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iMAST

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

FY 2006 Annual Report

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A Message from the Director

Thank you for looking over our Fiscal Year 2006 annual report. These few pages represent the culmination of a one-year effort by the men and women of the Institute for Manufacturing and Sustainment Technologies (iMAST), as a component of the Applied Research Laboratory (ARL) at Penn State. We strive to better equip our Sailors and Marines and help them keep their equipment at the readiness levels our nation needs to fight The Global War on Terrorism. iMAST is a Navy Manufacturing Technology (ManTech) Center of Excellence established by the Office of Naval Research for the purpose of providing focal points for the development and technology transfer of new manufacturing technology, processes, and equipment in a cooperative environment with industry, academia, and U.S. Navy centers and laboratories. Navy ManTech Centers of Excellence:

- serve as corporate residences of expertise in particular technological areas
- develop and demonstrate manufacturing technology solutions for identified Navy manufacturing requirements
- facilitate the transfer of developed manufacturing technologies to the U.S. industrial base

This report describes this years projects, executed within the six technical areas that are especially resident in the materials and manufacturing office of ARL Penn State. Along with the technologies, descriptions of completed and on-going projects are provided. These are representative examples of our competencies. ARL is proud of its 66-year history supporting the U.S. Navy and the Department of Defense with advanced engineering and science, applied to help solve today's technical challenges and accomplish the mission. In addition, iMAST and ARL have reach-back capability to the vast resources of The Pennsylvania State University, to further support our Navy and DoD charter.

While the men and women of ARL are proud of the role we play in supporting national security, I am hoping that you will see that ARL is more than your standard-issue academic institution. ARL has over 1000 research engineers, scientists and staff, dedicated to full-time DoD mission-related support. We are the largest research center at Penn State. We pride ourselves in our ability to transition immature technology to (at least) the prototype level. And we deliver on time. We have state-of-the-art research facilities operated by some of the best researchers in the country. Additionally, we have a focus on delivering what the customer wants WHEN they need it. Our omnibus contract with the Naval Sea Systems Command can be used to fund projects rapidly for any military organization.

We are a Department of the Navy/Department of Defense asset. We are here to help. Take advantage of us!

Timothy D. Bair

Timothy D. Bair
Director, Institute for Manufacturing and Sustainment Technologies
ARL Penn State

"I think adapting not just to change, but speed of change, is critical."

Admiral Mike Mullen, USN Chief of Naval Operations

PENNSTATE iMAST

Applied Research Laboratory
Institute for Manufacturing and
Sustainment Technologies

What is iMAST?

The Institute for Manufacturing and Sustainment Technologies (iMAST) is a Department of the Navy Manufacturing Technology (ManTech) Center of Excellence located at The Pennsylvania State University's Applied Research Laboratory in State College, Pennsylvania.

Formally established in 1995, the institute is comprised of seven technical thrust areas:

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

iMAST provides a focal point for the development and transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, other Navy acquisition, and in-service use. 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. Sponsored under Navy contract N00039-97-0042, iMAST provides manufacturing technology support to the systems commands of the U.S. Navy and Marine Corps.

Mechanical Drive Transmission Technologies

Technology Leader: Suren Rao, Ph.D.

Mission

To assist in the enhancement, revitalization, and resurgence of the transmission industrial-base sector of the United States. This assistance is necessary for several reasons. It is essential that this particular industrial base remains viable, competitive, and robust in order to effectively address U.S. Navy, Marine Corps, and DoD modernization and surge requirements. Further, this industrial sector is critical to the national transportation infrastructure and, therefore, needs to remain responsive and competitive to address national interests. In order to achieve the stated objectives, iMAST needs to be recognized as a national resource. Since it is the industrial sector that supplies the DoD with mechanical drive transmission components and systems, it is essential that this recognition be derived from both industry and government sectors alike. The broad technological objectives driving the research and development agenda of iMAST are noted by the following stated DoD goals:

- Reduce transmission weight by at least 25 percent
- Reduce vibration and noise by at least 10 dB
- Increase MTBR (mean-time-between-removals) by 20 percent
- Reduce procurement and operating costs (affordability)

Continued influx of industrial, dual-use sponsored research has been a prominent feature of the Drivetrain Technology Center during this current year. Featured among them has been the program to qualify ausform finishing for aerospace gears sponsored by Boeing Mesa, with partial support from the ONR DUS&T program and a variety of smaller projects from industrial organizations such as New Venture Gear, John Deere, Genesis Corporation, and Harley Davidson. Also active have been evaluation programs for new materials for gear applications including powder metal alloys and high-hot-hardness steels.

These projects are the direct result of establishing one of the most comprehensive testing and evaluation facilities in the nation for gears and gear materials at the Drivetrain Technology Center, together with a state of the art gear metrology facility. This metrology laboratory includes a one of a kind M&M OP 9000 CNC (Computer Numeric Control) Gear Measuring Machine with two measuring stations. One station is based on a conventional touch probe and the other is based on the optical gear tooth measuring system, being developed at ARL.

The mechanical drive systems transmission thrust areas include the following:

- Develop advanced manufacturing processes and equipment
- Improve current manufacturing techniques
- Evaluate advanced hot-hardness steels for improved performance
- Characterize impact of materials and related processing on component strength and durability
- Characterize impact of component accuracy on performance
- Develop improved metrology equipment and techniques for enhanced component accuracy
- Analysis of drive systems designs for improved performance

Unique Capability

Drive System Component Materials Testing is an essential requirement to validate process qualification in support of high-performance transmission technology. Rolling Contact Fatigue (RCF) testers for simulating gear tooth contact, Single Tooth Fatigue (STF) testers for evaluating bending fatigue, and Power Circulating (PC) testers for contact fatigue testing on gears are essential equipment. ARL Penn State has one of the most comprehensive and unique collections of transmission testing equipment in the United States. Both RCF and STF testing can be conducted at temperatures of up to 400°F. Variable PC 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.

Super-Finishing of CH-46 Transmission Gears

Project Leader:
Suren Rao

The objective of this program is to establish the durability of aft transmission gears during the depot rework process of the CH-46 Sea Knight. The traditional practice of swapping out new gears is considered an expensive replacement practice, whereas repairs using the REM process bring substantial cost avoidance to the program. This project will establish the durability of “super finish” gears, documenting reduction in heat losses due to super finishing process. Gears that are still serviceable will be reprocessed for incorporation during the depot process.

Performance Testing of Ausform Finished Gears

Project Leader:
Nagesh Sonti

The objective of this project is to evaluate the surface durability and strength of ausform finished gears as compared to conventionally processed gears. Program tasks include developing the tooling and process parameters to ausform finish the 48 teeth, 6” PD test gears. The second phase of the program involves developing specialized tooling and processing techniques to enable ausform finishing of the root/fillet regions of the gear teeth, in addition to the tooth flanks. Pitting and bending fatigue as well as scoring resistance of test gears will be evaluated to establish the performance enhancement of ausform finished gears as compared to ground gears. The project will establish the quantitative design information that will facilitate implementation of the process for high performance drive train applications. The project is applicable to transmission components used in air, surface, undersea and ground combat weapon systems, and Boeing Mesa is actively participating in the program with cash and in-kind support.

Experiments to optimize the rolling die tooth profile for ausform finishing were conducted during the year and after five iterations a final die tooth grind is currently in process. These experiments have clearly shown that achieving tooth accuracy for aerospace gears (AGMA Class 12 and better) will be significantly aided by the development of a process model. These verified analytical process models will enable the definition of die tooth geometry, required to achieve that level of gear accuracy, with a minimal number of iterations. The effort of developing process models for ausform finishing forms a significant part of the Boeing Mesa/ONR sponsored DUS&T program, currently underway. Fatigue testing of base line gears and design of rolling dies for root rolling development have been accomplished, as a part of this effort, in the last year.

Ausform Finishing of Bearing Races (Non-ManTech)

Project Leader:
Nagesh Sonti

The objective of this project is to evaluate advanced surface enhancement techniques including ausform finishing in conjunction with multilayered coatings to enhance surface durability, wear and corrosion resistance, and thereby, the mean-time-before-overhaul of transmission bearings. Enhanced surface strength due to ausforming has the potential to substantially improve the power density of transmission bearings. The project will develop the tooling and processing techniques for bearing raceways, and involve comprehensive bearing testing to establish the comparative performance of surface enhanced bearings. The project is structured with substantial in-kind contribution from Rexnord in terms of specimen manufacture and bearing endurance testing. Project supports multi services and multi weapon systems, and the demonstration component is a cylindrical roller bearing from AAAV main transmission.

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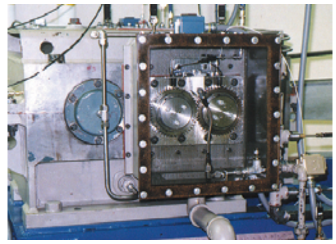

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Unique Capability

Ausform Finishing is the process of heating a case-hardened steel specimen to a red-hot temperature, quenching it to a working temperature, followed by rolling it to maximize strength and geometry. ARL Penn State possesses the world's only production-capable double-die ausform finishing machine.

Non-Contact Workpiece Positioning System (Non-Mantech)

Project Leader:
Suren Rao

The ultimate objective of this project is to reduce costs and lead-time in the machining of large precision drive train components such as transmission housings. The approach being pursued, under this program structure, is to eliminate the use of physical surfaces on the component as datum. The use of physical surfaces as datum during machining is a methodology that has remained unchanged since the dawn of machining and is susceptible to creating inaccurate parts due to variety of reasons. Some of these reasons are inaccuracies in the datum surfaces themselves, ingress of chips, burrs and dirt between matching datum surfaces, etc. In spite of a significant amount of care being currently exercised in the manufacture of such components, to overcome these problems, high scrap rates are not uncommon. Further, the use of physical datum surfaces for precision machining requires the design, manufacture, storage and retrieval of very expensive, part specific work holding tooling. All the drawbacks of this methodology, listed, results in excessive costs in the manufacture of these components and very long production lead times.

The solution being explored is to develop the methodology of defining a "VIRTUAL" datum on the part before machining and the methodology to identify this datum on the machine tool before initiating the machining part program. This would enable the part program to be exercised for where the part is, on the machine, thus resulting in a more accurate part in less time.

This methodology, utilizing a laser-triangulation probe has been developed on a 5-axes machining center and shown to be capable of machining the 3 primary bores of SH-60 main transmission input housing in about half the time while maintaining the specified part print accuracy between the bores. This system was demonstrated to Sikorsky Aircraft and Navy personnel on the 5-axes Machining Center at ARL's Garfield Thomas Water Tunnel machine shop. Based on the successful demonstration Sikorsky Aircraft is planning an installation at its Stratford facility and is evaluating various alternate schedules, based on their shop load, to implement the Non-Contact Workpiece Positioning System. Once the time frame is selected an "industrially hardened" system will be installed on a select machine tool at Sikorsky Aircraft.

In-Situ Gear Error Measurement

Project Leader: William Mark

At the request of the Naval Sea Systems Command, the development of a method of measurement and associated signal processing for precision determination of the amplitudes of gear tooth undulation errors was completed and programmed on a digital computer. The method was tested and successfully used for in-situ measurement of undulation-error peak-to-peak amplitudes in the range of 0.01 to 0.30 microns (meters × 106). Also, a method for computing the "influence functions" of gear tooth elastic deformations on lines of tooth contact, including accurate computation of the local contact (Hertzian) component of deformations, was completed and successfully implemented on a pair of helical gears.

Unique Capability

A Navy Metrology Laboratory located at ARL Penn State provides the U.S. Navy with 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. The laboratory provides the Navy with an on-call 48-hour resident resource for addressing gear metrology technical issues related to naval weapon systems platforms.

Process Development of Advanced Gear Steels for High-Performance Transmission Application (Non-ManTech)

Project Leader: Nagesh Sonti

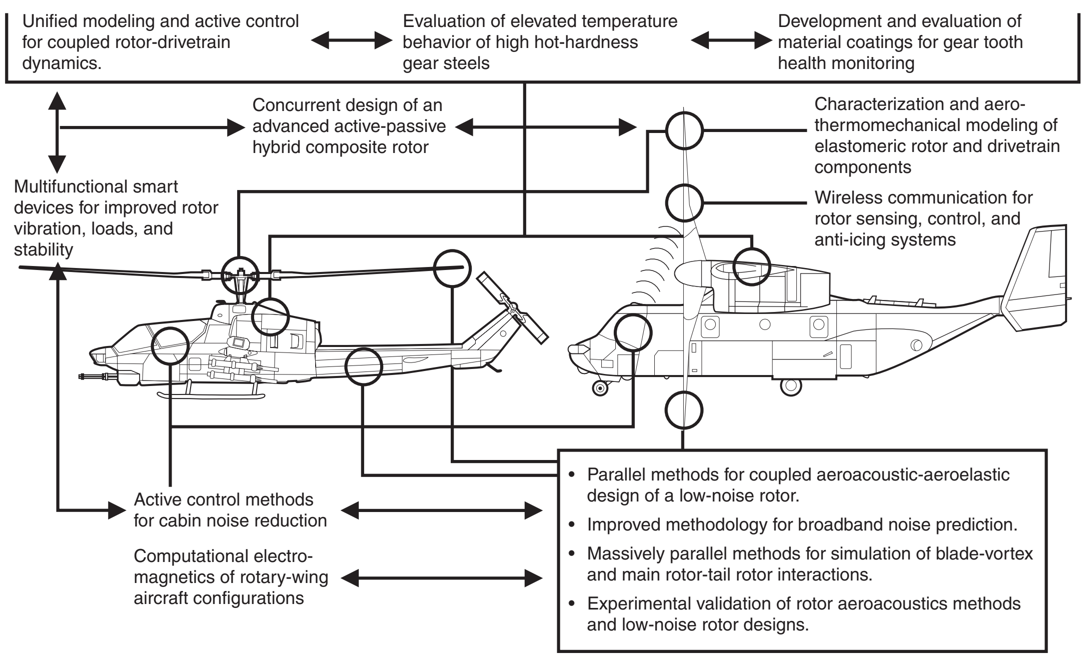
This project continues to evaluate the durability, fatigue strength, and scoring resistance of selected advanced gear steels for air vehicle and turbine engine applications. The project tasks include heat treatment and manufacturing process optimization; manufacture of precision gear test specimens; dimensional and metallurgical test specimen inspection before-and-after testing; single tooth bending fatigue testing, rotating surface fatigue testing, scoring resistance testing; and the establishment of a comprehensive advanced gear steel data base for use by design engineers. The project is funded by an advanced materials coalition of ten industrial members including Allison Engine Company, Allvac (An Allegheny Teledyne Company), Arrow Gear Company, Bell Helicopter Textron, Boeing Helicopters, Boeing Precision Gears Incorporated, Carpenter Technology Corporation, Latrobe Steel Company, Sikorsky Aircraft Corporation, and The Purdy Corporation.

This program will develop affordable improved fatigue- and scoring-resistant materials for high-performance drive system components including gears, bearings, and shafts. Reliable materials manufacturing processing data will be established, as well as fatigue and scoring resistance data which is required by design engineers for improving power density, reliability, and life-cycle-cost drive systems. Concurrent investigation of four advance steels was conducted throughout the year and will continue into fiscal year 2000.

Penn State Vertical Lift Research Center

Director: Ed Smith, Ph.D.
Project Leaders: Tom Donnellan and Greg Johnson

iMAST continues to play a supporting role with Penn State's Rotorcraft Center of Excellence. The center of excellence is one of three centers in the country that conduct long-term basic and applied research in rotorcraft technology. 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.



Gear Research Institute

Co-located with the Drivetrain Technology Center at Penn State, the Gear Research Institute provides additional expertise relative to mechanical drive transmission efforts ongoing at the Applied Research Laboratory. Although not affiliated with the Navy ManTech Program, the Gear Research Institute, which is sponsored by industry, provides a conduit for Navy ManTech since partnering with industry is an essential element of the program.

A not-for-profit corporation, the Gear Research Institute is organized to provide and supplement gear-related technology requirements by conducting research and development, consulting, analysis and testing. The Institute is a leading proponent of Cooperative Pre-Competitive Research. When requested, however, it also serves individual companies. Since its inception in 1982, the Gear Research Institute has conducted technology programs in the following areas:

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

Over the last two decades extensive research and test data has been accumulated and published in a large number of reports to the sponsors. The Gear Research Institute has all its research and other related activities conducted at Penn State's Applied Research Laboratory.

Test Facility

The Gear Research Institute is equipped with state-of-the-art test capabilities. These include Rolling Contact Fatigue (RCF) testers for low and high temperature roller testing, Power Circulating (PC) gear testers for parallel axis gears with a 4-inch center distance (testers can be modified to accommodate other center distances), Single Tooth Fatigue (STF) testers for spur and helical gears, Single Tooth Impact tester, and worm gear testers with 1.75- and 4-inch center distances. Extensive metallurgical characterization facilities are also available at Penn State, in support of the Gear Research Institute.

Current Sponsors

The activities currently underway are under the sponsorship of three research blocs. The sponsorship of each bloc is the following:

Aerospace Research Bloc

Boeing Helicopters	Rolls Royce	Pratt & Whitney
Honeywell	Avio Group	Purdy Corporation
REM Chemicals	Sikorsky Aircraft	

Vehicle/Industry Research Bloc

Dana Corporation	General Motors	Eaton Corporation
New Venture Gear	REM Chemicals	

Efforts are currently underway to establish a bloc focused on evaluating hard coating systems for power transmission applications.

Trustees and Committees

POC:
Suren Rao

The Gear Research Institute is governed by a tripartite Board of Trustees representing the membership of the Institute, the American Society of Mechanical Engineers (ASME), and the American Gear Manufacturers Association (AGMA). For the research effort, each Research Bloc creates its own Steering Committee whose responsibility is to select and guide programs within their respective bloc.

Materials Processing Technologies

Technology Leader: Tim Eden, Ph.D.

Mission

To perform applied research, development and engineering on materials and materials processing in support of the manufacturing requirements of the Department of Defense and the domestic industrial base. To satisfy these requirements, ARL Penn State capabilities in advanced metals and ceramics development, materials processing, electronic materials and surface technologies. Our focus is to act as a leader in the field of material science by providing innovative solutions to the material technical challenges of today and tomorrow. Our goal is to minimize the acquisition and life cycle costs of DoD weapons and support systems.

The Material Processing Division had three ManTech projects on-going during the fiscal year showing the wide technical base, knowledge, and vast expertise of division personnel. The objective of each program is to provide a complete material solution and develop viable transition path. On all the programs the root cause of the problem or final component properties are determined. A solution is then identified and a technical program developed for implementation to realize the objectives. In programs such as the Corrosion Resistant Coatings for Magnesium Transmission Gearboxes for SH 60R/S Seahawk, a procedure is being developed to improve the corrosion resistance of magnesium alloy used in the transmission gearbox housings. This program is using leverage funding with an Environmental Security Technology Certification Program (ESTCP) titled Supersonic Particle Deposition Technology for Repair of Magnesium Aircraft Components. The transition for the Navy will be through NADEP-Cherry Point.
Coating optimization and corrosion testing are now in progress.

The materials processing thrust is organized into three departments:

- Metals and Ceramic Processing
- Advanced Coatings
- High Pressure Laboratory

Technical capabilities include coating for corrosion resistance, wear resistance, thermal barriers, environmental barriers and functional tailoring of materials and laminate structures, and higher performance aluminum alloys. Division technology has been applied to near-net shape forming of high temperature materials and nanomaterials.

Unique Capability

Spray Metal Forming is a rapid solidification process that can significantly enhance the properties and microstructures of engineering alloys and can also create new alloy compositions not possible using conventional processes. The process begins with the atomization of a metal stream with inert gas. The stream collected onto a plate or mandrel, is sufficiently void free and can be used in the as-sprayed condition or further processed by forging, extrusion, or rolling. The ARL Penn State metal forming plant is a multi-use pilot plant that can spray both ferrous and non-ferrous alloys. The plant has the capability to spray form materials into billets, sheets, and tubes. It is the only plant in North America dedicated to the development and optimization of high-temperature and high-strength aluminum alloys. ARL is currently producing high-strength alloys with yield strengths up to 105 ksi and ductility between 9 and 13%, high-temperature aluminum alloys that maintain working strength up to 300ºF, and metal-matrix composites.

Corrosion Resistant Coatings for Magnesium Transmission Gearboxes for SH 60R/S Seahawk

Project Leader:
Tim Eden

The objective of this project is to develop a corrosion resistant coating for the magnesium alloys used in the transmission gearbox housings of the UH60 Seahawk. The coating will be applied using the High Velocity Particle Consolidation Process (HVPC). This process is also known as the Cold Spray Process. The HVPC process deposits the coating in the solid state and reduces or eliminates any adverse thermal effects that are part of conventional thermal spray processes. The coating will be applied are made from ZE 41 magnesium alloy. During use, the magnesium alloy is subject to corrosion and pitting damage. When the damage reaches critical levels, the component must be replaced. The ability to refurbish damage components will improve readiness and will save millions of dollars. In addition to the magnesium transmission housings there are several other components of fixed wing and rotorcraft that experience similar problems.

Efforts include selection of the optimal coating material, optimization of the coating process, economic analysis, and transition of the technology. Coating optimization and corrosion testing are now in progress. Coatings are being evaluated for density, hardness, adhesion strength, and corrosion resistance.

This program is using leverage funding with an Environmental Security Technology Certification Program (ESTCP) titled Supersonic Particle Deposition Technology for Repair of Magnesium Aircraft Components. A Joint Test Protocol (JTP) will be developed through the ESTPC. The JTP will receive input from ARL-Penn State, the Navy, the Army, DoD maintenance depots, JSF, and from the OEMs. The transition for the Navy will be through NADEP-Cherry Point.

Hot Section Corrosion Protection for 501-K34 Gas Turbine

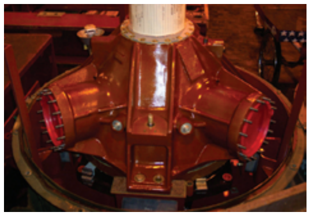
Project Leader:
Douglas Wolfe

501K34 blades, vanes and tracks have limited life due to type II hot corrosion, and are not meeting the design specification of 20,000 hrs, with many, but not all, first stage blades failing at approximately 10,000 hours. More than 15 sets of blades have been pulled from the field due to corrosion attack, 2 sets of blades being pulled with as little as 10,000 hours, and two turbines having failed to date. The two failures to date are attributed to "under platform" corrosion attack.

The current proposed solution in applying corrosion-resistant coatings that can extend component life. Efforts are underway in changing the presently used argon shielded plasma spray CoCrAlY coating to a PtAl diffused coating to resolve this problem. Part of ManTech efforts include prescreening metallic coating materials and coating deposition processes for improved corrosion resistant performance. In addition, corrosion resistant thermal barrier coating systems are being explored that will further extend the life of gas turbine components under severe hot corrosion environments while allowing a wide range use of low grade fuels available without GT component degradation or decreased engine performance.

In addition, it is desirable to reduce the manufacturing cost in applying corrosion resistant metallic CoCrAlY coatings by alternative technologies including HVOF, low pressure plasma spray (LPPS), and atmospheric plasma spray (APS) processes. NAVSEA desires to replace some engine components and test thermal barrier coated components under the same hostile environment for comparison with EB-PVD CoCrAlY coated components which are being phased out.

The main objectives of this project are identifying a corrosion resistant coating system and coating deposition processes that will improve the life of gas turbine vanes for the 501K34 gas turbine generator weapon system and deliver coated hardware for field



SH-60 Transmission Gearbox

ASP1431 Stage I Vanes showing corrosion damage

Stage I compressor blisk showing leading edge damage

testing consisting of the best matrix coating system. In order to understand the failure mechanism or contributing factors in the premature failure of 501K34 gas turbine vanes factors such as water vapor and sulfur-based (and vanadium-based) salt corrosion will be individually determined. This effort is being carried out in many phases. In the initial phase, thermal cyclic testing of coated samples will be carried out in dry air and water vapor and at two temperatures (900°C and 1100°C). Type I and Type II hot corrosion testing will be performed at the Naval Surface Warfare Center Carderock Division, Bethesda MD in a marine salt air, sulfur-doped NATO F-76 environment using a burner rig test facility that simulates engine-operating conditions. Down selection of the best performing coating system will then be evaluated in ASMET/Field testing. There is number cost sharing involved with the project with participants from NASA, NAVSEA, NAVAIR, FCT, Rolls Royce, DVTI, ISU, UCONN, Trans Tech and PSU.

Erosion Resistant Coatings for Stage I Compressor Components

Project Leader: Douglas Wolfe

1st Stage compressor blades of T700 (composed of GEAM355 stainless steel) engines exhibit leading edge (LE) curl damage associated with large particle and high angle (60o to 90o) impingement of erosive media. These blisks have limited/reduced life due to continuous erosion and curling of the leading edge. Decreased service life and increased maintenance costs occur as the realized time-of-flight (2500 hours) is only half of the expected time-of-flight (5000 hours), and in some aggressive environments (Iraq and Afghanistan), approximately only 100 hours (50 x less) are realized. The approximate repair cost is $110,000/engine, and it is estimated that there are several thousand engines requiring continuous repair of 1st Stage compressor components, currently made of GEAM355 stainless steel. Therefore, repairing engines with significantly reduced mean-time-between-overhaul due to the leading edge curl phenomenon is a major cost driver in the total cost of ownership of H-60 helicopter fleet. There is presently a corrosion resistant coating applied to the components, but under erosive conditions, the protective barrier is removed rather quickly providing little to no benefit. An alternative corrosion coating system is also desired. Leading edge curl of the 1st stage airfoils adversely impacts vehicle performance by decreasing engine special high performance between 20-30%, increasing engine fuel consumption, increasing engine temperature, and decreasing engine stall margin. It is anticipated that a better understanding of the Leading Edge mechanism, will assist in proper selection of duplex or multilayer coatings to resist erosion at high impact angles and against large particles.

Efforts include metallurgical evaluation of the leading edge and to perform mathematical models in an effort to better understand the causes of the leading edge curl phenomena. Preliminary results suggest that it is the result of a combination of large particle impact and erosion causing plastic deformation. Current ManTech project includes prescreening high angle and low angle erosion resistant coating materials to be incorporated into a duplex or multilayer coating system to minimize erosion and increase stiffness are being investigated. The primary objective of this project is to identify and implement a duplex or multilayer erosion resistant coating system with improved erosion resistance over a wide range of abrasive particle impingement angles for increased life of the H-60 helicopter fleet. A key product of this work will be to establish a process methodology for applying duplex erosion resistant coatings capable of withstanding high angle impingement of erosive media (60o-

90o). Hard monolithic coatings (titanium nitride-based) are being considered as erosion resistant coatings to improve compressor blisk and component life. However, erosion of such hard coatings increases at higher angles of hard particle impingement (i.e., sand). Selective ductile metallic coatings show increased erosion resistance at these higher angles, but poor resistance at low impingement angles. Therefore, no single coating offers sufficient resistance to erosion at both high and low angles. The current project proposes to develop multilayer duplex coating system offering erosion resistance to both high and low angles of hard particle impingements through incorporating hard and ductile metallic coatings in duplex or multilayer design.

Completed Programs

F/A-18 F404 Fretting and Low-Cycle Fatigue Amelioration

Three Molybdenum (Mo) and three Nickel (Ni) coated blades along with six copper-nickel-indium (CuNiIn) coated blades were tested in the Accelerated Service Mission Endurance Test (ASMET) Engine Pegasus F402-RR-408B engine 12322 build 4 LPC. Wearcoat® was applied to the blades using a solgel process prior to the engine test. The Mo-Wearcoat® system showed the greatest resistance to wear. An additional set of 17 blades were coated using the Mo-Wearcoat® system. These blades were tested in a second ASMET. Successful completion of the test will completed the technical qualification of the process.

AAV Appliqué Armor

In this project the corrosion mechanisms for the appliqué armor were identified, and methods were developed to mitigate the corrosion on the armor currently in use and suggestions were made on how to improve the manufacturing process to make the armor more corrosion resistant. The investigation into the corrosion mechanism included visits to the marine bases where the armor was used to gain an understanding of the operating conditions that the armor is exposed to, how the armor is strode and maintained, and the issues the AAV units face in using the armor. From these interactions, coating requirements were developed. One of the main requirements was that the corrosion coating had to be very damage tolerant.

Several coatings were tested including organic and inorganic primers, zinc, aluminum, and zinc/aluminum. Laboratory tests for corrosion resistance and damage tolerance showed that an aluminum coating has the best combination of properties. Four complete sets of armor were coated and installed on AAVs to field test the armor. One set was complete coated with al using the HVPC process, one set had the inside surface (surface facing the vehicle) coated with Al using the HVPC process and on the outside (surfacing away from the vehicle) a thick zinc rich primer was applied, one set was complete coated with al using a wire arc thermal process, and one set had the inside coated with al using a wire arc thermal process and a thick zinc rich primer was applied to the outside. An edge protection system using a compliant polymer was applied to all sets of armor. The armor that was coated on both sides with Al using the HVPC process showed the best corrosion resistance during the deployment.

This project showed that the armor can be refurbished at less that 50% of the cost of new armor. Money for new armor became available before the completion of the field testing. The thick zinc primer and the edge protection system were incorporated in the manufacturing process. The cost of a new set of armor was 10% less that the original purchase. The Al coating can be incorporated during refurbishment of the armor.

HVPC system at ARL-Penn State

The coating is still intact on the dove tail section of a blade after completion of the ASMET.

Marines installing refurbished armor on a AAV

Test fixture to simulate dynamic loading of the arresting gear cable.

Unique Capability
High-Velocity Particle Consolidation (HVPC) is a coating technology that originated in the former Soviet Union. This technology has been transitioned to the U.S. domestic industrial base. This technology is based on the supersonic acceleration of coating particles, which imbed themselves into a substrate, causing a coating to build. The process is a combination of mechanical bonding and solid state welding between the particles and substrate and between particles. The process operates below the melting threshold of both the particles and the substrate, thus there is good bond strength between the coating and substrate, with no substrate melting or recrystallization. Benefits include allowance for the alloying of coating, high productivity and high deposition rate, and deposition efficiencies. The R&D facilities that support this technology are unique in that they are used for research into nozzles, coating development, costing modeling and process development.

Aircraft Carrier Arresting Gear Poured Cable End Sockets

This goal of this project is to find a potting material that can replace the zinc in potting the arresting gear cable end sockets to the arresting gear cable. The use of zinc as a potting material can lead to hydrogen embrittlement of the cable. The new material had to have a reduced potential for hydrogen embrittlement, have a cure or process temperature equal to or lower than zinc, and have to have similar processing time. The epoxy system Epon 862/ Epon 58005/ Epi-Cure 9552 /TS-720 binder was selected for full-scale testing. Six sections of cable with the sockets were prepared for testing. These included a zinc baseline. The tests were conducted over the temperature range of -15°F to 150 °F. A special test rig was designed and fabricated to simulate the dynamic loading of the cables. Some setting of the epoxy occurred during testing. Results are being review by NAWC-Lakehurst.

Laser Processing Technologies

Technology Leader: Rich Martukanitz, Ph.D.

Mission

To develop new manufacturing processes which capitalize on the unique features of high energy processing technologies and to transfer them to both Navy and industrial centers to immediately benefit the Navy's evolving requirements for fleet readiness at the lowest possible life-cycle cost.

The research conducted is broad in scope, ranging from applied process and materials development through systems integration and technology transfer. Many programs begin as feasibility studies or demonstrations and then successfully evolve into programs for implementing the technology.

This division also continues to interact with industry through its laser processing consortium and sponsored research programs. Its success in developing and implementing laser processing technology may be traced to its balance of applied programs, basic research, and educational initiatives.

Torpedo Repair

Project Leaders:
Ken Meinert and
Ted Reutzel

Two programs, Repair and Refurbishment of Fatigue Limited Structures and Surface Removal by Fiber-Optically Delivered Lasers, were combined to form the Torpedo Repair program. Torpedoes are routinely fired in an exercise configuration to train sailors and to test the effectiveness of the system. After exercise firing, the torpedo is retrieved, refueled, and returned to service. However, as a result of this testing, the components in the system are often damaged due to operation, handling, and immersion in a seawater environment. These damaged components must be repaired or refurbished in order to maintain the high performance capabilities of the torpedo system. The repair methods currently used for the components have limitations, including the fact that the repairs are non-structural and frequently need to be reapplied at each repair cycle. As part of the repair process, the paint and anodized coating applied to the aluminum component must be removed.

Laser cladding was demonstrated as a method for providing a permanent structural repair on a number of aluminum alloys, including alloys generally considered unweldable by conventional methods. After the initial demonstration, specimens representing observed defects were repaired and tested, the results showing excellent bonding, a small heat affected zone, and adequate mechanical properties. The process was transferred during the course of the project to the Naval Undersea Warfare Center (NUWC) - Keyport Division. After the laser and workcell were operational, personnel at NUWC-Keyport began to develop the laser cladding process on-site, quickly demonstrating satisfactory laser clads on aluminum. Metallurgical analysis samples produced at Keyport were evaluated at ARL-Penn State to determine the quality of the clads and to provide suggestions for process improvements. After the process at Keyport had been optimized, repairs on actual components were initiated. To date a large number of components, many of which had been destined for scrap, have been repaired, successfully tested, and returned to fleet use. To date over $700K worth of assets have been removed from scrap and returned to service. Additional work will continue at ARL to improve the laser cladding process and to perform testing to aid in qualification of the process to meet Navy requirements.

Laser based coating removal offers advantages over the current repair process and is an excellent complement to the laser cladding process. Hard, damage-resistant coatings are used to protect the aluminum surface from the corrosive action of seawater. If damage occurs to the component, the current repair process removes all of the paint and anodized coating on component. After the repairs to the aluminum are made, the component is re-anodized and re-painted. There are two problems with those processes. The removal of the anodized coating is performed by chemical means and a small amount of aluminum is lost from the surface of the component. In addition, the anodize process converts some of the aluminum from the component into the coating, resulting in loss of material during each cycle. The powder epoxy paint system, used to protect the outer surface, employs a high temperature oven to attach and cure the coating. The curing temperature for the paint is within the region of aging temperatures for aluminum alloys. Each heating cycle thereby reduces the mechanical properties of the alloy. Use of laser based coating removal allows for the local removal of both the powder epoxy paint and anodize coating without damaging the surface of the material. A system will soon be in place at NUWC-Keyport to perform coatings removal. ARL will aid in setup of the system and will transfer the developed technology for use on torpedo components. ARL will perform additional testing and process improvements to aid in qualification of the process.

An additional phase is also planned to develop a method to locally apply and cure the paint over the repaired area. The anodized coating can be selectively applied over an area, but a method for selective powder epoxy paint application has yet to be developed. It is hoped that a method for localized curing can be developed using a laser. Development of such a method would allow for a full integrated process to make permanent structural repairs on torpedo components and provide a method to protect the components from additional damage.

Unique Capability

Laser-Aided Processing of Materials offers leading-edge advancements in precision high-speed or deep penetration welding operations with low cladding, cutting, drilling, heat-treatment, glazing, and free-forming component distortion. ARL Penn State has one of the country's largest high-power laser applications development programs in support of industry and the Department of Defense.

Laser Cladding as an Alternative to Chromium Plating for Ground Combat Vehicles

Project Leader:
Ted Reutzel

Recent environmental regulations have reduced the use of chromium electroplating. The Marine Corps commonly uses chromium electroplating for wear, corrosion, and dimensional restoration on a wide variety of components including ground combat and combat service support vehicles, as well as aircraft parts. Alternative coating materials and methods must be identified or developed to replace chromium electroplating. Replacement technologies must be cost-effective and meet demanding performance requirements imposed by challenging operational conditions. Further, replacement of chromium electroplating provides an opportunity for the Marine Corps to identify repair processes that actually expand the number of repairable parts. For example, laser cladding, which can deposit material much thicker than chromium plating, can be used to repair components that have dimensional restoration limit requirements.

The investigation of alternative technologies to chromium plating has been taking place in industry. Most notable is the use of laser cladding as a chromium plate replacement by heavy vehicle original equipment manufacturers. Components such as shafts and struts have been successfully repaired using laser-cladding techniques. This technique is now an industry-approved repair process/method. The primary focus of this program is suspension and drive train components found in the Marine Corps' LAV and AAAV-type vehicles. The program is also applicable to heavy combat service support trucks. Components used in Marine Corps vehicles often differ in composition from similar commercial or Army variants due to unique high-stress corrosive operating environments. The adaptation of laser cladding technology to Marine Corps vehicles will provide a cost-effective chromium plate alternative that provides the potential to increase the number of refurbishable components.

The program has developed a laser-clad repair for the propulsion shafts on the AAV. The shaft drives the water pump that propels the vehicle during its amphibious mode. iMAST identified a suitable repair material, developed the laser deposition process, established a post-clad heat treatment schedule, and provided vendor-supplied quotations for production work. Two shafts were repaired at iMAST and delivered to MCLB Albany. The shafts were inspected and found to be free of defects. The parts are now scheduled for field testing during FY 2001.

Laser Processing of Nickel Aluminum Bronze

Project Leader:
Ken Meinert

The goal of this project is to decrease the fabrication, repair, and refurbishment costs of nickel aluminum bronze (NAB) components and improve performance through laser materials processing technology. Laser materials processing of NAB offer many advantages over conventional processing technologies. Laser welding and cladding are low heat input processes when compared to arc-welding processes. Low heat input leads to reduced distortion, thereby meeting stringent tolerance requirement and reducing post-weld machining requirements. High material deposition rates can be achieved through laser processing, allowing for reductions in processing time. The performance of laser deposited NAB (both laser clad and laser welded) has been shown to equal or exceed that of conventionally arc-welded material.

This processing technology is being implemented at Norfolk Naval Shipyard's Naval Foundry and Propeller Center through the recent development, integration, and procurement of a robot Nd:YAG laser welding system. Process development for laser beam welding of marine components has been utilized to drive the design of this system. The robotic welding system, scheduled for delivery in the first quarter of 2000, will represent the most advanced Nd:YAG laser welding system to date.

Nd:YAG Laser Repair of Aircraft Carrier Catapult Trough Covers Track Wear Surface

Project Leader:
Rich Martukanitz

Catapult trough covers on aircraft carriers require substantial refurbishment due to the severe operating environment typically encountered. There are four catapults/carrier, with approximately 100 trough covers per catapult. The channel shaped area of the trough covers provides a rolling/bearing surface for the launch shuttle to roll as it accelerates the aircraft from zero to 160 mph in three seconds. The base material of the channel is a high yield carbon steel (HY-100) and operates in a harsh environment of mixed salt water spray and air at elevated temperatures. This combination causes corrosion products to form on the wear surfaces which act as an abrasive causing accelerated wear of the wheel and track surfaces. When the track surfaces wear beyond tolerances (.050 inches), they are replaced with new trough covers. The worn trough covers are unable to be weld-repaired by existing welding processes due to excessive distortion caused by the welding. On the other hand, the low heat input of laser processing enables the channels to be resurfaced with clad metal. New cost is approximately $25K/trough cover, but laser cladding can be done for less than $10K per cover. It is estimated that 400 covers per year will need repaired during the course of several more years. Laser cladding can generate a savings of approximately $6M per year.

This ManTech program will expand the application of Navy developed Nd:YAG laser weld repair technology to the repair of worn surfaces with a superior, longer lasting corrosion and wear resistant material and transition this program onto the production floor.

Advanced Composites Technologies

Technology Leader: Kevin Koudela, Ph.D.

Mission

To conduct applied research on advanced materials and structures for marine applications with emphasis on acoustics, reliability, affordability, and technology transfer.The benefits of advanced composites include weight savings of 25–50% over conventional materials, acoustic signature reduction, and corrosion resistance.

Challenges

The challenge of composites is that it must address traditional design requirements relative to strength/stiffness as well as hydrodynamic and acoustics. Additionally, it must also address unique requirements pertaining to environmental effects, fatigue and impact, attachments/joints, and manufacturability and inspectability.

Advanced SEAL Delivery System

Project Leader:
Eric Strauch

This project is providing materials and process engineering support to include design certification test support. During the fiscal year new composite material was identified for the nose and aft shell stiffeners. Composite material systems were qualified on hull number one. C-bar and J-bar attachments brackets designs were qualified via supplemental tests.

Unique Capability

Marine Composites offer the potential for significant weight reductions, a decrease in life-cycle costs, and signature reductions. ARL Penn State has a complete composite design, prototype fabrication and testing facilities in-house as well as an extensive network of proven subcontractors. Capabilities include acoustically tailored composite structures, processing and characterization of thick section composites, low-cost fabrication techniques, and life qualification for composites.

Current efforts within the Advanced Composites division relative to Navy and Marine Corps issues include: naval platform programs, torpedo programs, acoustic control, advanced material life prediction, and protective coatings.

Manufacturing Systems

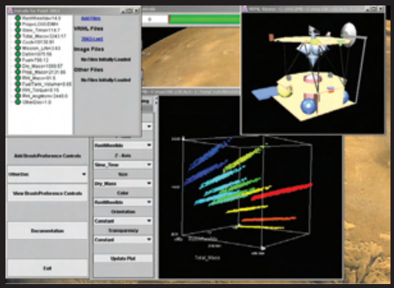
Technology Leader: Mark Traband, Ph.D.

Misson

To perform research, advanced development and implementation in design and manufacturing systems, through the integration of information technology and product and process design. Historically, the development of manufacturing systems has been decoupled from the process of design. A major focus of current research is therefore in developing methodologies to automate and/or more tightly integrate the design process, cost estimating, and manufacturing system design. Virtual prototyping of component and manufacturing system designs enables engineers to explore a much larger set of design options, resulting in more robust designs, with shortened leadtimes, and reduced lifecycle cost.

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.



ARL Trade Space Visualizer being used to explore satellite conceptual designs

Trade Space Exploration

The Trade Space Exploration (TSE) method, developed at ARL with ONR support, is derived from Balling's design by shopping paradigm, and it allows a decision-maker to first explore the design space and then choose an optimal design from a set of possible designs. The TSE method can be divided into three primary steps: model building, experimentation, and exploration. The model building step creates a system model by coupling subsystem models into a constrained system that can be used to generate many potential designs. The experimentation step selects the values of inputs used to generate the range of feasible designs to be created in the model building step. The last step is the exploration of the resulting set of designs to look for known trends as a form of validation of the models and to act as a decision-making tool. Key to this step 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.

Technology Application
ARL has developed a Trade Space Exploration for satellites that uses the ASTV. The system has the capability to generate design concepts (virtual prototypes) for spacecraft. Virtual prototypes consist of the design data necessary to form high-level parametric cost estimates, design data necessary to ensure satisfaction of system requirements and compatibility between subsystems, and geometric data sufficient to show relative sizing and placement of subsystem components.

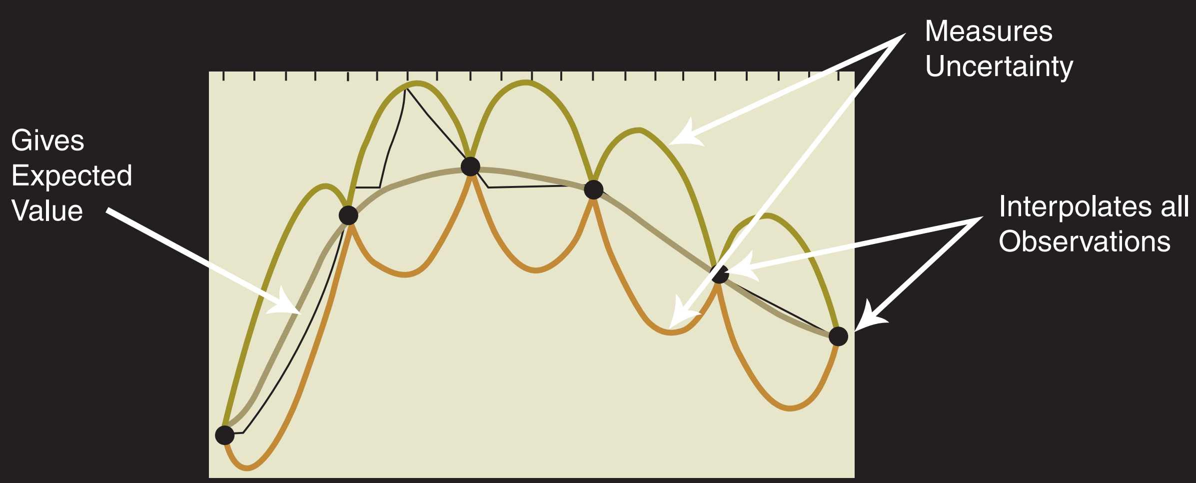
Metamodeling

The design by shopping paradigm has proven to be very useful to decision-makers in understanding the possible trades available to them, giving them evidence to support their decision of a final design. One difficulty with the paradigm is it requires a significant number of model evaluations. Metamodels, models of models, are low fidelity models used as computationally efficient surrogates of the original subsystem analyses, a high fidelity model (HFM). Kriging models are used as metamodels in the TSE method because they can interpolate a set of observations of an HFM. Additionally, since a kriging model is a probabilistic model, it can quantify the uncertainty associated with the model.

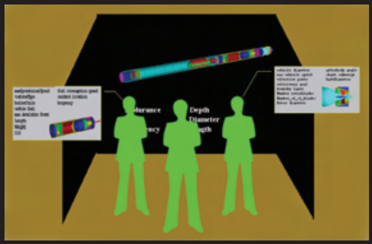
Current research is developing methods to quantify uncertainty and risk in design by using the probabilistic nature of the kriging model. These methods will use Monte Carlo simulations, varying the input uncertainties to a potential design, to quantify the resulting performance uncertainty. Additionally it will perform a sensitivity analysis that will identify the sources of performance uncertainty, including model uncertainty. The results of this uncertainty analysis can be used to improve the model uncertainty by including additional information near the design of interest.

Technology Application

Current multi layered, multi functional material structures rely heavily on combination solutions. In essence, dedicated layers are incorporated that meet requirements associated with particular aspects of a defined threat while providing little or no utility in performing the other various functions. For instance, armor solutions are often parasitic from a structural load bearing perspective. ARL is working on an optimization scheme for multi layered systems that includes the development of an in depth understanding of interface characteristics. The optimization of these complex materials will require the use of extremely complex analysis codes that can be applied at various levels and length scales pertinent to new platform implementations. Using metamodels for the complex codes will enable a much broader range of the design trade space to be evaluated, ensuring the development of more optimal multi functional materials.



Kriging Model – A Spatial Stochastic Model



Immersive Environment

Virtual Design Environments

The next generation of system engineers and decision makers want to explore the possible limits of a design space quickly. ARL Penn State has developed a virtual conceptual design environment to allow the engineer to virtually explore design trade-offs and the complex design space of an engineering product. The system generates virtual prototype models in a CAVE-like environment that meet a set of user specified requirements and technology options. The user can navigate around the model and interact with the model directly through voice and gesture recognition. The user may vary mission and design requirements and the model will change its form dynamically to meet the new specifications. In addition to this capability the user can visualize the complex function space of the model and interact with the visualization. A complex function space often involves higher dimensional data sets. In the immersive environment users will be able to view projections of higher dimensional data onto three-dimensional space, and choose points in the function space to select designs for further analysis. After they choose a point in the function space the virtual prototype will transform to represent the selected design point.

Current research work is focused on the designer’s need for quick data access and customized data views in a virtual environment. This work extends the current virtual environment into a multi-user, multi-discipline design tool. The new environment will allow engineers to collectively view how design parameter changes affect subsystems as well as overall weapon characteristics. A unique innovation of this proposed work is that the environment will provide individually customized data views to each of the subsystem experts as well as system level data sharing for all participants.

Technology Application

ARL has developed a Virtual Design Environment for a 6.25” torpedo, or Anti-Torpedo Torpedo. In this environment the user is presented with a virtual weapon design. They interact with the weapon through voice commands and gesture recognition. For example they modify a design requirement, such as the torpedo’s endurance, by raising and lowering their hands. The virtual torpedo will dynamically change shape and topology to meet the new design requirements. Through voice commands the user requests to see a detailed view of the array configuration or view the array beam formation. This environment provides a real time visual interface between the weapon design space and the weapon physical features.

Manufacturing Process Simulation

Closing the loop between product design and manufacturing process design enables engineers to rapidly assess the impact that design changes have on process sequences, product flow, and manufacturing lead times. A useful method for manufacturing process design is discrete event simulation (DES) modeling. These tools enable:

- Assessment of proposed manufacturing facilities prior to capitalization, to include visualization of the facility, material handling, process bottlenecks, part routing, and worker and machine utilizations,
- Analysis of the impact of new work on an existing facility, and
- Evaluation of alternative dispatching rules or production schedules in an existing facility.

ARL has teams of analysts and model builders experienced in several different simulation modeling languages. Typical tasks in a project go beyond simply building a model and may include data collection, distribution fitting, verification and validation, and output analysis. In addition, basic simulation modeling capabilities are often extended through the use of immersive visualization, web access to remote models, custom user interfaces, and database/Excel integration.

Technology Application

ARL is currently working with the USMC Maintenance Center in Albany, GA, under ONR sponsorship, to reduce re-manufacturing costs and improve the quality of their products and services within their backshop areas, in particular, the painting and cleaning shops. Discrete event simulation models have been developed for the existing hull paint, component paint, and steam cleaning shops and serve as the baseline in this project. As process improvement concepts are developed, the simulation models will be updated to include the proposed process changes (e.g., new equipment, process time reduction, etc.). The output of these updated simulation models will be compared with the output of the As-Is simulation models and used in cost benefit analyses to evaluate the merit of implementing the proposed changes in the shops. The goal is to reduce backshop lead time, especially non-value-added shop time.

In addition to the USMC project, ARL is currently working on two FY07 projects supporting one of the Navy's newest class of ships, the Littoral Combat Ship (LCS). In two separate projects, ARL plans to use discrete event simulation to support new facility design, evaluate proposed production lines, and understand shipyard material and work flow at the two shipbuilders awarded the Flight 0 contracts for two LCS ship designs: Austal USA in Mobile, AL and Marinette Marine Corporation in Marinette, WI.

Integrated Data Environments

The product development lifecycle for any weapons system begins with the definition and capture of customer requirements and proceeds through product design and tradeoffs, analysis and simulation, development of manufacturing processes, testing, and product support. The evolution of a product through these phases involves many transitions of data through the organizations involved with these processes. A significant amount of technology and data may be lost during these transitions, resulting in significant reinvention costs. In many organizations, engineering information is not well managed, and may be scattered throughout the organization in a variety of unconnected databases, computers, and notebooks. Often, data is duplicated in several locations, leading to confusion about which data is the most current.

DES Model of the Component Paint Shop at USMC Maintenance Center Albany with proposed Paint Chain Conveyor System

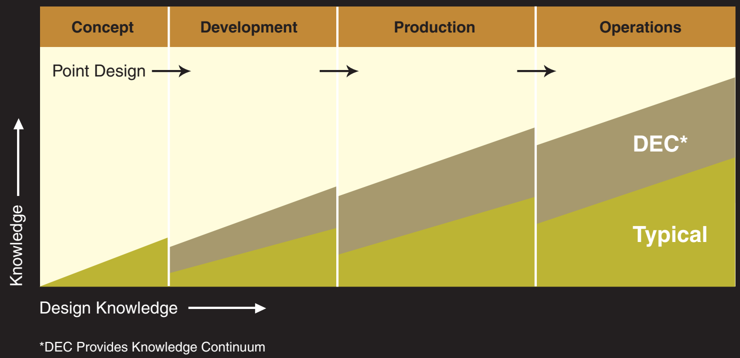
The use of integrated data environments (IDE's) is a strategy for providing access to product and process information electronically, and moving that data (which may include CAD models, results of simulations and analyses, cost estimations, and testing data) through its lifecycle. IDE's typically span many parts of and organization, connecting users through a network (increasingly, via the internet) to electronic representations of product information.

One class of software that is often used to manage product-related data in an IDE is known as Product Data Management (PDM). PDM systems manage all forms of data throughout a product's life cycle, including information such as 2-D drawings, 3-D models, tooling programs, specifications, design analyses and hard copy documents to cite a few examples. PDM systems do not create product data as do CAD systems, but manage the files once created.

Technology Application

With the emphasis on cost effective commercial, off the shelf solutions to facilitate the functional and data needs of the Navy's Surface Ship Torpedo Defense (SSTD) program, ARL has created the Distributed Engineering Center (DEC) to manage the program's data throughout the weapon systems' lifecycle. ARL performed a requirements analysis and evaluated the commercial PDM solutions available; these requirements were based on DOD acquisition guidelines, other acquisition programs best practice, and the SSTD and NAVSEA design agent requirements. A number of best-of-class PDM systems were evaluated by ARL to determine which met the requirements of cost, functionality, and capability. ARL installed and configured the software to provide control of unclassified documentation and product data, and to allow collaboration between users across many Navy and contractor organizations. Future plans call for the installation of a separate classified PDM system with access via an encrypted network.

Goal: Minimize Knowledge Loss at Transition Points



Retention of Design Knowledge Using an IDE

Systems Operations and Automation

Technology Leader: Ed Crow

Mission

The Complex Systems Monitoring and Automation Department develops, demonstrates, inserts and transfers new technologies to monitor and control the health and operation of mechanical, electrical, and electrochemical systems to DoD, other government and industrial customers. The Complex Systems Monitoring and Automation Department applies a systems engineering approach to analyzing customer problems, then identifies applicable technologies and formulates an engineering implementation to solve the problem. Where applicable technologies are not available, department personnel develop new fundamental science and technology, with the same end goal of technology insertion and transfer.

The Complex Systems Monitoring and Automation and Applied Enterprise Systems Departments comprise the Systems Operations and Automation Division. Together, we develop solutions that implement a continuous information thread for complex systems from sensor data through actionable information in a commercial Enterprise Resource Planning system. The departments are currently working to assist the Marine Corps and U.S. Army in exploring the automation of information insertion for the transformation of logistics and support systems.

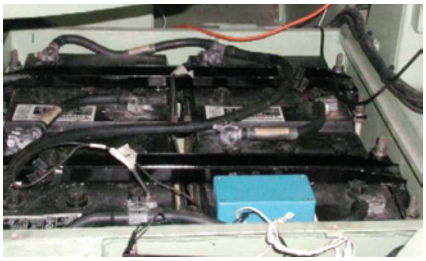
Complex system monitoring applies sensors to collect data from subsystems and components, analyzes the data to extract knowledge, applies automated reasoning to interpret data for the user, and estimates the health and performance of the system to track system degradation. Traditional and intelligent control systems are applied to control performance, reduce noise and vibration, and to automate manned, man-in-the-loop and fully autonomous systems. The department has worked on technology development, insertion and transfer projects for system monitoring and automation for a number of DoD platforms including JSF, the Marine Corps Expeditionary Fighting Vehicle, the Marine Corps Light Armored Vehicle, DDX, DDG and CG-class warships, and the Army's HEMTT truck.

Battery Diagnostics and Prognostics

Project Leader: Karl Reichard

Complex System Monitoring and Automation personnel have developed battery health monitoring technology capable of fast, reliable predictions of battery state of charge, state of health, and state of life with performance errors <5%. The system uses a patented ARL design for measuring critical internal battery parameters and ARL developed algorithms for determining state of charge, state of health and state of life. The state of charge measurement provides a measure of current capability with greater accuracy than





traditional voltage and current measurements. The state of health provides an accurate assessment of the degradation modes affecting remaining useful life for the battery and state of life provides an assessment of remaining charge cycles. Together, the state of health and state of life measurements provide real prognostic health information. The battery health monitoring system can be embedded in a battery, charging system, or the vehicle electrical system and communicates battery prognostic information over an OSA-CBM compliant interface.

Accelerated Capabilities Initiative: Machinery Diagnostics and Prognostics (Non-ManTech)
Project Leader:
Karl Reichard

A team of iMAST engineers continue to address condition-based maintenance (CBM) capabilities related to producing a CBM capability demonstration on a Navy weapon systems platform. The team continues to develop a new hybrid modular smart device for monitoring the condition of complex mechanical equipment. The team has been given access to unique test facilities and domain expertise provided by NSWC Philadelphia and NCCOSC San Diego. The Ben Franklin Technology Center of Southeastern Pennsylvania continues to support the technology transfer effort to industry.

Unique Capability
Gear Performance Prediction indicates transmission error of meshing gear pairs by identifying vibratory excitation caused by gear tooth geometry imperfections and elastic deformation. ARL Penn State has developed a method to rigorously predict from first principles the transmission error contributions from detailed generic descriptions of gear tooth geometric imperfections (measured by dedicated gear metrology equipment).

Technologies for Gear Performance Prediction Using Precision Optical Measurement (Non-ManTech: A NIST Advanced Technology Program Project)

Project Leaders: William Mark and Karl Reichard

M&M Precision Systems Corporation of Dayton, Ohio and the Drivetrain Technology Center proposed and were awarded a technology project to rapidly measure and quantitatively relate gear-tooth errors to gear performance, thereby providing to gear manufacturers and builders of gear manufacturing equipment the capability to focus on controlling those error patterns on gear teeth that are significant sources of vibration, noise, and other imperfections in the functioning of meshing gear pairs. A high-speed optical sensor capable of obtaining topographical measurements of manufacturing error patterns on gear teeth will be developed as part of this project.

A NIST ATP program was awarded to M&M Precision Systems Corporation, manufacturer of precision CMM touch probes. ARL is subcontractor to M&M for both the noncontact optical sensing system as well as gear performance prediction capabilities based on the optical measurements. The M&M program involves enhancement of gear optical inspection calibration techniques to provide absolute measurement capabilities.

Repair Technology

Technology Leader: Timothy Bair

Powered by the Office of Naval Research Manufacturing Technology (MANTECH) program, Repair Technology (REPTECH) is the Navy's only Center of Excellence dedicated to improve Navy and Marine Corps depot repair and maintenance capabilities. REPTECH applies appropriate technologies to improve capabilities of the remanufacture and repair community and plays a central role in discovering and utilizing emerging technologies for the Navy. Because lifetimes of the Navy and Marine Corps' assets are increasing — sometimes beyond their designed life — Repair Technology investments are needed to close gaps between the current capability of the repair depots and the sustainment needs of the weapon system. REPTECH reduces the depot, shipyard or logistic base's risk to schedule, costs, and performance of repairing the fleets weapon systems by answering the business decision questions.

iMAST has been designated by the Navy as the resident coordinating center for its Repair Technology program.

Charter

- 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
- Projects are executed under the direction of the REPTECH Working Group
- Communicate 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

The REPTECH Working Group (RWG) is a Navy system's command management level team that oversees all REPTECH projects. It consists of one technology integration management representative from NAVSEA, NAVAIR, MARCOR, NAVSUP, and SPAWAR with an ONR MANTECH Program Officer (ONR 361) as the RWG chair. The RWG meets semi-annually to review all current projects as well as discuss new potential efforts. RWG was created to develop a coordinated approach to executing and identifying REPTECH needs for the Navy and Marine Corps.

HAZMAT Analyzers for Rapid on-Site Analysis
POC:
Janice Keay

Reduce costs and time associated with the analysis of hazardous materials in coatings on naval vessels.

Customer:
Pearl Harbor Naval Shipyard
NAVSEASYSCOM
Portsmouth Naval Shipyard
Norfolk Naval Shipyard
Puget Sound Naval Shipyard

Solution: Develop a portable or hand-held analyzer to rapidly determine PCB, Pb, and Chromate levels in various surface coatings on naval vessels.

Benefits:
- Reduce labor and analytical costs
- Reduce analytical time, decision making and planning times
- Improve remediation process cycle times

Helicopter Blade Refurbishment

POC:
Ted Reutzel

Reduce costs, improve quality, eliminate human error, and increase capability for Helicopter Blade paint removal processes.

Customer: NADEP Cherry Point
NAVAIRSYSCOM
Sikorsky Aircraft

Solution: Develop a repeatable, quality, cost-effective Helicopter Blade paint removal process for CH-53, Ch-46D/E, and CH-60 helicopters. Process selected is ND:YAG laser paint stripping solution.

Benefits:
- Reduce labor from 20 hours to 4 – net cost-avoidance $180K/year
- Improve artisan quality of life – current process is labor intensive
- Reduce worker health safety risk
- Reduce damage to substrate
- Improve processing capability

Polycan Fabrication

POC:
Paul Swanson and Mark Traband

The current fabrication process for polycans is mostly manual and labor intensive. Each layer of poly is custom fit with tight tolerances. Innacuracies can cause slight variation in the complete can. Both the forming process and distortions during the fit up and welding processes cause these inaccuracies in assembly.

The Polycan process is on the critical path for overhauling/refueling US Navy submarines.

Customer: Portsmouth Naval Shipyard
Pearl Harbor Naval Shipyard
NAVSEASYSCOM

Solution: Reduce lead time for Polycan fabrication. Develop parametric CAD models of all cans, automate CMM programming for can cavity profiles, automate reverse engineering can cavity profiles, and improve machining and waterjet-cutting processes of polycans.

Benefits:
- Eliminate Polycan production from critical path
- Reduce production costs
- Reduce lifecycle costs
- Improve scheduling of polycan production

Submarine Vertical Launch System Tube Repair
POC:
Ted Reutzel

Develop a method to more efficiently repair US Navy Submarine Vertical Launch System (VLS) Tubes by implementing a laser cladding techniques.

Customer: COMSUBPAC
NAVSEASYSCOM
Pearl Harbor Naval Shipyard
Puget Sound Naval Shipyard
Norfolk Naval Shipyard
Portsmouth Naval Shipyard

Solution: Determine root cause of corrosion damage in VLS tubes. Develop, test and implement a convertible motion device to laser clad and re-dimension the affected tube to original specifications.

Benefits:

- Reduce life cycle costs of tube
- Increase fleet readiness
- Reduce VLS tube repair time
- Decrease or eliminate future corrosion in tube
- Improved depot personnel quality of life

M198 Howitzer Mechanism Tester
POC:
Eric Little

Implement a Howitzer recoil mechanism testing system that will reduce costs, improve logistics, and shrink the rebuild schedule for the USMC Barstow, CA, depot. The current testing procedure is inconsistent in quality and creates a bottleneck on the depot's schedule.

Customer: USMC Maintenance Directorate
USMC Logistics Base Barstow
USMC Logistics Base Albany

Solution: By bringing the recoil testing in-house and designing the system to include both the M198 and M777 Howitzers, as well as potentially the M1A1, the depot will reduce costs to repair and turn-around USMC assets needed in the War.

Benefits:

- Lower test costs
- Less testing time
- Streamlining of test scheduling
- Safer and less rigorous conditions for test personnel
- On-site test facility which can be used as a diagnostics tool
- Less environmental impact due to testing
- Fewer personnel required for testing

CH-46 Gear Repair

POC:
Suren Rao

Due to operations, the Naval Aviation Depot at Cherry Point (NADEP CP), NC, scraps over $1M worth of transmission gears a year during overhaul of CH-46 aircraft. ARL REPTECH has uncovered a super finishing process that can remove the surface damaged layers of the gear tooth while maintaining metallurgical and dimentional quality of the gear. If the strength and durability of the gear can be demonstrated to be comparable to “new” gears then scrap gears can be reused. Further, the improved surface finish of the repaired gears will result in extended service life and reduced heat generation in the gear mesh.

Customer: NADEP Cherry Point
NAVAIRSYSCOM
Boeing Aircraft

Solution: Demonstrate gear strength and durability and implement the REM Superfinishing process at NADEP CP for the CH-46 Sun Gears that will reduce scrap, improve wear resistance and reduce heat losses in the transmission.

Benefits:
- Reduced gear procurement costs
- Improved surface quality of repaired gears will provide extended service life
- Improved surface quality of repaired gears will reduce heat losses in the gear mesh
- Since new gears are a long-lead item, availability of repaired gears would impact aircraft overhaul time

Submarine Alignments and Inspections

POC:
Paul Swanson

The inspections and alignments required on submarines during naval depot availabilities are difficult, time consuming, and costly. This project will review three inspection/alignment tasls required on 688 Submarines in the sail, torpedo tube, and steering/dive plane areas. The project is to implement new cost-effective inspection technologies to improve the current inspection and alignment process of the three selected areas.

Customer: NAVSEASYSCOM
Portsmouth Naval Shipyard
Norfolk Naval Shipyard
Puget Sound Naval Shipyard and Intermediate Maintenance Activity
Pearl Harbor Naval Shipyard and Intermediate Maintenance Activity

Solution: Using the standard engineering approach, ARL REPTECH will evaluate and/or develop the necessary inspection and alignment techniques to reduce the costs of this job for the depot as well as improve the user-friendliness.

Benefits:
- Captured featured data:
  - Provides electronic records for archival
  - Validates/Invalidates alignment
  - Encourages statistical analysis
  - Provides Reverse Engineering capability
- Reduced downtime
- Increased reliability
- Fewer repair costs
- Increased flexibility

Technology Insertion Opportunities for Navy ManTech

The iMAST technologies listed below are available for application within the Navy ManTech Program. Sponsorship, however, is required from a Naval or Marine Corp. Systems Command (SYSCOM) in order to initiate a program. For more information on the technology, contact the project leader noted. For more information on how to initiate Navy ManTech projects, contact your respective SYSCOM ManTech representative. Each year, technology "issues" are entered into a database by respective systems commands. These issues are then reviewed and prioritized by a Navy ManTech executive steering committee. The committee selects appropriate projects within an established funding range to support Navy and Marine Corps fleet requirements.

Thermoacoustic Refrigeration

POC:
Bob Keolian

ARL Penn State is developing a thermoacoustic chiller (TRITON) with a 3-ton cooling capacity (10 kW) for shipboard application under ONR's Environmental Requirements Advanced Technology (ERAT) Program. The cooling produced by the unit is created by a standing acoustic wave that expands and compresses inert gas within a porous plastic medium called a stack. Heat exchangers on each side of the stack carry away waste heat on one side and chilled water on the other side.

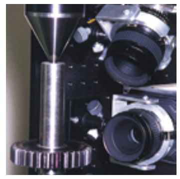
The acoustic wave is developed by a high-efficiency linear electric motor operating like a large loudspeaker. There are no HFCs or CFCs involved in creating the cooling. In addition, there are no sliding seals or other moving parts in the system other than the linear motor. This means no lubrication or maintenance of the chiller is required. To date, a 4-watt thermoacoustic cryocooler has been demonstrated on a Discovery space shuttle mission (STS-42) in 1992, and a 400-watt system was operated for a week to cool radar electronics on the USS Deyo (DD-989) in 1995. The TRITON 10 kW unit will be demonstrated at a land-based test site in during late year 2000. If successful, it will undergo sea trials during FY02/03 timeframe. This technology will provide the Navy with an the opportunity for environmentally benign cooling in critical areas as a distributed system rather than a centralized one.

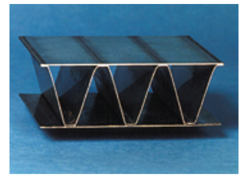
Manufacture of Laser-Cut and -Welded Housings for High-Performance Transmission Application

POC:
Rich Martukanitz

ARL Penn State has demonstrated the feasibility for affordable advanced laser cutting and welding techniques in concert with high-strength materials to produce welded transmission housings that will meet the performance requirements for ground combat vehicles, as well as rotorcraft and VSTOL aircraft employing high-performance transmissions. ARL is capable of establishing cost and performance benefits of a laser cut and welded housings versus conventional cast housings.

The use of a welded steel structure has a number of advantages and benefits over cast aluminum and magnesium transmission housings. These include comparable production costs with dramatically reduced manufacturing lead times, lower weight designs (permits mini-lube systems), reduced lifecycle costs, high temperature operation, improved heat transfer capability, improved damage tolerance, and field repairability.




Noncontact High-Speed Gear Inspection

POC:
Karl Reichard and William Mark

ARL Penn State has demonstrated the feasibility of developing an economical noncontact high-speed precise gear surface inspection system for DoD depots and gear manufacturers. The benefits of this technology include reduced gear inspection time by a factor of 100, improved gear inspection accuracy via high spatial sampling, enhanced gear production efficiency with potential on-line inspection, and greatly reduced production costs due to increased quality assurance and lower number of false rejects. Applications in military and commercial sectors include mechanical drive transmission inspection requirements associated with virtually all motor vehicles, aircraft, and powered marine vehicles, as well as most machine tools, military combat vehicles, industrial robots, and many household appliances.

A previous NIST stamp-of-approval review for the optical measurement technique has prompted increase interest in this technology. Sensor progress includes examination of speckle compensation methods for coherent light sources including a new high-power laser diode with pigtailed fiber optic delivery. Two methods for dynamic reflectivitiy nonuniformity compensation (DRNC) have been developed and fully tested. A compact and rugged mechanical assembly for the optical head has been designed and is being fabricated.

LASCOR: Lightweight Structural Panels

POC:
Ted Reutzel

ARL Penn State has developed a laser-welded corrugated (LASCOR) metal paneling process which provides a stiffness and strength comparable to conventional steel plate, but at greatly reduced weight. LASCOR has demonstrated its durability by showing favorable resistance to fire, blast, ballistic impacts. LASCOR can be manufactured in a variety of configurations and used with different alloys for customized properties.

These properties make it a strong competitor for conventional structural steel panels wherever weight reduction is a concern. Application has been made within the top sail structure of the USS Mount Whitney where approximate weight was reduced by 10,000 pounds.

Pericyclic Transmission

POC:
Gary Neal

The need for an advanced, high-efficiency variable rotor speed main transmission system that features split torque, split path, reduced-parts, and pure rolling contact power transfer via kinematic/kinetic pericyclic technology is being addressed by ARL Penn State. Current planetary and bull gear main transmission drives are fixed ratio systems that preclude changing rotor speed. The basic architecture of planetary and bull gear main transmission drives tend to preclude achievement of a major increase in power-to-weight ratio (SHP/LBs) and reduced cost due to the number of high precision, high-cost, weight components, and their reliability challenges.

The pericyclic variable rotor speed drive has a higher probability to achieve the power density, reliability and cost goals identified for the Joint Transport Rotorcraft and other system upgrades.

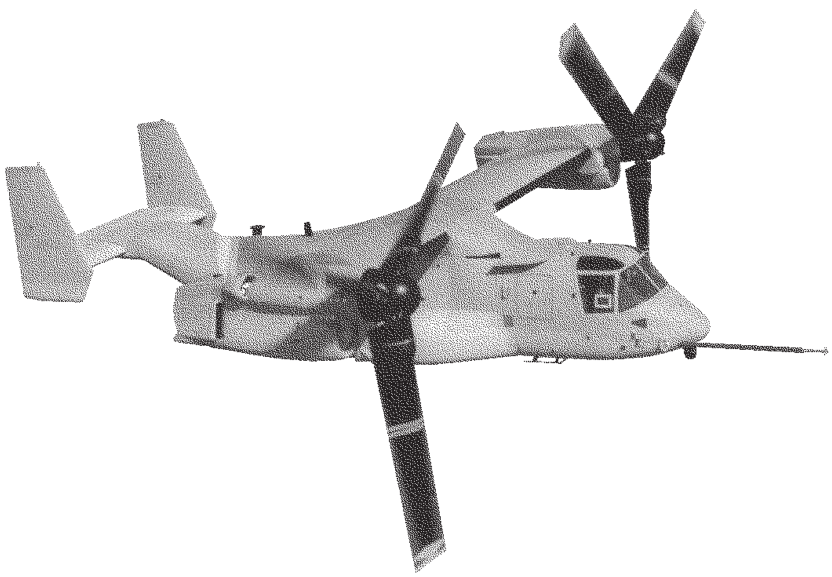
Spray-Formed Aluminum Alloys for High Performance Jet Engine Application

POC:
Tim Eden

This validated spray-formed high-temperature alloy process is optimized for component manufacturing for jet engine fan and stator vanes. The process is available for evaluation and implementation. Using the unique capabilities of the spray forming equipment resident at ARL Penn State, this process is integrated for engine design and verification efforts.

Air Vehicle Technology Group

Integration of advanced materials, manufacturing processes, tooling and fixturing will facilitate reduction in life-cycle costs, empty-weight/gross-weight ratio, vibration and interior noise. These efforts will also facilitate increases in payload/gross weight ratio, mission range, survivability, and operational availability. All improvements are made more affordable due to significant reductions in labor and in operating and support (O&S) costs.



Repair Technology
- NDI technologies (shearography)
- Coating application and removal
- Component repair methods

Landing Gear System Technologies
- Laser cladding
- Spray formed HS aluminum alloys

CBR Technologies
- Photon-based cleaning of CBR agents
- Laser-based cleaning of CBR agents

Other
- Conceptual design trade studies
- Manufacturing process modeling

Rotor System Technologies
- Rotor blade NDI (finds delamination)
- Control of radiated sound power

Powertrain Technologies
- Performance prediction
- Rapid prototyping
- Drive shaft laser balancing
- Condition monitoring
- Wear-resistant coatings via cold gas dynamic spraying and EB–PVD
- Spray-formed HT aluminum alloys
- Localized laser HT and cladding for wear and corrosion resistance

Health Usage Monitoring System Technologies
- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- MMI for troubleshooting and diagnostics

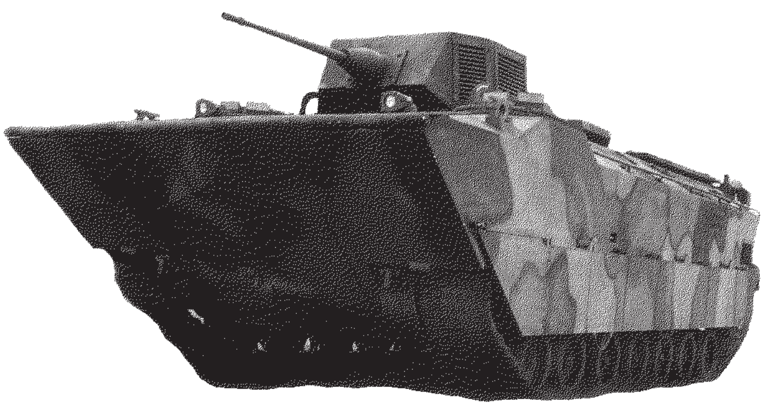
Drive System Technologies
- Advanced gear and bearing steels
- Laser fabricated housings
- Laser probe workpiece positioning
- Ausform finished gears and bearings
- Intelligent noncontact measurement of spiral bevel and face gears
- Gear noise control
- Design for power density

Signature Reduction Technologies
- Composite thermal tiles
- Radar cross-section reduction
- Acoustics

Airframe System Technologies
- Laser fabricated flooring
- Composite sandwich panels for noise control
- Spray formed HS aluminum alloys
- Protective armor

Ground Combat and Combat Service Support Vehicle Technology Group

The integration of advanced materials, manufacturing processes, tooling, and fixturing will result in reductions in gross weight, vibration, interior noise, and life-cycle costs as well as increases in mission range, survivability, and operational availability. These improvements are made more affordable due to significant reductions in labor and in operating and support (O&S) costs.



CBR Technologies

- Photon-based cleaning of CBR agents
- Laser-based cleaning of CBR agents

Track Vehicle System Technologies

- Lightweight HS materials
- Laser cladding and heat treating

Structural System Technologies

- Armor systems
- Materials and design

Other

- Conceptual design trade studies
- Manufacturing process modeling

Powertrain Technologies

- Performance prediction
- Rapid prototyping
- Drive shaft laser balancing
- Condition monitoring
- Wear-resistant coatings via cold gas dynamic spraying and EB-PVD
- Spray formed HT aluminum alloys
- Localized laser HT and cladding for wear and corrosion resistance

Drive System Technologies

- Advanced gear and bearing steels
- Laser fabricated (cut and welded) housings
- Laser probe workpiece positioning
- Ausform finished gears and bearings
- Intelligent noncontact measurement of spiral bevel and face gears
- Gear noise control
- Design for power density

Health Usage Monitoring System Technologies

- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- MMI for troubleshooting and diagnosis

Repair Technology

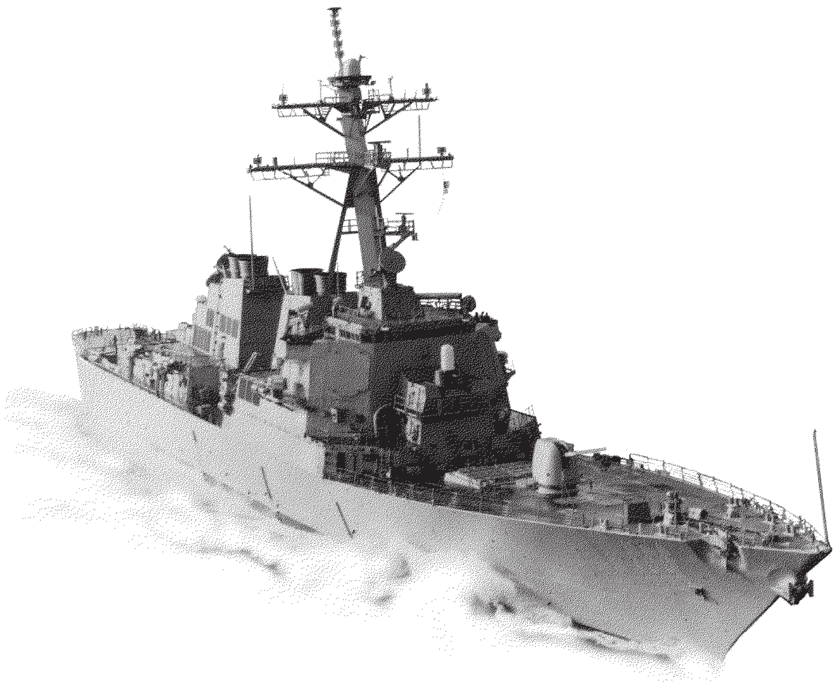
- NDI technologies (shearography)
- Coating application and removal
- Component repair methods (laser cladding)

Signature Reduction Technologies

- Composite thermal tiles
- Radar cross-section reduction
- Acoustics

Naval Surface Platform Technology Group

The integration of advanced materials, manufacturing processes, tooling and fixturing will result in reductions in gross weight, vibration, interior noise, and life-cycle costs, as well as increases in mission range, survivability, and operational availability. These improvements are made more affordable due to significant reductions in labor and in operating and support (O&S) costs.



Stack Gases Monitoring And Treatment

Autonomous Ship Systems
- Intelligent control
- Remote sensors
- Condition-Based Maintenance
- Advanced lubricants

Information Technology
- Electronic data transfer
- Intelligent management of documents and data

Propeller
- Design
- Cladding
- Repair
- Materials

Deck and Deckhouse Materials
- LASCOR
- Composite materials
- Non-skid surfaces

Laser Processing
- Welding
- Cutting
- Cladding
- Forming

Drivetrain Technologies
- Advanced gear materials
- Optimizing tolerances for performance

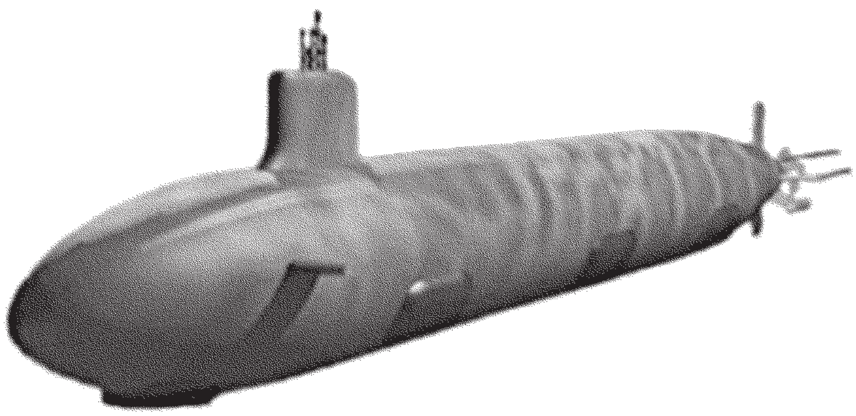
Rudder/Appendages
- Coatings
- Materials

Dispersed Auxiliary System
- Acoustic refrigeration

Other
- Environmental systems
- Lifecycle engineering (REPTECH)
- Wear and corrosion-resistant alloys for structures, valves, and tubing
- Conceptual design trade studies
- Electro-optics
- Paint removal
- Manufacturing process modeling

Naval Sub-Surface Platform Technology Group

The integration of advanced materials, manufacturing processes, tooling and fixturing will result in reductions in gross weight, vibration, interior noise, and life-cycle costs, as well as increases in mission range, survivability, and operational availability. These improvements are made more affordable due to significant reductions in labor and in operating and support (O&S) costs.



Combat Systems
- Advanced torpedeo systems
- Anti-torpedeo torpedeo

Auxiliary Systems
- Acoustic refrigeration

Other
- Environmental systems
- Lifecycle engineering (REPTECH)
- Wear and corrosion-resistant alloys for structures, valves, and tubing
- Conceptual design trade studies
- Manufacturing process modeling

Autonomous Ship Systems
- Intelligent control
- Remote sensors
- Condition-Based Maintenance
- Advanced lubricants
- Information systems

Drivetrain Technologies
- Gear performance prediction
- Reduced noise and vibration design
- Condition monitoring

Hull
- Laser forming, welding, and cutting
- Laser cutting, welding, and welding of structural shapes
- Sonar dome fairings
- Improved paint removal and application systems

Information Technology
- Electronic data transfer
- Intelligent management of documents and data

Propellor
- Design
- Inspection
- Free-form fabrication
- Manufacturing support
- Repair

iMAST Facilities and Equipment

Mechanical Drive Transmission

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

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

Gear Dimensional Inspection Facility

- U.S. Navy's Gear Metrology Laboratory
- Only DoD neutral testing site for verifying measurement accuracies related to gear specifications
- 48-hour advance notice capability for emergency gear repairs

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.

Materials Processing

Spray Metal Forming

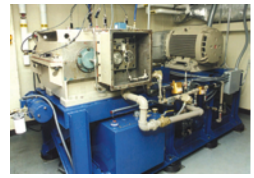
- 5,000 sq. ft. facility
- Full metallographic and surface characterization capabilities
- Research scale/pilot plant
  - – Melts up to 120 lbs kgs of aluminum
  - – Produces billets (10” diameter x 16” length), strip (12” x6”x 2.0”), and tubes (3” diameter x 12” length)
- Melt and filtration system
- Small extrusion press
- Capability to produced metal matrix composites

High-Velocity Particle Consolidation

- Computer controlled system
- Production scale equipment
- Process development

Nanophase Material Facilities

- Vacuum and controlled atmosphere hot press
- Nanoparticle handling capabilities



Surface Technologies

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

High Temperature Cyclic Oxidation and Humidity Testing

- Advanced coating department at PSU has 4 high temperature furnaces capable of thermal cyclic testing up to 1300°C in atmosphere and two controlled environments such as humidity
- 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

Advanced Coatings

Industrial Prototype Electron Beam Physical Vapor Deposition (EB-PVD)

- Prototype scale unit that has six electron beam guns
- Average power capacity of each gun is 45 kW for a total of 270 kW
- Additional flexibility in having a three ingot continuously feed system individually or simultaneously for the synthesis of complex compounds through co-evaporation processes
- Overall, the chamber is approximately 90cm in length, 90cm in width, and 90 cm in height
- Evaporation rates range from 0.5 nm to 100 μm per minute depending on the material

Lab scale Electron Beam Physical Vapor Deposition (EB-PVD)

- One EB gun (8kw)
- Four 25cc hearths
- Cold cathode ionization source with chamber size of 66cm x 60cm x 100cm
- Up to four different materials can be deposited
- Multilayered coatings, direct evaporation, reactive evaporation, IBAD processes can easily be performed in this unit

Sputter Deposition

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

Ion Beam Assisted Deposition

- PSU also has 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 the samples prior to deposition to facilitate coating adhesion. In addition, when used during deposition, microstructure, crystallographic orientation, 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

Laser Processing

- 14-kW cw CO2 laser system
- 2.0-kW cw and pulsed CO2 laser systems
- 6-kW Diode-pumped cw Nd:YAG
- 3-kW cw Nd:YAG
- 400-W pulsed Nd:YAG
- 10-W Q-switched Nd:YAG
- Diode-pumped Q-switched Nd:YAG operating at 3rd harmonic
- 200-W excimer laser
- Laser Articulating Robotic System (LARS)
- Large-scale gantry

Technology Transfer Facilities

- Support equipment (e.g., robotic, linear and rotary workstations, etc.)
- Support equipment
- Two 3.0-kW cw Nd:YAGs at Puget Sound Naval Shipyard
- 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 24-foot gantry

Advanced Composites

Filament Winding Facility

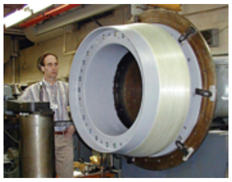
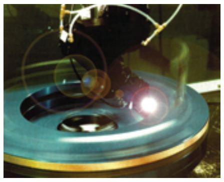
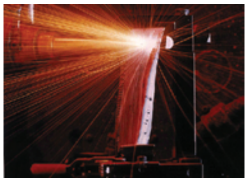
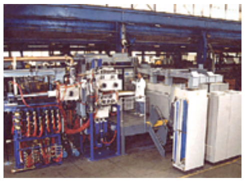
- 4-axes computer controlled filament winder and ancillary support equipment for both “wet” and prepreg fabrication.

Layup/Autoclave Cure Facility

- Computer controlled autoclave, equipment and facilities for prepreg hand layup/cure of advanced composite materials and for structural bonding with film adhesives.

Machining Facility

- Specially-equipped shop for the machining of composite test specimens to ASTM/SACMA configurations.

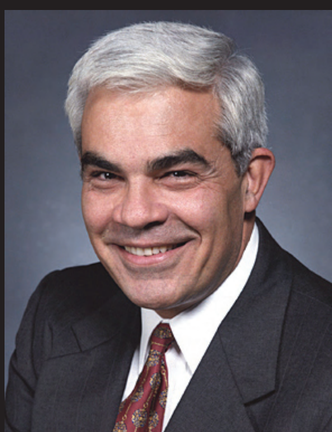
Mechanical Testing Facility	■ Instrumented impact, static and servo-hydraulic test frames for strength, fatigue and fracture mechnanics characterization of advanced composite material systems. Data used to generate material allowables databases.
Resin Transfer Molding Facility	■ Resin meter/mix and vacuum equipment for fabricating hardware by both closed mold resin transfer molding (RTM) ■ Open mold vacuum assisted resin transfer molding (VARTM) processes.
Ultrasonic Facility	■ Ultrasonic NDE facilities and acoustic emission diagonostic equipment for quailty assurance inspection of composite and metallic structures, adhesive bondlines and in-service damage assessment.

Materials and Manufacturing Division has access to the Pennsylvania State University state-of-the-art characterization facility for analyzing various materials, selective analytical techniques are listed below:

Microscopy	■ Atomic force microscopy (AFM), Energy dispersive x-ray spectroscopy (EDXS), Orientation imaging microscopy (OIM), Scanning electron microscopy (SEM), Transmission electron microscopy (TEM)
Surface and thin film	■ Auger electron spectroscopy (AES), Electron probe microanalysis (EPMA), Energy dispersive x-ray spectroscopy (EDXS), Secondary ion mass spectrometry (SIMS), x-ray photoelectron spectroscopy (XPS))
Structural analysis	■ Fourier transform infrared (FTIR), Raman spectrometry, x-ray diffraction (XRD), x-ray reflectivity, Multi-point BET analyzer (BET)
Chemical analysis	■ Direct couple plasma-atomic emission spectrometry (DCP-AES), Inductively coupled plasma-atomic emission spectrometry (ICP-AES), Inductively couple plasma-mass spectrometry (ICP), Ion chromatography
Thermal analysis lab	■ Differential scanning calorimetry (DSC), Differential thermal analysis (DTA), Thermogravimetric analysis (TGA)
High temperature cyclic oxidation and humidity testing	■ Advanced coating department at PSU has 4 high temperature furnaces capable of thermal cyclic testing up to 1300°C in atmosphere and two controlled environments such as humidity. ■ Additional furnace available for conversion to corrosion testing depending on the test set-up

A wide variety of characterization techniques allows for a more complete analysis of the microstructure and composition of the coatings which dictate the coatings properties and performance.

Faculty, Staff, and Sponsors







Edward G. Liszka
Director,
Applied Research Laboratory,
The Pennsylvania State University

Thomas M. Donnellan
Associate Director,
Materials and Manufacturing,
Applied Research Laboratory,
The Pennsylvania State University

Timothy D. Bair
Director, Institute for Manufacturing and Sustainment Technologies,
Applied Research Laboratory,
The Pennsylvania State University

Gregory J. Johnson
Research Institute Administrator, Institute for Manufacturing and Sustainment Technologies,
Applied Research Laboratory,
The Pennsylvania State University

Rear Admiral William E. Landay, III USN
Chief of Naval Research,
Office of Naval Research

John Carney
Director,
U.S. Navy's Industrial and Corporate Program Department,
Office of Naval Research

Greg Woods
Navy Program Manager, Institute for Manufacturing and Sustainment Technologies at ARL Penn State,
Office of Naval Research

Applied Research Laboratory

Edward G. Liszka

B.S., Electrical Engineering, The Pennsylvania State University
M.S., Engineering Acoustics, The Pennsylvania State University
Ph.D., Applied Physics, The Catholic University of America

The eighth director of Penn State's Applied Research Laboratory, Dr. Liszka 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 20 interdisciplinary laboratories, centers, and institutes in the University's Inter-college Research Programs, ARL performs over 60 million dollars worth of research and development in the areas of undersea weapons guidance and control systems, advanced closed-cycle thermal propulsion systems 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, Dr. Liszka served as Chief Scientist (Research and Technology) for the Office of Naval Research, which he assumed after serving as Associate Director for Undersea Systems at ARL.

Thomas M. Donnellan

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

Dr. Tom Donnellan is 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

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 Technology. 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, Tim was working to extend ARL's reach into Autonomic Logistics, condition-based maintenance applications, advanced repair technology, and space-based sustainment programs.

Tim has more than 26 years of logistics and program management experience as a senior officer in the U.S. Air Force. Tim'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, Tim was the deputy director, Directorate of Logistics Management, Ogden Air Logistics Center, Hill Air Force Base, Utah. He also served as an investigative staff member of the Columbia Accident Investigation Board.

A native of Williamsport, PA, Tim is a graduate of Penn State University. He holds master's degrees from the Air Force Institute of Technology and also the Industrial College of the Armed Forces.

Gregory J. Johnson

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

Mr. Johnson is the research institute administrator for the iMAST effort at ARL Penn State. Mr. Johnson previously served as executive assistant to the Deputy Assistant Secretary of the Navy for Research, Development & Acquisition. Prior to that assignment he served as the ground anti-armor program manager at the Marine Corps Systems Command. A former Naval Aviator, Mr. Johnson served in various operations and aircraft maintenance assignments to include maintenance test pilot positions with Japan Aircraft Company and China Airlines. Mr. Johnson is currently a Ph.D. candidate in public administration.

Office of Naval Research

Rear Admiral
William E. Landay, III USN

During January of 2006, Rear Admiral Landay became the 21st Chief of Naval Research to command the Office of Naval Research (ONR). As Chief of Naval Research, RAdm Landay manages the science and technology programs of the Navy and the Marine Corps from basic research through manufacturing technologies. In addition to his position as Chief of Naval Research, RAdm also assumed the duties of Director, Test and Evaluation and Technology Requirements in the Office of the Chief of Naval Operations, and Deputy Commandant of the Marine Corps for Science and Technology, Headquarters, U.S. Marine Corps.

A 1978 graduate of the U.S. Naval Academy, Admiral Landay was commissioned was commissioned as a Surface Warfare Officer. His first assignment was as Gunnery Assistant and Combat Information Center Officer in USS Hepburn (FF 1055). Subsequent sea tours included Ship Control Officer in USS Nicholas (FFG 47), Commanding Officer of USS Aquila (PHM 4), and Commanding Officer of USS Paul Hamilton (DDG 60). During Rear Adm. Landay's tour, Paul Hamilton was awarded the Battle Efficiency "E" for operational performance, two Silver Anchor awards for retention excellence, and the Spokane Trophy for outstanding Combat Systems Readiness.

Ashore, he has served as a Team Training Instructor and Harpoon course director at Fleet Combat Training Center, Pacific; C4I Program Officer and Executive Assistant to the Director of Command, Control, Communications and Computer Systems at the United States Transportation Command. Acquisition tours included assignment as Surface, Strike, and Underwater Warfare Manager and Fleet Support Officer in the Aegis Program Office; Executive Assistant to the Commander, Naval Sea Systems Command; Deputy for Fleet and Lifetime Support in the Program Executive Office, Theater Surface Combatants; and Executive Assistant and Naval Aide to the Assistant Secretary of the Navy (Research, Development and Acquisition). As a Flag Officer he served as the Program Executive Officer for Littoral and Mine Warfare from 2004 through 2005.

The admiral holds a B.S. degree in Systems Engineering from the Naval Academy and an M.S. degree in Systems Technology (C4I) from the Naval Postgraduate School. He is also a graduate of the Program for Management Development at the Harvard Business School. He was the 1998-99 Navy Fellow in the Defense Systems Management College, Military Research Fellowship Program. He is a level 3 certified Acquisition Professional and a Proven Subspecialist in C4I Systems.

Rear Adm. Landay's personal awards include the Distinguished Service Medal, Legion of Merit (3 awards), Defense Meritorious Service Medal, Meritorious Service Medal (2 awards), as well as various unit awards.

John Carney

Mr. Carney is the director of the U.S. Navy's Industrial and Corporate Program Department, Office of Naval Research. Mr. Carney is responsible for the Navy's Independent Research and Development, Manufacturing Science and Technology, Small Business Innovation Research, and Cooperative Research and Development Agreements programs.

A native of Sterling, Virginia, 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.

Greg Woods

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. A mechanical engineer, Mr. Woods holds a bachelor of science degree from Tennessee State University, as well as an engineering management and system engineering certificate from George Washington University. A native of Memphis, Tennessee, Mr. Woods has over 20 years experience in surface ship structural integrity design, as well as materials design and application expertise with NAVSEA and NSWC-Carderock Division.

Points of Contact

John Carney
(703) 696-0352
(703) 696-8480 *(fax)*
carneyj@onr.navy.mil

Steve Copley, Ph.D.
(814) 863-7140
(814) 863-1183 *(fax)*
smc21@psu.edu

Eddie Crow
(814) 863-9887
(814) 863-0673 *(fax)*
ecc1@psu.edu

Tom Donnellan, Sc.D.
(814) 865-6345
(814) 865-0865 *(fax)*
tmd11@psu.edu

Timothy Eden, Ph.D.
(814) 865-5880
(814) 863-0006 *(fax)*
tje1@psu.edu

Tom Hite
(703) 313-8990
(814) 863-1183 *(fax)*
tmh9@psu.edu

Gregory Johnson
(814) 865-8207
(814) 863-1183 *(fax)*
gjj1@psu.edu

Janice Keay
(814) 865-3536
(814) 863-4128 *(fax)*
jms32@psu.edu

Robert Keay, Ph.D.
(814) 865-7222
(814) 863-4128 *(fax)*
rek10@psu.edu

Kevin Koudela, Ph.D.
(814) 863-4351
(814) 865-8979 *(fax)*
klk121@psu.edu

Ed Liszka, Ph.D.
(814) 865-6343
(814) 865-3105 *(fax)*
egl4@psu.edu

Tina Ludwig
(814) 863-1178
(814) 865-0865 *(fax)*
tsl105@psu.edu

William Mark, Ph.D.
(814) 865-3922
(814) 863-1183 *(fax)*
wdm6@psu.edu

Richard Martukanitz, Ph.D.
(814) 863-7282
(814) 863-1183 *(fax)*
rxm44@psu.edu

Ken Meinert
(814) 863-7281
(814) 863-1183 *(fax)*
kcm104@psu.edu

Dan R. Metrey
(814) 865-2053
(814) 865-8979 *(fax)*
drm12@psu.edu

Gary Neal
(814) 863-5468
(814) 863-1183 *(fax)*
gln103@psu.edu

Suren Rao, Ph.D.
(814) 865-3537
(814) 863-1183 *(fax)*
sbr1@psu.edu

Karl Reichard, Ph.D.
(814) 863-7681
(814) 863-0673 *(fax)*
kmr5@psu.edu

Edward Reutzel
(814) 863-9891
(814) 863-1183 *(fax)*
ewr101@psu.edu

William Sabol
(814) 863-3004
(814) 863-4128 *(fax)*
wjs4@psu.edu

Jogender Singh, Ph.D.
(814) 863-9898
(814) 863-2986 *(fax)*
jxs46@psu.edu

Nagesh Sonti, Ph.D.
(814) 865-6283
(814) 863-1183 *(fax)*
nxs7@psu.edu

Mark Traband, Ph.D.
(814) 865-3608
(814) 863-4128 *(fax)*
mtt1@psu.edu

Charles Tricou
(814) 863-4459
(814) 863-4128 *(fax)*
cst101@psu.edu

Bob Walter
(814) 863-8876
(814) 863-0673 *(fax)*
rlw9@psu.edu

Dennis Wess
(814) 865-7063
(814) 863-4128 *(fax)*
dbw105@psu.edu

Douglas Wolfe, Ph.D.
(814) 863-0316
(814) 863-2986 *(fax)*
dew125@psu.edu

Greg Woods
(703) 696-4788
(703) 696-8480 *(fax)*
woodsg@onr.navy.mil

Mike Yukish, Ph.D.
(814) 863-7143
(814) 863-4128 *(fax)*
may106@psu.edu

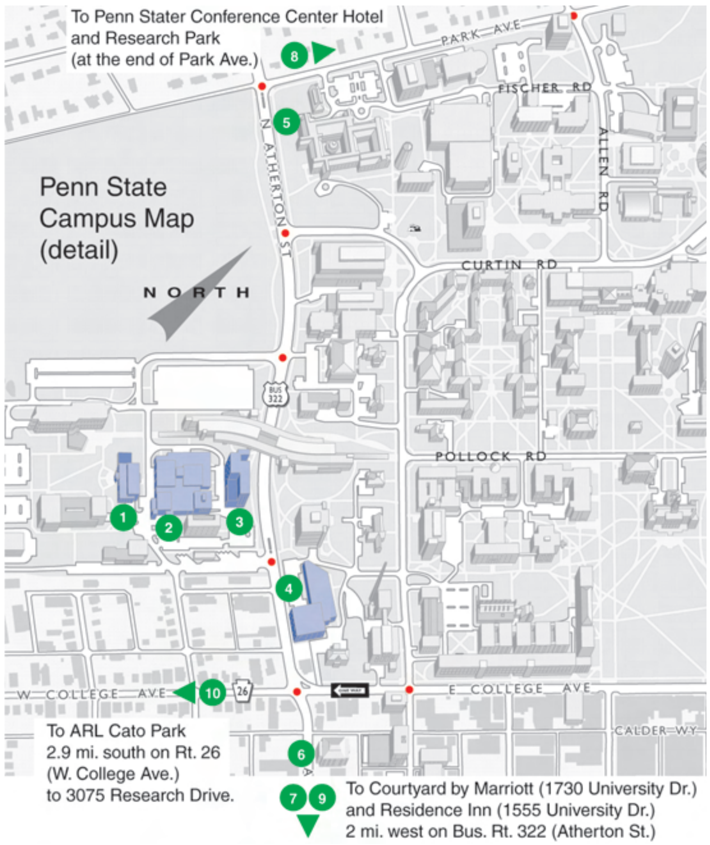
iMAST

ARL Penn State
P.O. Box 30
State College, PA 16804-0030
(814) 863-3207
(814) 865-0865 fax

iMAST on the World Wide Web: www.arl.psu.edu/capabilities/mm_imast.html

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.

Traveling to ARL Penn State



1. Applied Science Building
   (814) 863-9825
2. Research West Building
3. ARL Water Tunnel
   (814) 865-1741
4. Applied Research Laboratory
   (814) 865-3031
5. Nittany Lion Inn, (814) 865-8500
6. The Atherton Hotel
   (814) 231-2100
7. Courtyard by Marriott
   (814) 238-1881
8. Penn Stater Conference Center
   Hotel, (814) 863-5000
9. Residence Inn
   (814) 235-6960
10. ARL Cato Park, (814) 863-9751

From Philadelphia

There are two routes. (1) Take the Northeast extension of the Pennsylvania Turnpike (I-76) to I-80. From I-80, exit at Exit 24 (Bellefonte). Follow Route 26 to State College; or (2) take the Schuylkill Expressway to the Pennsylvania Turnpike (I-76). Use Exit 19 (Harrisburg East) follow I-283 to I-83 and proceed north on I-83 to the I-81 interchange. Then follow I-81 west to Route 322/22 west Exit. Proceed west on Route 322 through Lewistown to State College.

From Pittsburgh

Follow Route 22 to Duncansville, Route 220 (bypassing downtown Altoona and Tyrone) through Port Matilda and then Route 322 (Business–also called North Atherton Street) to State College. A scenic route follows Route 22 beyond Duncansville to Water Street, Route 45 to Pine Grove Mills and Route 26 to State College.

From Washington, D.C.

Several routes are available: (1) Take Route I-270 to Frederick, I-70 to Breezewood, Pennsylvania Turnpike (I-76) for 18 miles to Bedford/Altoona exit (Exit 11). (The toll fee is approximately 80 cents.) Follow Route 220 to Port Matilda and then Route 322 Business (also called North Atherton Street) to State College; or (2) follow I-270 to Frederick, Route 15, past Gettysburg, through Camp Hill to Route 322 west to State College passing by Lewistown; or (3) take I-95 or the Baltimore/Washington Parkway to Baltimore, west loop I-695 to I-83 north. Continue on I-83 north to I-81 interchange. Then follow I-81 west to Route 322/22 Exit. Proceed west on Route 322 passing Lewistown to State College.

From New York City

The suggested route is via the George Washington Bridge to I-80. In Pennsylvania, exit from I-80 at Exit 24 (Bellefonte) and follow Route 26 south to State College.

From the West

Take I-80 to Exit 20 (Woodland) just east of Clearfield, then Route 322 east to State College. One may also exit I-80 from Bellefonte and follow Route 26 south to State College.

By Bus

Trailways and Greyhound Lines connections are available to and from State College.
Trailways (814) 238-7362
Greyhound (814) 238-7971

By Plane

Daily flights from Pittsburgh, Philadelphia, Detroit, Harrisburg, Dulles, Baltimore, and Cincinati serve the State College area through the University Park Airport (State College), located five miles from campus. Limousine or taxi service is available for all flights.

Reservations and information:
USAir Express (800) 428-4253
United Express (800) 241-6522
Northwest Airlink (800) 225-2525
Delta Express (800) 221-1212

Private or chartered aircraft may fly into University Park Airport (State College). Please call (814) 355-5511 to make arrangements. Facilities exist for overnight accommodations, fuel and maintenance service.

Rental Cars

At the airport. Reservations and info:
National (814) 237-1771
Hertz (814) 237-1728

Hotels (partial listing)

The Nittany Lion Inn (on campus)
(800) 233-7505 (814) 865-8500

Penn Stater Conference Center Hotel (PSU Research Park, shuttle, car/cab)
(800) 893-4602 (814) 863-5000

The Atherton (walk to campus)
(800) 832-0132 (814) 231-2100

Courtyard by Marriott (shuttle)
(800) 321-2211 (814) 238-1881

Hampton Inn (car/cab)
(800) 426-7866 (814) 231-1590

Days Inn Penn State (car/cab)
(800) 258-3297 (814) 238-8454

Residence Inn by Marriott (shuttle, car/cab)
(800) 331-3131 (814) 235-6960

About ARL Penn State





Solving challenges for the U.S. Navy for over a half a century, the Applied Research Laboratory at Penn State has demonstrated innovation and practicality in technology-based research. The Applied Research Laboratory is one of four U.S. Navy academic research centers in the country. While ARL has served as a Center of Excellence in undersea technology, it has also facilitated Penn State in becoming second among U.S. universities in industrial R&D funding.

Its broad-based effort is supported by a full-time complement of more than 500 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.

ARL Washington D.C. Office
(Ballston)
801 North Quincy Street, Suite 120
Arlington, VA 22203
(703) 312-6990
(703) 312-0095 fax

ARL Organization by Core Competency

Penn State ARL

Core Centers

- Drivetrain Technology Center
- Electro-Optics Science & Technology Center
- Institute for Emerging Defense Technologies
- Institute for Manufacturing & Sustainment Technologies
- Navigation Research and Development Center

Major Programs

- Ausform Gear Finishing
- Night Vision and Fiber Optics
- Force Protection
- Non-Lethal Defense
- Repair Technologies
- GPS Development

Information and Network Systems

Core Competencies

- Information Science and Technology
- Navigation Research and Development Center
- Communications Science and Technology

Major Programs

- Condition-Based Maintenance
- High-Accuracy Fiber-Optic Gyro
- Robust GPS Communications
- Integrated Air Defense Support
- Ocean Sampling Mobil Network
- Damage Control Automation for Reduced Manning

Fluids and Structural Mechanics

Core Competencies

- Fluid Mechanics
- Flow and Structural Acoustics
- Computational Mechanics
- Hydroacoustics

Major Programs

- Virginia Class Propulsor (NSSN)
- Seawolf Quieting (SSN-21)
- Super-Cavitating Vehicle
- NOO Unmanned Vehicle
- Reactor Main Coolant Pump Loop (SEA 08)
- Flow Control

Materials and Manufacturing

Core Competencies

- Manufacturing Systems
- Materials Processing
- Laser Processing
- Drivetrain Technology Center
- Electro-Optics Center
- Advanced Composites Materials
- Repair Technologies
- Systems and Operations Automation

Major Programs

- Ausforming Finished Bearing Races (AAAV)
- Ausform Gear Qualification (DUST/MV-22)
- Spray Metal Forming (JSF)
- Cold Gas Dynamic Spraying (AAAV)
- Femtosecond Laser Processing
- Electron Beam-Physical Vapor Deposition

Undersea Systems

Core Competencies

- Autonomous Control and Intelligent Systems
- Systems Analysis
- Energy Science and Power Systems
- Acoustics
- Emerging Defense Technologies

Major Programs

- Long-Endurance, Low-Frequency, Acoustic Source LELFAS (ATD)
- Anti-Torpedo Torpedo (ATD)
- Multi-Platform Broadband Processing
- Vortex Combustor Power Source
- Wick Combustor Power Source(UUV)
- HYDROX Power Source
- NOO Unmanned Vehicle

FY-06 Navy ManTech Project Activity

NavSea

S0949 Propulsor Affordability Initiative - Cook
S0962 HAZMAT Analzers for Rapid On-Site Analysis -J. Keay
S0994 VLS Tube Repair - Martukanitz
S1016 Polycan Fabrication Improvement - Swanson
S1017 Hot Section Corrosion Protection for 501-K34 Gas Turbine - Wolfe
S1019 Development & Implementation of Collarless Construction Techniques for DDX - Martukanitz
S1020 Manufacturing Process Modeling Technology, Phase III: Implementation Support - Traband
S1034 Overspray Elimination Through the Development of High Transfer Efficiency - Tricou
S1052 Automated Materials Joining & Flexible Fixture Design to Support Product Centered Structural Fabrication - Sabol
S1063 Development of Next Generation Salinity Indicating System for CVN Carriers - J. Keay
S1064 Long-Life Non Skid for CVN Flight Deck - Tricou
S1065 Modeling & Simulation for Carrier Construction Planning & Sequencing - Ligetti
S1068 Automated Measurement System - Reutzel
S1069 CVN-21 Composite Applications for Weight Reduction - Juska
S1070 Laser Welded Lightweight Structure Panel Fabrication and Application to CVN-21 - Martukanitz
S2023 Brush Electroplating - Mikesic
S2025 Submarine Alignments and Inspections - Swanson
S2031 Improved Advanced Surface Ship Closures - Copley
S2067 Optimization of Carrier Material Procurement - Byrne
S2068 Low Heat Input Welding for Thin Steel - Kelly
S2069 Aircraft Carrier Propulsion System Health Monitoring - Lebold
S2072 Carrier Tank Coatings - Tricou
S2073 Development & Implementation of Laser Beam Welding Shipyard Applications - Martukanitz
S2074 Virginia Class Submarine Facility Optimization - Ligetti
S2086 Shipyard Simulation-Optimization Decision Support System for Lead Time Reduction - Finke
R0834 Plastisol Repair Rapid Response - Metrey

Marine Corps

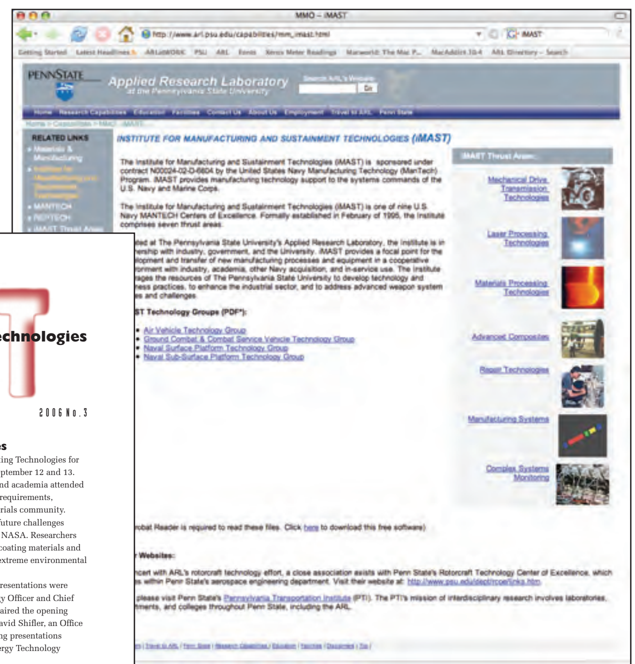
C0934 AAV Enhanced Applique Armor Kit Product Improvement - Eden
C2026 M198 Howitzer Mechanism Recoil Testing - Little
C2142 Clean & Paint LEAN Production Optimization -Krieger

NavAir

A0909 F/A-18 F404 Engine Fretting & Low Cycle Fatigue Amelioration - Eden
A0933 Aircraft Carrier Arresting Gear Poured Cable End Sockets - Eden
A0967 Aircraft Applique: Database Development & Removal Technologies - Metrey
A1014 Helicopter Blade Refurbishment - Reutzel
A2027 Unique Identifier Implementation Assessment - Tillotson
A2028 Repair of CH-46 Transmission Gears by Super Finishing -Rao
A2087 Erosion Resistant Coatings for Stage I-Compressor Components - Wolfe
A2027 Unique Identifier Implementation Assessment
A2028 Repair of CH-46 Transmission Gears by Super Finishing
R0834 Plastisol Repair Rapid Response

Technology Transfer Event Participation

Defense Manufacturing Conference '05, Orlando, FL
American Helicopter Society Forum 62, Phoenix, AZ
Showcase for Commerce, Johnstown, PA
Navy League SeaAirSpace Expo 2006, Washington D.C.
ICALEO 2006, Dearborn, MI
ShipTech 2006, Biloxi, MS
Showcase for Commerce Armstrong County, Kittanning, PA
ONR Naval Partnership Conference 2006, Washington D.C.
Marine Corps League Modern Day Marine Expo, Quantico, VA
Surface Navy Association Symposium, Crystal City, VA



PENNSTATE ARL

iMAST

Institute for Manufacturing and Sustainment Technologies

A U.S. Navy Manufacturing Technology Center of Excellence

QUARTERLY 2006 No. 3

Successful Coatings Workshop Convenes

An International workshop on "Advanced Materials and Coating Technologies for Extreme Environments" was held at Penn State University September 12 and 13. Approximately 140 participants from industry, government and academia attended the two day program. The workshop linked field experience, requirements, materials and technologies with various members of the materials community. The workshop also provided a forum to address current and future challenges facing the Department of Defense, Department of Energy, and NASA. Researchers and end-users were able to exchange information about new coating materials and technologies needed to extend the life of components under extreme environmental conditions including oxidation, erosion, corrosion, and wear.

Twenty-six distinguish speakers and 17 poster presentations were offered at the workshop. Dr. William Frazier, Chief Technology Officer and Chief Scientist for the Naval Air Systems Command opened and chaired the opening session. Dr. Frazier was followed by presentations from Dr. David Shifler, an Office of Naval Research program manager. Rounding out the opening presentations was Dr. Udaya Rao, a program manager with the National Energy Technology Laboratory, Department of Energy in Pittsburgh, PA..

The first session highlighted the gap between designed turbine system requirements and actual material performance when systems are introduced to extreme performance environments. A special session was organized to address *in situ* health monitoring of coated components under extreme environmental conditions. These presentations were headed by Dr. Jeff Eldridge (NASA Glenn Research Center), Dr. William Ellingson (Argonne National Laboratory), and Dr. Aravinda Kar (materials professor, University of Central Florida). Discussion leaders addressed some of the methods and unique techniques being investigated for increasing turbine system coating performance and reliability. Incorporation of *in situ* health monitoring of coated components was also addressed. This technology offers significant potential relative to system operational availability due to reduced machinery down time and the ability to pinpoint maintenance repairs where and when they are needed.

Dr. Robert R. Romanosky, who is manager of the Advanced Research Technology at the Department of Energy's National Energy Technology Laboratory in Morgantown, West Virginia, was guest speaker at the workshop evening dinner. Dr. Romanosky provided a comprehensive overview on "25 Years of Materials Progress for Future Energy Systems: Past, Present and Future." The overview addressed the Department of Energy's materials performance requirements for future energy systems.

Focus On Laser Processing Technologies

Continued on Page 6

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ARL Penn State
P.O. Box 30
State College, PA 16804-0030

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