechanics. The gun tube can be precisely and accurately rotated in either direction as well as guided with more precise control into the gun cradle. The new gun tube wrench mounts securely to the gun tube with rubber padding on the surfaces of contact prohibiting damage to paint and coatings while reducing surfaces scratches or further damage to the gun tube. The new design prevents potential damage to the bridge cradle and the gun tube, allowing greater control and precision during removal and installation, thus increasing safety and improving the overall process.

The gun tube wrench was designed using Computer Aided Design (CAD), was fabricated using Computer Aided Manufacturing (CAM) and is an approved SMART (Supply and Maintenance Assessment and Review Team) Initiative. For Army wide use and reproduction purposes of the gun tube support tool CAD drawings, dimensions and a material list is electronically available. The new gun tube wrench was designed and tested by Maintenance Activity Vilseck (MAV) and TACOM personnel repetitively and preferred for use over the original issued gun tube wrench based upon the overall ability to control and align the gun tubes on several howitzers.

MAV's characteristics include competence, innovation and continuous improvement, thus making us a strong and reliable partner for our customers and the US Army.

2016 Maintenance Innovation Challenge

Mast boom lift for wash rack operations

PROBLEM STATEMENT

Problem: Extensive wash rack operations in view of retrograding and repair requirements, also during winter season resulting in a high accident risk for cleaning personnel. Two serious accidents already occurred during the past 12 months.

Scope: The project focuses on the improvement of safety during wash rack operations, especially while climbing onto and off heavy equipment.

Achieved Goal: Reduced safety risk to a minimum in order to prevent accidents.

BENEFITS

Reduction of cost intensive accidents and potential handicaps for our employees, and improved work environment for our cleaning personnel.

Ergonomics are significantly improved and the process is much faster.

Return on Investment (ROI):
Tangible savings of roughly $ 9,000 annually (pending work load), which will amortize investment within 4 years.

TECHNOLOGY SOLUTION

Maintenance Activity Kaiserslautern procured a mast boom lift with bucket which drastically reduced the risk of accidents. Allows worker to easily reach all recessed or embedded areas on the equipment as well as high surfaces like roof structures. All process steps can be worked in a safe manner. Up and down stepping/climbing by using steps and walking on top of Vehicles, e.g. Tank trucks, are nearly eliminated. Furthermore the man hours required for agricultural cleaning was reduced.
The elimination of scaffolds, stepladders and high-pressure fresh water lances allows the worker to steam clean surfaces all at once.

Lever Modification Gunner's Primary Sight M1series Tank

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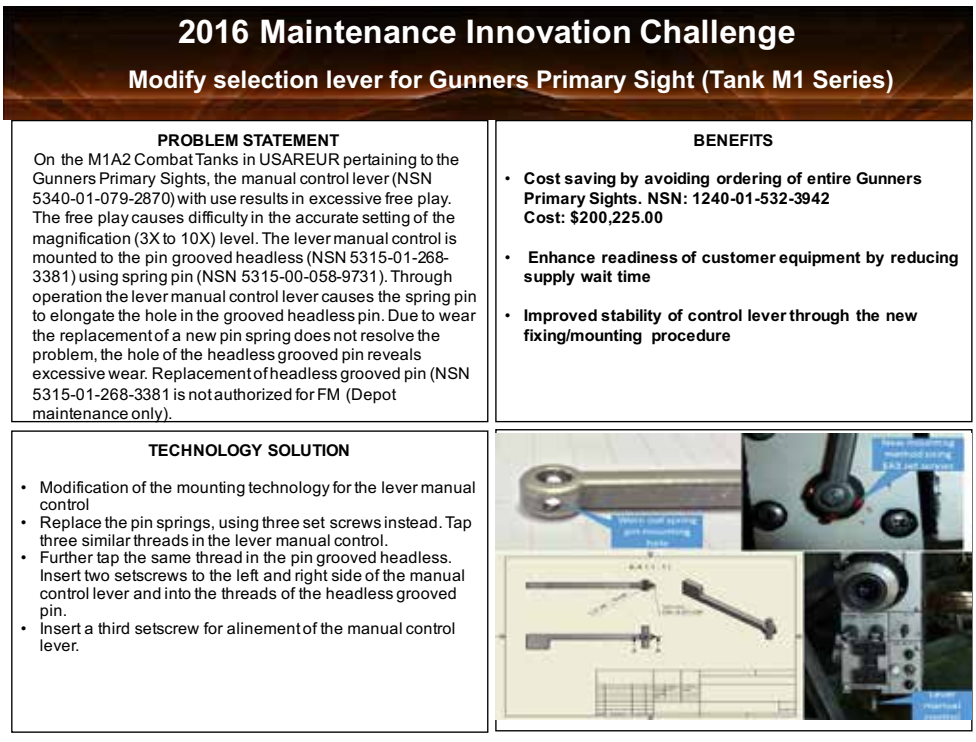
The current manual control lever (NSN 5340-01-079-2870) for the Gunner's Primary Sight on the M1 series Tank wears with use resulting in excessive free play and inaccurate control. The excessive free play impacts the ability to expediently select accurate settings between the selected ranges of (3X to 10X) magnification. Adjusting control becomes sloppy and inaccurate due to the wear of the control lever where mounted to headless spring pin, the control lever's pin spring mount holes become oblong-ed and are no longer circular creating excessive free play. The manual control lever is mounted using a spring pin (NSN 5315-00-058-9731) to the headless grooved pin (NSN 5315-01-268-3381).

Current repair requires the entire Gunner's primary sight (NSN 1240-01-532-3942) to be sent to Depot Maintenance as replacement of the Headless Grooved Pin is not authorized at (FM) Field maintenance level. The cost of a Gunner's Primary Sight is costs $200.225.00. Simply replacing the Pin Spring does not solve the problem as the excessive play resides control lever mount and the headless grooved pin.

A simple modification in the mounting of the manual control lever through the use of EA3 set screws in lieu of the current configuration. Tapping holes with three similar sets of threads into the manual control lever as well as tapping threads into the headless grooved pin. Inserting two setscrews on the left and right sides of the manual control lever and one into the threaded slot for the headless grooved pin improves stability, control and reduces wear.

Costs avoidance savings occur in the continuous ordering and replacement of entire Gunner's Primary Sights (NSN 1240-01-532-3942) along with increased reliability and accuracy of operation of modified Control Levers/Headless Grooved Pins. This modification leads to reduction of Non-mission-capable (NMC) equipment as well as Non-mission-capable-Supply (NMCS). Newly modified Control Levers provide stability during adjustments as well as superior control accuracy over unmodified applications.



RELIABILITY IMPROVEMENT (HARDWARE)

Sphere Brake System

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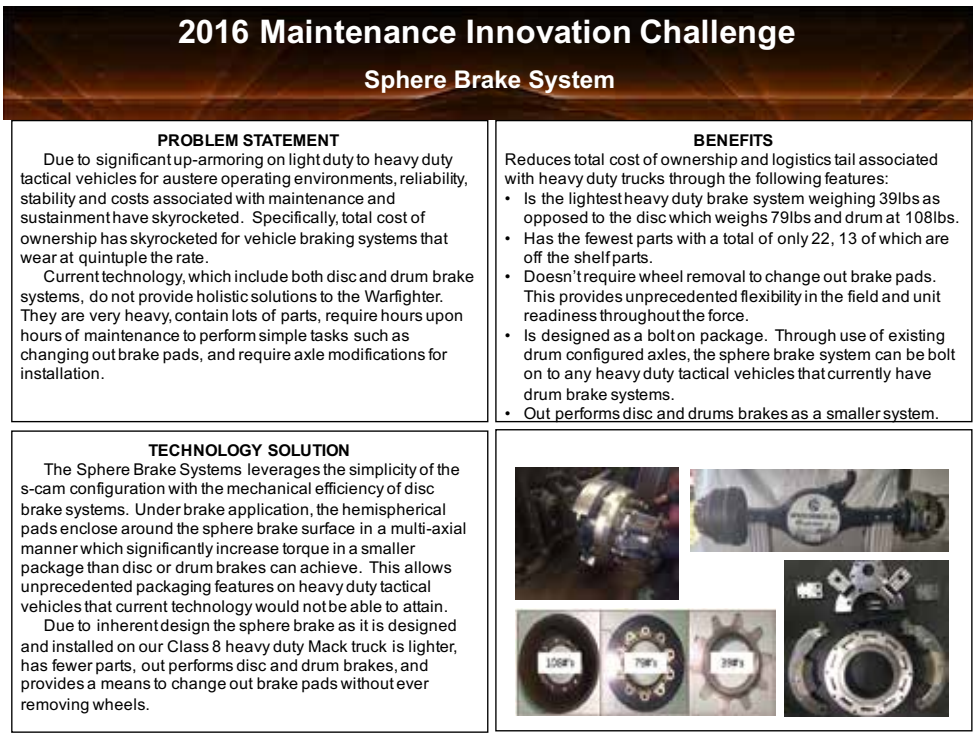
The DoD is faced with underperforming brake systems that cannot bear the heavy up-armoring and increased duty cycles of heavy duty tactical vehicles. This forces units to maintain higher levels of inventory, increase budget expenditures on maintenance for vehicle fleets, increased downtime and longer logistics tails into combat. Sphere Brakes, LLC presents a revolutionary heavy duty brake system that paves the way for the future. Leveraging only benefits of the disc and drum brake systems, a sphere brake provides a holistic solution that reduces overall total cost of ownership, fleet downtime and the logistics tail while optimizing performance and safety for heavy duty tactical vehicles.

Compared to disc and drum brake systems, it is significantly lighter. For our Mack class 8 truck, the drum weighs 108lbs, a disc weighs 79lbs and our sphere weighs only 39lbs. The sphere brake system has fewer parts. Of the 22 parts, 13 are off the shelf, significantly driving down inventory levels at the unit level. It is the first heavy duty brake system that allows the Warfighter to change brake pads without having to remove 200lb wheels using a 40lb 1" drive impact wrench. This not only provides unprecedented maintenance flexibility in the field, but unprecedented unit readiness in garrison.

We have designed this brake system as a bolt on kit for drum configured vehicle platforms, unlike disc brake systems which require axle and hub modifications. Leveraging the single brake surface like a drum brake with the heat dissipation capability as a disc brake, the sphere brake performs as a much smaller brake allowing for additional light weighting opportunities throughout the pneumatic subsystems on the vehicle. Such light weighting occurs at spring chambers, modulators, and compressors. This weight reduction also offsets up-armoring and additional electrical components that are in high demand for the Warfighter without compromising their safety.



Exoskeletal Arm for Overhead Grinding

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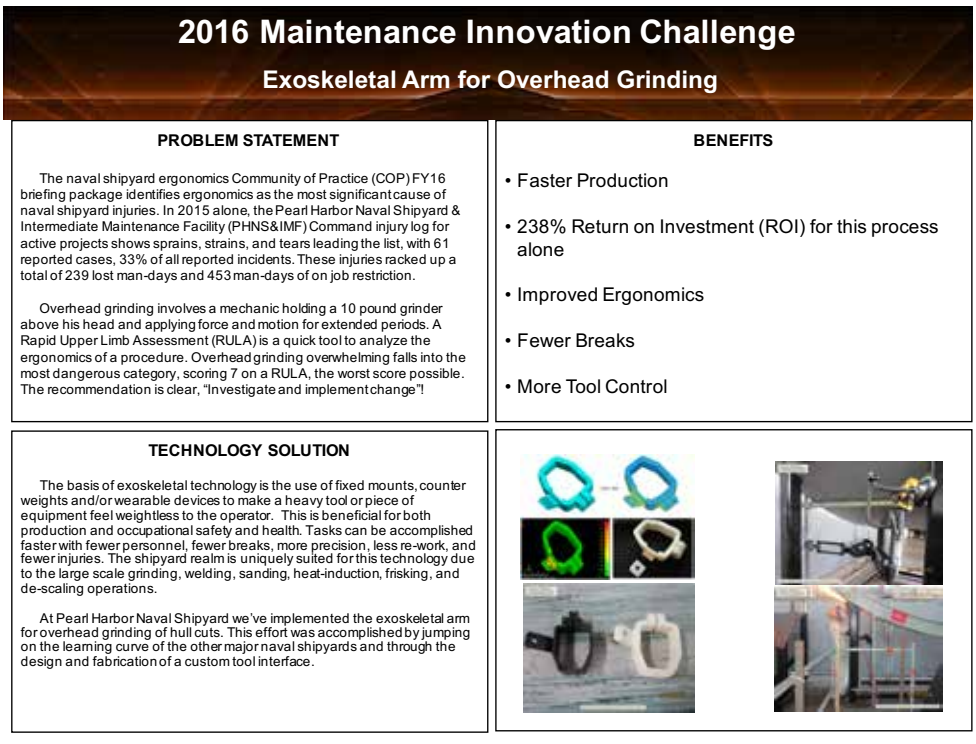
During the 2015 Department of Defense (DOD) Maintenance Symposium, Lieutenant General Michael Dana, Deputy Commandant Installations and Logistics, listed exoskeletal technology as one of the most desirable opportunities for execution in the maintenance value chain. The basis of exoskeletal technology is the use of fixed mounts, counter weights and/or wearable devices to make a heavy tool or piece of equipment feel weightless to the operator. Tasks can be accomplished faster with fewer personnel, fewer breaks, more precision, less re-work, and fewer injuries. The shipyard realm is uniquely suited for this technology due to the large scale grinding, welding, sanding, heat-induction, frisking, and de-scaling operations.

Even when performing processes as prescribed and complying with safety measures in place, work related injuries still occur. The naval shipyard ergonomics Community of Practice (COP) FY 16 briefing package identifies ergonomics as the most significant cause of naval shipyard injuries. In 2015 alone, the PHNS&IMF Command injury log for active projects shows sprains, strains, and tears leading the list, with 61 reported cases, 33% of all reported incidents. These injuries racked up a total of 239 lost man-days and 453 man-days of on job restriction. One of the best ways to mitigate the risk of ergonomic related injuries and lost production while also increasing efficiency and quality is through the implementation of exoskeletal technology.

As of 2016, PHNS&IMF had yet to adopt exoskeletal technology. The goal was to introduce the technology in a meaningful way to show immediate results. This would help quell the resistance to change. Through communication with the other three major shipyards the decision was made to pilot an exoskeletal arm for overhead grinding. A Rapid Upper Limb Assessment (RULA) is a quick tool to analyze the ergonomics of a procedure. Overhead grinding overwhelming falls into the most dangerous category possible, scoring 7 on a RULA, the worst score possible. The recommendation is clear, “Investigate and implement change”! Also, overhead grinding on recent jobs at PHNS&IMF was averaging a cost performance factor under 60%, which is extremely poor.

From the onset we established a clear goal, ‘ensure the equipment fits the task vice fitting the task to the equipment’. Prior to conducting trials, we created a custom tool interface to hold the standard grinders our welding shop utilizes. A prototype of the interface was printed using additive manufacturing. Finite element analysis (FEA) led to cutting the final interface design out of scrap steel on our water-jet. The final interface grips the tool around its center of gravity, will not interfere with the grinder exhaust ports, and has a tremendous safety factor. The data collected from our trials proved the technology extremely beneficial to production quality/time, ergonomics of the user, and user/customer satisfaction. Aside from the ergonomic benefits there’s a projected ROI of 238% for overhead hull cut grinding alone. The exoskeletal arm will be utilized on an upcoming hull cut installation aboard a 688 Los Angeles Class fast attack submarine at PHNS&IMF and work will continue to implement the technology in other areas across the shipyard.



F-16C Hydraulic Spider Line Jig

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Problem: Inability to fabricate hydraulic spider line assembly (P/N: 16H202-94) on the aircraft and complexity of fabrication resulted in 2 out of 3 assemblies being unsuitable for use and subsequently discarded.

Root Cause: The spider line is a hydraulic manifold used on the F-16. It has various hydraulic lines radiating from the manifold giving it a spider-like appearance. Spider lines are manufactured organically. Their asymmetrical configuration make them very difficult to manufacture. Traditionally a technician forms each line, then manually aligns them into position using measurements taken from the old spider line, and then applies permanent pressure collars to hold each line in place. However, lines have a tendency to slip due to the pressure/torque used causing the spider line to not properly align in the aircraft. The unit must be scrapped and a new one manufactured. On average it takes 3 attempts and up to 48 hours to produce 1 suitable spider line.

Results: After analyzing the problem a jig* was designed, using materials on-hand, that simulates the aircraft structure and facilitates the fabrication/assembly of the spider line. The jig enables the technician to position and hold the hydraulic manifold and lines in the same position as when installed in the aircraft. The technician can then install the pressure collars (locking the lines in place) without lines shifting. Use of this jig had produced the following results:

Error Proofing/Fabrication: Rework has been reduced from 3:1 to 1:1 ratio. Since implementation of the jig Aviano AB as fabricated 8 spider line assemblies with 0 rework.

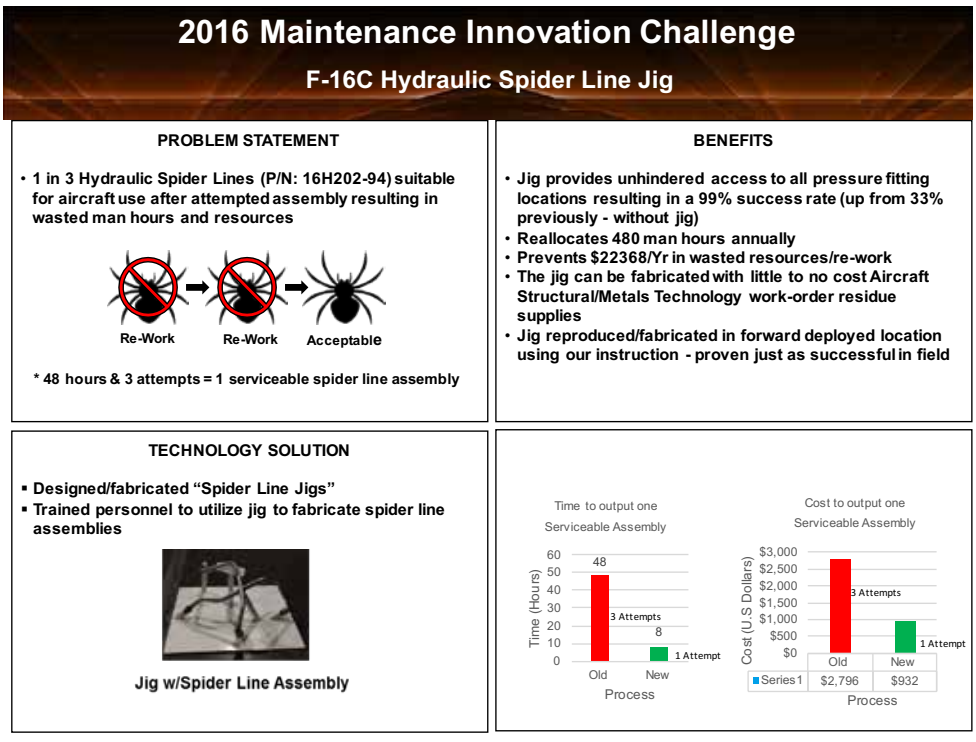
Ease of Use: Before implementation of the jig, fabrication of spider line jig was a highly technical and complicated tasked reserved for only the most experienced technicians and still had a high quantity of rework. However, use of the jig has enabled this task to be performed by journeyman technicians without rework.

Fabrication Time: The time required to produce a serviceable spider line has reduced from 48 hours to 8 hours, equating to an 83% reduction in delivery time and saving 480 maintenance hours annually.

Deployable/Dependable: A second spider line jig was assembled at Bagram AB using the fabrications plans developed at Aviano AB. The jig was field tested and produced the same results with an additional 6 spider lines being fabricated with 0 rework.

Reduction of Fabrication Costs: A single spider line costs $932 to fabricate. The previous 3:1 ratio meant that, on average, it cost $2796 to produce one serviceable spider line. Use of the jig saved $1864 per fabrication and more than $22K annually.

*A jig is a device used for holding work and for guiding a machine tool to the work.



RELIABILITY IMPROVEMENT (HARDWARE)

In-System Maintenance Robotics

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The Naval Shipyards are responsible for the depot maintenance of various Navy vessels and are in the early stages of forming an increased functionality to create a long-term, modular environment that enables rapid growth and adaptation to support future technologies. A key element of this environment is the development and deployment of various-sized unmanned and autonomous robots that can perform in-systems assessments and repairs.

Industry and DOD continue to make strides to leverage the budding robotics industry. Some of the applications have been put into Intelligence, Surveillance, and Reconnaissance applications in the air-land-sea military spaces. Industry and academia have also tailored smaller solutions for infrastructure assessments (e.g., piping and bridges) and the bio-medical fields (e.g., surgical applications). Only recently have the Naval Shipyards begun to evaluate how to employ robotics technologies for the advancement of their mission.

Coincident with these advances, the National Institute of Standards and Technology is in the process of developing acceptance testing for robotic systems. The increasing capabilities of the robotics technology are approaching the point of transition to actively enhance depot maintenance operations.

This effort proposes to engage industry partners in a progressive series of challenging maintenance applications to aid the DOD maintenance community in the development and fielding of robotic solutions:

- Exterior system corrosion and fatigue assessment - This task would adapt existing commercial and DOD solutions to perform assessments of uneven surfaces open to the atmosphere. This assessment would also entail dynamic mapping for any future repairs.
- Exterior system repair and preservation – This task would move beyond the assessment efforts and perform repair and preservation actions without the need for humans proximate to the site(s).
- Interior tank assessment – This task is expected to negotiate a more complex space including baffles and intervening structures (e.g., pipe runs) to discern the condition of the underlying tank structure.
- Interior tank surface repair, preparation, and preservation – This task would move in the complex space and perform weld/epoxy repair, ensure adequate surface cleaning and preparation, and then apply a preservation coat to ensure the long-term viability of the tank. Creation of the anthology of the repair, including non-destruction testing, would be required.
- In-system piping inspection and repair – This task would be the culmination of the effort as the spaces would be more constrained than previous efforts. A series of progressively smaller diameter pipes would be selected to gage the effectiveness of the various robots.

These unmanned and autonomous solutions, whether in individual or swarm configurations, are expected to yield increased worker efficiencies through concurrent, augmented, and autonomous efforts. Properly constructed and deployed, the in-system robots will also provide real-time data into a unified system to allow more expedient problem resolution than currently exists.

The development of these solutions is necessary, and the time has come to adapt the existing robotics technology to increase the capacity of the DOD maintenance community.

RELIABILITY IMPROVEMENT (HARDWARE)

Plasma Enhanced Melter (PEM) and Hydrogen Production

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Navy depot maintenance providers create a large volume of industrial wastes much of which is hazardous as defined by 40 CFR 261. Current wasting methods include containerizing, shipment, treatment, and disposal by private vendors, however even after being placed into a landfill or treated, the Navy is responsible for proper long-term disposal. In 2016, this in perpetuity cradle-to-grave approach to hazardous waste management cost the Navy $29M in a settlement with the Environmental Protection Agency for wastes disposed between 1969 and 1970 at the Gorst Creek Landfill in Kitsap County, Washington. Severing this future liability may be possible while simultaneously producing hydrogen that can be used in various applications through a technology developed by InEnTec, known as the Plasma Enhanced Melter (PEM).

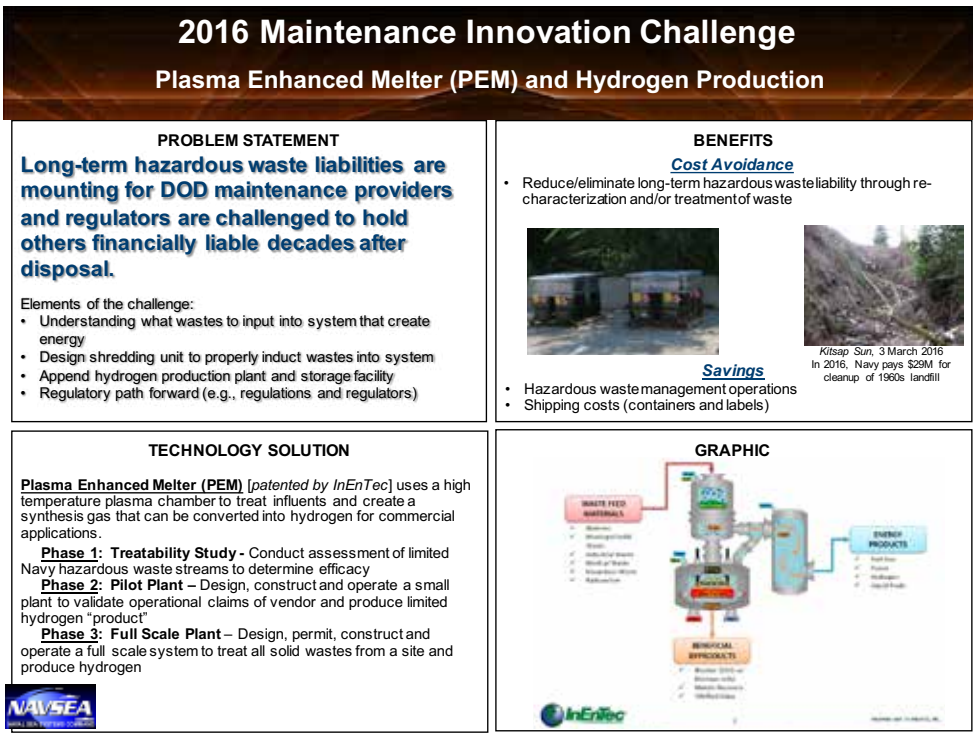
InEnTec has deployed numerous systems around the globe to treat various solid wastes, and in some cases to also treat Polychlorinated Biphenyl and Asbestos wastes. The longest running system has been operational since 2003. The process uses a high temperature plasma chamber to break-down compounds into a metals stream, a vitrified glass, and a synthesis gas. The Navy, through funding from the Office of Naval Research, is investigating the potential to harness synthesis gas for the creation of hydrogen.

The Navy is assessing the efficacy of the PEM technology through a three phased approach:

- Phase 1: Treatability Study [currently underway] – Assesses the ability of the PEM to create a sufficiently positive product using a limited number of non-radiological Navy waste streams. Included in this study will be the requisite dialog with state and federal regulators to gain alignment on the potential follow-on phases.
- Phase 2: Pilot Plant – This phase designs an induction shredder and installs a small-scale plant to process non-radiological "feedstock" that can be used to create a hydrogen "product". Many wastes are not expected to qualify as "feedstock," but design, installation and operation of the plant should allow the Navy and regulators to gain further confidence in the PEM system.
- Phase 3: Full Scale Plant – Contingent on successes during Phase 2, extensive permitting, and public involvement, this Phase proposes to treat all solid wastes from a Navy installation.

This effort assesses the potential to recycle items coming from the Naval Base Kitsap (NBK) – Bremerton site which is normally in the top ten generators of hazardous waste in Washington state. With the planned arrival and recycling of the inactivated USS ENTERPRISE, large quantities of hazardous wastes are expected that may benefit from treatment using the PEM technology. Phase 3 may not reside at NBK-Bremerton, but is intended to put into full production the touted capabilities of the PEM.

Other large quantity hazardous waste generators throughout the DOD complex as well as larger remote sites may benefit from potential diversion and/or treatment of current waste streams. The creation of hydrogen may also provide an opportunity to hasten deployment of this technology in pursuit of improving the environment while reducing the current and long-term costs associated with management of various wastes.



Navitas Systems Starlifter Lithium Forklift Battery System

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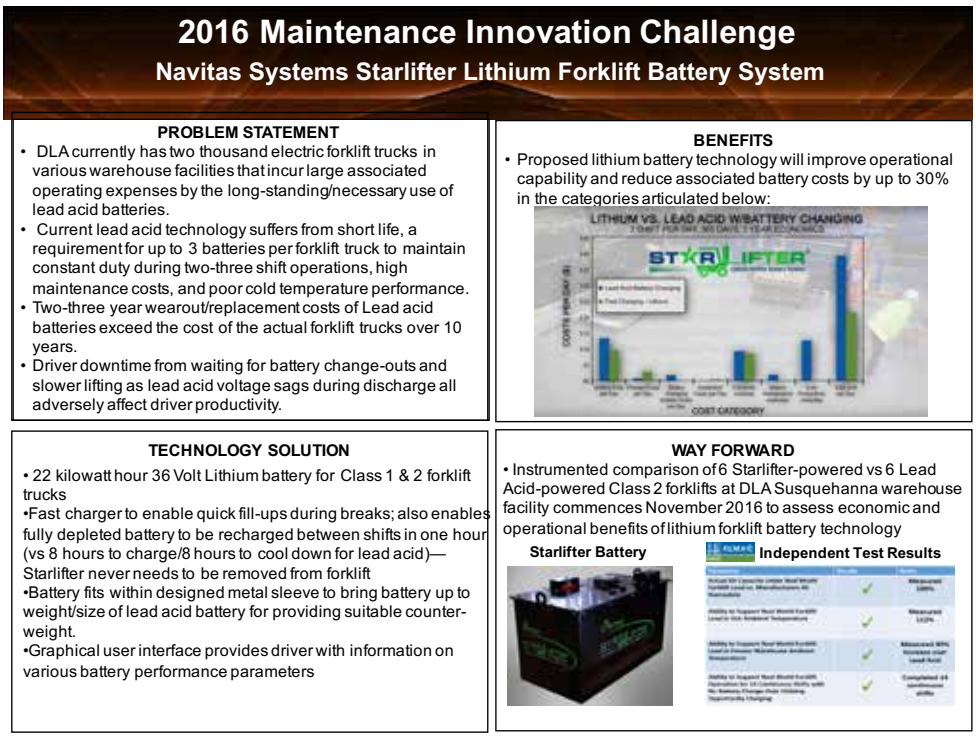
The Department of Defense owns and operates large fleets of Class 1 & 2 forklift trucks for material handling purposes. Many of these forklift trucks are electric, powered by very large lead acid batteries. While sufficient for low intensity warehouse applications, the 100+ year old lead acid chemistry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

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

Because lead acid battery technology achieved a performance plateau several daces ago, there haven't been any good solutions to the above problems. As these issues are inherent to the chemistry of the lead acid battery, there is very little technology that can be brought forward to solve these issues, which all together result in a very high labor overhead to maintain and service large fleets of lead acid batteries used in forklift applications.

Navitas Systems will be showcasing at the DOD Maintenance Symposium its industry-leading line of Class 1 & 2 lithium forklift batteries called StarLifterTM. Starlifter's benefits include:

- Zero maintenance-- no watering, no hydrogen off-gassing ; no dry-out in high temps unlike lead acid
- Very long cycle life – up to 5 to 10x that of lead acid
- Ability to charge to 100% capacity in just 1 hour--vs 16 hours with lead acid
- Stiffer voltage resulting in "peppier" operation of the forklifts when driving & lifting
- Higher round trip efficiency-- lower charging utility bills and cool temperature operation
- 40% greater battery runtime retention vs lead acid in cold warehouse applications
- Ability to continuously run forklifts for 3-shift per day operation for a week with opportunity charging-- just two 15 minute charges and one 30 minute charge per truck
- Use of one lithium battery per truck, which never needs to be removed from the truck
- Elimination of most of the requirements for a battery room
- Dramatically lower labor costs associated with battery maintenance
- Faster and "peppier" forklift trucks operation enabling greater productivity



E-2D Rotodome Assembly Maintenance System (RAMS)

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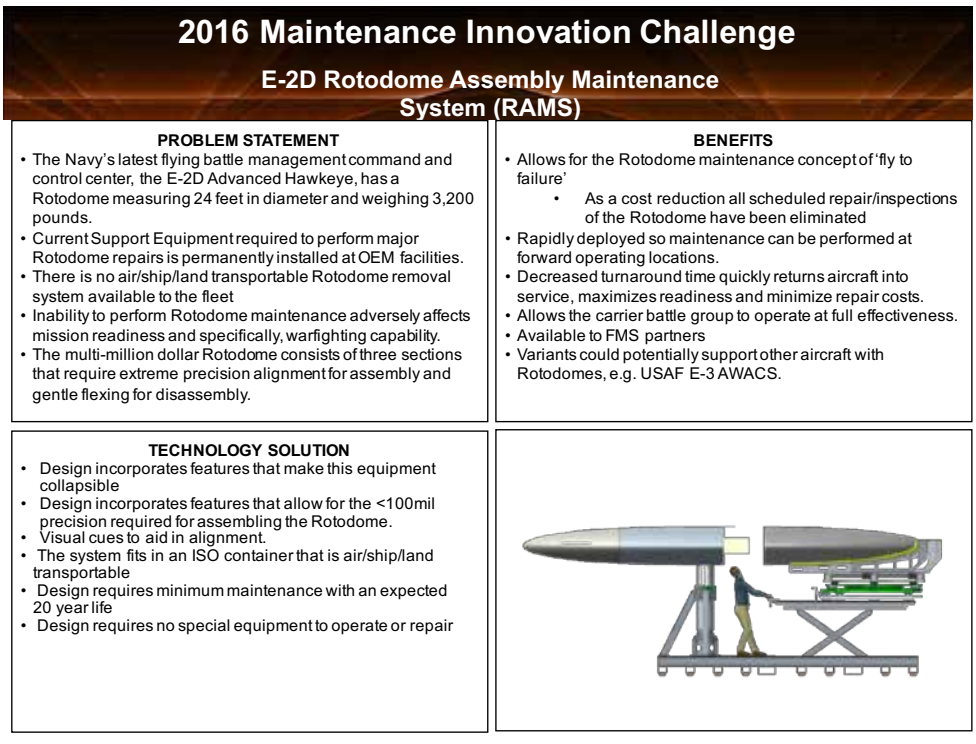
Current Support Equipment (SE) required to perform major Rotodome repairs to the E-2D Advanced Hawkeye is permanently installed at Original Equipment Manufacturer (OEM) facilities, which presents difficulties for maintainers. To combat this challenge, the E-2D SE Integrated Program Team organically designed and manufactured the Rotodome Assembly Maintenance System (RAMS) at NAWCAD Lakehurst. The RAMS significantly increases Fleet readiness by providing an air/ship/land transportable maintenance solution for the 24-foot diameter, 3,200-pound Rotodome. 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 Rotodome, has introduced a completely new maintenance concept for the Rotodome. The new Rotodome maintenance concept is "fly to failure," which has prompted an innovative approach to maintenance of the Rotodome. In order to facilitate this maintenance concept, the Support Equipment (SE) required for assembling the Rotodome needs to be transportable to anywhere in the world. This transportability challenge engendered an innovative design to the traditional SE concept and hardware. Required SE, only located at OEM facilities, is not a viable option for the fleet maintainers/facilities or Depot/Fleet Readiness Center (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. In response to this technology gap and the new fly to failure maintenance concept, the E-2D SE IPT commenced the in-house development of the RAMS. The team has developed a system that can be transported by air/land/sea in an ISO container and then assemble/disassemble the Rotodome with ease and high precision. The RAMS represents a major departure from legacy SE. Often, this SE is non-transportable due to size. Aligning the three sections of a Rotodome to the stringent requirements across the entire cross-section of the Rotodome is a formidable technical achievement. Coarse alignment is achieved with a scissor jack and a system of linear screws and bearings. Fine alignment is achieved with the pneumatic system, which controls standard shop air to inflate a system of airbags, allowing RAMS to precisely position Rotodome sections without damaging the composite material. Disassembling the Rotodome will also be simpler and carries less risk of inducing damage than in the past due to the innovative pneumatic airbag system. The team also had the foresight to consider the needs of the end user and developed tooling to aid in alignment of the large dome which includes visual cues via lasers and parallelism gauges. Thought also went into creating an easy and intuitive control system that met human engineering specifications. RAMS underwent successful test in June 2016 at Northrop Grumman facilities in St. Augustine, highlighting the transportability of the RAMS. Testing occurred over two days and passed requirements in all areas of disassembly and subsequent reassembly of a fielded Rotodome. The team overcame the detrimental effect of an OEM-only maintenance capability and provided a truly mobile maintenance solution.



Innovative Training Solutions

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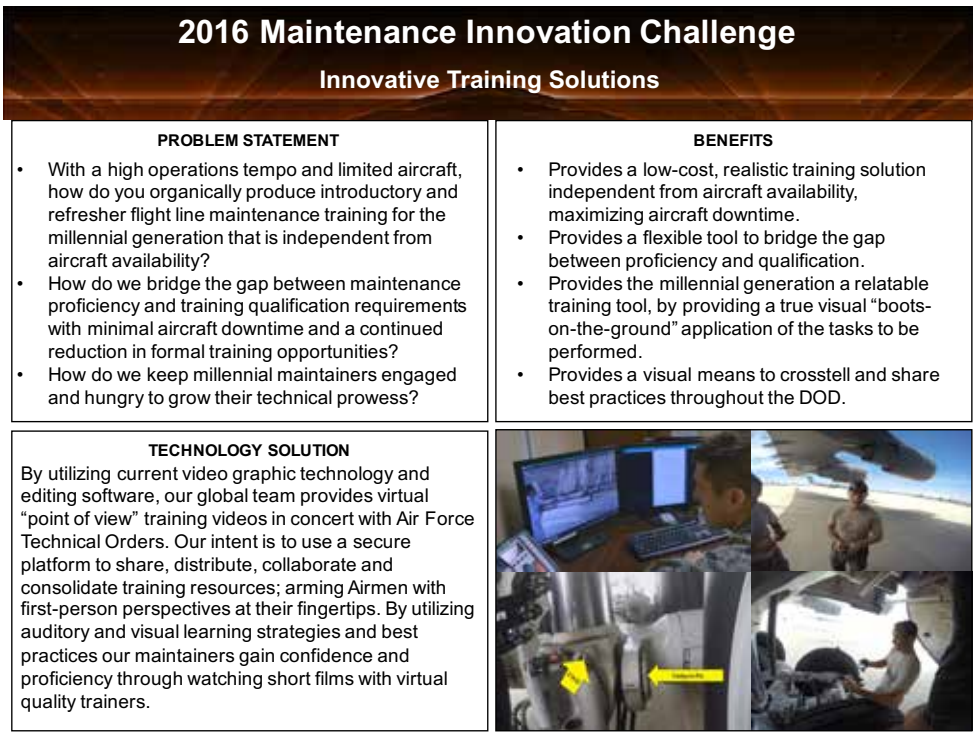
Historically, the world's greatest Air Force has successfully MAINTAINED superior airpower by consistently adapting to our adversaries and pursuing innovative, cutting edge solutions. With rapid advances in modern technology, it is vital that today's Airmen remain in stride with these advances so tomorrow's Airmen can fly, fight and win. This summary outlines low-cost, innovative training solutions that can be utilized to invest in our Airmen's future and ultimately the health of our Air Force.

Today, when maintainers PCS from different weapon systems, they are faced with the task of learning new equipment and procedures while continuing to support our daily mission. Conventional methods, such as on-the-job training and regional training courses, are crucial to building confident, proficient Airmen. However, as we modernize our fleets we must modernize our training methods as well. Using the Just-In-Time learning model and current video capturing devices and editing software, our global team aims to achieve virtual "point of view" training videos using a secure cloud platform to share, distribute and consolidate training resources. This project will give our Airmen quality first-person training when they need it, where they need it, at any time.

Air Mobility Command and the Air Force will benefit exponentially by having an on-line library of maintenance training videos. Point of View (POV) cameras such as GoPros, Olfi cams and iSAW Edge devices can actively record training events and then be edited, uploaded and shared, creating an enterprise wide active learning platform that bolsters confidence in training, innovation and critical thinking. Creating vivid and engaging cross-tell will help spread best practices across the enterprise.

The ultimate purpose of these videos is to bridge the gap between qualification and proficiency. Furthermore, this low cost solution, could open doors for additional agencies within the Air Force and DOD by providing a means to share ideas and innovate.



Project Apollo

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Coupling the world of 'open source' innovation with hyper velocity learning.

One promising initiative bridging the space between advanced technologies and deck-plate implementation focuses where creativity so often begins: the Waterfront, learning environments, and communities that connect them. The project is a departure from traditional instruction as it promotes problem-based, hands-on learning where personnel are empowered to create their own ideas and test them out. This unconventional method uses learning modules, open online courses and mentoring to empower personnel to provide innovative maintenance solutions in this rapidly shifting landscape of the digital age.

The initial event concluded April 2016, and was centered on the potential and limitations of Additive Manufacturing. During the course of the challenge, participants learned how to use CAD, design thinking, and rapid prototyping on machines costing less than $1500. The following are concrete examples of the enormous maintenance potential when we democratize innovation, both across emerging technologies and user access.

Plastic housing adapters attached to the side of radios break easily; once broken the entire adapter cable is useless. The solution; design a clip that attaches to the antenna and wraps around the housing cord. (CVN-75) fabricated 70 adapters for a cost avoidance of $4,321/month.

Design of a Television-Direct-to-Sailor Feed Horn Bracket. Without the bracket the focal point shifts due to vibration and the signal is lost. The alternative was to replace the entire Assembly; total cost of avoidance of $2,827.11 per ship.

The dual wing brass rotary switch knobs on every ship seems to be missing. Most of the time you can only obtain them if you order a complete switch box, but it would be easy to issue each ship (once each ship had a printer) a disc with the various common used items pre-loaded, so parts can be easily downloaded, printed and then installed.

Technicians were having issues while performing maintenance on the Vertical Launching System Deluge System. Technicians use pliers to open the valve while wearing gloves and goggles due to the corrosive chemicals. The solution was designing a tool that attached to the quick disconnect in order to pull the center pin in a controlled manor. To minimize spillage, the device had a standard hose connection.

Another entry was a special alignment tool that slides over the end of the SLQ-32 Direction Finding Receiver, enabling ships force to easily replace radomes with the correct angle and spatial requirements.

2016 Maintenance Innovation Challenge

Fleet design challenges: education with the warfighter in mind

PROBLEM STATEMENT

- Technological advances are maintaining fast paced upward momentum, and the need to restructure how we approach learning and implementation of technology must be revolutionized or we will be crippled by changing times.

BENEFITS

- unique combination that cultivates the technical education and skills necessary for maintenance personnel to continue to develop and implement agility, knowledge, and self-sufficiency.
- Promotes collaboration, both among individual command and agencies
- The power of open sourcing designing is that anyone can tailor and implement the designs for their own community.
- Challenges not only utilize 21st century technology, but they also serve to inspire an innovation ecosystem.

TECHNOLOGY SOLUTION

- Challenges are one path that federal agencies have taken to drive innovation and solve mission-centric problems; from technical, scientific, to creative.
- With a challenge competition, a "seeker" poses a problem or question to the public and "solvers" respond and submit solutions.
- John P. Holdren, Director of the Office of Science and Technology Policy stated that "COMPETES gives every department and agency the authority to conduct prize competitions … accelerating problem-solving by tapping America's top talent and best expertise wherever it may lie"

TRU-CLIP (MARMC Norfolk, VA 2016)

TV-DTS (MARMC Norfolk, VA 2016)

One of the more complex designs consisted of a robotic arm that uses a camera to scan and inspect radar antennas. The robotic arm scans along the surface, providing pictures and video to allow sailors to inspect for damage. The robotic arm is easily installed without the use of scaffolding, which costs an estimated $30,000 and requires field service technicians.

By acquiring the experience of designing and making, participants gain a deeper knowledge about emerging technologies, machines, materials, and processes. Both challenge platforms and fabrication facilities are aimed at encouraging creativity and require broad participation to be successful. Together they create technical prototyping platforms for maintenance invention; a place to create, learn, and mentor.

Confined Space Monitoring System for a Safe and Efficient Maintenance Complex

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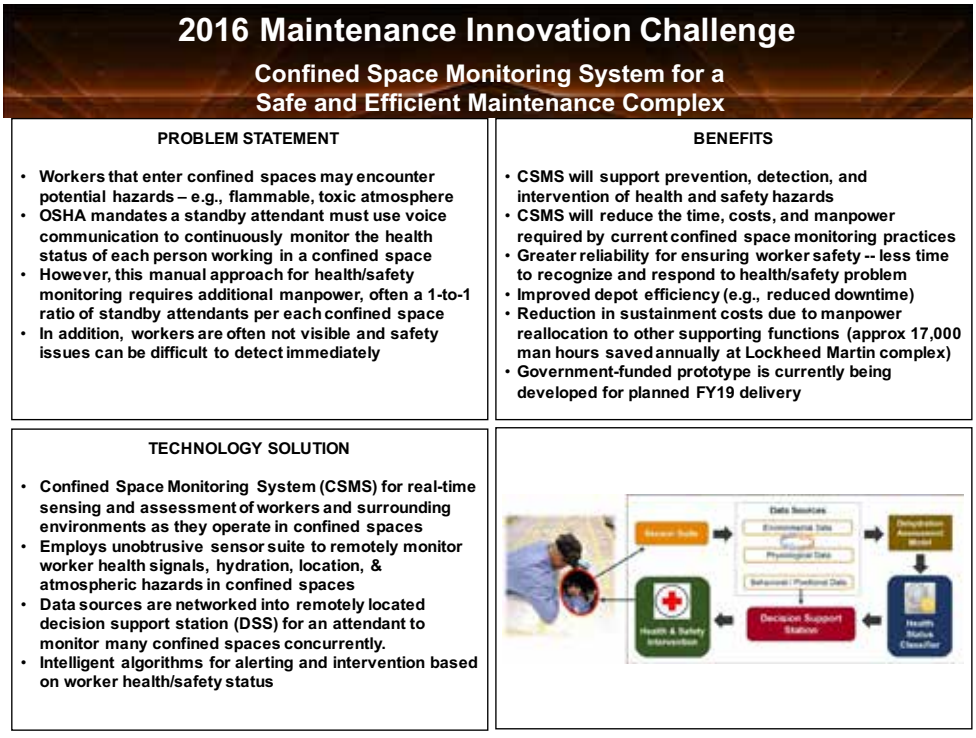
Problem: According to AFI 91-203 (Air Force Consolidated Occupational Safety Instruction), workers that enter confined spaces may encounter potential hazards including insufficient oxygen supply, flammable or explosive atmospheres, toxic gases, and electrical or mechanical hazards. Because a person in a confined space is usually not visible to standby attendants, in accordance with OSHA regulations, a standby attendant must use voice communication to monitor the person's status. To accomplish this, however, additional manpower is required to fulfill the standby attendant role during the performance of any work inside of a confined space, often at a 1-to-1 ratio. When focused on health and safety monitoring, standby attendants are unable to perform any other functions. In addition, communication intervals are often spaced out (e.g., 15-minute increments), meaning there could be a delay in responding to an emergency situation if a person in a confined space was injured between communication times.

Solution: To address this challenge, we are leveraging SBIR technologies to develop a Confined Space Monitoring System (CSMS) that will enable real-time sensing and assessment of maintenance workers and their surrounding environments as they operate in confined spaces and other potentially hazardous areas. The CSMS will employ an unobtrusive sensor suite to remotely monitor worker health signals, hydration, location, & atmospheric hazards in confined spaces. These data sources are networked into a remotely located decision support station (DSS) for an attendant to monitor many confined spaces concurrently. The CSMS will utilize intelligent algorithms for alerting and intervention based on worker health/safety status. The CSMS will also facilitate coordination with emergency responders.

Benefits: The CSMS will support prevention, detection, and intervention of health and safety hazards while greatly reducing the time, costs, and manpower required by current confined space monitoring practices. The result will be greater reliability for ensuring worker safety, improving depot efficiency, and reduction in sustainment costs. Of note, Lockheed Martin Aeronautics has actively used a preliminary version of this concept at their C-5 complex, resulting in approximately 17,000 man hours saved annually since late 2014.



Flightline Cross Utilization Training

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Maintenance of antiquated and aging defense systems is becoming increasingly challenging due to hard or non-procurable items, particularly with forward deployed vessels or remote operating units. These situations pose extreme and exhausting logistic challenges, which in turn significantly impact the combat readiness of our forces.

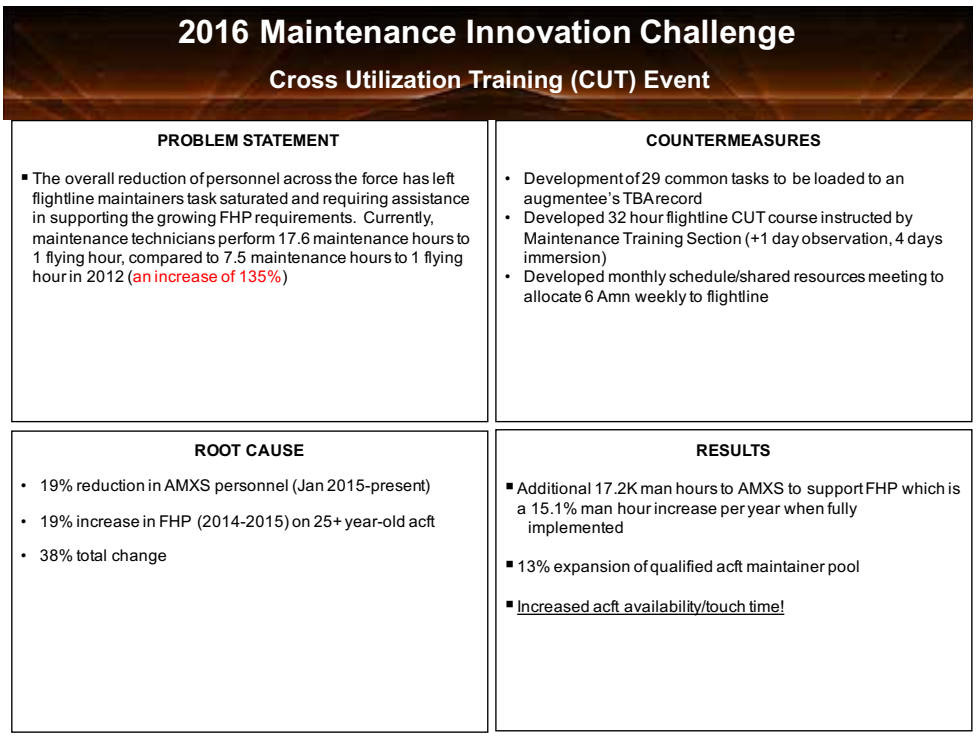
A game changing approach to alleviating this problem is to facilitate the ability to reverse engineer required components (if design is not readily available) or safely redesign for temporary voyage repair utilizing rapid manufacturing technologies, including 3d printing. Through both access and education, this scenario was tested over the past year through a partnership between Applied Systems & Technology Transfer (AST2), USN and USMC. The main objective was to increase accessibility of design and manufacturing equipment to all defense personnel, and stimulate learning and problem solving skills for the next generation of warfighters.

Navy's maintenance command and AST2 developed compact mini Fabrication Labs; integrating design stations, INVENT3D printer and a CNC mill at a cost of <$10,000 ea. Two systems were deployed on forward operating vessels. Sailors with little to no manufacturing background quickly adopted and developed exceptional solutions. For example, sailors reverse engineered and small batch produced a frequently replaced Radio clip (TRUCLIP). In addition to cost avoidance of over $12,000 in two months, sailors proved effectiveness by allowing accessibility and peer to peer learning. Additionally, sailors reverse engineered and produced a mission critical nitrogen purge kit to replace corroded wrap around panel brackets on F/A-18 aircraft, a life-saving plastic adapter for anesthesiologists waste gas machine, and a fixture for the radar test bench set preventing a critical 10 day work stoppage.

Two spin-off initiatives were taken into further demonstration of the technology's potential. First, a Navy-wide Fleet design challenge was created. Eighteen exceptional concepts were received that could potentially improve efficiency, reduce cost and hazards. Second, USMC's 1st and 2nd Maintenance Battalions were trained and equipped in collaboration with SPAWAR and HQMC. Marines learned to assemble INVENT3D printers, and designed and manufactured a number of replacement parts. Examples include the Power Take Off Yok Shifter for the AAV that reduced total procurement/replacement time from 200 to one day and AN/VRC-110 Vehicle Amplifier Unit with a 79,400% ROI. The 1st Maintenance Battalion, working with SPAWAR, advanced the development of an Expeditionary Manufacturing Unit that recently won SPAWAR's Lighting Bolt Award. Similarly the TRUCLIP won the Fleet design challenge and was transmitted jointly by dignitaries including VADM Cullom and LG Dana for printing on the International Space Station.

The training programs and equipment also stimulated problem solving skills, and as VADM said, sailors and marines proved that the 'sky is no limit' when they are provided with both tools and training.

Further development and deployment of this approach is planned. USN and USMC are to deploy additional Fabrication Labs. AST2 is supporting ODU in developing Fleet Maker Workshops to train over 300 Navy personnel over the next few years. The program will also be extended to both Army and the Air Force.



Aircrew Emergency Oxygen Simulator

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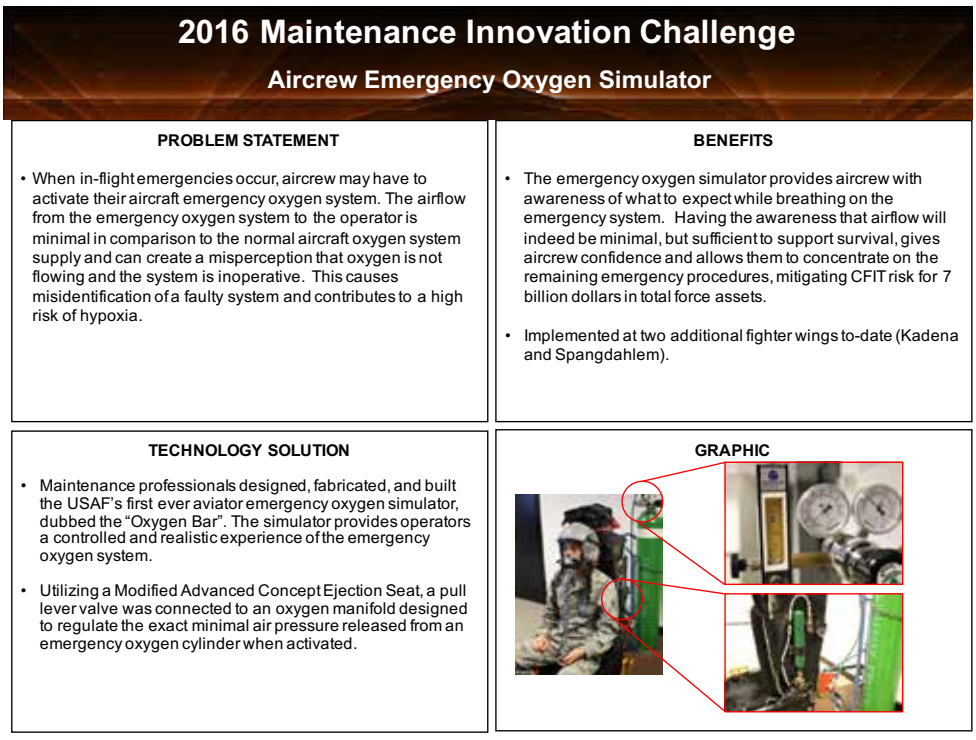
A major problem had been identified at the 48th Fighter Wing, Royal Air Force (RAF) Lakenheath, United Kingdom. When F-15 in-flight emergencies occur, aircrew may have to activate their emergency oxygen system, which provides them with an emergency source of oxygen for use in the event of hypoxia symptoms, total oxygen/pressurization failure, or ejection from the aircraft from 25,000 to 50,000 feet. When an aircraft undergoes rapid decompression or oxygen system failure, the time of useful consciousness for aircrew may be 60 seconds or less. The airflow from the emergency oxygen system to the operator is minimal in comparison to the normal aircraft oxygen system supply and can create a mis-perception that oxygen is not flowing and the system is inoperative. This chain of events has been known to cause symptoms of hypoxia in the event of an in-flight rapid de-pressurization and/or an oxygen system failure.

This lack of system familiarity and confidence presented a persistent need to train aircrew that may have to use this system to ensure they remain safe in the event of an emergency. The Electrical and Environmental Section of the 48th Maintenance Group immediately got to work on a solution. These maintenance professionals designed, fabricated, and built the USAF's first ever aviator emergency oxygen simulator, dubbed the "Oxygen Bar". A Modified Advanced Concept Ejection Seat was adapted to mimic the oxygen bailout bottle when activated by aircraft operators. The simulator provides operators a controlled and realistic experience of the system when it is activated. Additionally, the team authored an academic plan to educate aircrew on the functions and operational use of the aircraft oxygen breathing regulator and emergency oxygen system activation. Aircrew sit in the trainer, don their helmet and mask, connect to the simulated oxygen system, and pull the valve open to start the system simulation.

The results, praised by the Commander of the 48th Fighter Wing, were second-to-none. Research by the US Air Force shows 80 percent of aircrew members with no experience of decompression or oxygen failure wait as long as 15 seconds to respond correctly to an emergency. The "Oxygen Bar" provides aircrew with familiarity of what to expect while breathing on their emergency system. Having the awareness that airflow will indeed be minimal, but sufficient to support survival, gives trained aircrew confidence and allows them to concentrate on the remaining emergency procedures, mitigating a risk to life and total aircraft loss. In the eight months since the simulator was implemented, the team has trained 108 aircrew. This capability guarantees Combatant Commanders war ready operators and aircraft. This training decreased pilot response times, maximized the decision-making window, refined operator techniques, and enabled pilots to quickly focus on aircraft recovery. Knowledge of this training was shared across the CAF and implemented by two additional fighter wings. The innovation was further showcased to Air Force Material Command and United Nations leaders. Declared as aviation's way forward, the "Oxygen Bar" simulator provides the capability to train 300 pilots at a $101 gross annual cost.



THE CHALLENGE IS ON!

Maintenance Innovation Challenge

2017 DoD Maintenance Symposium

December 4-7, 2017 | Calvin L. Rampton Salt Palace Convention Center | Salt Lake City, Utah, USA

The Principal Deputy Assistant Secretary of Defense for Logistics and Materiel Readiness is challenging you to submit your maintenance related innovations. An evaluation board comprised of maintenance subject matter experts will select six candidates to participate in the challenge during the 2017 DOD Maintenance Symposium, December 4-7, 2017. Revolutionary or Evolutionary; showcase your maintenance innovation that offers a real solution and value to the DoD Maintenance Community to help us 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 4, 2017 in Salt Lake City.

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 — focused on current or potential maintenance operations or management — and strictly avoid commercialism
- Must be feasible or practical
- Abstract must be submitted in Word format using the template provided (abstract 300-500 words only)
- Include a PowerPoint Quad Chart (template details & requirements to follow)
- Entries from previous years will not be accepted
- All submissions must be cleared for public release

All abstracts that meet the minimum criteria listed above will be posted on a public website and included in a Maintenance Innovation Challenge summary booklet, that will be distributed to symposium attendees on site. From the eligible abstracts, an evaluation board comprised of maintenance subject matter experts will select six finalists to present at the 2017 DoD Maintenance Symposium. Each presenter will be allocated exactly 15 minutes, including audience Q&A. The winner will be selected by the Maintenance Executive Steering Committee and Joint Group on Depot Maintenance Senior Leaders, and recognized at a Symposium Plenary Session.

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

If you have any questions or need further information regarding the 2017 Maintenance Innovation Challenge Please contact Kristie Saber of SAE International at kristie.saber@sae.org

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