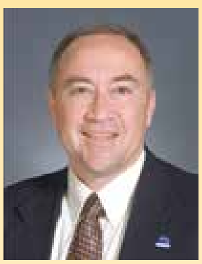
Newsletter 2016 No.1

iMAST

Institute for Manufacturing and Sustainment Technologies

IN THIS ISSUE

DIRECTOR'S CORNER



Timothy D. Bair

I thought I'd start out this year's edition of the iMAST newsletter with some bragging. Success in the U.S. Navy Manufacturing Technology (Navy ManTech) business is directly related to implementation and the resulting Return on Investment (ROI) the taxpayer gets when we do our job well. With that thought in mind, about once a year I like to conduct a quick scrub of iMAST's effectiveness in terms of dollars saved by virtue of our projects' successful completions. As a means of communicating impact, I review all the business cases for the acquisition and life cycle saving projects, as documented in our project plans and the feedback from depots, shipyards and Original Equipment Manufacturers (OEMs), to come up with actual dollars saved (or avoided) as a result of iMAST's execution (either alone or in collaboration with another center of excellence) of our RepTech and ManTech projects.

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DMC 2015: The Future is Now

iMAST once again participated in the annual Defense Manufacturing Conference (DMC) held in Phoenix, Arizona. The theme of this end-of-year event was: "The Future is Now… Creating Innovative Paths Towards Game-Changing Results". DMC remains the nation's largest annual forum for enhancing and leveraging the efforts of scientists, engineers, managers, technology leaders and policy makers across the defense manufacturing industrial base. Leaders from government, industry, and academia continue to have an opportunity to exchange perspectives and information about critical Department of Defense (DOD) industrial base policies, sector analyses and manufacturing technology programs for the production and sustainment of affordable defense systems. The forum fosters presentations discussing initiatives aimed at addressing enhanced defense and related national manufacturing capabilities and requirements.

Since its inception in 1969 as the Manufacturing Technology Advisory Group (MTAG) Conference, DMC has provided the defense community with a forum for presenting the latest innovative manufacturing technology developments. Average attendance is well over 1000, divided between government and industry participants, with a small complement from academia. Attendees range from CEO- and Flag Officer/SES-level to working-level manufacturing-oriented engineers, scientists and business practice/policy makers. DMC continues a long-standing tradition of presenting the requisite policy, strategic investment planning, program management, risk mitigation, and workforce

Tim Bair provides overview brief on ARL Penn State's iMAST Program

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DIRECTOR'S CORNER

The Repair Technology (RepTech) projects completed over the last couple years equate to approximately $22 million that would have otherwise been expended every year. This number is based on the shipyard's and depot's best estimates of what was spent during an average year using the old process before the RepTech innovation was put in place. Projects included in this category include the Vertical Launch System repair that recently completed 12 tubes on the USS Jefferson City at Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility, the implementation of Eddy Current in combat vehicle overhaul at our Marine Corps depots, and the Cold Spray repair of several parts for Fleet Readiness Center South-West and NAVAIR. We hope to grow that number greatly in the next couple of years.

Navy ManTech projects are tracked similarly, but are predominantly accounted for as traditional cost savings in that the results of the ManTech effort mean the ship cost is cheaper to the Navy and U.S. Taxpayer. As an example, the savings credited to iMAST/ARL for the Virginia-Class Submarine program equate to about $23 million dollars saved per hull. This savings is based on formally assigned savings with the shipbuilder and the program office, as well as predicted savings for ongoing projects. Most of these projects will continue to save U.S. Navy acquisition dollars throughout the planned buy and (potentially) future ships as well.

"MISSION ACCOMPLISHED" for us is seeing the results of our work on the ships, aircraft or ground combat vehicles. For the U.S. Navy's ManTech program (and the taxpayer) being good stewards of the people's trust is the definition of success. Unfortunately, we're not perfect. If you seek to innovate, risk of failure is always a factor to be managed and minimized. The U.S. Navy ManTech program accommodates risk management by putting transition planning upfront and at critical stages as the project evolves. The potential of a technical success and implementation failure is always present. Occasionally these "failures" are turned into a success story when the technology matures, or the program circumstances change. When you rely heavily on technology and technical innovation for your bread and butter, you have to learn ways to reduce risk. One of our favorite approaches has been the use of incremental development based on the use of mature technology (as the starting point), incorporating new technology as a modification and not as the sole aspect of the innovation. This helps transition to the OEM as well as enlists industry as a transition agent for manufacture and assembly.

I hope you enjoy our newsletter. The efforts of the ARL Materials Processing Division to implement cold spray into mainstream Navy and Marine Corps shipyard/depot processes have been case studies in successful transition of technology. Please feel free to contact us if you have any questions about our feature article in this issue – or our mission.

Tim Bair

PROFILE

Dr. Timothy J. Eden holds Ph.D. and M.S. degrees in Mechanical Engineering from The Pennsylvania State University. He received a B.S. in Mechanical Engineering from the University of Utah. Dr. Eden is head of the Materials Processing Division within Penn State's Applied Research Laboratory. The Materials Processing Division includes the Advanced Coatings Department, the Metals and Ceramic Processing Department, High Pressure Test Facility and the Drivetrain Technologies Center.

Dr. Eden has been working in Cold Spray technology for the past 17 years. Other areas of active research include high performance (ultra-high strength and high-temperature) aluminum alloys, thermal management systems, corrosion and wear resistant coatings, materials characterization and testing, process improvement and optimization, functionally tailored and laminate materials, and consolidation processes for materials. He can be reached at (814) 865-5880 or by email at tje1@arl.psu.edu.

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Focus on Materials Processing

Cold Spray Based Multifunctional Manufacturing and Repair System

by Timothy J. Eden, Ph.D.

[Editor's Note: Navy ManTech program efforts continue to pay dividends throughout the Department of Defense, as well as within the U.S. Navy and Marine Corps team. The Pennsylvania State University's Applied Research Laboratory (ARL Penn State) via ARL's Institute for Manufacturing and Sustainment Technologies (iMAST), a U.S. Navy Manufacturing Technology Center of Excellence, has consistently been evolving Cold Spray technology to the benefit of air, ship, and ground combat vehicles - especially as it pertains to repair. Most recently iMAST has been working with the Naval Sea Systems Command (NAVSEA) at the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) to develop, validate, and transition repairs for shipboard components. This effort continues through a Navy ManTech Repair Technology (RepTech) project titled: "Cold Spray Repair of Shipboard Components." (S2580)]

VRC Metals photo released

The Materials Processing Division of the Applied Research Laboratory was awarded a Defense University Research Instrumentation Program (DURIP) for a Cold Spray based Multifunctional Manufacturing and Repair System. The system will greatly enhance the Cold Spray capabilities of the Navy and will be used to support current Cold Spray projects in the DoD and industry, as well as the development of processes for dimensional repair, structural repair, and additive manufacturing. The Cold Spray system is a VRC GEN III system that has the high heat pressure capabilities required to perform repairs to shipboard components that are currently being developed, as well as for repairs that have been identified for future development.

CURRENT NAVY COLD SPRAY PROJECTS

Through meetings at PSNS & IMF, several components were identified that either did not have existing repair processes, or approved repair processes were inadequate for restoring the components to their original specifications. The components were ranked by material, urgency of repair, and probability of success. The top 10 components were identified. From this list, four different components each fabricated from a different material were selected for repair. The repairs required evaluating and developing a Cold Spray repair process that employs higher pressure and temperature capabilities than were available on the Cold Spray system at ARL Penn State. To develop these repairs ARL Penn State worked with the Cold Spray Team at the Army Research Laboratory, VRC Metals, Moog, and United Technologies Research Corporation (UTRC).

Hydraulic Actuator Body Repair

The first component selected was TD-63, an Al-6061 T6 hydraulic actuator body. The area where the actuator connects to the actuator body suffers from extensive corrosion damage due to exposure to seawater. A drawing of the actuator body and the areas where the corrosion damage occurs are shown in Figure 1. The damage occurs inside a bore that has a diameter of approximately 4 inches and a depth of approximately 8 inches. Typical corrosion damage is shown in Figure 2.

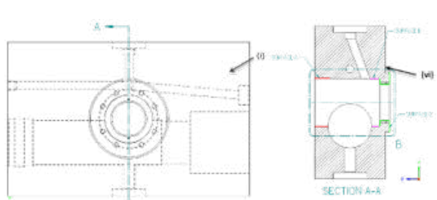

Figure 1. Drawing of TD-63 Al-6061 hydraulic actuator body. The areas that need to be repaired are indicated in the drawing.

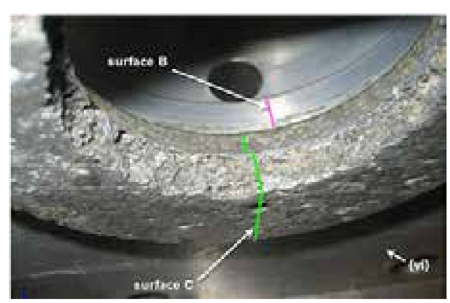

Figure 2. Photograph of the corrosion damage on TD-63.

The actuator body is machined to remove the corrosion damage and prepare the surface for the Cold Spray process.

The repairs were developed using the VRC Gen III system. New nozzles were designed to apply the coatings to the internal surfaces of the bore. Helium (He) was used as the process gas to deposit Al-6061 powder supplied by Valimet, Stockton, CA.

The Cold Spray process parameters for Al-6061 had been developed prior to this project. Mockups with the same geometry as the actuator body were fabricated, and repair processes were developed on the mockups. The mockups were sectioned and examined to verify that the repair met adhesion and density requirements. A mockup that has been sectioned is shown in Figure 3.

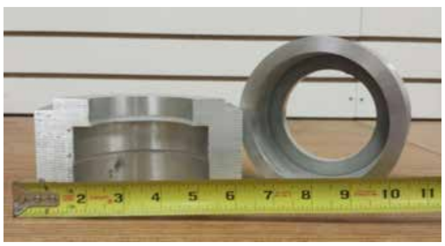

Figure 3. Photograph of the mockup used to develop and validate the Cold Spray repair on the AL-6061 actuator body.

Test coupons were sprayed to determine the adhesion strength per ASTM C633 and amount of porosity. A block of the material was produced. Tensile samples were fabricated and tested per measured ASTM E8. The adhesion strengths were greater than 11,000 psi. The tensile strength was approximately 30,000 psi. Corrosion tests showed that the deposited Al-6061 had virtually the same potential for corrosion as the actuator body.

The surfaces that needed to be repaired were grit blasted to roughen the surfaces, and then cleaned prior to the application of the Al-6061 powder. Sufficient Al-6061 powder was deposited on the surface to allow for final machining to specified dimensions. The actuator body after Cold Spray deposition of the Al-6061 powder is shown in Figure 4. The actuator body after it has been machined is shown in Figure 5.

After the actuator body was machined, it was installed and pressurized to ensure that the repair met the requirements. Two actuator bodies have been repaired and have been granted 2- year limited use approval. They are currently in service.

Figure 4. Photograph of the Al-6061 actuator body after Cold Spray deposition.

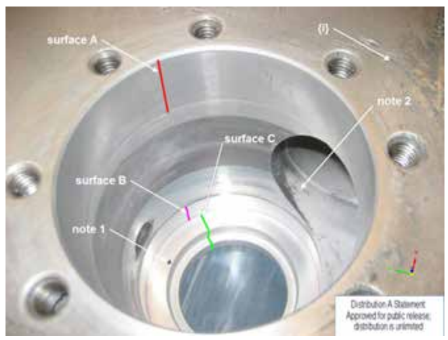

Figure 5 Photograph of the Al-6061 actuator body after final machining.

After two years, the actuators will be inspected and a determination will be made to extend the use approval for a longer period of time. A third actuator body will be repaired using a 5XXX series Aluminum alloy developed by a joint effort between the U.S. Army Research Laboratory and UTRC, to improve the corrosion performance and maximize strength and ductility.

This was the first Cold Spray repair that was approved by the Naval Sea Systems Command. The repair also showed the versatility of the Cold Spray process to repair internal surfaces and demonstrated that the new angled nozzle designs can apply high quality coating at off- normal angles.

The Cold Spray repair can be performed in two weeks. The lead time for a new actuator body is approximately one year. The cost of repairing the actuator bodies is approximately 20% of the cost of a new body.

Motor End-Bell Housing Repair
The motor end-bell housing holds the bearing that supports the spinning armature. Vibrations that occur during operation cause the bearing to wobble which cause the adjacent material to deform creating additional vibration in the motor.

Eventually the bearing must be removed and the housing repaired. The current repair is to plate the area with copper. A coating that is harder and more durable than the copper plating is needed. The repair can be applied to a number of different size motors.

The Cold Spray process is ideal for repairing the electric motor end-bell housings. The Cold Spray can easily deposit the 0.05 inches of material required. Three different materials were selected for evaluation. Steel rings were fabricated with the same bore dimensions as the motor end-bell housings. Copper (Cu), Nickel (Ni) and Nickel Chrome – Chrome Carbide (NiCr-Cr_3C_2) were deposited on the internal diameter (ID) and on one flat surface of the rings. A steel ring with a 9.5 inch outside diameter (OD), a 6.5 inch ID and a height of 1.5 in that was coated with 0.05 inches of copper is shown in Figure 6.

Figure 6. Photograph of a steel ring with 0.05 inch of Cold Spray deposited copper.

The ring was machined in a lathe to demonstrate the machinability of the copper coating. The machined ring is shown in Figure 7 (next page). The Cold Spray copper coating will be masked and the remaining surfaces will be plated with copper following the approved procedure. This will allow for direct comparison of the Cold Spray and plating processes for

Figure 7. Photograph of a steel ring that had 0.05 inches of copper deposited by Cold Spray after being machined in a lathe.

deposition of Cu. Additional machining will be performed on the ring. The hardness of both coatings will be measured. Samples will be removed that will allow the adhesion strength of both the Cu plating and the Cold Spray Cu to be determined following ASTM C633.

The Cu was deposited using Helium (He). The adhesion strength measured per ASTM C633 was 8,800 psi. Two additional rings were coated with copper and sent to the IMF for testing. Two steel rings will be coated with Ni and two with NiCr-Cr_3C_2. These two materials can be deposited with both nitrogen (N2) and Helium. A steel ring coated with NiCr-Cr_3C_2 was machined to demonstrate the machinability of the coating. The machined ring is shown in Figure 8. The adhesion strength for both the Ni and the NiCr-Cr_3C_2 was greater than 11,000 psi. The failures occurred in the adhesive used in the adhesion test.

Figure 8. Photograph of a steel ring showing that had 0.05 inch of NiCr-Cr3C2 deposited by Cold Spray after being machined in a lathe.

All three coating materials show promise for replacing the Cu plating repair on the motor end-bell housings. These coatings can be used to replace copper plating on a number of difference components.

Repair of Navy Bronze

The U.S. Navy uses bronze in a number of different applications. The bronze suffers from corrosion damage. A repair process was developed for C90300 bronze. The powder selected was DT-31 supplied by AcuPowder. Helium was used to deposit the powder. Adhesion and corrosion tests were performed on the coated samples. The adhesion strengths were over 11,000 psi. The coating has virtually the same corrosion potential as the substrate and there was no evidence of crevice corrosion. A micrograph of the DT-31 powder on the C90300 substrate is shown in Figure 9. The micrograph shows a dense uniform coating.

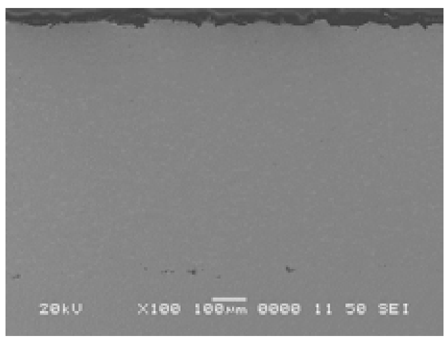

Figure 9. Microstructure of the DE-31 Powder deposited on a C90300 substrate.

The process was developed to repair a dove tail in a bearing. The coating met the adhesion and corrosion requirements. Additional development is needed to qualify the repair.

The process parameters developed for repair of the dove tail were used during the repair of the CVN #1 Main Circulating Water Pump Casing. The surfaces where the pump shaft was in contact with the housing experienced various degrees of corrosion and wear damage. These surfaces were repaired and inspected. The repaired pump casing was technically approved by NAVSEA 05Z4, SEA 0-P2 and SEA 05V1 and programmatically approved by SEA 08. It is a major temporary approval for unrestricted operations until 30-April-2019 at which time the pump casing will be inspected and a decision will be made on making the repair permanent.

This repair can be applied to a number of different bronze components.

Repair of 70/30 CuNi

The body of the swing check valve is made of 70/30 CuNi alloy. The plate that swings to open and shut the valve is made from a titanium alloy. The sealing surface of the valve corrodes and loses the ability to seal. The swing check valve body and the areas that need to be repaired are shown in Figure 10.

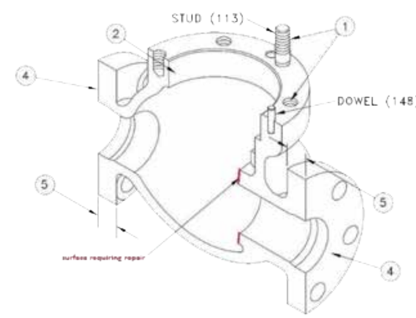

Figure 10. A schematic of a 70/30 CuNi swing check valve body with the area that needs to be repaired is shown in red.

There is limited access for the repair of the valve. Mockups were machined for the development of the repair process. The mockups had a similar internal geometry as the valve body. After the mockups were coated, they were sectioned and the microstructures were examined. A mockup is shown in Figure 11.

The adhesion strength of the 70/30 CuNi coating was greater than 11,000 psi. There

Figure 11. Photograph of a mockup of the swing check valve.

was no evidence of crevice corrosion and the coating and substrate have the same corrosion potential. Three mockups have been repaired. The process has been modified and one more mockup is currently being repaired. Once the mockup is approved the Swing Check Valve will be repaired. The valves can be repaired for 20% of the cost of a new valve. The repairs can be completed in much less time than a new valve can be purchased.

Cold Spray Summary
Four Cold Spray repairs were developed using a high pressure Cold Spray system. Two of the repairs, the Al-6061 hydraulic actuator bodies and the Main Circulating Water Pump Casing have been given temporary approval. The two other repairs, copper plating replacement and the 70/30 CuNi repairs are in the process of being qualified.

The Cold Spray process can save the Navy millions of dollars in direct savings by repairing damaged components that currently do not have approved repairs of or that have inadequate repairs. Additional savings will result from greatly decreasing the time to repair the components and avoiding long lead times required to purchase new components.

The number of applications for Cold Spray continues to increase with each successful repair. The Cold Spray activity in the Navy is reviewed in regularly scheduled teleconferences. New applications are being identified as improvements in the Cold Spray equipment increases the number of materials that can be deposited are identified.

Multifunctional Manufacturing and Repair System
ARL Penn State was awarded a DURIP to purchase a multifunctional manufacturing and repair system. The design of the system was based on the system developed under an OSD ManTech project lead by the Army Research Laboratory. The system consists of a state-of-the-art VRC Gen III Cold Spray System, a Milltronics BR5100iL CNC machining station, an ABB six-axis robot and a touch probe. The system is depicted in photo and graphic in Figure 12.

Figure 12. The Multifunctional Manufacturing and Repair System.

The Gen III Cold spray system has a maximum pressure of 1000 psi (6.9 bar) and a maximum temperature of 1472°F (800°C). The system can operate on air, N2 and Helium. The system can be integrated with a robot. The system is palletized, but can be used as a hand-held portable system. The system records and stores operating data, and uses a touch screen to set and change the temperature, pressure, powder feeder and the process gas type. The system can be remotely controlled using a computer with a CAT5 cable connection. The system also has a power filter to allow for operation with a poor quality power source.

The Milltronics BR51000IL is a CNC-controlled state-of-the-art milling station that interfaces with solid SOLIDWORKS. A MB-900 dimensional probe will be integrated in the system. It will be used to determine the dimensions of the parts that will be repaired or produced by additive manufacturing. The robot is a multi-axis ABB robot that will interface with SOLIDWORKS.

The Cold Spray System, robot, touch probe and the milling station are integrated into a turn-key system. This will allow a complete Cold Spray repair to be performed on a single system. A CAD or SOLIDWORKS model of the component can be loaded into the system. A touch probe can be used to verify the dimensions. Finally, the CAD program can be used to develop the robot program for coating and machining the component.

To perform the repair, the component is fixtured on the Milltronics table. The damaged areas will then be machined to prepare them for the Cold Spray process. The Cold Spray coating is deposited before the component is machined to specific final dimensions. If required, machining and Cold Spray processing can be repeated until the desired results are achieved. The system has the capability to handle large components, up to 5000 pounds.

Summary
The state-of-the-art Multifunctional Manufacturing and Repair System greatly enhances the capabilities of the Cold Spray process, which is currently benefitting the U.S. Navy and Marine Corps. ARL Penn State plans to continue evolving and transitioning this technology for the Department of Defense. Future developments will include additive manufacturing and advanced structural repair. ARL will also continue to focus on the development of powders for additive manufacturing, which will further increase the number of repair solutions available to the various supporting repair facilities.

ARL Penn State remains engaged in the development of a comprehensive Cold Spray model process that is currently being led by the Army Research Laboratory's Center for Cold Spray at Aberdeen, Maryland.

ACKNOWLEDGEMENT
The author wishes to express appreciation for the support of ARL Penn State's Multifunctional Manufacturing and Repair System program by the Institute for Manufacturing and Sustainment Technologies (iMAST), a U.S. Navy Center of Excellence under contract by the U.S. Navy Manufacturing Technology (ManTech) Program, Office of Naval Research. The author would also like to express appreciation to the following individuals for their support: Mr. John Carney and Gregory Woods (Office of Naval Research); Thomas Stamey and John Albrecht (Puget Sound Naval Shipyard & IMF); Victor Champagne (Army Research Laboratory); Christian Widener and Rob Hrabe (VRC Metals); and Chris Howe (Moog Inc.).

INSTITUTE NOTES

U.S. Navy released photo

Eric Petran, P.E. - Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility.

U.S. Navy released photo

Admiral Scott H. Swift USN, Commander, U.S. Pacific Fleet (3rd from right), pauses for group photo with Mr. Petran (far left) and fellow colleagues following a shipyard capabilities and innovation awareness tour. The photo was taken immediately following a briefing about the VLS-LCRS program effort developed at Pearl Harbor Naval Shipyard & IMF, in cooperation with ARL Penn State and NUWC-Keyport.

Federal Engineer of the Year Award

One of the things iMAST experiences on a regular basis is the opportunity to collaborate with outstanding professional engineers within the various circles of the Departments of Defense, Navy, and Marine Corps. The synergy developed often results in highly creative solutions that address (in particular) repair, maintenance and overhaul efforts, especially as it relates to U.S. Navy ManTech program efforts. On that note, ARL Penn State/iMAST is pleased to report that Naval Systems Command (NAVSEA) electrical engineer Mr. Eric Petran was chosen as one of 34 federal agency department engineers to receive the 2016 Federal Engineer of the Year award – presented annually by the National Society of Professional Engineers (NSPE). Selected to represent the U.S. Department of the Navy and NAVSEA, Mr. Petran is one of seven Navy recipients who received the award at a ceremony recently held at the National Press Club in Washington, D.C..

Currently assigned as an engineer at the Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility, Mr. Petran's project activities include the development of new maintenance processes and 3-D modeling to improve maintenance training. In concert with his association with ARL Penn State, Mr. Petran collaborated with iMAST to implement a recent successfully completed Navy ManTech Vertical Launch System (VLS) Laser Cladding Repair System project which welds and machines critical bands within specific launch tubes. To date, the Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility (PHNS & IMF) is currently the only shipyard with that repair capability. Notes PHNS & IMF commander, Captain Jamie Kalowsky: "Petran's leadership, coordination, teamwork, dedication and commitment as the Shipyard's lead engineer for implementing advancements in innovation and technology are instrumental in increasing our capability and capacity of repair and maintenance processes."

On behalf of ARL/iMAST we wish to extend our congratulations to Mr. Petran and look forward to addressing future challenges with him and other professionals within the various shipyards and depots iMAST supports via the U.S. Navy ManTech program.

COVER STORY

Continued from Page 1

education and training efforts necessary for efficient technology adoption and resilient force shaping impact in a period of shrinking defense budgets.

iMAST participants this year included Tim Bair, Director of ARL Penn State's Institute for Manufacturing and Sustainment Technologies, Todd Palmer, Ph.D. – who gave a presentation on iMAST's VCS Retractable Bow Plane Repair program effort. Also attending was Dan Finke, Ph.D., who served on the Digital Manufacturing Common panel. We are proud to also note that our iMAST/National Shipbuilding Research Program (NSRP) project: "Navy Standard Pressure Activated Watertight Door (NSPAD)" was one of six outstanding finalist projects for the annual Defense Manufacturing Technology Achievement Award.

Next year's DMC will be held in Denver, Colorado (28 November through 1 December). More news to follow.

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"I do not want to be in a position of technological parity or inferiority with anyone in the world."
—Frank Kendall, Under Secretary of Defense for Acquisition, Technology and Logistics

CALENDAR of EVENTS 2016

10-12 May	**NCMS/CTMA Annual Integrated Project Meeting**	**Suffolk, VA**
16-18 May	**Navy League Sea-Air-Space Expo**	** **National Harbor, MD**
17-19 May	**American Helicopter Society Forum 72**	**West Palm Beach, FL**
21-23 June	**Applied Reliability Symposium**	**San Diego, CA**
12-15 Sep	**Fleet Maintenance and Modernization Symposium**	**Hampton Road, VA**
27-29 Sep	**Modern Day Marine**	** **Quantico, VA**
3-5 Oct	**AUSA Expo**	**Washington, D.C.**
28 Nov - 1 Dec	**Defense Manufacturing Conference**	****Denver, CO**
5-8 Dec	**DoD Maintenance Symposium**	**Albuguerque, NM**

**** Visit iMAST booth**