



PennState
Institute for Manufacturing
and Sustainment Technologies

2016 Annual Report



The Pennsylvania State University
Applied Research Laboratory

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On the Cover:
U.S.S. Gerald R. Ford (CVN 78), photo courtesy Huntington Ingalls Industries

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Director's Message

Timothy Bair
iMAST Director

This year marks my tenth anniversary as director of the Institute for Manufacturing and Sustainment Technologies at ARL Penn State. It has been a great ride so far. I can reflect (with confidence) that we remain on the right track towards addressing the various challenges we have embarked upon with respect to supporting the U.S. Navy-Marine Corps Team – as well as the Department of Defense in general.

The summary of support expounded in this report reflects a concerted effort to support the Navy ManTech Investment Plan espoused by the Office of Naval Research. Although our budget has remained relatively static over the years, we continue to get the most bang for the buck for our customers. The biggest change in the ManTech paradigm has been the emphasis on the major acquisition platforms. As you peel back the layers of implication, it is clear this is not an easy task. We continue to push forward with respect to current and future challenges facing the naval services – and the Department of Defense.

Many of our projects are nearing completion and are undergoing testing at outside facilities. That Navy and Marine Corps program offices are willing to let us take on the risk and cost of testing new technologies speaks well for the technical promise of the projects, not to mention confidence in our engineers. But this is not the time to rest on our laurels. We continue to look at the future of manufacturing and repair technologies. Ten years ago Additive Manufacturing, as well as Advance Manufacturing Enterprise tools, were just starting to evolve. Industry as now embraced those tools and are being putting in place. These leading edge insertion opportunities could not come into play without the dedication being put forth by our engineers and their supporting staff.

In concert with our efforts, I am enjoined to also restate (in particular) the value our repair technology brings to the table. As you may (or may not) know, iMAST is leading the Navy-Marine Corps team's repair, overhaul, and sustainment initiative through our Repair Technology (or "RepTech") program. The RepTech program is chartered to reduce the cost of maintaining the fleet. While the number of ships, aircraft, and vehicles has decreased over the years, the age of the remaining assets has risen. With increased operating tempos, the need to reduce the costs and time spent in the depots and shipyards is ever more critical. Given the limited funding available for Repair Technology, we have judiciously selected projects that maximize benefits to the fleet. We will continue to concentrate on technology that can be used at multiple shipyards or depots. By using a lead depot to demonstrate the technology, then working with the systems commands to implement it across the board, we can reap the biggest benefit for the Navy.

Thank you for your time and interest in iMAST, ARL and The Pennsylvania State University. Please feel free to contact us if you have any questions.

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

About ARL Penn State



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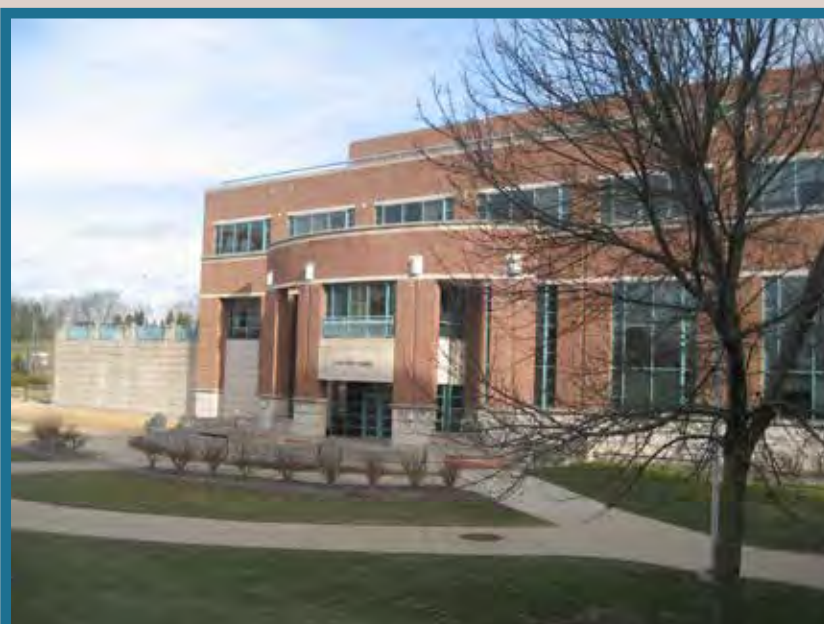
The Institute for Manufacturing and Sustainment Technologies resides within the Applied Research Laboratory (ARL) at The Pennsylvania State University (University Park campus). UARCs are strategic United States Department of Defense (DoD) research centers associated with universities. UARCs were established 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 Columbia-class submarines, CVN 78-class carrier, DDG 51-class destroyers, CH-53K King Stallion, and the F-35 Lightning (Joint Strike Fighter).

Strategic Plan



Sikorsky released photo



U.S. Navy released photos

2016 Technology Transfer Events Participation

Attended Events

- Surface Navy Association Symposium 2016, Crystal City, VA
- Navy League Sea-Air-Space Expo 2016, National Harbor, MD
- ONR Technology Innovation Display Day 2016, The Pentagon, Washington, D.C.
- Showcase for Commerce 2016, Johnstown, PA
- Joint Defense Manufacturing Panel Meeting, State College, PA
- Defense Manufacturing Conference 2016, Denver, CO
- RepTech Working Group Meeting, MDMC Albany, GA



https://www.arl.psu.edu/centers_imast.php

State College Hosted Events

- Materials and Manufacturing Board Meeting
- RepTech Working Group Meeting
- Marine Depot Maintenance Command Meeting



iMAST Navy ManTech 2016 Portfolio of Projects

A2647 — Additive Manufacturing Repair of AV-8 LPC Seal



Affordability Focus Area: Metal Processing and Fabrication & Repair

Stakeholder: NAVAIR PEO (T)

Platform(s): Navy Marine Corps Aircraft

Objective — Repair AV-8B Harrier engine part by use of Additive Manufacturing to maintain aircraft availability.

Additive Manufacturing (AM) is recognized by NAVAIR as a means to bring "...a revolution in how we sustain our systems" (VADM David Dunaway). This technology has clear potential to benefit Navy sustainment activities, including: direct part replacement, fabrication of repair parts, and refurbishment of worn or corroded parts. The AV-8B aircraft employs an F402 engine from Rolls Royce that experiences wear at bolted contact points on the low pressure compressor Stage 2 seal ring. There is no currently approved repair, so NAVAIR must rely on replacement from a vendor with long lead-time.

This project was developed to implement a qualified laser-based directed energy, deposition buildup repair process for this component. However, before this potential can be realized for aviation components, the U.S. Navy must develop and demonstrate repair qualification and certification procedures for specific targeted components. This Institute of Manufacturing and Sustainment Technologies (iMAST) project will 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 Fleet Readiness Center East (FRC East) or a designated 3rd party. These procedures will address a high-priority repair need within the AV-8B F402 engine — excessive vibration due to surface wear on the Low Pressure Compressor 2nd Stage Rear Seal Ring at bolted contact points to the 3rd Stage Rear Seal Ring.

Payoff

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. A supply forecast provided by FRC East suggested that the projected number of spare seal rings is expected to be exhausted, and AV-8B aircraft will be grounded by mid-2016 if another resupply order is not filled or another source of manufacture/repair is not established beforehand.

The cost avoidance and operational benefit associated with avoiding having multiple jets grounded for several months in 2016 has been stressed to the project team by FRC East as motivation to pursue suitable AM repair options for these units. Moreover, the headway gained through this project will be leveraged by follow-on efforts to further apply the benefits of AM technologies to other Navy applications.

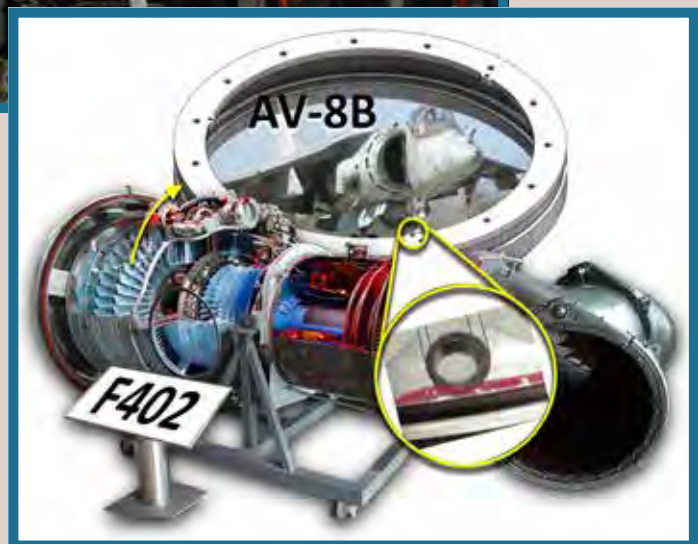
Implementation

Results of this project will be implemented on the aforementioned seal rings when the following conditions have been met: (1) successful completion of the project, (2) acceptance of the technology by the Program Office, Program Executive Officer (PEO) and/or the Management Representative of the Industrial Facility, and (3) acceptance by the relevant Navy Technical Code. The iMAST project team and NAVAIR stakeholders are working toward implementation.

POC: *Steven Brown and Ted Reutzel, Ph.D.*



U.S. Navy released photo



S2599 Ultra-High Pressure Water Jet Removal of Special Hull Treatment Using Dual-Track Crawler System



U.S. Navy released photo

Affordability Focus Area: Metals Processing and Fabrication/Repair

Stakeholder: Puget Sound Naval Shipyard

Platform(s): Submarines

Objective — Incorporate ultra-high pressure water jet removal system on Special Hull Treatment using dual-track crawler system.

Removal of Special Hull Treatment (SHT) from submarine hulls is performed using an ultra-high pressure (UHP) water jet. Currently, shipyards use UHP hand-lances to remove SHT. SHT removal using UHP hand-lances is slow and is a safety hazard for operators. The objective project is to design, fabricate, test, and deliver a dual-track UHP SHT removal system. The dual-track SHT removal system will be a semi-automated process. The dual-track crawler system will use higher pressure and flow rates than can be used with hand-lances. For these reasons, the dual-track crawler system will improve removal efficiency, improve safety, and reduce labor in the waste cleanup process.

Payoff

According to Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNSY&IMF) an estimated 1000 man-hours were expended (April 2013 through April 2014) for SHT removal from submarines using the standard hand-lancing technique. PSNSY&IMF subject matter experts (SMEs) estimate around 35 percent labor reduction will be realized using the dual-track system. These labor reductions result from the elimination of the operator safety limit (60-minute blast-time restriction), elimination of the frequent cycling the trigger on and off due to poor visibility, and elimination of the requirement to maintain a second person as safety watch.

SMEs estimate the shipyards will see a 50 percent reduction in cleanup cost as a result of the reduced cleanup labor with the introduction of an on-board vacuum collection. Vacuum collection is not currently feasible due to the tendency of removed SHT material to clog the vacuum collection equipment. The use of a dual-track system will enable precise control of particle size which enables vacuum collection at the point of generation. Finally SMEs estimate approximately a 35 percent reduction in labor for edge cleanup prior to reinstallation of new tiles. The estimated total cost savings per hull is \$120K per year/per yard and the estimated total annual cost savings to the Navy is \$360K/year. The return on investment over five years is: 3.5:1.

Implementation

The Institute for Manufacturing and Sustainment Technologies (iMAST) plans to demonstrate the system at PSNSY&IMF in the first quarter FY16. The transition path is direct technology insertion at the submarine-supporting shipyards. System complexity is at an appropriate technology level for maximum transition ease.

POC: *Charles Tricou*



U.S. Navy released photo

S2580 — Cold Spray Technology for Shipboard Components to Reduce Costs



U.S. Navy released photo

Affordability Focus Area: Metals Processing and Fabrication/Repair

Stakeholder: NAVSEA Puget Sound Naval Shipyard

Platform(s): Surface ships and submarines

Objective — Incorporate Cold Spray technology for repair of shipboard components in order to reduce costs.

Puget Sound Naval Shipyard and the Intermediate Maintenance Facility (PSNS&IMF) have identified several repair and maintenance issues on aging sea water exposed components 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. Alternative repair processes are needed that are more durable, require fewer man-hours, and are more cost-effective.

The objective of this effort is to develop cold spray repairs for hydraulic actuators, priming pumps, seawater pump channel rings, and electric motor end bell bore and rotors. Included in the repair process are validation of the process parameters and coating properties, qualification test results, process parameters, material and process parameters, and coating procedures. The cold spray process is being developed as an alternative repair process for several of the repairs that have been identified. The process can be used on a number of different material systems. The low heat input makes the process ideal for many aluminum and brass components which cannot be weld repaired due to heat distortion and change in temper of the base material. In many instances, damaged components are replaced and scrapped. Four components were selected for repair by cold spray based on the substrate / coating material combination, urgent need or long lead-time, the number of components requiring repair, frequency of repair, and the potential return on investment (ROI).

Payoff

The payoff include a repair process for components that either do not have an approved repair process or the repair processes cannot meet the operational requirement. Additional benefits include: improved readiness by repairing long lead-time items, reduced environmental impact, and improved life-cycle affordability. Repairs can be performed at a vendor location, at a naval shipyard, or shipboard. A cost avoidance of over \$1.25M has been identified for the repair of aluminum components. Greater savings can be realized through the repair of 70Cu/30Ni, bronze, and brass components. All repairs can be performed using the same cold spray system.

Implementation

Implementation of the repair processes will be through PSNSY. A business case analysis will be conducted to determine the most cost-effective and efficient implementation path. The analysis will include parameters such as equipment costs, workload, equipment maintenance, and need for qualified operators. Options include installing and maintaining cold spray equipment at PSNSY, performing repairs at a vendor location, or having a vendor perform repairs on-site. Final implementation is underway.

POC: *Tim Eden, Ph.D*



DoD released photo

C2477 — Crack Detection in USMC Vehicles



U.S. Navy released photo

Affordability Focus Area: Metals Processing and Fabrication/Repair

Stakeholder: Marine Corps Logistics Command

Platform(s): Ground Combat/Combat Service Support Vehicles

Objective — Incorporate under-paint inspection technology to improve depot maintenance planning for ground combat and service support vehicles.

Currently, the U.S. Army and U.S. Marine Corps depots completely disassemble vehicles to remove camouflage, topcoat, and primer paint to inspect for cracks. The inability to detect cracks without disassembly and paint removal results in wasted time and funding. The objective of this project is to define and implement a new or modified non-destructive evaluation/non-destructive testing (NDE/NDT) technique for inspection of large assembled and painted USMC combat vehicles and other deployable vehicles assigned to the depot. The USMC 2014 Strategic Plan includes refurbishing 925 Light Armored Vehicles (LAVs) and approximately 1,500 MRAP-All Terrain Vehicles (M-ATVs). Each of those vehicles, using the current inspection procedures, would require all paint removed prior to evaluation. The goal of this project is to avoid unnecessary paint removal by introducing new NDE technology that will accurately identify structural cracks through paint. In accordance with Albany MCLB approved inspection requirements, if cracks of sufficient size and shape are not detected, no structural or protective repair is necessary.

Review of inspection reports for 259 LAVs revealed approximately 30 percent of the vehicles had no more than one crack. For these vehicles, a robust NDE method capable of locating cracks through the paint would enable, low-cost repair and overhaul. Additionally, 50 percent of cracks discovered were in five easily accessible locations on the exterior hull of the LAVs. Detection of easily accessible cracks would obviate the need to disassemble and remove paint in pristine areas of the vehicle. The successful implementation of a robust inspection technology will provide the vehicle-specific structural assessment for improved depot repair and re-paint process logistics.

Payoff

Eight hundred vehicles are processed through USMC Maintenance Depots each year. The proposed crack detection inspection process may only require removal of paint from damaged areas. Assuming only 25 percent of total vehicle areas will require paint removal and repaint as a result of damage and repair — cost savings are estimated at \$4.23M per year for a five-year return on investment of more than 47:1. Qualitative benefits from this project include: increased vehicle availability, better production planning process, improved painting throughput, reduced hazardous waste stream (less paint and blast media), and flexible pre-repair planning for material acquisition.

Implementation

The through-paint inspection technology, including relative NDT calibration standards, developed through this project has been used to date at MCLB Albany. The Technical Warrant Holder (TWH), MDMC, will have decision authority for fully implementing this new non-destructive inspection protocol that was successfully demonstrated at Albany, Georgia on depot inducted vehicles. Implementation will occur soon.

PI: Clark Moose

U.S. Navy released photo



S2573 — HDC-1 Bearing Improvement



U.S. Navy released photo

Affordability Focus Area: Metals Processing and Fabrication/Repair

Stakeholder: NAVSEA PMS 450

Platform(s): Virginia-Class Submarine

Objective — Greatly extend life of Virginia-Class HDC-1 bearing.

The Virginia-Class Submarine (VCS) 10-inch Hover and Depth Control (HDC) hull and backup valves are manufactured in accordance with the Submarine Valve Hall and Backup Hovering System Assembly and Details. The valve assembly consists of a poppet valve (hull valve) and a ball valve (back-up valve) in a common body. The valves are actuated independently by two hydraulic actuators. There have been recent occurrences of the hull valve failing to operate properly. The failures occurred between two and four years after the valves were placed in service, short of the design goal of six years. The operating problems were a result of failures in the hull actuating mechanism. General Dynamics Electric Boat (GDEB) conducted an analysis to determine the source/cause of the failures. The main cause of the failure is attributed to overloading and lack of lubrication of the split bearing assembly.

The objectives of this effort are to determine the failure mechanism, down-select a solution to improve system reliability, and test and demonstrate a system solution (possibly including a material/design modification to address the bearing failures and extend the service life of the HDC-1 valves to 96 months) in order to support increased ship and component availability through the Extended Dry-Docking Selected Restricted Availability (EDSRA) cycle.

Payoff

This project determined the failure mechanism and developed a solution to greatly increase the bearing life. Modifications to the lubrication system in testing show that an extension to 108 months between servicing is achievable. The cost of the bearing assembly is over \$5K and the labor to replace the bearing assembly is approximately \$40K. In addition, the projected increase to operational readiness by preventing bearing failures is the biggest benefit.

Implementation

Implementation is to occur through General Dynamics Electric Boat (GDEB). Together, GDEB and NAVSEA PMS 450/392 are committed to this project as a means to reduce total ownership costs by significantly reducing unplanned maintenance and enabling extension of major availabilities. Implementation will be accomplished through changes to the process specifications for producing the bearing assembly. Technical authority and implementation decisions will be made by PMS 450/392 and GDEB personnel who have been intimately involved with the fabrication, maintenance, and operation. Implementation began in third quarter FY16.

PI: Tim Eden, Ph.D.

ARL released photo



U.S. Navy released graphic

S2545 — VLS-LCRS Updates for Production Readiness



U.S. Navy released photo

Affordability Focus Area: Metals Processing and Fabrication/Repair

Stakeholder: NAVSEA PMS 450 and PMS 392

Platform(s): Submarines

Objective — Accelerate repair of VLS tubes via improvements to laser cladding process.

Corrosion and pitting around the counter-bore sealing surfaces of Vertical Launch System (VLS) tubes have been repaired traditionally by labor-intensive manual brush electroplating. These repairs are relatively short-lived and require frequent rework. A prototype mechanized Laser Cladding Repair System (LCRS) was demonstrated at Pearl Harbor Naval Shipyard & Intermediate Maintenance Facility (PHNSY&IMF) in 2010 aboard the USS Chicago with mixed reviews. The repairs were much better than traditional plating, but the lack of sufficient spare parts and a concern for the lack of a back-up system produced a concern for the system's "production readiness." This project updated the system's production readiness by reducing risks associated with usage. This risk reduction project was funded through the Navy ManTech program as well as through the Naval Undersea Warfare Center, Keyport (NUWC-DIV KPT) and PHNSY&IMF. The ManTech project objectives included assessed improvements to 1) system reliability, and 2) overall system repair time of the VLS-LCRS tool upon failure of individual system components. For example, a new optical fiber reel was developed to facilitate ease of use, protection of the fiber during storage, and support the quick replacement of the fiber upon failure/damage.

Payoff

To compare traditional electroplating repairs of VLS tubes to similar repairs using the VLS-LCRS, a cost benefits analysis was conducted by NUWC-DIV KPT in April 2012 using data compiled from PHNSY VLS Value Stream Analysis (VSA) 9/09. This analysis included the Pacific Fleet 688-class submarines (higher incidence of corrosion damage), thus yielding conservative values in consideration of tubes on the entire Navy fleet of submarines. The analysis did not consider cost savings from HAZMAT reduction, thus making the estimated ROI even more conservative. The cost avoidance

was estimated at \$6.2M over 10 years with a conservative return on investment (ROI) of 4.9. Laser cladding repairs are expected to be more durable than brush electroplating repairs and last up to 10 years. The number of tubes needing repair was estimated to be 12 tubes per major overhaul (one per sub every six years) and four tubes per moderate overhaul (one per sub every year), resulting in approximately 75 tubes per year (45 percent of the PAC Fleet 688-class VLS tubes per year) NUWC-DIV KPT's cost benefits analysis reduced this estimate to 1/3 of the noted tubes for an even more conservative approach.

Implementation

All VLS-LCRS equipment and project deliverables were transferred to PHSNY. Implementation occurred on the USS Asheville in December 2014. Moreover, PHNSY&IMF continues to endorse usage of the VLS-LCRS, as it was effectively deployed on the USS Jefferson City for the repair of her VLS tubes. PHNSY&IMF is actively seeking additional boats for future implementation.

PI: Ted Reutzel, Ph.D.



U.S. Navy released photo

S2449 — VCS Retractable Bow Planes System Improvements



U.S. Navy released photo

Affordability Focus Area: Metals Processing and Fabrication/Repair

Stakeholder: NAVSEA PMS 450

Platform(s): Virginia-Class Submarine

Objective — Add insulation coatings to retractable bow plane cylinder rods to improve and increase seal life and extend maintenance interval.

The retractable bow plane extend / retract hydraulic cylinders and seals on Virginia-Class Submarines (VCS) are experiencing premature failure. These failures are attributed to the build-up of calcareous deposits on the Monel® K-500 bars used in the fabrication of these components. Subject rods are placed in a cathodic protection system and are susceptible to the formation of calcareous deposits since no protective coatings are applied to them. When the seals fail, an unplanned dry-docking or cofferdam is required to replace the seal. Current experience shows the seals are failing on average of once every 12 months. The original seal life was designed to correspond within 72 month Extended Dry-docking Selected Restricted Availability (EDSRA) schedules. With EDSRA schedules expected to be extended to 96 months, a means to increase the seal lifetime is needed.

The objective of this project was to optimize a thermal spray coating solution for extend / retract cylinder rods in the VCS retractable bow plane system. The coating had to be robust enough to adhere to the Monel® K-500 rod with no cracking taking place over the prescribed month between major maintenance events or overhaul.

Payoff

The primary payoff is cost avoidance by reducing unscheduled maintenance events thereby complying with the planned maintenance periodicity extension from 72 to 96 months. Analysis of cost savings expected in concert with the addition of the insulating coating to extend/retract cylinder rod was completed by General Dynamics Electric Boat (GDEB). A cost savings of approximately \$9.6M over the life of each submarine is expected. This cost savings estimate is based on the savings of nearly 29 seal system replacements over the life of each submarine; that details out to a cost of \$330K per seal. Total life cycle cost savings on the VCS is just under \$300M.

Implementation

This project was divided into two primary phases. The first phase covered the optimization of the thermal spray coating. In this phase, the adhesion strength of the coating was increased by more than 50 percent, and it has undergone testing on a full-scale test stand at GDEB for more than 4000 cycles of service. The coating exceeded the required adhesion strength and performance levels developed by iMAST and defined by GDEB. NAVSEA has given its approval for implementation and the project has proceeded to vendor qualification. A vendor has been identified and has completed work defined in the qualification test plan. Once the vendor passes this qualification test, NAVSEA's approval will be given and the implementation process will be completed. The project has been transitioned to GDEB for implementation and production of assets for installation on Block IV VCS as part of their new construction. This project was led by iMAST, with a portion of the work performed by the Naval Shipbuilding and Advanced Manufacturing (NSAM) Center.

PI: Todd Palmer, Ph.D. and Doug Wolfe, Ph.D.



U.S. Navy released photo

S2600 — Shipyard Capacity Planning Tools at BIW



Affordability Focus Area: Automated Tools, Advanced Manufacturing Enterprise
Stakeholder: NAVSEA PMS 400D and PMS 500
Platform(s): DDG 51/DDG 1000

Objective — Transition Capacity Planning Tools to Bath Iron Works to support production demands.

Capacity planning is the process of ensuring that production capacity is matched to demand. Capacity planning enables facilities to meet critical delivery schedules at minimized costs. Bath Iron Works (BIW) has legacy production information systems that can be used to facilitate more robust capacity planning analyses. However, the capabilities of these tools are not fully exercised due to significant upfront customization of the systems to meet initial implementation requirements that limits their analysis capabilities. In addition, planners often employ a plethora of “tools” (spreadsheets, databases, etc.) to understand the demands on resources such as labor, machines, fixtures, or space under their control. Therefore, there are increased chances of disparate plans being developed that are not efficiently synchronized to the master production schedule.

The objective of this iMAST project is to develop a shipyard-wide capacity planning system that enables the BIW planning organization and construction management personnel to conduct both long-term, shipyard-wide and short-term, shop-level capacity planning for critical shipyard resources in support of their DDG 51 and DDG 1000 shipbuilding programs. Specifically, this project will develop a central data system, long-range and shop-level capacity planning tools, and integrate the previously transitioned Spatial Scheduling Tool into the system.

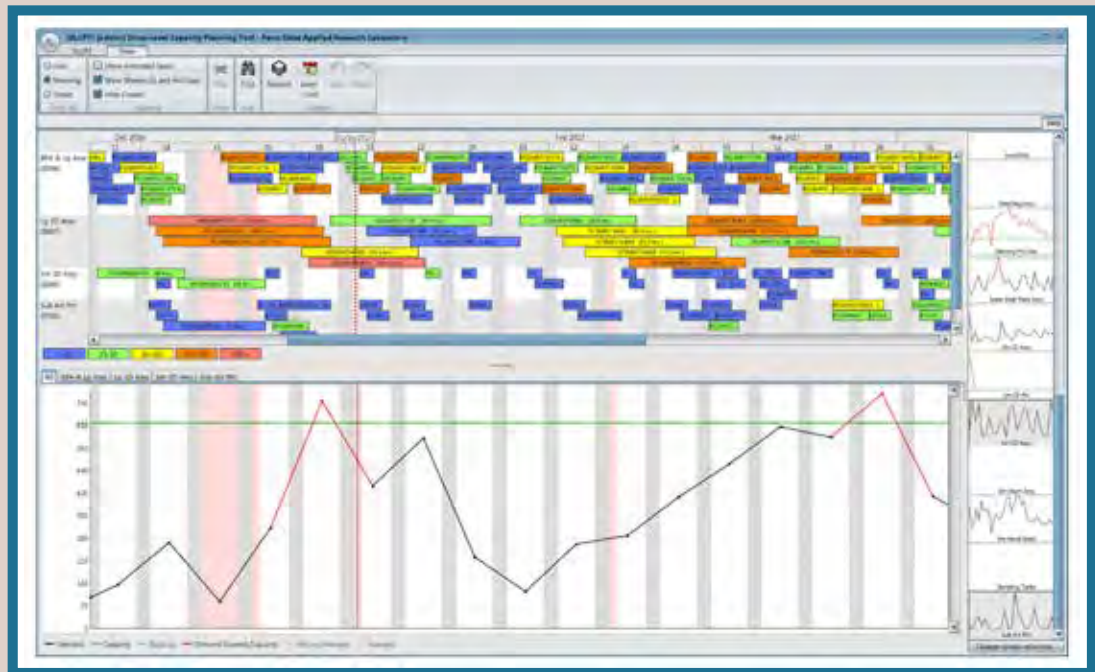
Payoff

The implementation of the capacity planning tools at BIW is expected to result in a reduction of overtime trade-labor hours and a reduction of labor hours for production planning and control personnel. The Capacity Planning System will speed up the time to develop capacity plans and enable rapid mitigation when existing plans require modification. BIW projects the savings for production and planning personnel to be an estimated \$741K/hull, resulting in a one-year ROI of 6:1. In addition to the quantitative benefits, qualitative benefits are expected to include improved visibility of potential space conflicts in advance of production and reduced non-value-added ship product movement.

Implementation

Prototype versions of the Long-Range and Shop-Level Capacity Planning and integrated Spatial Scheduling tools were demonstrated and transitioned to BIW planning department incrementally during Phase 1 of this project. These demonstrations included members from the user community and planning department management. Several iterations of the software were delivered and tested by the BIW user group and are beginning to be transitioned into the planning process workflow. Phase 2 will continue to develop the tools focusing on the development and transition of the Shop-Level Capacity Planning Tool. Transition is underway.

PI: Chris Ligetti



S2550-A-B —Trade Friendly Locating Dimensional Techniques



U.S. Navy released photo

Affordability Focus Area: Advanced Manufacturing Enterprise/Metals Processing and Fabrication

Stakeholder: NAVSEA PMS 450

Platform(s): Submarines

Objective — Employ trade-friendly locating dimensional technologies to improve productivity.

Metrology technologies have dramatically increased their functionality and purpose for modern manufacturing. General Dynamics Electric Boat (GDEB) has capitalized on this technology by acquiring and using modern metrology systems for various Virginia-Class Submarine (VCS) alignments and inspections but the technologies of choice are currently limited to certified and highly trained tradesmen and engineers. GDEB VCS modular construction (hull sections and hull decks) requires the tradesman's ability to quickly and accurately obtain metrology coordinate placement data during manufacturing operations, not post-manufacturing inspection and alignments.

The goal is to determine the feasibility and cost-effectiveness of GDEB "trade personnel" friendly dimensional locating metrology technology for immediate incorporation into the VCS manufacturing processes. This ManTech project is divided into two distinct phases, executed similarly to other standard process improvement efforts. The project team will focus on both the physical requirements as well as the information requirements to prepare a tradesman to perform their work. In Phase 1, a total of 15 different metrology systems were evaluated against the defined requirements. Of these 15 systems, two were identified as meeting the requirements. The final two systems have demonstrated through execution of an evaluation test plan that they are capable and viable for prototype testing. One system is being prototyped in Phase 2, currently underway. This system was the top pick for 'trade friendliness' and earned the highest score during the technology evaluations. Phase 2 is focused on testing of the down-selected technology identified and qualified based upon the requirements obtained during the Phase 1 investigation. While the primary focus of this project is the VCS Program, it also offers opportunities to improve manufacturing processes for the Ohio Replacement (OR) Program.

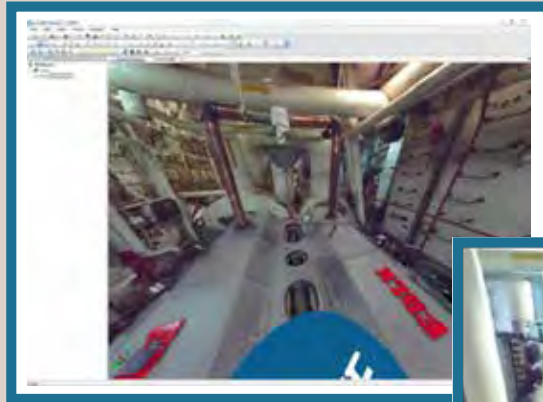
Payoff

This technology, once implemented, can potentially save an estimated \$860K per VCS hull and Ohio Replacement hull. These savings will result from replacing or enhancing common mechanical measurement tooling.

Implementation

Implementation is expected to employ a phased approach, where the most beneficial opportunities will be assigned higher priority and implemented first. This project may be in the process of being implemented in production of VCS hulls. The schedule for implementation activities, however, is dependent on project results. This project is a joint COE effort between Naval Shipbuilding and Advanced Manufacturing (NSAM) Center and the Institute for Manufacturing and Sustainment Technologies (iMAST).

PI: Sean Krieger





Repair Technology

Timothy Bair
Technology Leader



Repair Technology

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.



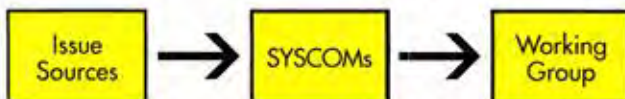
U.S. Navy released photo

Repair Technology

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



Implementation...through shipyards, depots, logistics supply centers, and OEM/contractor facilities



CHARTER

...Apply new, emerging technologies to improve the capabilities of the repair community
...Improve repair processes and the affordability of repair facilities



Closing the gap...between the capability of the repair process and the sustainment requirements of the weapon system

U.S. Navy released photos



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.

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 CO2 laser, all operating in the far infrared regime). This resource includes:



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- 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.

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)

Lasers

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



ARL released photo

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

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.



ARL released photo



ARL released photo

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:

- 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



ARL released photo

CIMP-3D Facility



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.

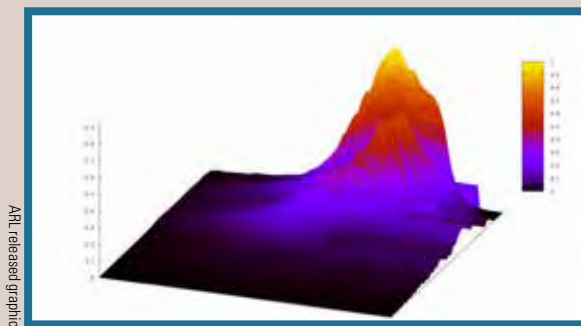
Facilities and Unique Capabilities:

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



Enhanced inspection tools can 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



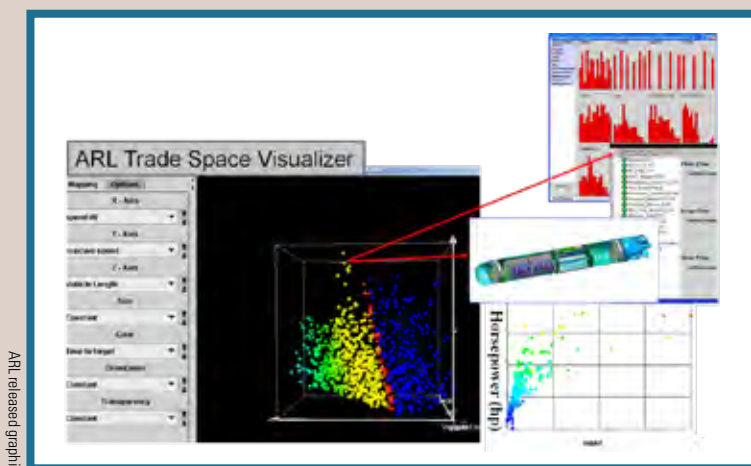
U.S. Navy released photo

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.



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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.



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.

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.

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UNIQUE CAPABILITY

Critical Element Design, and Analysis and Testing

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

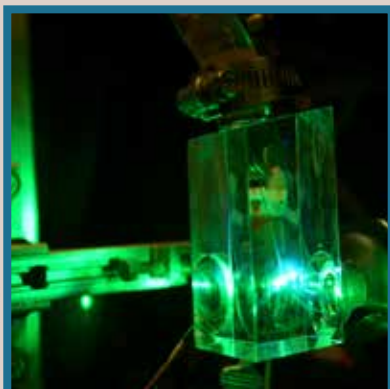
manufacturing technologies are then used to fabricate these test articles that are instrumented and tested to capture data that can be used to verify and/or refine developed numerical models. While such individual capabilities exist in other organizations, the division has streamlined the Critical Element 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.



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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.

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.

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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.

UNIQUE CAPABILITY

High-Rate Fatigue Test and Evaluation

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.

To predict fatigue failure thresholds of composite components, a new fatigue prediction method has been developed. 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.



In-air Testing



In-water Testing

ARL released photos



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.

Facilities and Unique Capabilities:

MATERIAL CONSOLIDATION



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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

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)

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)



ARL released photos

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 ($Z=10^{13} \Omega$)
- 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
- Metrolane M4L Plasma Etcher (Litho descum, surface 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

- Kurt 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, AlGaIn
- 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



ARL released photos



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.



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, with guidance from the Office of Naval Research, we continue to build our reputation as a national resource. The broad technological objectives driving our research and development agenda are driven by the following 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

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.



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

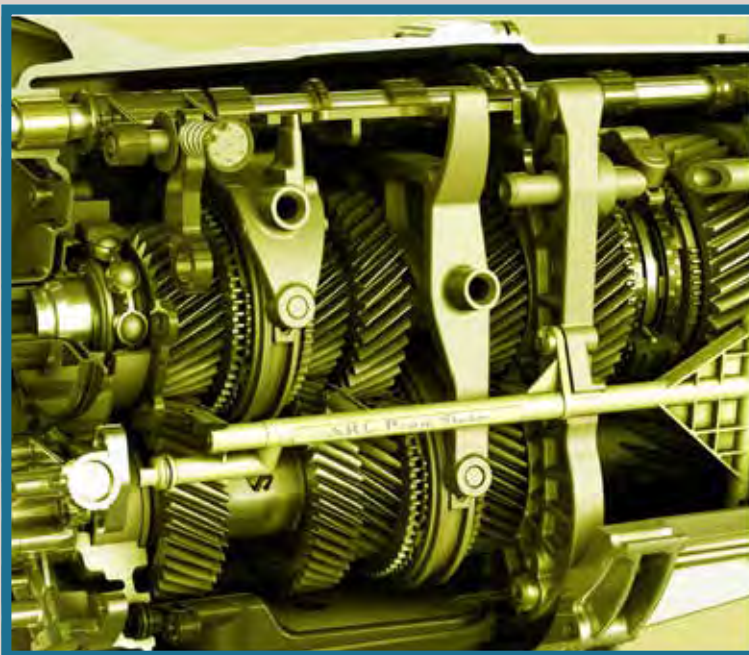
ARL's Drivetrain Technology Center is host to resident U.S. Navy provided gear metrology equipment (with supporting artifacts). The center serves as a neutral or "honest broker" testing site for verifying measurement accuracies related to gear specifications. This capability is fundamental and basic 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.



ARL released photos

Gear Research Institute



Transmissions

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...

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 funded 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)

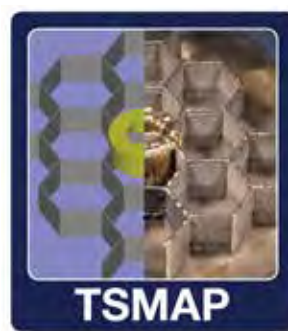
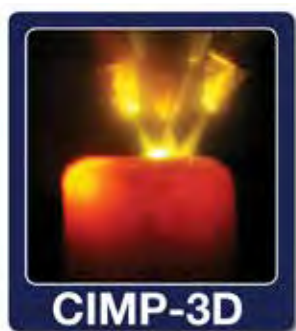
This program is developing FAST-based process technology for rapid, low cost fabrication of high performance armor for personnel and vehicle systems.

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.



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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
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.



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.



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.

Office of Naval Research

Sponsor Profiles



Rear Admiral David J. Hahn USN

Chief of Naval Research

Rear Admiral David J. Hahn recently assumed leadership of the Office of Naval Research, becoming the 26th Chief of Naval Research with concurrent flag responsibilities as Director, Innovation Technology Requirements, and Test & Evaluation (N84). Admiral Hahn succeeds Rear Admiral Mathias W. Winter who has assumed duty as deputy director, Joint Strike Fighter Program, Under Secretary of Defense for Acquisition, Technology and Logistics. The admiral arrives at the Office of Naval Research following duty as special assistant to the Deputy Chief of Naval Operations for Information Warfare.

A 1985 honor graduate of the United States Naval Academy, Admiral Hahn earned his Dolphin pin and served aboard the USS Casimir Pulaski (SSBN 633), USS William H. Bates (SSN 680) and USS Springfield (SSN 761), deploying to the North Atlantic and Western Pacific, conducting multiple strategic deterrent patrols. Ashore, Admiral Hahn served as flag lieutenant to Superintendent, U.S. Naval Academy; squadron engineer, Submarine Development Squadron 12; action officer, Joint Staff in the Command, Control, Communications and Computers(C4) Directorate; and legislative fellow on the staff of U.S. Senator John Warner. Admiral Hahn commanded the USS Pittsburgh (SSN 720) from September 2003 to January 2007. In command, Admiral Hahn deployed to the Caribbean Sea and Pacific Ocean, and conducted an Engineering Overhaul in Portsmouth, New Hampshire.

Since becoming an acquisition professional in 2007, he has served as Joint Test and Evaluation test director and program manager, Advanced Submarine Research and Development. He has also served as major program manager, Submarine Combat and Weapon Control Systems program. In addition to his Bachelor of Science degree in mechanical engineering from the U.S. Naval Academy, Admiral Hahn holds a Master of Business Administration degree from George Mason University and has completed the Massachusetts Institute of Technology Seminar XXI program in International Security Affairs.

Admiral Hahn's personal awards include Defense Superior Service Medal, Legion of Merit, Defense Meritorious Service Medal, the Meritorious Service Medal (three awards), the Navy and Marine Corps Commendation Medal (four awards), the Navy and Marine Corps Achievement Medal and various campaign and sea service awards.



Brigadier General Julian D. Alford USMC

Vice Chief of Naval Research

Commanding General, Marine Corps Warfighting Laboratory

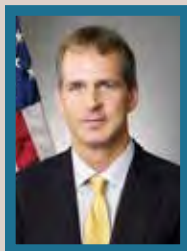
Brigadier General Alford attended West Georgia College and, as a sophomore, enlisted in the Marine Corps Reserves in 1985. Following graduation from college he was commissioned as a Second Lieutenant of Marines in December of 1987.

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 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.

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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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