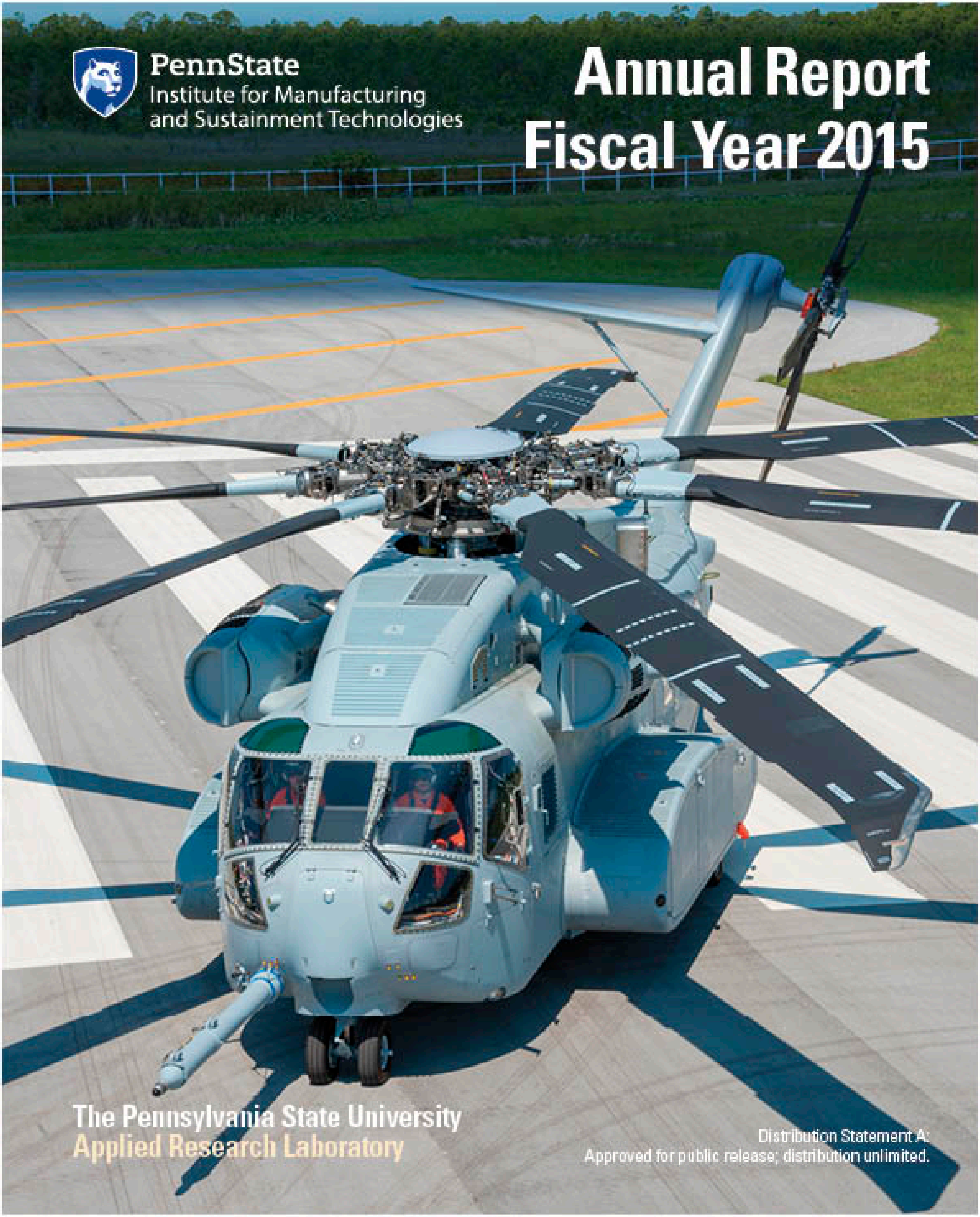

PennState
Institute for Manufacturing
and Sustainment Technologies

Annual Report
Fiscal Year 2015

The Pennsylvania State University
Applied Research Laboratory

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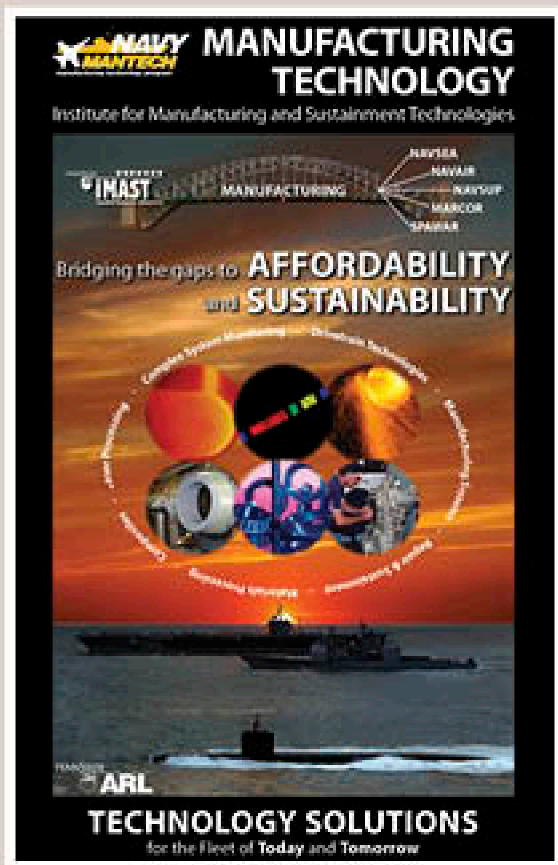

On the Cover:
CH-53K King Stallion, U.S. Navy photo courtesy Sikorsky.

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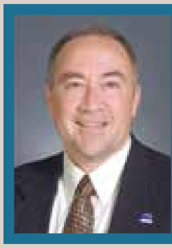


Director's Message

Timothy Bair
iMAST Director

On behalf of the Applied Research Laboratory at Penn State and its U.S. Navy Manufacturing Technology Program Center of Excellence, the Institute for Manufacturing and Sustainment Technologies (iMAST), I am pleased to present our annual report for Fiscal Year 2015. We designed this Annual Report to provide a sample of the work conducted throughout FY-15, as well as a summary of the resources uniquely available here to support the Navy ManTech mission. As an integral part of the ONR ManTech family, our mission is to make the Navy's next generation of ships, aircraft and various weapons systems more affordable throughout both the acquisition and life cycle spans of these systems. ARL permits iMAST to leverage off the inherent capabilities the laboratory maintain in order to further capture and economically exploit the resources already supporting the U.S. Navy-Marine Corps Team.

Success for iMAST is measured in two simple terms, implementation and return on investment. Implementation is metal, composites or new manufacturing technology on the Navy's ships, aircraft and ground combat vehicles that support and protect our Sailors and Marines every day. This year iMAST supported over 30 Navy ManTech projects that cover the spectrum of the Department of the Navy's responsibilities, with emphasis on reducing total ownership costs. Our projects focused on light armored combat vehicles in depots, submarines, destroyers and the F-35 in manufacture as well support for the shipyards and depots, to name a few.

One of iMAST's advantages, as a result of being hosted by ARL and Penn State, is our ability to act as a focal point for the development and transition of new manufacturing technologies and processes, as well as identify enhanced materials and applications in a cooperative environment with Navy and Marine Corps Systems Commands. Successful implementation drives us to engage with cognizant technical authorities supporting industry and other Navy centers as we mature project ideas into Navy programs and practices. In other words, we solve challenges with advanced as well as mature technologies applied in innovative ways.

The Navy ManTech-funded projects we executed over FY-15 relied primarily on the expertise of ARL's Materials and Manufacturing Office (MMO). These core areas of expertise include composites, materials, laser processing, manufacturing systems, condition-based maintenance, drivetrain systems, and innovative manufacturing technology. However, ARL brings many more tools to the ManTech challenge such as modeling and analysis, weapon system development expertise as well as advanced technology program management, to name a few.

Our numerous ManTech projects also take advantage of ARL's expertise in systems engineering, as well as computational fluid dynamics, finite element modeling and advanced manufacturing enterprise tools. When advantageous, we can also leverage the extensive research depth of the greater Penn State University. If you remember nothing else from this report, I hope you'll remember that Penn State's Applied Research Laboratory and (of course) iMAST is a DoD resource dedicated to supporting the Navy-Marine Corps Team within a coordinated DoD industrial and manufacturing technology-based effort.

Thank you for your time and interest. Please do not hesitate to contact us if we can help or answer any of your questions about our program and its various efforts.

Tim Bair

iMAST: Serving the Navy-Marine Corps Team

The Institute for Manufacturing and Sustainment Technologies (iMAST) is a U.S. Navy Manufacturing Technology (ManTech) Center of Excellence, sponsored by the Office of Naval Research. Located at The Pennsylvania State University's Applied Research Laboratory in State College, Pennsylvania, the institute was formally established in 1995. The institute is comprised of seven technical thrust areas:

- Repair Technology
- Laser Processing Technologies
- Manufacturing Systems
- Composites Technologies
- Materials Processing Technologies
- Systems Operations and Automation
- Mechanical Drive Transmission Technologies

As noted, iMAST is resident within Penn State's Applied Research Laboratory, which serves as a DoD University Affiliated Research Center (UARC). iMAST provides a focal point for the development and transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and the Navy. The Institute leverages the resources of The Pennsylvania State University to develop technology and business practices that enhance the industrial sector's ability to address advanced weapon systems issues and challenges for the Department of Defense. The "reach-back" capability into Penn State's strong R&D engineering foundation provides significant science and technology capability which iMAST exploits in a cost-effective manner. Sponsored under Navy contract N00024-12-D-6404, iMAST provides manufacturing technology support to the systems commands of the U.S. Navy and Marine Corps.

U.S. Navy released photo

ARL Penn State

About ARL Penn State

PennState
Applied Research Laboratory

The Institute for Manufacturing and Sustainment Technologies resides within the Applied Research Laboratory (ARL) at The Pennsylvania State University (University Park campus). UARCs are strategic United States Department of Defense (DoD) research centers associated with universities. UARCs were established by the Director of Defense Research and Engineering (DDR&E), Office of the Secretary of Defense to develop and ensure that essential engineering and technology capabilities of particular importance to the DoD are maintained. Although UARCs receive sole source funding under the authority of 10 U.S.C. Section 2304(c)(3)(B), they may also compete for science and technology work unless precluded from doing so by their DoD UARC contracts.

The Applied Research Laboratory is one of five U.S. Navy University Affiliated Research Centers (UARCs) in the country. Solving challenges for the U.S. Navy and DoD for 70 years, ARL has demonstrated innovation and practicality in technology-based research. While serving the Navy and DoD as a technology base, it has also facilitated Penn State in becoming second among U.S. universities in industrial R&D funding.

ARL's broad-based effort is supported by a full-time complement of more than 1,000 scientists, engineers, technicians, and support staff, in addition to 200 associate members within the university. Through its affiliation with various colleges of Penn State, other universities, and consortia, it has extended capabilities to manage and perform interdisciplinary research.

The Applied Research Laboratory's charter includes and promotes technology transfer for economic competitiveness. This focus supports congressional and DoD mandates that technology from federally-funded R&D be put to dual use by being transferred to the nation's commercial sector

Core competencies within ARL have provided iMAST with an opportunity to directly contribute to manufacturing-related activities espoused by the Office of Naval Research's Manufacturing Technology Program (Navy ManTech).

ARL released photo

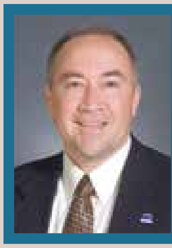
Navy ManTech Strategic Investment Plan

The Navy Manufacturing Technology (ManTech) Program is improving the affordability of naval platforms critical to the future force. Investments are focused on manufacturing technologies to assist key acquisition program offices in achieving their respective affordability goals. ManTech has specifically identified and funded affordability initiatives for the Virginia-class and Ohio Replacement submarines, CVN 78-class carrier, DDG 1000- and DDG 51-class destroyers, CH-53K King Stallion, and the F-35 Lightning (Joint Strike Fighter).

Sikorsky released photo

U.S. Navy released photos

Strategic Plan



Repair Technology

Timothy Bair
Technology Leader

Sustainment has never been as critical to the Navy-Marine Corps team as it is today. Recovery from a long term two-war effort and the budgetary limitations under Sequestration have emphasized the need for efficiency and increased reliability and availability. The fiscal realities facing the naval services have significantly increased the need to find or create cost-cutting measures that can reduce life cycle cost as well as enhance operational availability. The ONR ManTech, Repair Technology (RepTech) program, managed by iMAST, carries as its prime mission the drive to cut sustainment cost through advanced technology and development as well as mature technology applied in innovative ways. RepTech has the potential to create significant dollar savings (or cost avoidance), while concurrently enhancing operational readiness—especially at this critical juncture in time. This mission is especially critical as it directly impacts the support our Sailors and Marines need and deserve. iMAST is grateful to be entrusted with the conduct of this vital program.

Mission

Designated by the Navy as the resident coordinating center for the repair technology effort, RepTech's charter includes:

- Apply emerging technologies to improve the capabilities of the repair community.
- Improve repair processes and the affordability of repair facilities.
- Execute S&T projects which directly affect depot-level maintenance.
- Execute projects under the direction of the RepTech Working Group.
- Communicate innovation to implementation agents across DoD by all means available.
- Reduce duplication of effort in RepTech-related R&D.
- Leverage program funding with funds from other programs and agencies.

Management Structure

Oversight for the RepTech program is facilitated by the RepTech Working Group (RWG), which is chaired by ONR (Mr. Greg Woods) and consists of one technology integration management representative from NAVSEA, NAVAIR and MARCOR. The RWG meets semi-annually to review all current projects as well as discuss new potential efforts. The RWG was created to develop a coordinated approach to executing and identifying the RepTech needs across the Navy sustainment enterprise; surface, subsurface, air and ground combat forces.

USMC released photo

Fiscal Year Activities Included:

VCS Retractable Bow Plane Rod Repair **-S2449**

The overall objective of this program was to optimize and implement a thermal spray coating solution on extend/retract cylinder rods in the retractable bow plane system of VIRGINIA class submarines. This coating must be robust enough to adhere to the rod and not display cracking over the duration between maintenance availabilities. It must also be resistant to the formation of calcareous deposits, compatible with the seals in the hydraulic cylinders, and not promote enhanced wear of the seals during operation.

U.S. Navy released photo

A multi-phase program was undertaken designed to culminate with implementation of a coated extend/retract cylinder rod on a new VCS. The first phase of the program was directed at building upon the technology development activities completed during a previous PMS 450 funded (ARL executed) effort. In this previous effort, several coating solutions were investigated, and thermal spray coatings were selected as the path forward. Using the knowledge obtained from this previous work, the thermal spray processing of a two material coating systems was improved during phase two. In this iMAST project, the processing parameters were optimized to obtain maximum coating adhesion strengths and extended life. Extensive testing was successfully conducted on coupons as well as full scale rods including adhesion and wear testing. The new plasma spray system was approved and in work for a near term implementation at General Dynamics Electric Boat.

(POC: Todd Palmer / Doug Wolfe)

VLS-LCRS Updates for Production Readiness **-S2545**

The overall objective of this project was to update the Vertical Launch System Laser Clad Repair System (VLS-LCRS) for production readiness and minimize the risk of breakdown associated with system usage. This risk includes unexpected costs and/or delays related to system downtime during a ship's availability. Pearl Harbor Naval Shipyard and Intermediate Repair Facility (PHNSY) had identified VLS-LCRS reliability as the primary impediment to full implementation, and was intimately involved throughout the development of this project. The reduction in risk was accomplished via activities funded through this ManTech program as well as NUWC-DIV Keyport and PHNSY. The RepTech efforts were assessed by the timely achievement of the following goals, each of which addresses recommendations for improving 1) system reliability, and/or 2) overall system repair time after failure of individual system components. The ROI was based on a conservative estimate that 33% of the VLS tubes per year require repair at the outset, followed by less frequent repairs once brush electroplating repairs (lasting 1 yr.) are replaced by laser clad repairs (lasting 2 periods). Keyport produced a draft benefits analysis ("PAC Fleet VLS Tube [688-class] Repair Analysis", April 2012) showing a ten-year cost avoidance of $6.2M, and an ROI of 4.9. This project successfully concluded this year and the VLS-LCRS was used on the USS Jefferson City.

(POC: Steve Brown)

Ships Checks Using 3D Scanners -S2536

The objective of this project was to implement a secure CAD-based environment system to capture an on-board industrial ship propulsion area, as well as other ship compartments in collaboration with Puget Sound Naval Shipyard and Intermediate Repair Facility (PSNSY) and NAVSEA. The focus of this project was based on: 1) an evaluation of laser metrology inspection technology, and 2) the development of a process for capturing the point-cloud inspection data, manipulating the data into a CAD based environment and allowing the data to be revealed and displayed for NAVSEA mechanical engineering upgrade and repair work in the Navy shipyards.

The project is targeting implementation in the propulsion system area, but can be used in any shipyard refurbishment, repair and upgrade to Navy ships and their systems. The project's cost-avoidance is obtained through:

- Improved configuration management of ship systems
- Accurate detail of the as-manufactured and current configuration
- Reduced ship inspection verifications/validations
- Reduced human error from tape measure inspections
- Improved pre-planning process knowledge and data
- Reduced travel team size required per ship checks

This project has successfully transitioned to PSNSY and is in the process of being incorporated into their planning infrastructure and will be used in future ship's checks site visits.
(POC: Sean Krieger)

Crack Detection in USMC Combat Vehicles -C2477

The objective of this iMAST project was to define and implement a new or modified NDE/NDT capability for inspection of large assembled and painted USMC combat vehicles. The inability to detect cracks in Marine Corps combat and service support vehicles without disassembly and paint removal is time consuming and costly. Currently, the depots completely strip each vehicle and remove camouflage, topcoat, and primer paint layers prior to conducting a comprehensive visual and metrology inspection.

The Marine Corps Maintenance Directorate and the Marine Depot Maintenance Command (MDMC) requested iMAST assistance in evaluating non-destructive evaluation/non-destructive testing (NDE/NDT) technologies for detecting cracks under painted Marine Corps combat and service support vehicles. The down selected NDE/NDT method, Eddy Current Array, is being used to inspect vehicles assigned to the depot that are eligible for fleet deployment. The most

USMC released photo

significant payoff from successful implementation of the down selected NDE/NDT method is a decrease in throughput time associated with inspection, repair and re-painting of USMC combat vehicles. This reduction will result in improved USMC combat vehicle mission readiness. This project successfully concluded and Eddy Current Array is being used in the MDMC - Production Plant Albany processes.
(POC: Clark Moose / Rance Maruszewski)

Improved Topside Non-Skid Removal for Submarines **-S2494**

The objective of this project was to remove nonskid from the topside of submarine hulls safely, quickly and with no damage to the underlying hull treatments. Project results will be used on both Seawolf-class and Virginia-class submarines (VCS). The project team's approach was to design and build a nonskid removal machine to replace the current system of hand sanding and grinding. The project looked at several different technical approaches and selected the best all-around solution as an Ultra-high pressure water jet tool. To facilitate rapid and effective implementation, the iMAST team is involving a UHP equipment manufacturer from the outset.

This project successfully transitioned to a PMS 392-funded project designed to build in several safety and industrial hardening features. This project, scheduled to end in FY-16 will result in each yard getting a new system capable of removing the nonskid, without damaging the substrate, in less than 3 shifts.
(POC: Charlie Tricou)

Cold Spray Technology for Shipboard Components Repair **-S2580**

The objective of this effort is to develop cold spray repairs for proposed shipboard components including the repair process, validation of the process parameters and coating properties, qualification test results, process parameters, material and process parameters, and coating procedures. There are many components on Navy's ships that do not have a viable repair method. Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNSY) has identified several repair and maintenance issues on a number of different ships. As sea water exposed components age, more repairs are required due to corrosion of the base metal. Components that routinely need repaired/replaced include valves, pumps, actuators and periscope masts. The components are made of different materials including Al-6061-T651, brass, Monel (~70Ni-30Cu), 70/30 Cu-Ni and Inconel.

Current repair processes for this extensive corrosion damage include electroplating, epoxy patches, and welding. These repairs can be very labor and time intensive and the parts are condemned and replaced routinely. Four components have been selected by PSNS personnel for evaluation of repair by cold spray. The selection of the components was based on probability of success, the substrate/coating material combination, urgent need or long lead time, the number of components requiring repair, frequency of repair and the ROI. The four components are:

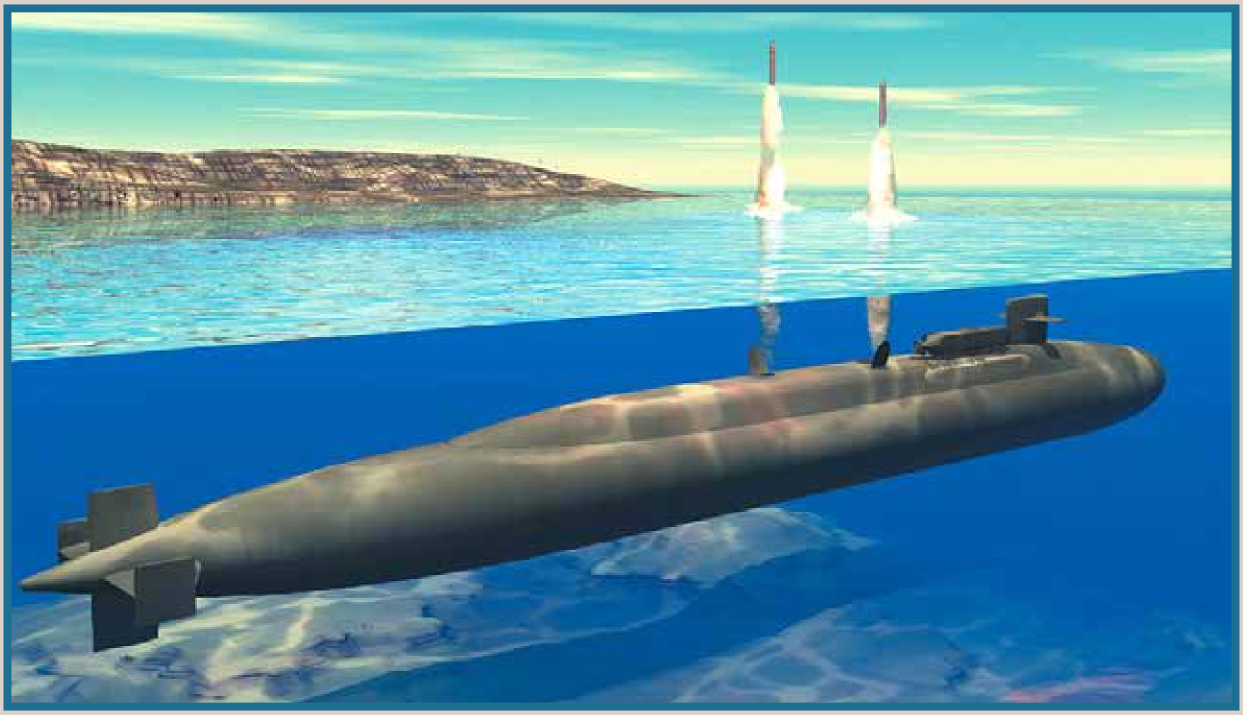
- Hydraulic Actuators/Controllers (Al 6061)
- Priming Pumps (Nickel/Aluminum/Bronze or Brass)
- Seawater Pump Channel Rings (70Cu-30Ni ASTM B369, Alloy C96400)
- Electric Motor End Bell Bore and Rotor Repair (Cast Iron and Steel)

The repair process and qualification for the Hydraulic actuators has successfully implemented and repaired parts are currently installed on active ships. The process definition and qualification of the remaining components is expected to successfully implement in early FY-16.
(POC: Tim Eden)

HDC-1 Bearing Improvement -S2573

The objective of this project was to validate the failure mechanism, down-select to a solution to improve system reliability, test and demonstrate a system solution. The Virginia-class Hover and Depth Control (HDC) hull and backup valve assembly consists of a poppet valve (hull valve) and a ball valve (backup valve) in a common body. There have been several recent occurrences of the hull valve failing to operate properly between two and four years after the valves were placed in service. The main cause of the failure were attributed to overloading and lack of lubrication of the split bearing assembly. During operation, it is believed that the friction between the bearing and the rod increases, requiring additional force to operate the valve. The large frictional forces can cause the bearing assembly to rotate, damaging the rubber and triggering excessive bushing wear against the bolts that hold the connecting rod together.

This project has successfully transition to NAVSEA who will be developing the engineering configuration change to include the experimentally proven material/design modification that will address the bearing failures and extend the service life of the HDC-1 valves thereby supporting increased ship and component availability through the Extended Dry-Docking Selected Restricted Availability (EDSRA) cycle. Successful implementation will result in improved system and ship availability, increased system reliability and programmed maintenance periodicity and savings over five years of approximately $0.8M.
(POC: Tim Eden)

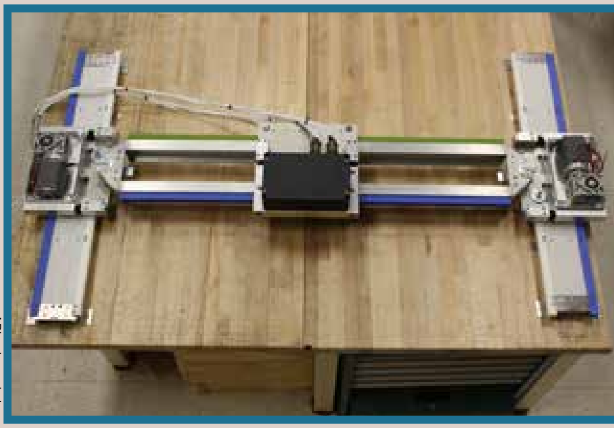


US Navy released graphic

Dual Track Special Hull Treatment Removal -S2599

The object of this project is to design, fabricate, test and deliver a semi-automated dual-track ultra-high pressure (UHP) Special Hull Treatment (SHT) removal system. The dual-track system utilizes a crawler, which enables shipyards to use higher pressures and flow rates than human operators can safely handle using hand-lances. With the dual-track crawler system, shipyards will reduce labor while simultaneously improving removal efficiency and safety. Shipyards will save substantial additional labor through reduction or elimination of waste cleanup.

UHP water jet is the only process approved for removal of SHT from Virginia-class (SSN 774) submarine hulls. Rotating-nozzle UHP water jet blasting does not damage steel. UHP hand lancing, however, does have the following



ARL released photo

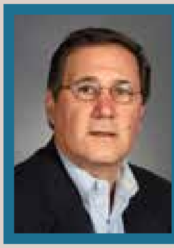
US Navy released photo

drawbacks:

- There are safety issues associated with the use of open-cycle UHP blasting hand-lances.
- SHT removal using UHP hand-lances is slow (~ 20 ft./hour).
- Shredded SHT clogs hoses, filters and pumps.
- The cost to clean up shredded SHT is substantial.

Ultra-High Pressure and flow rate strongly influence production rate. Unfortunately, increasing pressure and flow increases back-thrust, water vapor-induced visibility restrictions and worker fatigue. Removing hand-lances from the hands of the operators is the only sure way to address safety concerns. Track-mounted UHP systems make cleaner edge-cuts and are more stable. Blast nozzles always point at the hull, reducing risk of injury and risk of damage to non-targeted objects or materials. Track-mounted systems also enable addition of an on-board vacuum shroud, further reducing or eliminating the need for containments. This project aims to implement in FY-17 a track mounted, single operator system to improve task efficiency and significantly reduce injuries and worker fatigue.
(POC: Charlie Tricou)

iMAST funded projects are performed in cooperation with and directly support these DoD activities:



Laser Processing Technologies

Richard Martukanitz, Ph.D.
Technology Leader

Mission

The primary mission of ARL's Laser Processing Division is to develop and implement advanced laser processing technology for improving affordability through reduced acquisition and life-cycle costs, maintaining readiness and increasing performance of Navy and Marine Corps platforms. The secondary goal of the division is to ensure that advanced laser processing technology is available to meet the growing demand for efficiency and innovation while maintaining a national repository of laser technology for use by the U.S. industrial base in its efforts to preserve international competitiveness.

2015 Fiscal Year Summary

The division continues its quarter century tradition of developing and fielding advanced laser processing technology. As in the recent past, designs developed using a concurrent (mature technology along with innovation) technology approach to address the various Navy and Marine Corps manufacturing-related challenges. The lessons learned throughout the years has resulted in improved processing techniques that have been implemented to industry, and beyond.

The division has used the expertise within the Materials and Manufacturing Office to support qualification of new processes and designs. Navy ManTech project underway within the division included two project as noted below:

Fiscal Year Activities Included:

Laser-Based Repair Deposition Technology

The Laser Processing Division has been designated as the Department of Defense's Manufacturing Demonstration Center for additive manufacturing by the Defense Advanced Research Project Agency. The Center for Innovative Materials Processing – Direct Digital Deposition (CIMP-3D) is dedicated to advancing the state of the art in design, materials, processing, and characterization of parts made by direct digital manufacturing (DDM), also referred to as additive manufacturing, as an innovative method to improving readiness and reducing the cost of critical metallic components used in DoD systems. Additive manufacturing offers significant promise for increasing readiness and flexibility of current, legacy, and future DoD platforms and is discussed further as a Unique Capability within this division.

Deposition technology offers tremendous opportunities for restoring dimensional properties of high value components based on the ability to achieve high deposition rates, provide full metallurgical bonding to substrates, the component. The successful implementation of a laser-based repair system for Vertical Launch System tubes at Pearl resulted in a drive to leverage the equipment and the growing technical expertise in additional applications. This includes repair of main and auxiliary seawater valves and propulsion shafts. These efforts involve the development of portable laser repair aboard ships or within the shipyard repair facilities, further enhancing iMAST's ability to address defense-related manufacturing technology issues. The Naval Air Systems Command is working with CIMP-3D to assess and determine additive manufacturing applications within NAVAIR Fleet Readiness Centers (FRCs).
(POC: Ted Reutzel / Todd Palmer)

Additive Manufacturing for NAVAIR

-A2647

ARL released photo. Vice Admiral Dunaway touring CIMP-3D facility.

Additive Manufacturing (AM) is recognized by NAVAIR as a means to bring "a revolution in how we sustain our systems" (Vice Admiral David Dunaway, Commander, Naval Air Systems Command, quoted in SeaPower Magazine, April 8, 2014). This technology has clear potential to benefit Navy sustainment activities, including: direct part replacement, fabrication of repair parts, and/or refurbishment of worn or corroded parts. Before this potential can be realized for aviation components, however, the U.S. Navy must develop and demonstrate repair qualification and certification procedures for specific targeted components. This paper describes steps taken at ARL Penn State to advance AM technology for both manufacturing/fabrication and repair by developing a qualification test plan, a suitable repair process, and a technical data package to support the qualification, repair, and implementation of AM repair procedures at FRC East (or a designated 3rd party). These procedures address a high-priority repair need within the AV-8B F402 engine-fretting wear on the Low Pressure Compressor (LPC) 2nd Stage Rear Seal Ring at pinned contact points to the 3rd stage seal ring. A key payoff for the Navy will be the reduction in time associated with placing components and systems back into service, resulting in concomitant reductions in cost and addressing critical, improved readiness needs.

(POC: Steve Brown / Ted Reutzel)

Facilities and Unique Capabilities:

Commercial Lasers

The wide range of laser processing capabilities includes complete laboratories for microprocessing (Q-switched Nd:YAG lasers operating at the fundamental frequency, second harmonic, third harmonic, and fourth harmonic, Nd:VO4 laser operating at the third harmonic, and an excimer laser capable of operation in any one of four ultraviolet wavelengths) and macroprocessing (12 kW ytterbium fiber laser with two fiber deliveries, 5 kW diode-pumped Nd:YAG laser with three fiber deliveries, and a fast axial flow CO_2 laser, all operating in the far infrared regime). This resource includes:

ARL released photo

- Extensive array of direct digital manufacturing systems for repair or remanufacturing.
- Range of beam manipulation, data acquisition, and sensing capabilities.
- Extensive materials preparation and characterization capabilities.
- Laser processing educational programs.
- Eight full-time multi-disciplinary engineers (including 5 Ph.D.'s and 3 M.S. in materials science and mechanical engineering), 2 full-time laboratory technologists, and 1 administrative support staff.

Lasers

ARL released photo

Macro Processing
- 12.0 kW ytterbium fiber laser (1070 nm)
- 5.0 kW CO2 with enhanced pulsing (10,600 nm)
- 5.0 kW Nd:YAG CW (1064 nm)
- 3.0 kW Nd:YAG CW (1064 nm)

Micro Processing
- 500 W single mode ytterbium fiber laser (1070 nm)
- 400 W (avg.) pulsed Nd:YAG (1064 nm)
- 1 J/Pulse Q-Switched Nd:YAG (1064 nm)
- Nd:VO4 at 3rd Harmonic (355 nm)
- Nd:YAG at 2nd, 3rd, and 4th Harmonic (532, 355, and 266 nm)
- 0.5 J/Pulse Excimer (193-351 nm)

Work Cells
- Two 6-Axis Robotic Systems (ABB and Kuka)
- Large 5-Axis gantry system (3.4 m by 3.4 m)
- 5-Axis motion system (3 linear and 2 rotational)
- Various micro processing systems
- Optomec Corporation laser additive manufacturing cell

Technology Transfer Facility
- Support equipment (e.g., robotic, linear and rotary workstations, etc.)
- 4 kW Ytterbium fiber laser at Pearl Harbor Naval Shipyard with portable processing capabilities
- 2.4 kW cw Nd:YAG and robotic manipulator at Norfolk Naval Shipyard's Foundry and Propeller Center (Philadelphia, Pa.)
- 3.0 kW cw Nd:YAG laser at Naval Underwater Warfare Center, Keyport, Washington.
- 25 kW cw CO2 laser at ATS Corporation, Samford, Maine, with 7.3 m gantry

ARL released photo

UNIQUE CAPABILITY
Applied Laser Laboratory

ARL's Laser Processing Division encompasses one of the largest collections of commercial lasers for applied laser research in the United States. A fully staffed facility with an impressive array of capabilities, both in terms of equipment and expertise, provides support to the Department of Defense and the U.S. Navy.

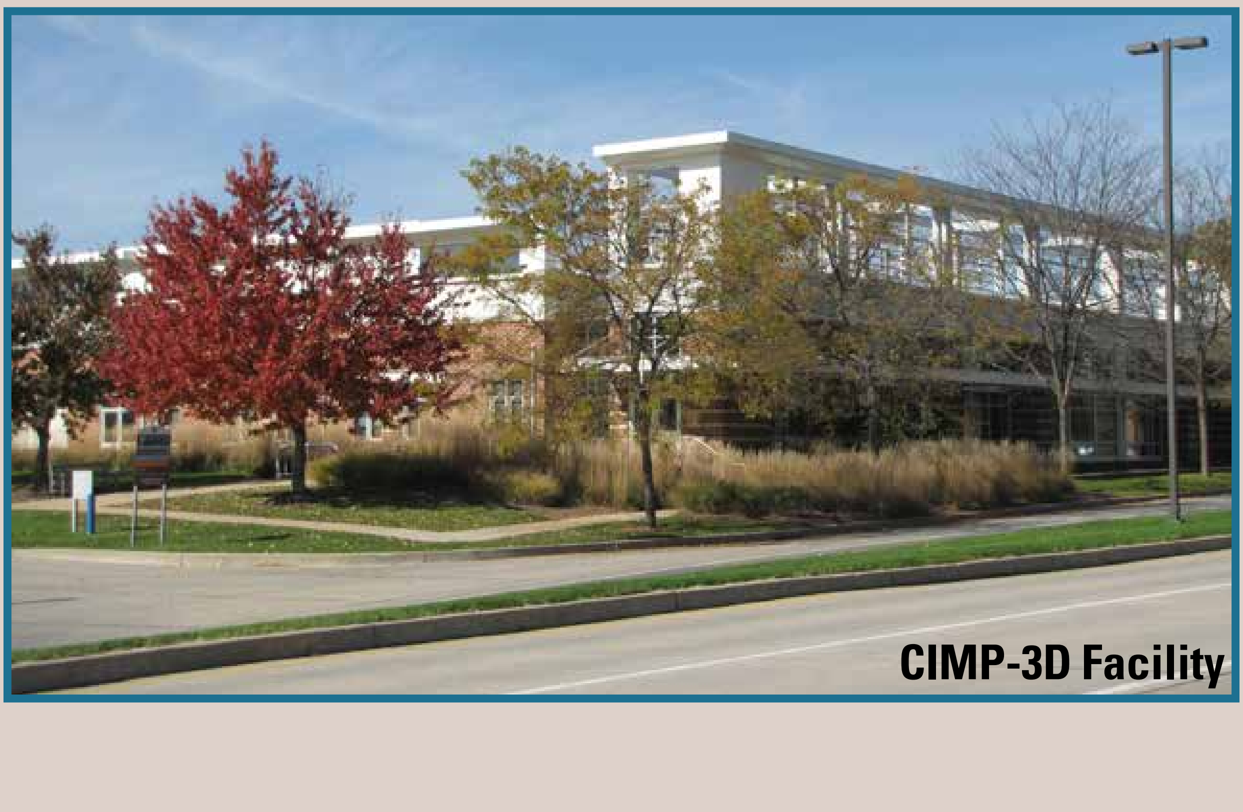
UNIQUE CAPABILITY

Additive Manufacturing (AM)

The Laser Processing Division has developed a leadership role in establishing a University-wide initiative in additive manufacturing under the Center for Innovative Materials Processing through Direct Digital Deposition (CIMP-3D) with the goal of establishing a world-class resource for Direct Digital Manufacturing (DDM) for critical applications. With a broad mission to advance and deploy DDM technology of metallic and advanced material systems to industry, CIMP-3D seeks to:

ARL released photo

- advance enabling technologies required to successfully implement DDM technology for critical components and structures
- provide technical assistance to industry through selection, demonstration, and validation of DDM technology as an "honest broker", and promote the potential of DDM technology through training, education and dissemination of information



CIMP-3D Facility

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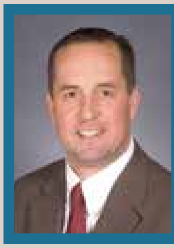
Manufacturing Systems



Manufacturing Systems Technologies

Mark Traband, Ph.D.
Technology Leader

Mission

To be a leader in the development, application and transition of advanced design, manufacturing, and repair systems and tools. To apply advanced information systems technology to product and process design, enabling engineers to explore a wider set of design options, resulting in more robust system designs, with shortened development lead times, and reduced lifecycle costs.

2015 Fiscal Year Summary

The Manufacturing Systems Division has continued to contribute to the ManTech affordability goals through the execution of several programs during FY-15. A number of efforts have been in the technical focus area of Advanced Manufacturing Enterprise, focusing on planning, scheduling, and lead-time reduction for manufacturing and assembly operations for Navy platforms. Another area of focus is in polymer coating formulation, testing, and application procedure development for ship platforms. Finally, the division has been active in RepTech projects, in order to reduce maintenance costs, including the removal of non-skid coatings from submarine special hull treatments.

Fiscal Year Activities Included:

Improved Topside Non-Skid Removal for Submarines -S2494

In this effort, ARL teamed with a high pressure (HP) waterjet tool manufacturer to create a device to remove multiple layers of thick epoxy nonskid coatings from soft elastomeric substrates. Prior to demonstration of the tool on the USS CONNECTICUT (SSN 22) and the USS TEXAS (SSN 775), shipyard preservation personnel and NAVSEA technical experts believed that waterjet at pressures above 12,000 psi would be too aggressive for this application.
The use of dual-rotating water jets mounted on a rotating plate to create epi-centric planetary motion, plus the use of robust Design of Experiments (DOE) experimental methodology, has resulted in a tool capable of safely removing nonskid from SHT at removal rates of 200 ft^2/hour compared to < 10 ft^2/hour for conventional sanding and grinding removal methods. The closed-cycle nature of this device has the potential to enable pier-side removal of nonskid coatings from submarines. The HP waterjet leaves a paint-ready surface, meaning nonskid removal and reapplication can be performed pier-side in days. Currently, nonskid removal is performed only in dry-dock and takes several weeks or months to perform.
(POC: Charlie Tricou)

Reverse Engineering Support for Components of Internally Transportable Vehicle (ITV) Platforms

Exploiting previous capabilities gained from Navy ManTech-generated program efforts, ARL has responded to a non-ManTech Marine Corps-tasked request to provide re-engineering support for components on the Internally Transportable Vehicle (ITV). The objective of this effort was to provide the Marine Corps with the engineering data needed for provisioning in support of diminishing manufacturing sources and material shortages (DMSMS) of the ITV variants, Prime Mover (PM) and Light Strike Vehicle (LSV). Approximately 25 components were identified for re-engineering, comprised of commercially off-the-shelf (COTS), modified COTS, and manufactured components/assemblies that are no longer supported by the Original Equipment Manufacturer (OEM). Exploiting capabilities derived from Navy ManTech activities, ARL Penn State is addressing this issue as part of its U.S. Navy University Affiliated Research Center (UARC) effort.

Within this project effort, ARL Penn State is evaluating performance specifications, operational requirements, maintenance and repair procedures in addition to dimensional and material analysis to define the product design data package complete with related component model(s) and item drawing(s). The item drawings developed are being used to manufacture test article(s) to verify and validate the component design. In addition to the design data, the technical data package delivered to the Marine Corps includes build results, assembly build guides (where applicable), proposed receiving inspection documentation, and sourced vendors to support future manufacturing. This program further validates the investment and innovation put forth by way of the Office of Naval Research Navy ManTech Program.
(POC: Darlene Mikesic)

Trade Friendly Locating Dimensional Techniques **-S2550**
ARL teamed with General Dynamics Electric Boat (GDEB) Quonset Point, evaluating the feasibility and cost-effectiveness of incorporating trade-friendly dimensional locating metrology technology into the Virginia Class Submarine (VCS) manufacturing processes while concurrently evaluating for application into the manufacturing plan for the Ohio Replacement Program. The previous assembly location and dimensional inspection process used the traditional string and tape measure process. Although a simple metrology solution process was required, GDEB also required a low cost system that provided three dimensional locations in (x,y,z)-space within a grid system on a curved and planar surface using technology compatible with reverse engineering and CAD systems already in place. The project is currently in the full prototype analysis phase where preliminary results show an improvement of layout quality as much as 0.400" and a productivity improvement factor of 7 regarding hangar installations.
(POC: Sean Krieger)

Shipyard Capacity Planning Tool Transition and Gap Analysis **-S2600**
The core of the Capacity Planning System is the Central Data System, a data repository with access to live production data, shipyard and ship-specific configuration data, and scenario management data that interfaces with a suite of front-end capacity planning tools. These tools include the Long-Range Capacity Planning Tool (LRCPT), which supports the development of resource-constrained long-range structural unit schedules and enhanced analysis capabilities; the Spatial Scheduling Tool (SST), which is integrated with the LRCPT through a configuration-managed scenario management system; and a Shop-Level Capacity Planning Tool (SLCPT) for lower level capacity planning in BIW fabrication shops. The software tools ensure that all planners and production controllers operate on the same information, and can conduct what-if analyses for future schedules and ship builds.
(POC: Christopher Ligetti)

U.S. Navy released photo

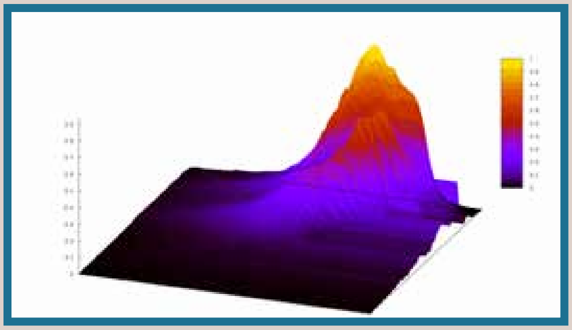
Facilities and Unique Capabilities:

Environmental Technology Laboratory

Conducts sampling and testing of air emissions from new and modified manufacturing processes for a wide range of airborne environmental contaminants including volatile organic compounds, toxic industrial chemicals, particulates, emission factors and opacity, and evaluates new sensors and analyzers for these measurements.

UNIQUE CAPABILITY

Enhanced Inspection Tools for Hydrocarbons


ARL released graphic

Enhanced inspection toolscan detect contamination on steel surfaces that can adversely affect coating performance. The current methods of visual inspection used to ensure SSPC – SP1 “oil-free” surfaces are little more than a crude go/no-go gauge, even with the use of black-light illumination. Current detection methods for oil & grease are inadequate to prevent hydrocarbon-contamination-related coating failures. For the first time, ARL has developed tools that provide a means to ensure compliance with SSPC-SP1 “oil-free” inspection requirements. The tools work by enhancing the extent of the fluorescent response of common hydrocarbon contaminants while simultaneously improving the ability of inspectors to see the fluorescent response. The lights used do not contain mercury and are safe for onboard use. The enhanced detection goggles meet the requirements for PPE and improve upon the safety of conventional eyewear used during UV-inspection.

Polymer Coatings Laboratory

addresses application, removal, inspection, formulation and testing of organic coatings. The lab also supports the development of surface preparation and cleaning processes and the development and testing of new tooling. particulates, emission factors and opacity, and evaluates new sensors and analyzers for these measurements.

UNIQUE CAPABILITY

High-Pressure (HP) and Ultra-High Pressure (UHP) Equipment and Processes


U.S. Navy released photo

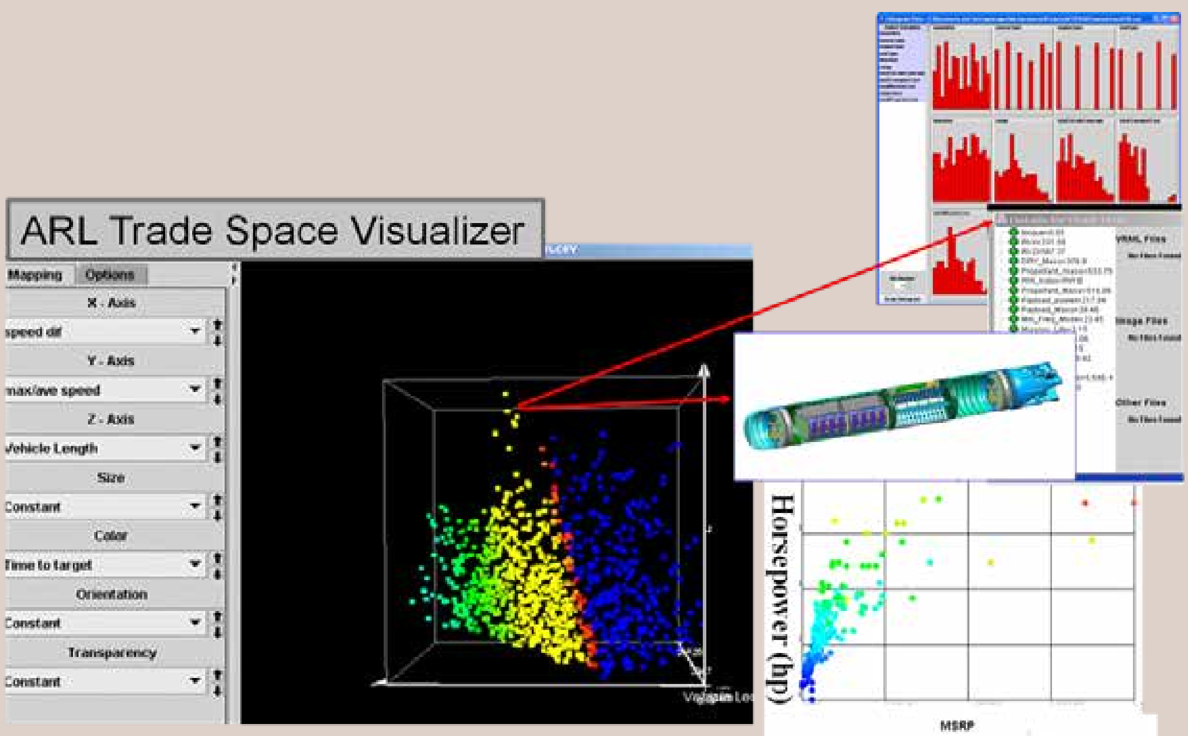
This equipment provides dramatic productivity improvement in shipyards. ARL has become a leader in the design, development and implementation of safe, innovative, High-Pressure (HP) and Ultra-High Pressure (UHP) waterjet tools and processes to solve some of the Navy’s most challenging preservation problems. Mechanical methods of surface preparation such as abrasive blast cleaning are ineffective at removing oil and grease contamination. UHP water jet blasting is effective at removing oil, grease, soluble salts and other contaminants from steel surfaces. ARL has developed and implemented HP and UHP tools and processes for surface preparation for applications and in areas not previously believed possible. Examples include: oil, grease and salt removal within the confined spaces of Normal Fuel Oil (NFO) and Sanitary (SAN) tanks on submarines, and nonskid removal from sensitive substrates.

Distributed Engineering Center (DEC)
A collaborative U.S. Navy facility that supports a Navy surface ship defense engineering program effort. Since 2002, this facility has facilitated cost-effective information exchanges across government, university and industry teams developing specific projects. This facility extends similar support to other Navy programs requiring collaborative engineering services.

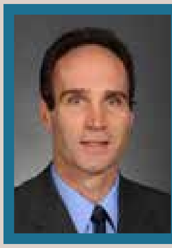
ARL released graphic

UNIQUE CAPABILITY
Rapid Design Space Exploration

For both product and process design, if performed early in the lifecycle of a product, can result in tremendous downstream benefits in both performance increases and cost reduction. By increasing the number of options considered, a more robust design and associated manufacturing process can result. ARL combines trade space exploration, multidisciplinary design optimization, advanced visualization tools, and process simulation to achieve the robust product and process designs. Key to this process is presenting large amounts of information in an easy to understand way. The ARL Trade Space Visualizer (ATSV) is a multi-dimensional visualization tool that is used to explore the relationships captured in the design data. It has the ability to explore multi-dimensional data, dynamically apply constraints and preferences, determine sensitivities for a selected design, and visualize design uncertainty.



ARL released graphic



Composites Technologies

Kevin Koudela, Ph.D.
Technology Leader

Mission

Conducts basic and applied research in composite materials and structures for DoD and commercial applications with emphasis on performance, reliability, affordability and technology transfer. Research and development efforts focus on critical composite design, quality assurance and manufacturing technology gaps that preclude composite material implementation. After successful demonstration, these next generation technologies are implemented according to critical warfighter needs. The Composites Division's core competencies are identified below.

2015 Fiscal Year Summary

The Composite Materials Division (CMD) continues to contribute significantly to the Navy ManTech mission by pushing composite manufacturing, operational life certification and non-destructive technologies to new levels. Specific development efforts during the fiscal year focused on continued formulation and fabrication of fire resistant high performance composite materials; formulation and characterization of novel and emergent coating systems; developed a low cost, corrosion resistant composite rotating coupling cover manufacturing method; optimized hybrid material configurations for turbomachinery applications, continued to develop and demonstrate low void content out-of-autoclave prepreg composite fabrication processes; developed and implemented a high cycle (≥ 10M cycles) in-water fatigue material property characterization method; demonstrated novel eddy current nondestructive inspection (NDI) technology; and developed a cutting edge capability in nondestructive evaluation using laser induced fluorescence techniques to detect heat damage of composites.

Fiscal Year Activities Included:

Laser Induced Fluorescence (LIF) Nondestructive Evaluation (NDE) Generation II Transition -A2476

This project addressed an approach to allow a smooth implementation of new non-destructive inspection (NDI) technology into aviation depots as part of their approved non-destructive evaluation (NDE) solution techniques for determining the extent of incipient heat damage to polymer matrix composites. A key deliverable of this effort was the development of a procurement specification which allows vendors to bid on the technology solution. This product specification will use a systematic approach which moves from the general requirements of the Laser Induced Fluorescence (LIF) NDE Generation (Gen) II, most of which have already been established, to the more specific components of the technology solution system configuration, equipment selection, and installation planning based on user feedback and the technology trends of the U.S. Navy. This approach leveraged additional funding from outside sources in order to procure equipment and implement the second generation builds of the depot-ready units for field testing.

(POCs: Dan Merdes / Clark Moose)

Facilities and Unique Capabilities:

Fabrication

Fabrication facilities include; a 3' diameter x 7' Baron autoclave with computer control to 250 psi maximum pressure and 825°F maximum temperature processing limits; meter/mix equipment with 2 component/solvent flush, heated pots/delivery lines, vacuum degassing and static mixer used for RTM and VARTM processing; a McClean Anderson filament winder with Compositrak control, 4 programmable axes suitable for both prepreg tow and wet winding; a 6' x 6' x 10' curing oven (500°F); a hydraulic mandrel extractor and a 150 ton press. In addition ARL-Penn State maintains a machine shop with 38 stations that include six 5-axis, three 4-axis and four 3-axis CNC machining stations. ARL also has access to 0°F walk-in freezers and standalone chest freezers.

UNIQUE CAPABILITY

Critical Element Design, and Analysis and Testing

ARL released photo

CMD has a proven track record and unique capability in the design, analysis, fabrication and test of critical elements to facilitate rapid implementation of advanced material structures for DoD applications. The full-spectrum of finite element and boundary element tools provides the capability to conduct both global and detailed structural analysis. This allows design of subscale or 'Critical Element' test articles that are used to duplicate salient in-service structural demands. Candidate manufacturing technologies are then used to fabricate these test articles that are instrumented and tested to capture data that can be used to verify and/or refine developed numerical models. While such individual capabilities exist in other organizations, the division has streamlined the Critical Element approach to rapid development of advanced material solutions to a unique extent. A true concurrent engineering protocol has allowed execution of 'paper to prototype' development and implementation of mission critical hardware in timescales on the order of 6 months to a year. Without uniquely integrated development and test capability of this type, such rapid turnarounds would not be possible.

Material Property Characterization

CMD possesses extensive test and evaluation facilities including a full microscopy laboratory and several test frames. Among these are two 33 Kip electro-mechanical test frames with a temperature controlled test chamber, five 5 Kip high speed test machines with 10 Hz maximum cyclic rate, one 220 Kip (4 post), one 110 Kip (4 Post) and three 22 Kip servo hydraulic test frames, and a drop-weight impact tester. An 8-channel acoustic emission system supports both sub-element and full-scale structural testing. Fiber volume fraction determination is routinely performed using acid digestion techniques. A high fidelity sand bath is resident for high temperature component heating tests.

Design and Analysis

CMD possesses state of the art design and analysis capabilities. Structural design and optimization is normally completed using commercial as well as internally developed finite element, boundary element, micromechanical, and three-dimensional lamination analysis programs. Tool and component design is typically conducted using a broad suite of CAE and CAM tools including ANSYS, ABAQUS, Nastran, LS-DYNA, PAM Crash, Unigraphics, IDEAS and ProE.

ARL released photo

UNIQUE CAPABILITY

Nondestructive Inspection

CMD and Manufacturing Systems Division are jointly developing cutting edge capabilities in non-destructive evaluation of structural polymer materials through fluorescence response techniques. The divisions have assembled unique test hardware to monitor high resolution spectral response changes applicable to thermal degradation and curing of polymer matrix composites. In collaboration with the NAVAIR Patuxent River, the divisions have led the unique application of direct fluorescence excitation of polymer matrix materials and high sensitivity spectrometers. Using well defined collection optics, the determination of spectral responses are independent of the matrix surface area fraction and are correlated to the measured structural response through chemometric analysis. All hardware components were selected for integration into field portable units and transition is currently underway. This non-contact inspection approach offers the capability to track and correlate thermal degradation of numerous composite matrix materials to structural degradation and provide monitoring of polymer matrix material cure regardless of environmental conditions to ensure required structural integrity.

UNIQUE CAPABILITY

Split Hopkinson Pressure Bar (SHPB) Test Facility

CMD has a custom designed SHPB facility that provides the unique capability to determine high rate material responses for low stiffness elastomers, engineering polymers, advanced composites, as well as high performance metallic systems and ceramics. CMD is in the process of using this capability to develop a database to facilitate the parameterization of new multi-scale material models used to evaluate candidate material systems capable of mitigating Traumatic Brain Injury (TBI) in personnel subjected to blast events.

ARL released photo

Nondestructive Inspection

A large scale vibration isolated 6' x 6' x 5' Coordinate Measurement Machine (CMM) is used to verify component tolerances down to 0.0005". Additionally, ARL Penn State possesses unique fiber volume fraction mapping software that allows fiber volume distributions to be determined from tag-end or sample sections. High sensitivity part quality measurements have been successful using broad band ultrasonic scanning. Ultrasonic waveform conditioning and signal analysis has provided sensitive technology that has the capability to determine both large scale (delamination or adhesive failure) and small scale (voids and porosity) defect distributions in complex structures. Additional capabilities are available to apply thermography, shearography, laser measurement and other techniques as appropriate to particular component scales and complexities.

UNIQUE CAPABILITY
High-Rate Fatigue Test and Evaluation

In-air Testing

In-water Testing

ARL released photos

A new high-rate composite fatigue test method has been developed which reduces 1E8 cycle test times from nearly a year to less than 1 month. A corresponding model method has been developed to predict component fatigue performance for defined transient operating spectrums. Tests to date have been successfully completed up to 1E7 cycles with total test time reduced by an order of magnitude versus conventional testing. The new model method uses the high rate test data in conjunction with ply-by-ply failure criteria combined with a rainfall method which provides fatigue life thresholds using a finite element analysis (FEA) model subjected to an unsteady transient load profile.

Long duration (1E7-1E8) fatigue test data are critical for quantifying material degradation and component performance for composite material systems. Current 1-5 Hz fatigue test methods may require a year or more to accumulate 1E8 cycle test results. A new high-rate test method has been developed and demonstrated which can reduce 1E8 cycle fatigue test duration to less than 12 days. The test method features a tuned carrier tube which cycles a composite test specimen at resonant frequencies. The method has been successfully demonstrated for 1E7 cycle testing. Completed testing has shown that required composite fatigue strain levels can be confidently maintained at the desired rates, that no unacceptable fatigue degradation of ancillary supporting hardware occurs, and that heating of the composite specimen can be managed using forced convective cooling. Follow on efforts are planned to confirm that material degradation during high rate testing is comparable to documented low rate fatigue results and to extend the testing to statistically valid sample sizes and longer time durations. The novel test hardware, composite specimen bonded to the tub and assembly attached to a conventional shaker is shown below.

To predict fatigue failure thresholds of composite components, a new fatigue prediction method has been developed. Model software was first developed to extract desired time domain directional strains from transient FEA component solutions at the elemental level. These strain data are then processed with newly developed software using established ARL composite analysis protocol to compute local ply-by-ply directional transient strains. Using a rainfall method, the ply-by-ply strains are then used to compute directional mean and alternating stresses for all closed loop fatigue cycles at the elemental level. These data in conjunction with material fatigue life threshold criteria can be assimilated to provide component life predictions. By using this newly developed modeling method, fatigue life of a composite component can be confidently predicted for a defined unsteady transient loading profile.

The combined testing and model method development technologies provide a new method for obtaining reliable composite material fatigue test data in a timely fashion and applying those test results to predictions of operational thresholds of full scale composite components. The test and model method development efforts are complete, and are recommended for follow-on validation testing and implementation.

Materials

Materials Processing Technologies

Tim Eden, Ph.D.
Technology Leader

Mission

To perform basic and applied research in a broad range of materials and material processing in support of the DoD and the U.S. industrial base. The Materials Processing Division develops and transitions innovative materials and material process technologies to solve critical technical challenges, address manufacturing and sustainment challenges, improve component and system performance and reduce procurement and life cycle costs. The division provides leadership in the fields of coatings, material testing and characterization, electronic materials, devices and sensors, and metal and ceramic processing. The materials processing thrust is organized into four departments:

- Metals and Ceramic Processing
- Advanced Coatings
- Electronic Materials and Devices
- High Pressure Laboratory

The unique combination of experienced faculty and staff and extensive materials processing and characterization facilities allow the division to quickly develop, validate and implement complete solutions to a wide range of technical challenges. The division has transitioned a number technologies and specific solutions to the DoD and industry. Specific areas of expertise include Cold Spray and Vapor Deposition technologies for corrosion resistance, wear resistance, thermal barriers, environmental barriers, electronic materials, electronic devices, antimicrobial and medical implants. Multifunctional nanograined materials and functional tailored coatings and laminated structures have been developed for improved erosion resistance, armor and cutting tools. Alloy development and processing include ultrahigh temperature and ultrahigh strength aluminum alloys for armor and engine applications, fragmenting steels, thermomechanical processing, failure analysis and modeling, as well as development and production of bulk and thin film crystals. Design and fabrication of electronic devices and sensors. Material characterization capabilities include corrosion, wear, erosion, mechanical properties, chemical and phase composition, surface properties, hot corrosion/high temperature oxidation, failure analysis, electrical characterization and microstructural analysis.

2015 Fiscal Year Summary

The Material Processing Division continues to address issues addressing U.S. Navy materials and manufacturing related challenges. Two Navy ManTech projects efforts are addressed on the following page. The objective of each project has been to provide a complete material solution along with developing a viable transition path. Our approach to these challenges is to identify the root cause of the issue, determine the component performance requirements and then develop the solution that will meet or exceed performance requirements. We are actively engaged to ensure that the solutions meet the technical and cost challenges, and that they are successfully transitioned.

Fiscal Year Activities Included:

HDC-1 Bearing Improvement -S2573

The Virginia-Class Hover and Depth Control (HDC) hull and backup valves experience degraded performance and failure during operation. The failures are attributed to over loading and a lack of lubrication on the main bearing assembly. The main bearing assembly is a split bearing composed of rubber and a bronze bushing. The objectives of this effort were to identify and duplicate the failure mechanism and develop, validate and implement a solution that will greatly extend the service of the bearing. A test fixture was fabricated to test the bearing assembly over a wide range of operating conditions. The bearing failure was reproduced and confirmed that the bearing failed due to lack of lubrication (grease) which increased the friction between the bearing and the crankshaft and the higher stem loads required to rotate the valve. The bronze bushing in the bearing was replaced with a GAR-MAX bushing. GAR-MAX is a filament wound composite material that has high-strength fibers encapsulated in a PTFE (teflon) filled epoxy resin and does not require lubrication. The same type of rubber was used on the GAR-MAX as was used on the bronze bushing. The ungreased GAR-MAX bearing was cycled 12,000 times at the maximum stem load without failure. A slight coating of grease was added to the GAR-MAX bearing per the installation requirements. The bearing was cycled through 12,500 cycles at maximum stem load. The test procedure was to run artificial seawater over the bearing for approximately 500 cycles, then allow the bearing to sit for 12 hours and then run the bearing for 500 more cycles without the artificial seawater. The sequence was repeated until the 12,500 cycles were performed. Compression tests on the bearing showed that rubber compressed the same amount for the bronze and GAR-MAX bushings. The 12,500 cycles represent service life. The drawings are currently being modified to allow the GAR-MAX bearings to be used as replacement bearings for the bronze bushings.


U.S. Navy released photo

(POC: Tim Eden)

Cold Spray Technology for Shipboard Components -S2580

iMAST identified a number of repair and maintenance issues that have the potential to be resolved through the use of cold spray technology. Cold spray repairs will replace copper plating and epoxy repairs on many of these components. The components are damaged by corrosion and wear. Two hydraulic actuators made from Al-6061 were repaired and proof tested. The first actuator repair was given a two year limited approval for use on a submarine. The second repair is for C903000, bronze alloy. The process parameters have been developed and characterization of coupons show that the coating exceeds the required adhesion strength and meets the corrosion compatibility requirements. Mockup parts have been coated and are in the process of being characterized. Once the process has been validated on the mockup parts, the C90300 components will be repaired. Components include tube bearings and priming pumps. The third repair is for a swing check valve that is made from 70/30 CuNi. The repairs have been performed on two mockup valves. The mockup parts are being characterized and after the repairs have been validated, the swing check valve will be repaired. The fourth repair is to replace copper plating with a cold spray coating on the cast iron and steel electric motor end bell and housings. Mockup rings have been coated and are being evaluated. After the adhesion strength and coating density are validated on two of the rings, four sets of two rings with different inside and outside diameters will be sent to Puget Sound Naval Shipyard and Intermediate Maintenance Facility for final machining and testing.

(POC: Tim Eden)

ARL released photo

Facilities and Unique Capabilities:

MATERIAL CONSOLIDATION

Cold Spray

- High pressure and portable cold spray systems
- Additive-Subtractive High pressure cold spray system (1000 psi, 900°C) coupled with a multiaxis machining station
- Cold Spray Characterization Lab – adhesion, corrosion, porosity, composition, hardness, wear

Spray Metal Forming – Aluminum and Copper Alloys

- Research scale/pilot plant for producing billets and tubes
- Small extrusion press for thermomechanical process development

UNIQUE CAPABILITY
Spray Metal Forming

ARL released photo

ARL/iMAST spray metal forming plant is a multi-use laboratory scale system that can be used to produce unique aluminum and copper alloys into billets, tubes or for cladding tubes. It is the only operational spray metal forming plant in North America. The billets are processed by forging, extrusion or rolling to produce the desired shape. Development efforts have focused on ultra-high strength aluminum alloys (105 ksi tensile strength, 10% ductility) for armor and structural applications, high temperature aluminum alloys (40 ksi yield strength at 575°F), Al-Si alloys for engine applications (strength retention after exposure to 300°F, excellent wear resistance) and copper alloys. Spray forming is a rapid solidification process that can significantly enhance the properties and microstructures of engineering alloys and produce metals with high alloying content that cannot be produced with conventional processing.

Vacuum Hot Pressing

- 100 ton press with 5 inch diameter ram
- Maximum temperature 1900°C
- Vacuum level 10-4 Torr or controlled atmosphere up to 2 psi

Hot Isostatic Press (HIP)

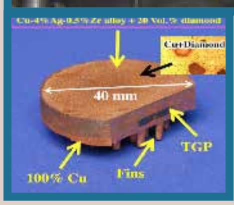
- Maximum pressure 30,000 psi (207 mPa), Maximum temperature 2200°C (3992°F)
- Vessel interior diameter 10 inch

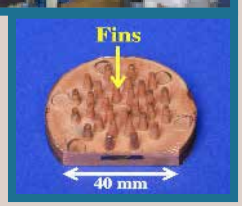
Spark Plasma Sintering (SPS) or Fielded Assisted Sintering Technology (FAST)

- HP D 25
- Load capacity 25 Tons, Maximum Temperature 2200°C, Maximum specimen diameter 80mm
- Power 10,000 amps DC, Environments N2, Ar, H2 (up to 1400°C)

UNIQUE CAPABILITY

Spark Plasma Sintering (SPS)





ARL released photos

Also known as Field Assisted Sintering Technology (FAST) is sintering technology that offers higher heat rates and lower sintering times than conventional consolidation processes that has several advantages including fast process times, reduced grain growth (retention of nanoscale features in nanomaterials), high density, and superior physical properties. SPS can be used to rapidly sinter metals, ceramics, and both metal and ceramic composites. Penn State has two systems that have a maximum operating temperature of 2200°C and can use vacuum, nitrogen, argon or hydrogen (maximum up to 1400°C). The HP D 25 has a 25 ton load capacity and an 80 mm maximum sample diameter and the HP D 250 has a 250 ton load capacity and a 300 mm maximum sample diameter. The system is capable of sintering materials in various environments. The system has been used to produce ceramic, metal and composite material systems include ceramic armor, high thermal conductivity materials, blanks for cutting tools, sputtering and x-ray targets, rocket nozzles and heat sinks. The 350 ton unit is the only unit at a research facility in the U.S.

- HP D 250
- Load capacity 250 Tons—Maximum temperature 2200°C
- Maximum specimen diameter 300mm
- Power 10,000 amps DC—Environments N2, Ar, H2 (up to 1400°C)

High Pressure Laboratory

- Cold Isostatic Pressing (CIP)
- 60 inch diameter x 165 inch - Max pressure 16,000 psi
- 18 inch diameter x 168 inch - Max pressure 20,000 psi
- 24 inch diameter x 60 inch - Max pressure 2,000 psi
- Simulation of deep sea pressure and temperature environments

Nanophase Material Facilities
- Vacuum and controlled atmosphere hot press
- Nanoparticle handling capabilities

Powder Processing and Handling
- Ball milling
- Cryogenic milling

Powder Processing and Handling
- Ball milling
- Cryogenic milling

ADVANCED COATINGS

Industrial Prototype Electron Beam Physical Vapor Deposition (EB-PVD)
- Industrial scale unit, six 45kW guns
- Capable of continuously feeding 3 ingots individually or simultaneously for the synthesis of complex compounds through co-evaporation processes
- Chamber is approximately 90cm in length, 90cm in width, and 90cm in height for accommodating large components
- Evaporation rates range from 0.5nm to 100µm per minute depending on the material

Lab Scale Electron Beam Physical Vapor Deposition (EB-PVD)
- One EB gun (8 kW), 4 – 25cc hearths allows up to 4 different materials to be deposited
- Cold cathode ionization source with chamber size of 66cm x 60cm x 100cm
- Multilayered coatings, direct evaporation, reactive evaporation and IBAD processes

Sputter Deposition
- Two 6" OrbiTorr sources (Sloan) for DC Magnetron or R.F. sputtering
- One 6" TriMag source (L.M. Simard)
- R.F. sputter cleaning of substrates
- DC biasing of substrates
- Six 7.5" diameter sample mounts with planetary rotation and variable source to substrate
- Substrate heating to 200°C

Ion Beam Assisted Deposition
- Penn State also has the capability of ion beam sputter deposition, ion cleaning, and microstructural enhancement with either 8cm gridded (Kaufman) or gridless (end hall) ion sources
- Both ion sources can be used to pre-clean samples prior to deposition to facilitate coating adhesion
- When used during deposition, microstructure, crystallographic orientation, residual stress, and properties can be tailored

Cathodic Arc Deposition
- The unit contains a minimum of three 2.5" arc sources
- The chamber size is approximately 20" x 20" x 20"
- Coating zone of 10" in diameter by 10" tall
- Radiant heaters and alternate surface conditioning capabilities (plasma cleaning)
- Infrared temperature sensing capabilities and gas flow metering (nitrogen, argon, acetylene, and hydrogen) for depositing metallic, nitride, boride, and carbide materials in monolithic, multilayer or functional graded structures

Surface Technologies
- Pin on disc and reciprocating wear tests
- Erosive wear testers
- Seal test rigs
- Controlled-environment test rigs
- High pressure hydro-static equipment

High Temperature Cyclic Oxidation and Humidity Testing

- Four high temperature furnaces capable of thermal cyclic testing up to 1300°C in atmosphere and two controlled environments such as saturated water vapor (humidity-controlled)
- Additional furnace available for conversion to corrosion testing depending on the test set-up

Dean Rig Hot Corrosion Testing Facility

- Provides comparable hot corrosion results to burner rig testing at a fraction of the cost and time
- Testing/evaluation of materials under Type I (900°C) hot corrosion environments
- Testing/evaluation of materials under Type II (700°C) hot corrosion environments
- Type of salt corrosion easily changed as well as sulfur-oxygen ratio for aggressive testing

Corrosion Testing

- Cyclic Corrosion Chamber
- Equipment: Singleton CCT-10
- Accelerated testing (weeks, months) in a simulated aggressive corrosive environment
- ASTM B117 Salt Fog, ASTM G44 Alternate Immersion GM 9540P, SAE J2334, others
- Stress corrosion cracking
- Electrochemical (DC & AC)
- Gamry PC4 Potentiostat, EG&G 273A Potentiostat (for high current applications)
- Electrochemical polarization, corrosion rate, galvanic corrosion, pitting resistance, and Electrochemical

Impedance Spectroscopy (EIS)

- ASTM G71 –Galvanic, ASTM G34 – Exfoliation, ASTM G78 – Crevice
- High impedance voltmeter (Z=1013 Ω)
- Conductivity/pH meter
- Crevice corrosion test cells
- Micro probe reference electrodes (50 micron)

Bulk and Thin Film Deposition and Characterization Lithography

- Electron Beam
- Vistec EBPG5200 electron beam lithography
- Photo
- GCA 8000 i-line Stepper
- GCA 8500 i-line Stepper
- Karl Suss MA/BA6 contact aligner

Etch

- High Density Reactive Ion
- Tegal 6540 HRe-CCP
- Plasma-Therm Versalock 700 ICP
- Magnetically Enhanced Reactive Ion Etch
- Applied Material Cluster MERIE
- Plasma Etch
- Metroline M4L Plasma Etcher (Litho descum, suface modification)
- Reactive Ion
- Plasma-Therm 720 RIE

Characterization

- Electrical
- Four Point Probe sheet resistance
- Micromanipulator 6000 Probe State and C-V/I-V test equipment

Microscopy

- Leitz Optical Microscopes
- Leo 1530 Field Emission Scanning Electron Microscope
- Nikon L200ND Optical Microscope
- Sputter Coater of gold & platinum for SEM/FESEM imaging
- FEI NanoSEM 630

Deposition

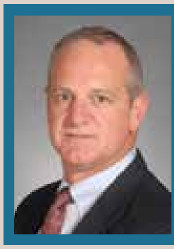
- Chemical Vapor
- Cambridge Savannah ALD

Evaporation
- Kurl Lesker e-gun & thermal evaporator
- Kurt Lesker Lab-18 E-gun & thermal evaporator
- Semicore e-gun & thermal evaporator

Process
- KLA-Tencor Alphastep 500 profilometer

Rapid Thermal Processing
- Alwin 21 AG610 Rapid Thermal Processing

Electronic Materials and Devices
- Material Synthesis Processes
- Chemical Vapor Deposition (CVD)
- Bridgman, Czochralski, SSR
- MPCVD
- Sublimation Synthesis, PVT
- Textured Electro-ceramic Processing
- Materials
- Silicon Carbide Bulk/Epitaxy
- Graphene, MoS2, 2D Materials
- GaN, AlGaN
- Bulk Oxides
- Diamond
- Thin Film Nitrides/Oxides
- Crystal Growth
- Nanofabrication Lab
- Materials Characterization
- Electrical (IV, CV, Resistivity)
- Structural/Microstructure (XRD, TEM)
- Surface characterization (AFM, Zygo)
- Device & Sensor Fabrication
- Piezoelectric Transducer Elements
- RF Transistors, Phototransistors
- SiC, GaN Diodes, PCS Switches
- Interdigitated Capacitors
- Radiation Detectors –IR, Neutron, Gamma



Systems Operations and Automation

Ed Crow
Technology Leader

Mission

The Systems Operations and Automation (SOA) Division develops, demonstrates, inserts and transfers new technologies to monitor and control the health and operation of mechanical, electrical, and electrochemical systems to DoD and other government and industrial customers. Within SOA, the Complex Systems Monitoring department applies a systems engineering approach for analyzing customer challenges. It then identifies applicable technologies and formulates an engineering implementation plan to solve the issue. The SOA division further develops solutions that implement a continuous information thread for complex systems from sensor data through actionable information in a commercial Enterprise Resource Planning system. The division has been historically focused on the science and technology of systems health monitoring. Finding its technology roots in embedded sensing, signal process and data fusion, the division is pioneering much of the technology, techniques and practices for engineers to apply condition based maintenance. In the early years, smart sensor development, coupled with improved processing power provided by digital electronics allowed rapid advancements in the ability to affordably and practical instrument equipment and achieve health and systems status monitoring. Under sponsorship from Navy and Army sources, the Systems and Automation (SOA) Division conducted many demonstrations of system health monitoring aboard ships, aircraft, rotorcraft, fixed facility and ground tactical vehicles. Along with maturing technology, the SOA Division was instrumental in the development and advocacy of standards pertaining to condition based maintenance information. And, as a leading academic institution nationally and internationally, we developed and taught the principals of reliability centered maintenance, condition based maintenance and systems health monitoring and management. More recently we have also assisted in the cost benefits analysis and analyses of alternatives as the various program managers within DoD are building condition based maintenance into their weapon platforms to realize the benefits of lower life cycle costs and increased operational availability.

2015 Fiscal Year Summary

While no FY-15 Navy ManTech projects were conducted, the division spent considerable time and effort supporting the implementation of condition based maintenance (CBM) within various DoD systems. Examples include events-based maintenance sponsored by the Marine Corps for the family of MRAP's, LVSR and MTVR. In this program maintenance, as well as recap and rework decisions, are based upon total historical usage. This allows a tailored and more focused approach to effecting necessary repair/replacement based upon objective evidence that there is a need. The division's Sensor to Enterprise effort dovetail into many of the ongoing iMAST project efforts that will enhance platform reporting status or requesting service—all the way to the high level enterprise where the request for supply or support can be efficiently and effectively executed. When fighting equipment can report

U.S. Navy released photo

Systems Operations

their status and health, demand can then be determined by the supply chain. Rather than being reactionary to an urgent need, demand can be anticipated. Supplies, support and transportation becomes more readily managed and arranged. This constitutes advanced tactical logistics, also known as Sense and Respond logistics.

U.S. Navy released photo

Facilities

Robotic Technology Laboratory

The Robotic Tech Lab contains remotely controlled air and ground vehicle platform assets. This facilitates the integration of robotic sensors, power storage and management of health care technologies, which provide operational support of specified DoD tactical and logistics operations. The Mechanical Diagnostic Test Bed was specifically designed and built by ARL Penn State to conduct run-to-failure testing on representative mechanical systems including gear train components and pumps. The testing capability provides the ability to generate discrete fault evolution data for the training and testing of advanced diagnostic, predictive and prognostic algorithms that can be applied and validated on full scale platforms such as gas turbine generators and ground combat system transportation assets loaned to ARL Penn State by the Navy, Marine Corps, and Army.

Mechanical Drivetrain Transmission Technologies & Gear Research Institute

Aaron Isaacson
Technology Leader

Mission

To assist in the enhancement, revitalization, and resurgence of the transmission industrial-base sector of the United States. It is essential that the drive system industrial base remain viable, competitive, and robust in order to effectively address U.S. Navy, Marine Corps, and DoD modernization and surge requirements.

This industrial sector is also critical to the national transportation infrastructure; therefore, it must remain responsive and competitive in order to address national interests. To achieve these stated objectives, iMAST, with guidance from the Office of Naval Research, continues to build its reputation as a national resource. The broad technological objectives driving the research and development agenda of iMAST are noted by the following stated DoD-stated goals:

- Reduce transmission weight by at least 25 percent.
- Reduce vibration and noise by at least 10 dB.
- Increase Mean-Time-Between-Removals (MTBR) by 20 percent.
- Reduce procurement and operating costs (affordability).

The influx of industrial dual-use sponsored research has been a prominent feature of the Drivetrain Technology Center. These mechanical- and material-related projects are an indirect result of prior Navy-sponsored S&T investments. Coupled with a robust gear metrology facility, the Drivetrain Technology Center provides a direct resource for the Navy relative to gear, transmission, material and metrology-related challenges impacting Navy and Marine Corps mechanical drive systems

2015 Fiscal Year Summary

During FY-15 the Drivetrain Technology Center (DTC) began looking into an effort to optimize and implement an advanced grinding process for machining forged nickel alloys. This would replace current fabrication methods, likely reducing manufacturing time and cost, while increasing parts quality.

The DTC continued its efforts to transition the ausform gear finishing technology for dual-use high-volume ground vehicle application. Ausform gear finishing technology, developed through a previous Navy ManTech program effort, shows potential for high-strength powder metal gear application for ground combat vehicles. This and other related projects leveraged by prior Navy ManTech activities demonstrate new gear manufacturing processes have the ability to replace conventional gear finish grinding for service support vehicles.

Leveraging previous unique Navy ManTech-sponsored efforts, core competencies remain online to address an array of gear fatigue performance studies of interest to the Navy, Marine Corps and Army, as well as the aerospace and wind turbine industries.Some of the ongoing and recently completed gear fatigue performance studies at the Drivetrain Center leveraging prior Navy ManTech efforts include:

USMC released photos

Facilities and Unique Capabilities:

Advanced Manufacturing Facility

- Provides equipment, tooling, processing, and inspection equipment to enhance industrial manufacturing process technology
- Permits affordable gains in component performance
- Reduces life-cycle costs
- Equipment: Ausform gear finishing machine Drivetrain Performance Testing Facility
- Permits comparative evaluation of new technologies to facilitate implementation
- Develops advanced materials technology databases for high-performance mechanical drive components
- Validates predicted gear performance behavior in terms of vibration/noise characteristics
- Equipment:
  - Gear tooth bending fatigue machines (3)
  - Gear tooth impact testing machine
  - Rolling/sliding contact fatigue testing machines (5)
  - Power circulating gear surface fatigue testing machines (2)
  - Power circulating gear bending fatigue testing machines (2)
  - Gear tooth scoring resistance testing machine (3)
  - Testek high speed power circulating gear testing machines (2)

UNIQUE CAPABILITY
Ausform Finishing

ARL possesses one of the few production-capable double die ausform finishing machines in the country. This process entails heating case-hardened steel specimens to a red-hot temperature, followed by quenching it to a working temperature that allows rolling to maximize strength and geometry.

ARL released photo

Prognostics Development and Testing Facility

Provides model-based testing and evaluation methods for in-service prediction of remaining useful life in material elements, components, subsystems, systems, and weapon systems platforms.

– Equipment: Power circulating gear box testing equipment

ARL released photo

UNIQUE CAPABILITY
Drive System Component Materials

ARL has one of the most comprehensive and unique collections of gear testing equipment in the United States. Both Rolling Contact Fatigue (RCF) and Single Tooth Fatigue (STF) testing can be conducted at temperatures of up to 400°F. Variable power circulating testing under load can be conducted from as low as 900 rpm to as high as 10,000 rpm at up to 1,400 hp. Testing is an essential requirement to validate process qualification in support of high-performance transmission technology. RCF testers for simulating gear tooth contact, STF testers for evaluating bending fatigue, and PC testers for contact fatigue testing on gears are essential equipment.

Dimensional Inspection Facility

– U.S. Navy's Gear Metrology Laboratory

– DoD neutral testing site for verifying measurement accuracies related to gear specifications

– On-call advance notice capability for emergency gear repair analysis

UNIQUE CAPABILITY
Navy Metrology Laboratory

ARL's Drivetrain Technology Center is host to resident U.S. Navy provided gear metrology equipment (with supporting artifacts). The center serves as a neutral or "honest broker" testing site for verifying measurement accuracies related to gear specifications. This capability is fundamental and basic for the advancement of mechanical drive transmission manufacturing science and technology. iMAST provides the Navy with an on-call resident resource for addressing gear metrology technical issues related to naval weapon system platforms.

ARL released photo

Materials Characterization

- Micro-hardness testing
- Failure analysis via optical and scanning electron microscopy
- Micro-structural analysis
- In-situ surface roughness characterization via replica fabrication and optical interferometric analysis
- Steel cleanliness evaluation via energy dispersive spectroscopy and element mapping.

Gear Research Institute

As a result of the U.S. Navy's extensive investment in gear-related technology, and resident expertise within ARL Penn State's iMAST program, an industry-sponsored resource known as the Gear Research Institute was physically transferred to the Applied Research Laboratory at Penn State during 1995.

Managed by ARL Penn State, the availability of this resource complements the mission of ARL's Drivetrain Technology Center. The Gear Research Institute provides a host of additional equipment the Drivetrain Technology Center can use with respect to its Navy ManTech-related activities. Partnering with industry is an essential element of the Navy ManTech program. The Gear Research Institute provides a direct conduit to the drive system manufacturing defense industrial base.

The Gear Research Institute, a not-for-profit corporation, is organized to provide and supplement gear-related technology requirements for conducting research and development, consulting, analysis, and testing efforts. The institute is a leading proponent of Cooperative Pre-Competitive Research. Since its inception in 1982, the Gear Research Institute has conducted technology programs in the following areas:

- Loss of Lube Gear Testing
- Austempered Ductile Iron
- Effect of Lubricant on Durability
- High-Hot-Hardness Gear Steels
- Induction Hardening of Gears
- Utilization of Boron Toughened Steels
- Effect of Surface Finish on Durability
- Technology Surveys
- Heat Treat Distortion
- Durability Testing of Gears
- Finite Element Modeling
- Technology Surveys
- Heat Treat Distortion
- Durability Testing of Gears
- Finite Element Modeling

ARL released photos

Vertical Lift Research Center of Excellence

Ed Smith, Ph.D.
Technology Leader

Tom Donnellan, Sc.D. and Greg Johnson
ARL Project Leaders

A unique resource available to the ARL/iMAST Air Vehicle Technology Group is Penn State's Vertical Lift Research Center of Excellence (VLRCOE), a DoD/NASA funded center resident within Penn State Aerospace Engineering Department. The center of excellence, which has close ties to NAVAIR, is one of three in the country that conduct long-term basic and applied research in rotorcraft and vertical lift technologies. Projects related to iMAST's mechanical drive transmission technologies include evaluation of elevated temperature behavior of high hot-hardness gear steels, unified modeling and active control methods for coupled rotor mechanical drive system dynamics, and development and evaluation of material coatings for gear tooth health monitoring. Navy ManTech efforts within the laser processing division have also addressed lightweight flooring structures for internal cargo handling. Penn State's Vertical Lift Center remains a valued resource to iMAST and its Navy and Marine Corps customers.

U.S. Navy released photo

ARL Materials & Advanced Manufacturing-Related Activities

ARL Penn State's Materials and Manufacturing Office continues to push the state-of-the-art in science and technology applications, and this corporate expertise is a valuable resource for the Navy and Marine Corps team. The following recent program summaries are provided to show the scope and leadership inherent within ARL Penn State's core capabilities—which continue to benefit the U.S. Navy and the Department of Defense...

DARPA Adaptive Vehicle Make Program

The recently completed DARPA Adaptive Vehicle Make (AVM) portfolio of programs was aimed at a five-fold compression of the development timeline for new DoD systems and platforms. Such compression will enable dramatic reductions in platform program costs in an environment of fiscally constrained DoD budgets. ARL Penn State played a key role in AVM through the execution of the iFAB Foundry. In this effort an information architecture was created that enables the establishment of rapidly-configurable, distributed, manufacturing team for the production of DoD systems. This architecture was demonstrated in the build and delivery of a full scale Amphibious Combat Vehicle Mobility Demonstrator in span of five months.

Reverse Engineering for Sustainment

ARL Penn State is contracted by MARCORSYSCOM to reverse engineer components and subsystems for ground systems. By generating government owned technical data and establishing qualified sources of supply, the team is addressing critical sustainment issues for Marine Corps platforms.

DARPA Open Manufacturing Program: Center for Innovative Materials Processing by Direct Digital Manufacturing (CIMP-3D)

ARL Penn State will serve as an Additive Manufacturing Demonstration Facility (MDF) for the DoD. As an MDF, CIMP-3D will serve as the organization which develops and transitions innovative additive manufacturing technologies into products of interest to the DoD. CIMP-3D also serves as a developer and repository for modeling tools relevant for additive manufacturing processes.

Army Benet Labs Additive Manufacturing for DoD Sustainment

Penn State is developing additive manufacturing approaches in support of the unique needs of the DoD maintenance community, such as reverse engineering of out-of-production components.

ONR Cyber Enabled Manufacturing

The objective of the CEMS effort is to develop systems that combine model-based processes with physical processes. In the context of Additive Manufacturing, Penn State is working to develop and demonstrate a software architecture that will ultimately enable "plug & play" operability for thermal, mechanical, material simulations, process planning, various process monitoring sensors, and feedback-based process control. This program is closely coordinated with the simulation and model development being fund under the DARPA MDF in CIMP-3D.

Accelerated Certification Technology for Additive Manufacturing

This program addresses the key technological issue with the use of additive manufactured components in structural applications – the certification process. Penn State will be developing concepts to enable streamlined certification of additive manufactured components.

Lightweight High-Performance Body Armor Ceramic Tiles by Field Assisted Sintering Technology (FAST)

This program is developing FAST-based process technology for rapid, low cost fabrication of high performance armor for personnel and vehicle systems.

New Manufacturing Initiatives OSD Technology Solutions for Manufacturing Advanced Products (TSMAP)

This program is applying PSU capabilities to help DoD small businesses accelerate product development of technologies of interest to the DoD; it will also provide cost- effective strategies for cyber security for small businesses.

Near Net Shaped Forming Components: Rocket Nozzles

This project is developing FAST-based processing concepts to produce near net shaped rocket nozzle made of high temperature refractory material such as tungsten and tantalum alloys.

ARL released graphics

Staff and Sponsors

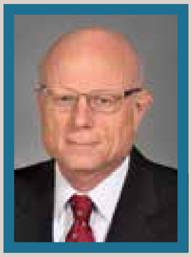
U.S. Navy released photo

Supporting the Navy - Marine Corps - Penn State Team

Applied Research Laboratory

Staff Profiles

PennState
Applied Research Laboratory



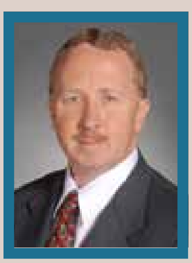
Paul E. Sullivan

Director, Applied Research Laboratory
The Pennsylvania State University

B.S., Mathematics, United States Naval Academy
M.S., Naval Architecture, Massachusetts Institute of Technology
M.S., Ocean Engineer, Massachusetts Institute of Technology

The 9th director of Penn State's Applied Research Laboratory, Paul Sullivan is the chief academic administrator of the Laboratory. He is responsible for directing the Laboratory's efforts in concurrence with Penn State's and the U.S. Navy's goal of being a naval technology base. As the largest of 10 interdisciplinary laboratories, centers and institutes under the University's Vice President for Research, ARL performs 150 million dollars' worth of research and development in the areas of undersea weapons guidance and control systems, advanced closed-cycle thermal propulsion for undersea weapons guidance and control systems, advanced closed-cycle thermal propulsion for undersea weapons, propulsor technology, hydrodynamics for undersea vehicles and weapons, and materials manufacturing science for a wide-range of other sea-air-ground combat systems. Prior to assuming directorship of ARL, Paul Sullivan served as Commander, Naval Sea Systems Command, culminating a distinguished 31 year career (1974–2005) as a Vice Admiral with service including both surface and submarine warfare officer experience. Additional career Navy highlights include service as program manager of the Seawolf-class Submarine Program (PMS 350) and the Virginia-class Submarine Program (PMS 450). Upon selection to flag rank, VADM Sullivan served as Deputy Commander for Ship Design Integration and Engineering, Naval Sea Systems Command.

Following retirement from the U.S. Navy, Admiral Sullivan joined USEC Inc, a global energy corporation, where he served as Vice President and Chief Engineer of the American Centrifuge Project, which is the only centrifuge uranium enrichment technology program based in America. Paul Sullivan has also served as Vice President of the American Society of Naval Engineers (ASNE).

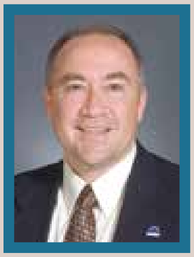


Thomas M. Donnellan

Associate Director, Materials and Manufacturing
Applied Research Laboratory, The Pennsylvania State University

B.S., Materials Engineering, Drexel University
M.S., Polymerics, Massachusetts Institute of Technology
Sc.D., Materials Science, Massachusetts Institute of Technology

Dr. Donnellan is the Associate Director for Materials and Manufacturing at ARL, Penn State. Prior to joining ARL, Dr. Donnellan served as Chief Scientist for materials at the Federal Bureau of Investigation. Prior to the FBI, Dr. Donnellan served as manager of structural sciences for Northrop Grumman Corporation. Previous to Northrop Grumman, Dr. Donnellan was the composites group manager for the Naval Air Development Center (NADC) at Warminster, Pennsylvania.



Timothy D. Bair

Director, Institute for Manufacturing and Sustainment Technologies
Applied Research Laboratory, The Pennsylvania State University

B.S., Biology, The Pennsylvania State University
M.S., Logistics Management, Air Force Institute of Technology
M.S., National Resource Strategy, ICAF

Mr. Bair is the director of ARL's Institute for Manufacturing and Sustainment Technologies. The iMAST mission is to support the U.S. Navy ManTech program as a focal point for the development and transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy acquisition and sustainment programs. Before assuming his current assignment, Mr. Bair was working to extend ARL's reach into Autonomic Logistics, condition-based maintenance applications, advanced repair technology, and space-based sustainment programs.

Mr. Bair has more than 26 years of logistics and program management experience as a senior officer in the U.S. Air Force. Mr. Bair's previous logistics experience includes flightline maintenance officer, wing maintenance operations officer, maintenance supervisor, maintenance squadron commander, Air Combat Command F-16 branch chief, operations group deputy commander, and logistics group commander. Prior to his Air Force retirement, Mr. Bair was the deputy director, Directorate of Logistics Management, Ogden Air Logistics Center, Hill Air Force Base, Utah. He also served as an investigative staff member of the Columbia Accident Investigation Board.

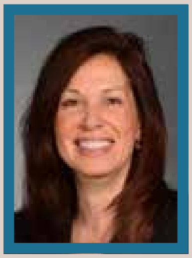
Gregory J. Johnson

Research Institute Administrator, Institute for Manufacturing and Sustainment Technologies
Applied Research Laboratory, The Pennsylvania State University

B.A., Pre Law, University of Hawaii
M.A., Education, Pepperdine University
Graduate, Defense Systems Management College

Mr. Johnson is the research institute administrator for the iMAST effort at ARL Penn State. Mr. Johnson previously served as executive assistant to the Assistant Secretary of the Navy for Research, Development & Acquisition as well as the Deputy Assistant Secretary of the Navy for Expeditionary Force Programs. Prior to that assignment he served as the ground anti-armor program manager at the Marine Corps Systems Command. A former Naval Aviator, Mr. Johnson served in various operations and aircraft maintenance assignments to include maintenance test pilot positions with Japan Aircraft Company and China Airlines. He was also a designated Marine Corps weapons and tactics instructor.

Staff

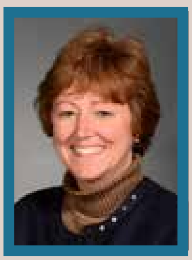


Brenda E. Kephart

Financial Coordinator
Applied Research Laboratory, The Pennsylvania State University

A.S., Business Administration, The Pennsylvania State University
B.A., Letters, Arts and Sciences with a minor in Labor Industrial Relations
The Pennsylvania State University

Ms. Kephart is the financial and administrative coordinator for ARL's Institute for Manufacturing and Sustainment Technologies at Penn State. A focal point for the development and transfer of new manufacturing processes within iMAST's Center of Excellence, Ms. Kephart plays an essential role in the program's implementation effort. Prior to joining iMAST, Ms. Kephart served in ARL's Undersea Weapons Office. She has more than 20 years' experience dealing with financial, logistics, and personnel issues.



Tina S. Ludwig

Business Manager
Applied Research Laboratory, The Pennsylvania State University

A.S., Business Administration, The Pennsylvania State University
B.S., Finance, The Pennsylvania State University

Ms. Ludwig is the Office Business Manager for the Materials and Manufacturing Office (MMO) at ARL, Penn State. Her duties include monitoring, analyzing and reporting the financial status of the five technical divisions and 2 technology centers (which includes iMAST) that fall within ARL Penn State's MMO. She is also the liaison between the MMO and ARL's Business Office.

Ms. Ludwig has 28 years of experience working with the Department of Defense. Prior to joining ARL, Ms. Ludwig worked for Raytheon–State College as a program planner and cost analyst.

Office of Naval Research

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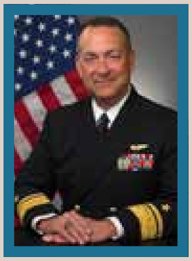


Rear Admiral Mathias W. Winter USN

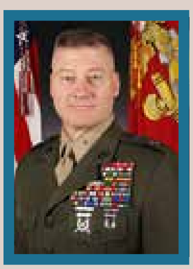
Chief of Naval Research

The 25th Chief of Naval Research, RAdm Winter has concurrent flag responsibilities as Director, Innovation Technology Requirements, and Test & Evaluation (N84).

A 1984 graduate of the University of Notre Dame, Admiral Winter received his commission through the Naval Reserve Officers Training Corps. He was designated a Naval Flight Officer in 1985. Admiral Winter served operational tours as an A-6E Intruder Bombardier/Navigator with Attack Squadrons 42, 85 and 34— making multiple deployments aboard aircraft carriers USS Saratoga (CV 60), USS America (CV 66), USS Dwight D. Eisenhower (CVN 69) and USS George Washington (CVN 73). Acquisition tours include assistant deputy program manager (DPM) for the Joint Standoff Weapon System; executive assistant to the Joint Strike Fighter (JSF) program director; chief engineer for JSF Integrated Flight and Propulsion Control; DPM for the Tactical Tomahawk All-Up-Round development program; chief of staff to the Program Executive Officer (PEO) for Tactical Aircraft Programs; and his major acquisition command tour as the Precision Strike Weapons (PMA-201) program manager.

Admiral Winter has served flag tours as the commander, Naval Air Warfare Center Weapons Division, China Lake/ Point Mugu, CA; assistant commander for Test and Evaluation, Naval Air Systems Command; and PEO for Unmanned Aviation and Strike Weapons. In addition to his Bachelor of Science degree in Mechanical Engineering from Notre Dame, Admiral Winter holds a Master of Science degree in Computer Science from the Naval Postgraduate School and another in national resource strategy from National Defense University's Industrial College of the Armed Forces; and a Level III certification in Program Management and Test & Evaluation from the Defense System Management College.

The Admiral's personal awards include the Legion of Merit (3), Defense Meritorious Service Medal (2), Navy Meritorious Service Medal (2), Navy and Marine Corps Commendation Medal (4), Joint Service Achievement Medal (2), Navy and Marine Corps Achievement Medal, Air Force Acquisition Excellence Award, Southwest Asia Service Medal, Kuwait Liberation Medal, and various unit and sea service awards.



Brigadier General Julian D. Alford USMC

Vice Chief of Naval Research
Commanding General, Marine Corps Warfighting Laboratory

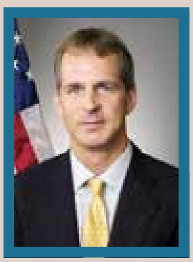
Brigadier General Alford attended West Georgia College and, as a sophomore, enlisted in the Marine Corps Reserves in 1985. Following graduation from college he was commissioned as a Second Lieutenant of Marines in December of 1987.

Brigadier General Alford's commands include rifle Platoon Commander, 3d Battalion, 6th Marine Regiment, 2d Marine Division during Operation Just Cause in the Republic of Panama and 81's Platoon Commander during Operations Desert Shield and Desert Storm; Light Armored Infantry Detachment Commander, 2d Battalion, 4th Marine Regiment, 24th Marine Expeditionary Unit (Special Operations Capable). As a Captain; Series Commander, Company Commander, 3d Recruit Training Battalion, MCRD Parris Island; Company Commander, 3d Battalion, 8th Marines, 2d Marine Division during Operation Assured Response in the U.S. Embassy, Monrovia, Liberia; As a Major; he commanded Recruiting Station, Nashville, Tennessee. As a Lieutenant Colonel; he commanded 3d Battalion 6th Marine Regiment, 2d Marine Division during Operation Enduring Freedom Afghanistan and during Operation Iraqi Freedom. As a Colonel: he commanded The Basic School, Quantico, Virginia.

Brigadier General Alford's staff assignments: As a Captain; Operations Officer, 3d Recruit Training Battalion, MCRD Parris Island. As a Major; Operations Officer, 3d Battalion, 8th Marine Regiment, 2d Marine Division; Executive Officer, 2d Battalion, 8th Marine Regiment, 2d Marine Division during Operation Iraqi Freedom; As a Lieutenant Colonel; Operations Officer,

6th Marine Regiment, 2d Marine Division, Faculty Advisor at the Marine Corps Command and Staff College. As a Colonel; Joint Operations Analysis Officer, Institute for Defense Analyses, during this assignment he deployed to Afghanistan and served as the Director of Strategic Effects, ISAF HQ, Kabul; Military Fellow, Council on Foreign Relations, New York City; Branch Head, Current and Future Operation, PP&O, HQMC. As a Brigadier General; he served as the Chief of Staff, CENTCOM, Joint Force Land Component Command, Kuwait.

Brigadier General Alford has attended The Basic School, the Infantry Officers Course, the Amphibious Warfare School, the Marine Corps Command and Staff College, and the Marine Corps War College.



John U. Carney

Director, Navy ManTech Program
U.S. Navy Industrial and Corporate Program Department
Office of Naval Research

Mr. Carney is the director of the U.S. Navy Manufacturing Technology (ManTech) Program. As director, Mr. Carney provides for the development of enabling manufacturing technologies, as well as the transition of this technology for the production and sustainment of Navy weapon systems to support the Fleet. Navy ManTech is currently focused on shipbuilding affordability. Reducing the acquisition cost of current and future platforms is a critical goal of the Navy, and ManTech aids in achieving this goal by developing and transitioning key manufacturing technology.

Mr. Carney received a B.S. degree in industrial engineering and operations management, as well as an M.S. degree in engineering management, both from Virginia Tech. Mr. Carney's technical interests include shipbuilding technology.

Gregory D. Woods

Navy Program Manager (for iMAST at ARL Penn State)
U.S. Navy Manufacturing Technology Program
Office of Naval Research

Mr. Woods is the Navy program manager for ARL Penn State's iMAST program. As program manager, Mr. Woods provides financial and programmatic oversight to iMAST, as directed by the Office of Naval of Naval Research. With over 20 years' experience in surface ship structural integrity design, as well as materials design and application expertise with NAVSEA and NSWC-Carderock, Mr. Woods provides a valuable resource for the iMAST team to draw from.

Mr. Woods received a B.S. degree from Tennessee State, as well as an M.S. degree in engineering management from The George Washington University.

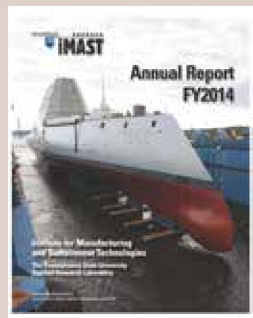
FY-2015 Technology Transfer Events Participation

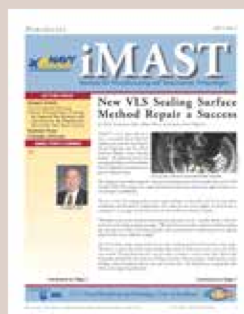
Attended Events

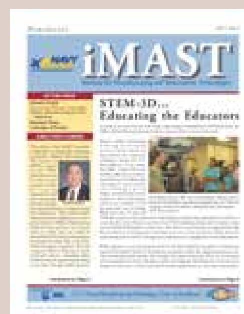
- Defense Manufacturing Conference 2014, San Antonio, TX
- Surface Navy Association 2015, Crystal City, VA
- Navy League Sea-Air-Space Expo 2015, National Harbor, MD
- ONR Future Force 2015, Washington, D.C.
- Showcase for Commerce 2015, Johnstown, PA
- NCMS Cold Spray Action Team Meeting 2015, Worchester, MA
- Joint Defense Manufacturing Panel Meeting, State College, PA
- ONR VCS/DDG 51/ LCS/CVN 78 Program Review Meeting, Charleston, SC

Hosted Events

- Materials and Manufacturing Board Meeting
- Closeout Meeting for NSRP Navy Standard Pressure Actuated Door (NSPAD)
- RepTech Working Group Meeting
- ONR Joint DDG 51 Review Meeting







Points of Contact

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PennState
Institute for Manufacturing and Sustainment Technologies

The iMAST World Wide Web site provides an overview of the Institute and its technical thrust area projects, information on upcoming events, facilities, and newsletters.

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