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iMAST

Applied Research Laboratory
Institute for Manufacturing and
Sustainment Technologies

FISCAL YEAR 1998

ANNUAL REPORT

Report Documentation Page

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A MESSAGE FROM THE PROGRAM MANAGER

The Manufacturing Technology Office of the Office of Naval Research sponsors the Institute for Manufacturing and Sustainment Technologies (iMAST) program at The Pennsylvania State University's Applied Research Laboratory (ARL). The iMAST programs develop technologies to enhance manufacturing practices that will reduce risk in fielding high-quality, reliable Navy and Marine Corps weapon systems. Our customers are the warriors of the fleet who serve at sea, in the air, and on land, both at home and abroad. With due respect, we are committed to leveraging the Navy's ManTech Program to help our warriors meet the unique battlefield challenges they will encounter as they forward deploy into the 21st century.

During the fiscal 1998 reporting period, iMAST continued to tailor its support using existing and innovative commercial technology for defense application. We continue to focus on creating and improving advanced manufacturing processes that will translate into significant risk reduction on Navy, Marine Corps, and other DoD manufacturing issues. We have made some minor internal organizational changes and have also added some special technology groups to exploit the multi-disciplinary nature within ARL as well as Penn State.

iMAST is organized into four technology thrusts: mechanical drive transmission technologies, materials science technologies, high-energy processing technologies, and repair technology (REPTECH). During the reporting period, we continued to expand our capabilities by upgrading facilities and by developing and initiating strategic government and commercial alliances as well. We continue to host national symposiums highlighting our technical expertise, and to sponsor detailed hands-on workshops for technology transfer to industry and government.

In 1999, we will continue to address the materials and manufacturing requirements of the Navy and Marine Corps systems commands while quickly and efficiently transitioning our projects into the government acquisition and support infrastructure along with the domestic industrial base. Our goal remains to aid the Department of the Navy in fielding reliable, state-of-the-art, cost-effective weapon systems that get the job done.

This annual report details our FY98 accomplishments and provides an insight into our capabilities and resident expertise. As always, I extend to you an invitation to learn more about our program. Do not hesitate to call our points of contact, to request published material, or, better yet, to come visit us. Most of all, please give me your feedback. Let me know how I can use our resources to help support you. I look forward to hearing from you.

Henry Watson

ManTech Program Manager
Applied Research Laboratory
The Pennsylvania State University

iMAST
FY1998
ANNUAL REPORT

THE INSTITUTE FOR MANUFACTURING AND SUSTAINMENT TECHNOLOGIES

iMAST is a nonprofit 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 four technical thrust areas:

- **Mechanical Drive Transmission Technologies**
- **Materials Science Technologies**
- **High Energy Processing Technologies**
- **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.

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Institute for Manufacturing and Sustainment Technologies

iMAST TECHNICAL THRUST AREAS

MECHANICAL DRIVE TRANSMISSION TECHNOLOGIES

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)

A Navy end-of-project demonstration for the double-die ausform finishing machine and the arrival and co-location of the Gear Research Institute were two significant highlights of the fiscal year. The ausform finishing project effort continues to have high Navy and industry visibility. The program has been developed into three phases. Phase I (development of the double-die machine) is considered complete. Phase II (performance evaluation) is now underway. Phase III (process qualification for DoD-wide application) will commence upon successful completion of phase II.

The mechanical drive transmission thrust is divided into three sections:

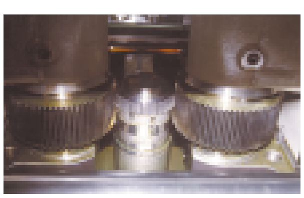
Advanced Manufacturing and Materials

Gear Metrology and Performance Prediction

Condition-Based Maintenance

Performance Testing of Ausformed Finished Gears

Advanced Manufacturing and Materials

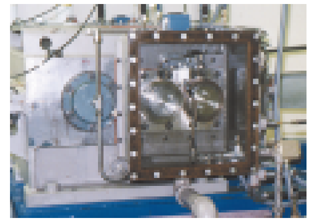


The objective of this project is to evaluate the surface durability and strength of ausform finished gears as compared to conventionally processed gears. The comprehensive gear evaluation program includes pitting, bending, and scoring resistance tests that will verify the performance enhancement achieved by ausform finishing for specific gear materials, geometry and processing conditions. 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. Boeing-Mesa is actively participating in the program with cash and in-kind support. During the past year, development of tooling and test gears for the ausform finishing of 8 DP, 6-in. PD spur gears was completed. Evaluation of pitting behavior of ausform finished RCF test specimens was completed. Manufacture, testing ,and calibration of power circulating test rigs required for the program were also completed. Quality evaluation and testing of baseline gears were initiated.

Project Leader: Dr. Nagesh Sonti

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.



Ausform Finishing of Bearing Races

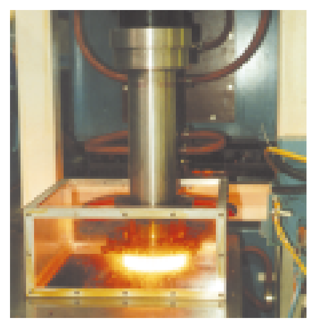
Advanced Manufacturing and Materials

The objective of this project is to develop advanced surface enhancement techniques (i.e., ausform finishing and multilayered coating) to enhance surface durability, and wear and corrosion resistance, and thereby to increase the mean-time-before-overhaul of transmission bearing raceways. The project will develop tooling and processing techniques for enhancing bearing raceways, and will involve comprehensive bearing testing to establish the performance of surface-enhanced bearings. The project is structured with substantial in-kind contributions from a major bearing manufacturer in terms of specimen manufacture, coating development and evaluation, and testing. This project supports multiservices and multiweapon systems. The demonstration vehicles identified include the CH-46 *Sea Knight* helicopter and the advanced amphibious assault vehicle (AAAV). Successful completion of the project will lead to an LRIP weapon systems qualification program integration, followed by large-scale commercial implementation.

Project Leader: Dr. Nagesh Sonti

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.

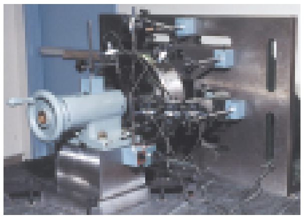


Non-Contact Workpiece Positioning System

Advanced Manufacturing and Materials

This project is designed to reduce setup time, increase accuracy, and reduce scrap in the machining of precision transmission components such as housings and gears. Current manufacturing methods use physical datum surfaces to locate the part on the machine tool during machining. This datum surface may be a nonfunctional feature that adds unnecessary costs, but it also results in variability of part location due to accuracy, especially when the part is subject to multiple setups. The use of physical datum surfaces is very sensitive to part location variation due to ingress of dirt, chips, etc., and rigid-body motions of the part due to clamping forces. This results in extremely long setup times to overcome these problems and increased production of scrap components.

The solution to this problem is the development of a laser-triangulation-based workpiece positioning system identifying strategically located precision artifacts on the part and determining the part reference axis after the part has been clamped on the machine



tool. A separate prior qualification step, after the artifact has been attached to the workpiece, identifies the relationship between the artifact and the part reference axes. A two-dimensional noncontact workpiece positioning system (NCWPS) using a laser triangulation probe was successfully demonstrated on a four-axes Fadal Machining Center to Sikorsky and NAVAIR representatives. A three-hole pattern was drilled and reamed using the NCWPS with random movement in part location between holes to simulate setup changes. Hole positioning accuracy of better than ±0.0002-in. was achieved without the use of traditional part setup methodology. A three-dimensional system NCWPS is currently under development. This system will be demonstrated on a Sikorsky SH-60 input gear box housing transmission component at a future date.

Project Leader: Dr. Suren Rao

Noncontact High-Speed Gear Inspection

Gear Metrology and Performance Prediction

The purpose of this project is to develop an economical noncontact high-speed precise gear surface inspection system for DoD depots and gear manufacturers. The benefits of this project 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 recent NIST review resulted in a stamp of approval for the optical measurement technique under development. 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 reflectivity nonuniformity compensation (DRNC) have also been developed and fully tested. A compact and rugged mechanical assembly for the optical head has been designed and is being fabricated.

Project Leader: Dr. Benjamin A. Bard

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).

In-Situ Gear Error Measurement

Gear Metrology and Performance Prediction

In response to a request by the Navy, the Drivetrain Center has developed a methodology for measuring sub-micron-amplitude gear-tooth errors of gears assembled in drivetrain systems. Successful accomplishment of the project goals has required major modifications of existing gear measurement apparatus, new measurement procedures, and innovative developments in measurement computer processing algorithms and software that minimize the contributions of measurement errors. Project accuracy requirements are significantly beyond the current state-of-the-art gear measurement technologies for in-situ gear measurement conditions.

Project Leader: Dr. William D. Mark

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.

Accelerated Capabilities Initiative: Machinery Diagnostics and Prognostics (Non-ManTech)

Condition-Based Maintenance

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.

Project Leader: Mr. William Nickerson

Technologies for Gear Performance Prediction Using Precision Optical Measurement

Non-ManTech Programs

(A NIST Advanced Technology Program Project)

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.

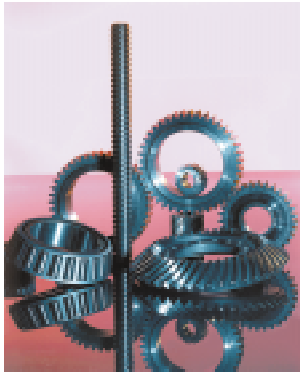
A NIST ATP program was awarded to M&M Precision Systems Corporation, manufacturer of precision CMM touch probes. ARL is subcontractor to M&M for both the noncontact optical sensing system as well as gear performance prediction capabilities based on the optical measurements. The M&M program involves enhancement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

Project Leaders: Dr. William D. Mark and Dr. Benjamin A. Bard

Process Development of Advanced Gear Steels for High-Performance Transmission Application

Non-ManTech Programs

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 1999.

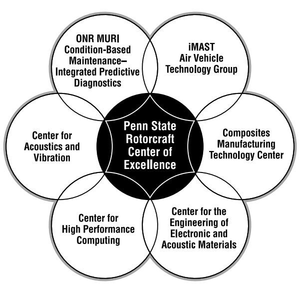
Project Leader: Mr. Al Lemanski

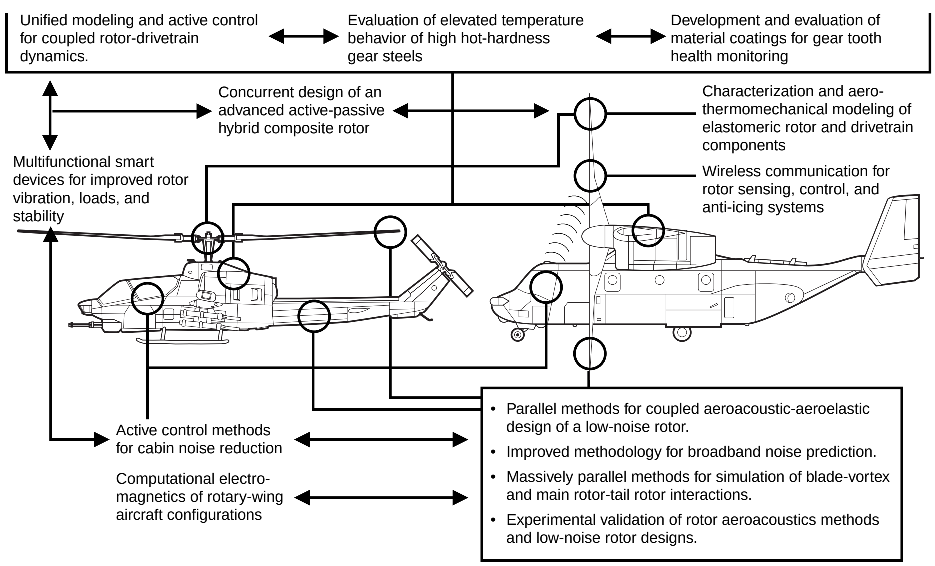
Penn State Rotorcraft Center of Excellence

Non-ManTech Programs

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.

Project Leader: Mr. Al Lemanski





MATERIALS SCIENCE TECHNOLOGIES

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 provides capabilities in advanced metals and ceramics development, materials processing, and surface technologies along with capabilities in polymer matrix composites. Our focus is to act as a leader in the field of materials 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.

During the fiscal year, significant technical advancements in support of the ManTech Program were achieved. In spray metal forming, a nickel-itrium-cobalt aluminum alloy, which holds great promise in supporting weight saving initiatives for the Joint Strike Fighter, was successfully manufactured and characterized. Preforms of fully densified nanograined material, which has the potential to revolutionize the manufacture of titanium components by minimizing tool costs, were successfully manufactured by ARL technologists. And significant technical progress was made to validate cold gas dynamic spraying as a low-cost coating technology to support weight saving initiatives in the Advanced Amphibious Assault Vehicle (AAAV) track system.

The materials science thrust is organized into three sections:

Metals and Ceramic Processing

Surface Technologies

Polymer Matrix Composites

Spray Formed Aluminum Alloys in Support of Joint Strike Fighter (JSF)

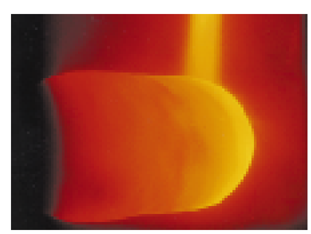
Metals and Ceramics Processing

This project is validating spray-formed high-temperature alloys and optimizing component manufacturing processes for fan stators in the JSF engine. Using the unique capabilities of the spray forming equipment resident at ARL Penn State, this project is integrated with the JSF engine design and verification efforts of Pratt & Whitney and is being monitored by the Materials Division of the Naval Air Warfare Center, Patuxtent River.

Project Leaders: Dr. Maurice Amateau and Dr. Timothy Eden

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 spray 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.



Titanium Machining Improvements for the F107 Engine

Surface Technologies

Current manufacturing methods dictate that the compressor section of the Tomahawk F107 engine be milled from a forging of solid titanium alloy. Due to the reactivity of titanium and its relative difficulty to machine, a single machine tool cannot be used to fabricate a complete compressor section. The tool must be changed frequently increasing the manufacturing cost of the component and affecting the machining tolerances.

This project applies nanograined material technology to manufacture prototype machine tools made from 100 percent amorphous nanograined materials. Results to date have shown that these prototype nanongrained cutting tools have 4 to 10 times the longevity of conventional cutting tools used to mill titanium. This technology has multiple applications. After validation on the F107 engine production line, the technology will be transitioned to the domestic industrial base.

Project Leader: Dr. Ram Bhagat

UNIQUE CAPABILITY

MICRO- AND NANOFABRICATION MANUFACTURING TECHNOLOGIES comprise the set of base technologies essential to the manufacture of micro- and nanoscaled electronic integrated circuits. These technologies include materials deposition, materials etching, and materials modification. ARL Penn State has unique access to state-of-the-art nanofabrication facilities. These facilities are located in Penn State's Research Park and contain over 3,600 square feet of class-1,000 clean rooms and 1,400 square feet of class-100 and class-10 clean rooms. These clean rooms contain the latest equipment for electron beam lithography, low-pressure chemical vapor deposition (CVD), plasma-enhanced CVD sputtering deposition, plasma and reactive ion etching and rapid thermal annealing tools. This facility can duplicate production environments for the manufacture of microcircuitry, flat panel displays and microelectromechanical devices (MEMs).

UNIQUE CAPABILITY

NANOGRAINED MATERIALS TECHNOLOGY deals with material particles below .5 microns. Taking advantage of recent advancements in nanograined powder production, ARL Penn State has focused its efforts on the consolidation of these nanograined powders into fully densified preforms (cutting tool blanks and inserts). The consolidation of the powders has been accomplished by a combination of microwave sintering and vacuum hot=pressing. The results are fully densified nanograined preforms fabricated into cutting tools used to mill titanium alloys. These preforms have achieved increases 4 to 10 times in cutting performance when compared to conventional cutting tools.

Advanced Manufacturing Processes for Advanced Amphibious Assault Vehicle (AAAV) Track Pins and Roadwheels

Surface Technologies

This project is evaluating two manufacturing technologies to provide component weight savings and improve maintainability on the track and roadwheel system of the AAAV. The first manufacturing technology being evaluated is the spray metal forming of a high-temperature aluminum alloy and the subsequent extruding of the alloy into track pins. These aluminum track pins will be evaluated as an alternative to the conventionally produced steel track pins. An aluminum track pin has the potential of providing over 450 pounds in combined weight savings for the AAAV.

The second manufacturing technology being evaluated is Cold Gas Dynamic Spraying (CGDS). CGDS will be evaluated as a coating process for the AAAV roadwheels. Using CGDS as a means to put down a sacrificial wear coating on the roadwheel has the potential of providing an additional 415 pounds in combined weight savings when compared to the current steel wear ring.

Project Leaders: Dr. Maurice Amateau and Dr. Anatoli Papyrin

UNIQUE CAPABILITY

COLD GAS DYNAMIC SPRAYING is a coating technology that originated in the former Soviet Union. This technology has been transitioned to the U.S. domestic industrial base. The technology is based on the supersonic acceleration of coating particles, which imbed themselves into a substrate, causing a coating to build based on friction welding. The process operates below the melting threshold of both the particles and the substrate, thus there is a good bond strength between coating and substrate, with no substrate melting or recrystallization. Benefits include allowance for the alloying of coatings, high productivity and high deposition rate, deposition efficiencies up to 80 percent, and production of free-standing structures for rapid prototyping. The international and domestic patent holder for Cold Gas Dynamic Spraying technology is resident at ARL Penn State. The R&D facilities that support this technology are unique in that they provide the capability to coat structures from 2 mm up to 24 in.

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

Surface Technologies

This project is evaluating fretting and low-cycle fatigue that adversely affects the compressor and fan sections of the F404 engine. The current configuration of the titanium fan blade and the titanium fan disk provides for a copper-nickel-indium coating on the blade root. This coating fails, causing the titanium to titanium wear, a process that leads to fretting and low-cycle fatigue. If not discovered in time, this wear can lead to catastrophic failure of the compressor section.

The project is evaluating the failure mechanisms of fretting and low-cycle fatigue and duplicating them in a laboratory environment. After establishing the baseline failure configuration, an optimum coating and/or coating process will be developed and implemented, and will eliminate/minimize fretting and low-cycle fatigue and the blade-disk interface. This optimum coating and/or coating process will be evaluated both in the laboratory and in actual fleet testing.

A capability supporting this project effort is adverse wear amelioration through advanced coatings designs and/or coating processes. By integrating capabilities resident throughout Penn State, considerable expertise can be focused on addressing the testing and evaluation of coatings and coating processes.

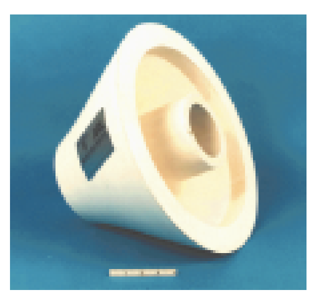
Project Leaders: Dr. Joseph Conway and Dr. Albert Segall

UNIQUE CAPABILITY

SIMULATION-BASED DESIGN (SBD) is the process of rapidly exploring a design space to evaluate the cost, performance, and design characteristics of multiple alternatives in the form of virtual system and process prototypes. It relies on an object-based information model-controlled software architecture to integrate heterogeneous, geographically distributed computer systems, and models and databases to synthesize and evaluate the alternatives in a “fly before buy” process. It can support geographically distributed development teams. ARL Penn State has developed and demonstrated a general, state-of-the-art SBD system. It is the first to be adopted by the Navy for simulation-based acquisition and is finding numerous other DoD and private sector applications.

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.



HIGH ENERGY PROCESSING TECHNOLOGIES

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 High Energy Processing thrust is a leading research and development activity focused on electron beam–physical vapor deposition (EB-PVD) and laser materials processing. Facilities include a world-class laser applications laboratory as well as a unique EB-PVD machine, capable of depositing a variety of industrial-quality coatings at rates up to 15 kilograms per hour.

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

The high energy processing thrust is organized into two sections:

Electron Beam–Physical Vapor Deposition

Laser Processing

In the EB–PVD area, a major achievement was the "end-of-project" demonstration of the large industrial coater, developed along the lines of the technology pioneered at the Paton Electric Welding Institute in Kiev, Ukraine. This unit was fabricated in the United States at Sciaky, Inc. (Chicago, IL) with the electron guns themselves being fabricated in the Ukraine. The unit features three separate ingots which can be evaporated either simultaneously or in series to produce unique coatings of alloys, functionally graded composition, or layered compositions. It has already produced thermal barrier coatings of outstanding quality and tool coatings of exceptional hardness, and has also exhibited the potential to "spot repair" worn areas of chrome-plated bearing surfaces.

A variety of notable milestones in laser processing were accomplished during the fiscal year. One milestone was the free forming of near net shapes by melting powder metals into desired shapes under computer control. Nickel-aluminum-bronze was shown to have an unusually fine grain structure when parts are fabricated in this fashion, potentially giving the final product a higher corrosion resistance than that produced by conventional casting. In another laser application laser cladding of corrosion-resistant coatings on the surfaces of retractable bits—sea trials of actual hardware are now underway. Fabricating ship structural shapes from flat sheet stock instead of forgings was accomplished and is projected to save approximately $1 million or more per ship if applied to a surface platform such as the DDG-51.

Ukraine Joint R&D

Electron Beam–Physical Vapor Deposition

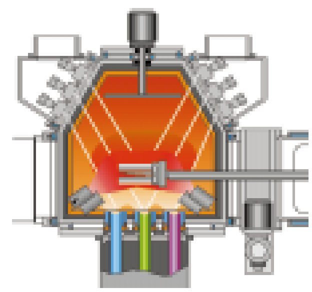
This project has established an Electron Beam–Physical Vapor Deposition (EB–PVD) pilot plant facility to evaluate and improve an EB–PVD process refined at the Ukrainian Academy of Sciences' Paton Welding Institute (PWI). The objective of this project is to integrate the results of the collaborative research and development (R&D) agreement with PWI, and to focus them to provide improved thermal barrier and wear-resistant coatings for Navy and Marine Corps weapon systems. The objective has two parts: (1) to provide improved coating processes across the spectrum of potential applications and (2) to establish a cost-effective source of EB–PVD equipment in the U.S. marketplace.

The EB-PVD process can also be used to replace current environmentally incompatible coating processes. Potential applications include the following: (1) various metal and ceramic coatings (i.e., oxides, carbides, nitrides) can be deposited at relatively low temperatures; (2) elements with low vapor pressure such as molybdenum, tungsten, and carbon are readily evaporated by this process; (3) EB–PVD is capable of producing multilayered laminated metal/ceramic coatings on large components by changing the EB–PVD processing conditions such as ingot composition, part manipulation, and EB energy; and (4) new cost-effective and more robust tool tip coatings will be provided to support Navy shipyards and depots.

Project Leaders: Dr. Thomas Schriempf and Dr. Jogender Singh

UNIQUE CAPABILITY

ELECTRON BEAM–PHYSICAL VAPOR DEPOSITION (EB–PVD) offers many desirable characteristics, such as relatively high deposition rates (100–150 micron/minute with an evaporation rate of 10–15 Kg/hr, dense coatings), precise composition control, columnar and polycrystalline, low contaminate, and high thermal efficiency. ARL Penn State has three EB-PVD research units, including a pilot plant coating facility.



Tool Coating

Electron Beam–Physical Vapor Deposition

To improve cutting and machine tool coatings for hard materials used in naval platforms and weapon systems, improvement in length tool life is necessary. This project will develop a cost-effective cutting tool coating process using EB–PVD with an ion beam assist. This process can be applied across a wide spectrum of cutting tools. The life of cutting tools is targeted to improve by 700 to 800 percent over uncoated tools, or 300 to 400 percent over TiN coated tools after applying multilayered hard coatings such TiC/Cr_3C_2 and TiC/TiB_2. An integral part of this project is transferring this technology to at least one tool company—at no cost to the project. Two companies, Vallenite Co. and Richter Precision Inc., have expressed interest in this technology.

Project Leader: Dr. Jogender Singh

Surface Removal by Optically-Delivered Lasers

Laser Processing

The objective of the program is to develop methods to fiber-optically deliver Nd:YAG laser beams at sufficient power levels to remove coatings without damaging the substrate. This will allow laser coating removal systems to be used for cleaning torpedoes, as well as larger structures such as aircraft fuselage and ship hulls without damaging the substrate and with minimal impact on the environment. Fiber-optic delivery will permit the use of simple and inexpensive beam-manipulation systems and possibly the use of hand-held cleaning devices. All of these innovations will have substantial impact on the lifecycle maintenance costs for a wide range of Navy and Marine Corps weapon systems platforms.

Project Leader: Mr. Ted Reutzel

Repair and Refurbishment of Fatigue-Limited Structures

Laser Processing

Many components used on Navy platforms are fabricated from materials that are heat-treated to attain specific properties required for the area in which they are used. As a result of wear and corrosion, components can be degraded to a point at which performance is impacted. Development, testing, qualification, and implementation of laser-based processing procedures for thermally sensitive materials and components will result in large cost savings. The primary process, laser cladding, is being qualified for less heat-sensitive components and alloys such as hard facing materials on valves and the bearing areas of shafts. Laser cladding of aluminum and titanium alloys will be targeted with a potential result that permits large cost savings for a number of platforms.

Laser processing has provided many benefits to the Navy and industry, as evidenced by the explosive growth of laser-based methods in virtually every area of manufacturing. The performance gains offered by high-speed, high-quality laser welding, cutting, surface treating, and other applications will provide an opportunity for further cost reduction and quality improvement to a wide variety of naval facilities.

Project Leader: Mr. Ken Meinert

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

Laser Processing

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 must 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' AAV 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.

Project Leader: Mr. Eric Whitney

Manufacturing of Laser Cut and Welded Housings for High-Performance Transmission Applications

Laser Processing

The goal of this project is to develop and demonstrate advanced laser cutting and welding techniques in concert with high-strength materials to produce a welded transmission housing that will meet the performance requirements of ground combat vehicles, as well as rotorcraft and VSTOL aircraft employing high-performance transmissions. Additionally, the program will establish the cost and performance benefits of a laser cut and welded housing using the Advanced Amphibious Assault Vehicle and/ or the Seahawk helicopter main transmission for comparison with 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 and with dramatically reduced manufacturing lead times, lower weight designs (permits mini-lube systems), reduced lifecycle costs, high temperature operation, making use of minimum weight system, improved heat transfer capability, improved damage tolerance, and field repairability.

Project Leader: Dr. Richard Martukanitz

Laser Processing of Nickle Aluminum Bronze

Laser Processing

Due to the decrease in the number of new submarine acquisitions, this project has been redirected from laser beam welding for fabrication of nickel-aluminum-bronze (NAB) propulsor and propeller systems to laser beam processing (i.e., welding and cladding) of NAB components. The project goal is to decrease the fabrication, repair, and refurbishment costs of NAB components and to improve their performance using laser materials processing technology.

Laser materials processing of NAB components offers many advantages over traditional NAB fabrication and repair methods. Laser deposited NAB (i.e., both weld and clad materials) has shown superior cavitation, corrosion, and wear resistance over both cast and wrought NAB base materials. Higher material deposition rates can be achieved using laser cladding (compared to that of conventional arc welding), resulting in less time required to repair components. Laser welding and cladding are lower-heat-input processes relative to conventional arc welding processes. This results in minimal distortion of NAB components, thereby meeting stringent tolerance requirements and requiring less post-weld machining of the components. The laser also allows for processing while the part is located on a machining device, without electrical isolation, thereby greatly decreasing repair costs by minimizing tedious and exorbitant material handling.

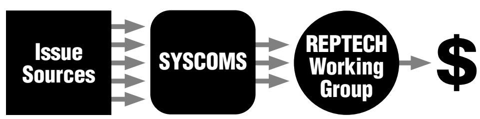
Project Leader: Mr. Ken Meinert

REPAIR TECHNOLOGY

Charter

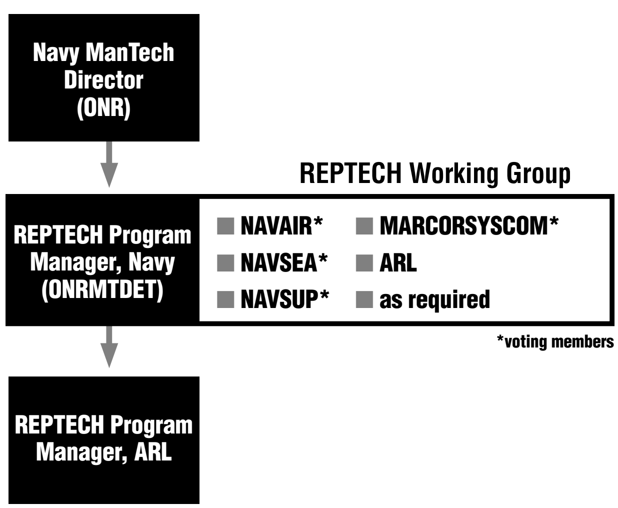
- Apply emerging technologies to improve the capabilities of the repair community
- Improve repair processes and the affordability of repair facilities
- Execute S&T projects which directly affect depot-level maintenance
- Communicate by all means available
- Reduce duplication of effort in REPTECH-related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

Manufacturing Technology (ManTech) and Repair Technology (REPTECH) are the two primary components of the U.S. Navy's Manufacturing Technology Program. ManTech serves to transition new technologies in production processes and equipment from R&D to the factory floor, whereas REPTECH applies appropriate technologies to improve capabilities of the remanufacture and repair community. REPTECH plays a central role in using emerging technologies to improve the repair process and the affordability of Navy and Marine Corps repair facilities. Repair technology investments are needed to close the gap between the capability of the repair process and the sustainment needs of the weapon system. The investments will reduce risks to schedule, reduce costs, and increase performance of repaired weapon systems. iMAST has been designated by the Navy as the resident coordinating center for its repair technology program.



Management Structure

The REPTECH Working Group chairperson is a representative of the Office of Naval Research Manufacturing Detachment (ONRMTDET). The REPTECH Working Group was created to develop a coordinated approach to identify repair requirements for the Navy and Marine Corps and consists of one representative and one alternate from each Naval and Marine Corps systems commands.



Rapid Nondestructive Inspection (NDI) for Bulkhead Dismantling

REPTECH Project Develop a rapid inspection technique for locating hidden structures during the dismantling of bulkheads.

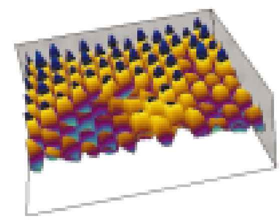
Customer: Puget Sound Naval Shipyard

Solution: Adapt/modify currently available ultrasonic inspection technology into a portable system for rapid location of hidden structures.

Benefits:
- Reduction in bulkhead dismantling time
- Reduction in miscutting of hidden structures
- Reduced environmental hazards to workers
- Ultrasonic technology is readily available to a wide variety of Navy inspection needs such as bulkhead repairs and modifications

UNIQUE CAPABILITY

ELECTRO-OPTICS FOR NONDESTRUCTIVE INSPECTION (NDI) of aerospace and marine vehicle components is crucial during both the manufacturing process and lifecycle testing phase. Electro-optical NDI techniques developed at ARL Penn State (e.g., phase-stepping digital shearography) carry unique advantages over traditional methods, including high flaw-detection sensitivity, speed, and noncontact nature. ARL Penn State has developed the world's only portable digital phase-stepping shearography head integrated with vacuum excitation for rapid on-site inspection. This capability is being developed for incorporation into the U.S. Navy and Marine Corps aviation and ground maintenance programs.



Treatment of Overspray at Dry-dock Painting Operations

REPTECH Project Develop a conceptual design that eliminates paint emissions and maintains environmental compliance.

Customer: Naval Surface Warfare Center, Carderock Division

Solution: Evaluate costs, compare treatment efficiencies, and modify existing technologies to remove particulates and organic compounds from painting operations in dry-dock.

Benefits:
- Maintain environmental compliance by eliminating particulate and organic emissions
- Adapt flexible system to dry-docks, aircraft hangers, and field service operations

Evaluation and Application for Polymer Coatings for Rudder Treatment

REPTECH Project Develop an improved coating to protect Navy ships from cavitation-induced damage.

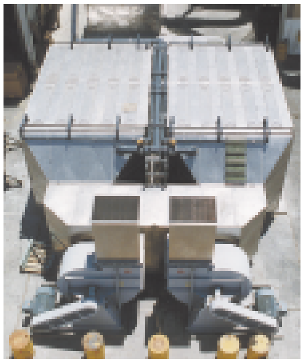
Customer: PMS 400, Naval Sea Systems Command

Solution: Develop and optimize improved cavitation-damage coatings by working with primary material and coatings vendors.

Benefits:
- Extends service time between scheduled dry-docking
- Minimizes repair of cavitation-damaged structures
- Environmentally friendly

Performance Understanding of the Barstow Air Treatment System

REPTECH Project



Determine overall VOC removal performance and regeneration efficiency to provide confidence in scale-ability of system upgrades and improvements.

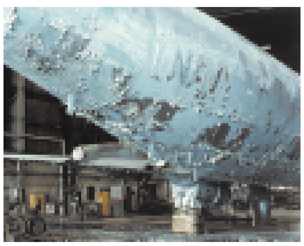
Customer: Marine Corps Logistics Base Barstow

Solution: Establish degree of VOC removal by each system unit and then provide data to validate scale-ability from 2,500 cfm to 45,000 cfm. Evaluate modifications for enhanced performance.

Benefits:
- Ability for technology transfer to other VOC/HAP-laden waste streams
- System understanding for improved operation and upgrade
- Potential 30 to 40 percent reduced capital costs of future systems

Improved Paint Stripping and Blast Media Technologies

REPTECH Project



Develop an approval process and an approval document for new or alternative paint removal technologies for use on U.S. Navy and Marine Corps aircraft.

Customer: Naval Aviation Depot Cherry Point

Solution: Working with the Naval Air Systems Command, commercial manufacturers, NADEP Cherry Point, and SpongeJet Corporation, identify the required tests, approval criteria, and approval process for new or alternative paint removal technologies.

Benefits:
- Significantly reduce approval cycle time
- Increase understanding of and confidence in new stripping technologies
- Increase the number of approved stripping technologies available to depots

HAZMAT Shelf-Life Monitoring

REPTECH Project

Evaluate the feasibility of a MEMS-based sensor system for characterizing hazardous liquid materials.

Customer: Naval Supply System/Naval Surface Warfare Center

Solution: Quantify the ability of various simple sensor features to discriminate between modes of deterioration in a candidate HAZMAT material.

Benefits:
- Retire material for cause rather than for premature reasons
- Verify material quality before use
- Reduce disposal costs and environmental impact
- Have opportunity for remedial action

NonContact Precision Gauging for Turbomachinery

REPTECH Project

Develop system for noncontact precision inspection of SSN-21 propulsor blades during machining process for system integration with current APOMS triangulation system.

Customer: Philadelphia Naval Shipyard/Naval Sea Systems Command

Benefits:
- Provides rapid feedback to machinist
- Reduces each machining iteration from 1 day to 15 minutes

Diagnostic Technique Qualification and Validation Using Fleet Data

REPTECH Project

Develop and validate a procedure that will qualify diagnostic techniques for mechanical equipment to avoid potential for excessive false alarms as Health and Usage Monitoring Systems (HUMS) enter the fleet.

Customer: Naval Air Systems Command

Solution: Collect valid data on a full squadron of H-46 aircraft. Archive and make available that data via internet for rapid analysis. Conduct measures of effectiveness/performance on all analyses conducted.

Benefits:
- Reduced false alarm rate during implementation of HUMS
- A dress rehearsal of squadron-level response to HUMS alerts

Spectroscopic Paint Characterization

REPTECH Project

Develop a spectroscopic system to enable rapid in-situ determination of heavy metals in paint for environmental and worker safety exposure compliance.

Customer: Puget Sound Naval Shipyard, Naval Sea Systems Command

Benefits:
- Provides rapid paint characterization
- Minimizes down time
- Reduces maintenance costs
- Ensures environmental safety compliance
- Provides potential to identify scrap metal for sorting and PCB measurements

Phase-Stepping Shearography for Noncontact NDI

REPTECH Project

Develop an in-situ full-field nondestructive inspection system for examining exterior aircraft surfaces for manufacturing defects and evaluating incidental damage repair requirements evaluation.

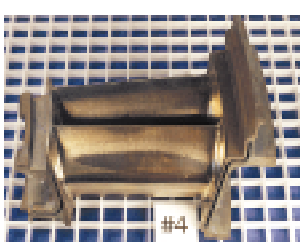
Customer: Naval Aviation Depot North Island

Benefits:
- Provides full-field (non-scanning) noncontact imaging
- Provides real time user-friendly feedback
- Provides high flaw-detection sensitivity
- Has robust interferometry for field inspection use

Environmentally Friendly NiAl Coating Stripping

REPTECH Project

Investigate an alternate environmentally-friendly technology for effective coating removal. The current methods for stripping coatings from blades and vanes is lengthy, hazardous, and difficult to control.



Customer: Naval Aviation Depot Cherry Point

Benefits:
- Reduces environmental impact
- Improves cycle times and process control
- Enhances surface finish of parts
- Potentially can reduce environmental impact and costs significantly

Supercritical Carbon Dioxide Gauge Cleaning

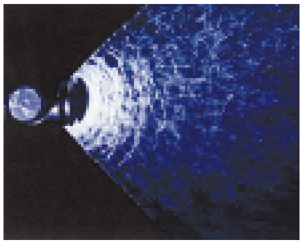
Develop an environmentally sound and cost-effective high-performance alternative to CFC-113 for cleaning gauges used in oxygen and high pressure air service.

Customer: Puget Sound Naval Shipyard, Naval Sea Systems Command

Benefits:
- Does not requires toxic or flammable solvents
- Reduces solvent costs
- Enhances cleaning performance
- Remains the only available option developed to date

UNIQUE CAPABILITY

PAINT REMOVAL AND APPLICATION can create waste and hazardous emissions. ARL Penn State has developed paint application and removal techniques that will reduce these by-products. Ongoing efforts include development of overspray collection devices, improvements in airless paint spray application to increase paint transfer efficiency, improved hydrogen embrittlement testing for chemical strippers, and a paint reactivation process for aerospace structures which will reduce manpower costs and substrate damage.



Paint Transfer Efficiency Improvement

Improve transfer efficiency during airless paint spray application operations by controlling the atomization process.

Customer: Naval Surface Warfare Center

Solution: Control the atomization process by forcing paint sheet breakup to occur in a specific mode, thereby controlling the paint particle size distribution.

Benefits:
- Significantly increases the transfer efficiency of the airless paint spray process
- Reduces or eliminates cleanup costs associated with overspray
- Reduces raw material costs by as much as 50 percent

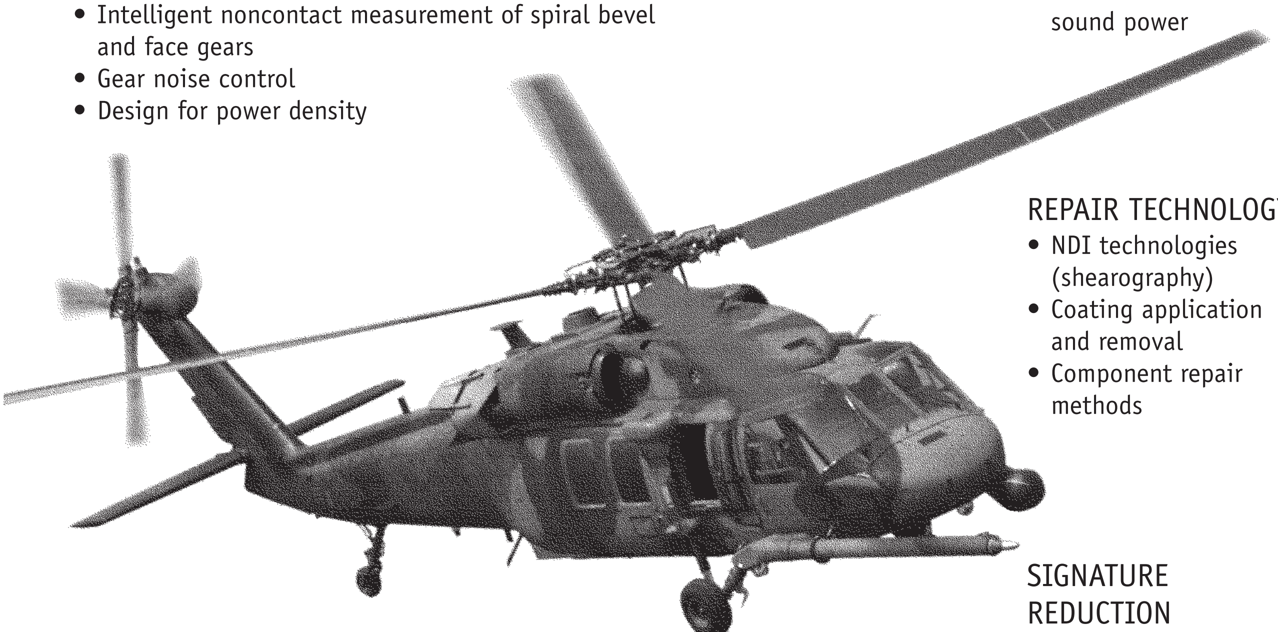
AIR VEHICLE TECHNOLOGY GROUP

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.

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

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

ROTOR SYSTEM TECHNOLOGIES
- Rotor blade NDI (finds delamination)
- Control of radiated sound power



REPAIR TECHNOLOGY
- NDI technologies (shearography)
- Coating application and removal
- Component repair methods

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

AIRFRAME SYSTEM TECHNOLOGIES
- Laser fabricated flooring
- Composite sandwich panels for noise control
- Spray formed HS aluminum alloys
- Protective armor

HEALTH USAGE MONITORING SYSTEM TECHNOLOGIES
- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- MMI for troubleshooting and diagnostics

SIGNATURE REDUCTION TECHNOLOGIES
- Composite thermal tiles
- Radar cross-section reduction
- Acoustics

LANDING GEAR SYSTEM TECHNOLOGIES
- Laser cladding
- Spray formed HS aluminum alloys

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.

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

REPAIR TECHNOLOGY

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

HEALTH USAGE MONITORING SYSTEM TECHNOLOGIES

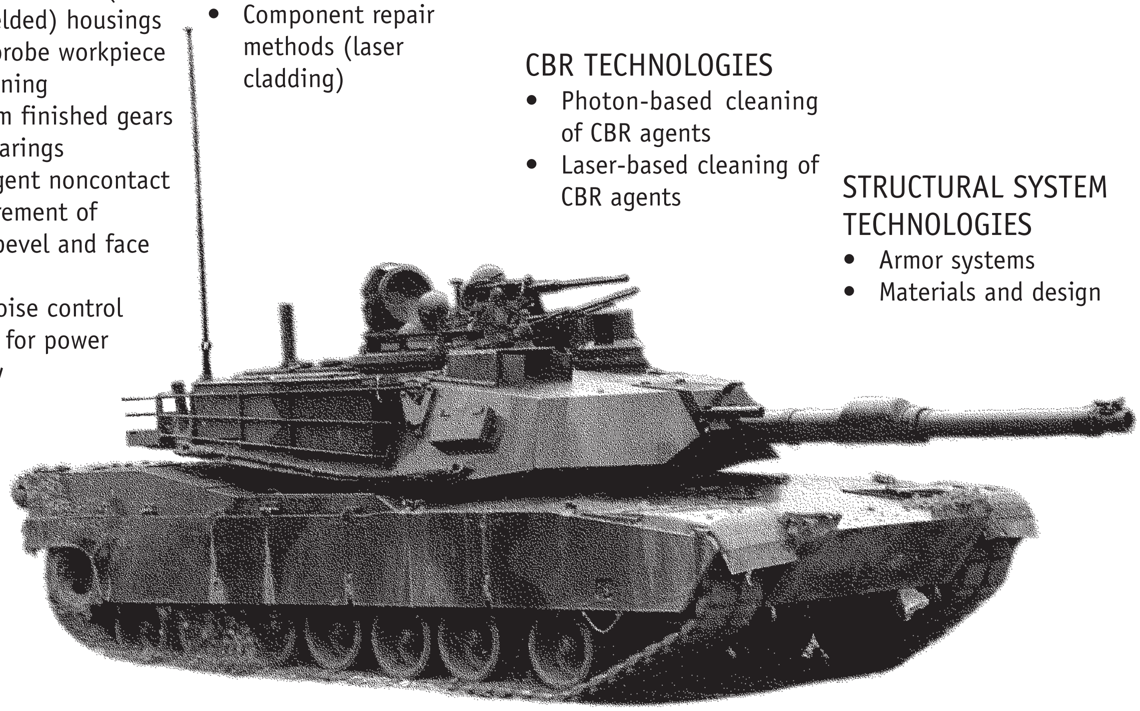
- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- MMI for troubleshooting and diagnosis

CBR TECHNOLOGIES

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

STRUCTURAL SYSTEM TECHNOLOGIES

- Armor systems
- Materials and design



TRACK VEHICLE SYSTEM TECHNOLOGIES

- Lightweight HS materials
- Laser cladding and heat treating

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

SIGNATURE REDUCTION TECHNOLOGIES

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

NAVAL 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.

LASER PROCESSING
- Welding
- Cutting
- Cladding
- Forming

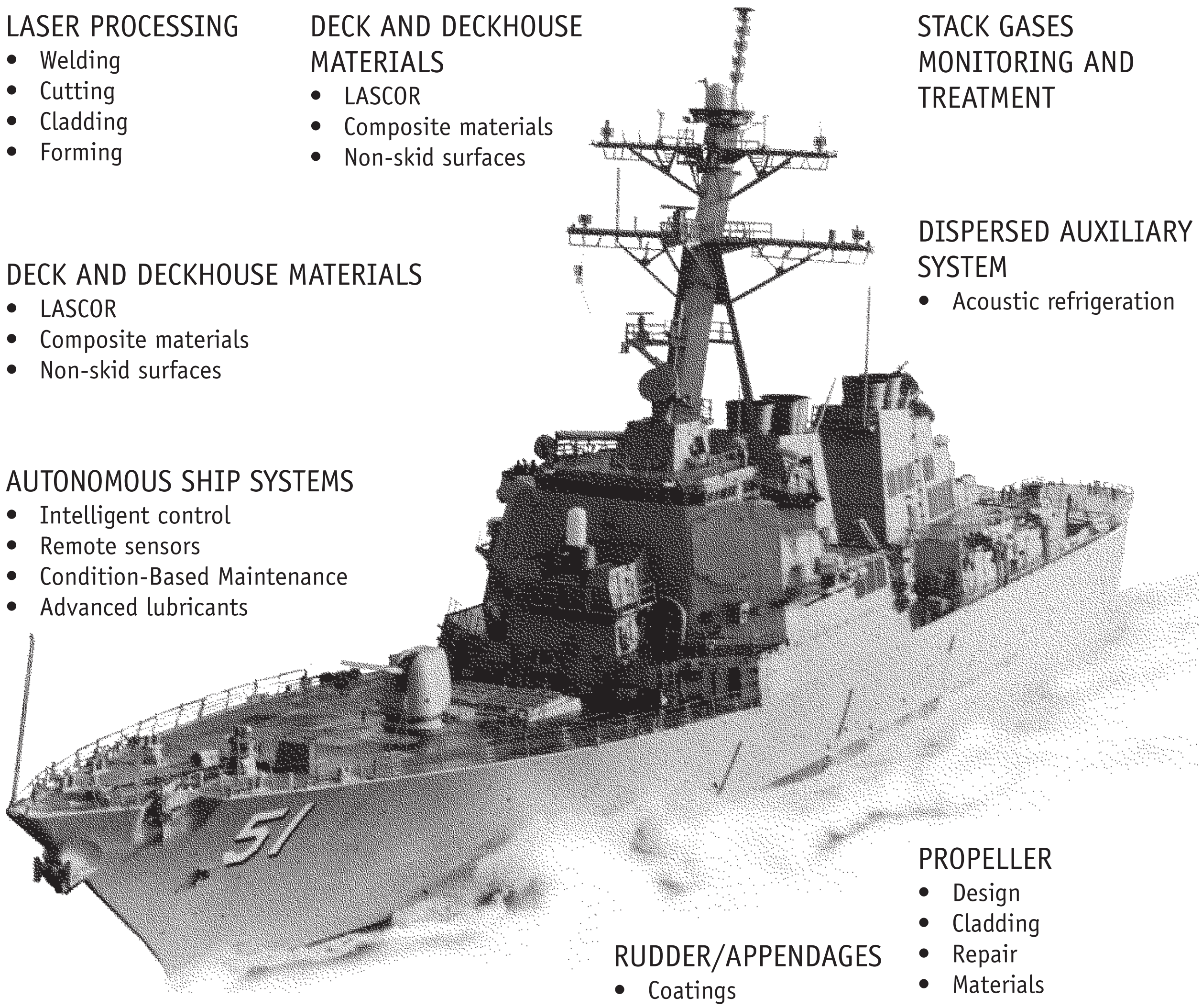
DECK AND DECKHOUSE MATERIALS
- LASCOR
- Composite materials
- Non-skid surfaces

STACK GASES MONITORING AND TREATMENT

DISPERSED AUXILIARY SYSTEM
- Acoustic refrigeration

DECK AND DECKHOUSE MATERIALS
- LASCOR
- Composite materials
- Non-skid surfaces

AUTONOMOUS SHIP SYSTEMS
- Intelligent control
- Remote sensors
- Condition-Based Maintenance
- Advanced lubricants



PROPELLER
- Design
- Cladding
- Repair
- Materials

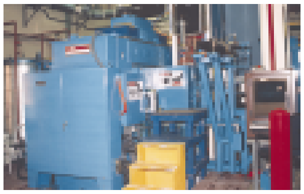
RUDDER/APPENDAGES
- Coatings
- Materials

OTHER
- Environmental systems
- Lifecycle engineering (REPTECH)
- Wear and corrosion-resistant alloys for structures, valves, and tubing
- Simulation-Based Design
- Electro-optics
- Paint removal

DRIVETRAIN TECHNOLOGIES
- Advanced gear materials
- Optimizing tolerances for performance

INFORMATION TECHNOLOGY
- Electronic data transfer
- Intelligent management of documents and data

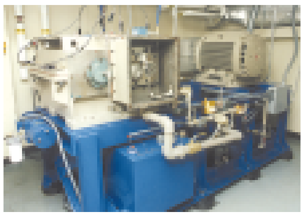
iMAST FACILITIES AND EQUIPMENT



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 SCIENCE

Spray Metal Forming

- 5,000 sq. ft. facility
- Full metalography and surface characterization capabilities
- Research scale/pilot plant equipment
  - – melts up to 65kg of aluminum
  - – produces billets (16" × 10"), strip/plate (12" × 6" × .8"), tubes (12" × 1")
- Capabilities to produce metal matrix composites

Cold Gas Dynamic Spraying

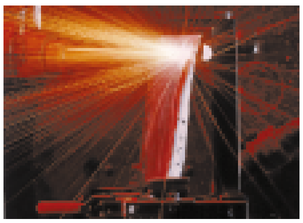
- Research scale equipment
- Capability to spray a variety of different materials on numerous substrates

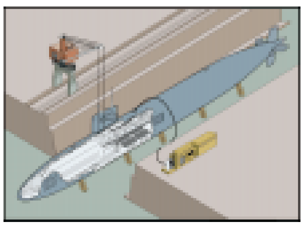
Nanophase Material Facilities

- Nanophase powder consolidation and sintering capabilities

Surface Technologies

- Pin on disc wear testers
- Erosive wear testers
- Reciprocating wear testers
- Seal test rigs
- Controlled-environment test rigs
- Facilities and expertise for lubricant development
- High-pressure hydro-static equipment
- Hot press for powders consolidations and laminated cermics

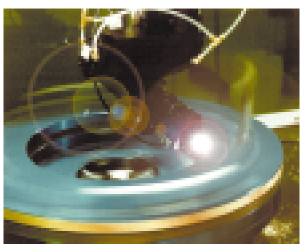




HIGH ENERGY PROCESSING

Manufacturing Science Research Facility

- 14-kW cw CO_2 laser system
- Two 1.5-kW cw and pulsed CO_2 laser systems
- 3-kW cw Nd:YAG
- 400-W pulsed Nd:YAG
- 10-W Q-Switch Nd:YAG
- 3-W Q-Switch Nd:YAG
- 20-W Cu Vapor Laser
- Laser Articulating Robotic System (LARS)
- Large-scale gantry
- Support equipment (e.g., robotic, linear and rotary workstations, etc.)



Technology Transfer Facilities

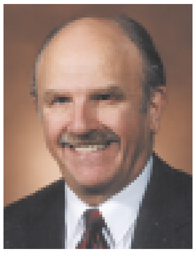
- 25-kW CO_2
- LARS
- 24' and 36' linear workstations
- Support equipment
- Two 3.0-kW cw Nd:YAGs at Puget Sound Naval Shipyard
- 2.4-kW cw Nd:YAG at Norfolk Naval Shipyard's Foundry and Propeller Center (Philadelphia, Pa.)

EB-PVD Facility

- 100 to 150 microns per minute deposition rate
- $1m^3$ chamber size
- Three independently controllable ingot feeders

FACULTY, STAFF AND SPONSORS

APPLIED RESEARCH LABORATORY



L. Raymond Hettche

B.S., Mathematics and Engineering, Bucknell University
M.S., Civil Engineering, Carnegie-Mellon
Ph.D., Civil Engineering, Carnegie-Mellon

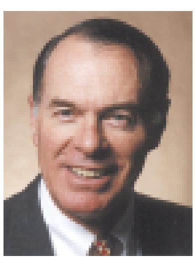
The seventh director of Penn State's Applied Research Laboratory, Dr. Hettche is the chief academic administrator of the Laboratory. He is responsible for directing the Laboratory's efforts in concurrence with Penn State's and the U.S. Navy's goal of being an undersea technology base. As the largest of 20 interdisciplinary laboratories, centers and institutes in the University's Intercollege 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.

Dr. Hettche also serves the U.S. Navy as a member of the Naval Research Advisory Committee (NRAC). He is a member of the Board of Directors for the Center for Neural Engineering which is sponsored by the Office of Naval Research. For the Department of Defense, Dr. Hettche serves as a member of the DoD Technical Review and Assessment Team for Ground and Sea Vehicles.

Henry E. Watson

B.S., Mechanical Engineering, Clemson University

Mr. Watson is Associate Director and Head of the Materials and Maufacturing Technology Division at Penn State's Applied Research Laboratory. Mr. Watson also serves as the program manager for the Institute for Manufacturing and Sustainment Technologies (iMAST) and also holds the academic position of Senior Research Associate.



Lewis C. Watt

B.S., Civil Engineering, Tufts University
M.S., Management Engineering, George Washington University
Graduate, U.S. Naval Test Pilot School
Graduate, Industrial College of the Armed Forces

Mr. Watt is deputy program manager for iMAST and program manager for the Repair Technology effort.

Maurice F. Amateau

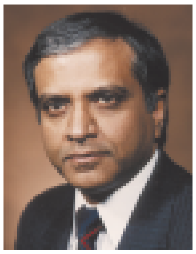
B.S., Metallurgical Engineering, Ohio State University
M.Sc., Metallurgical Engineering, Ohio State University
Ph.D., Metallurgy, Case Western Reserve University

Dr. Amateau's research interests include the design, processing, component fabrication, testing, and analysis of metal, ceramic, and polymer composite materials. Studies on tribological properties of metal matrix and ceramic composites. Evaluation of thermoset and thermoplastic composites for undersea applications including corrosion, impact fatigue, cavitation damage, and nondestructive evaluation. Development of ceramic laminate composites for high-temperature systems and for impact-resistant structures. Development of high-pressure casting techniques for net shape processing of metal matrix composites and a study of fabrication effects in thermoplastic composite materials such as graphite-reinforced polyphenylene sulfide and polyetherether ketone. Development and analysis of metal composite laminates for high-damping structures. Development of advanced gear finishing concepts including the thermomechanical processing of precision aircraft gears, gear heat treatment, and surface modification.

J. Thomas Schriempf

B.S., Solid State Experimental Physics, Carnegie-Mellon University
M.S., Solid State Experimental Physics, Carnegie-Mellon University
Ph.D., Solid State Experimental Physics, Carnegie-Mellon University

Dr. Schriempf is a recognized expert in the military applications of lasers, and he brings his extensive experience from the Naval Research Laboratory and industry to the development of laser applications.



Suren Rao

B.S., Mechanical Engineering, Bangalore University
M.S., Mechanical Engineering, McMasters University
Ph.D., Mechanical Engineering, University of Wisconsin at Madison

Dr. Rao's research interests are in the area of metal removal, structural dynamics, and metal forming. Dr. Rao has published numerous papers and holds several patents in the field of metal processing. Dr. Rao also serves as a professor of Industrial and Manufacturing Engineering in The Pennsylvania State University's College of Engineering.

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.

OFFICE OF NAVAL RESEARCH

RAdm Paul G. Gaffney, II USN

Rear Admiral Gaffney is the Chief of Naval Research, Office of Naval Research. Admiral Gaffney's distinguished military career has spanned nearly three decades and includes duty at sea, overseas, and ashore in executive and command positions. A graduate of the U.S. Naval Academy, the admiral was selected for immediate graduate education and received a master's degree in ocean engineering from the Catholic University of America. Admiral Gaffney completed a year of study as an advanced research fellow at the Naval War College where he graduated with highest distinction. The admiral also holds an M.B.A. degree from Jacksonville University.

David A. Rossi

Mr. Rossi is the director of the U.S. Navy's Industrial Program Department, Office of Naval Research. Mr. Rossi 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. Prior to his service with the Department of the Navy, Mr. Rossi served in senior management positions within industry.

A registered professional engineer, Mr. Rossi received a B.S. degree in mechanical engineering from Ohio Northern University and an M.B.A .from Rensselaer Polytechnic Institute.

Steven M. Linder

Mr. Linder is the Director for the U.S. Navy Manufacturing Technology (ManTech) Division, Office of Naval Research. Mr. Linder is responsible for managing the ManTech Program, Best Manufacturing Program, and the Navy's six Centers of Excellence. He is tasked with developing, coordinating and integrating program policy, procedures, and content throughout the U.S. Navy, and works in cooperation with the joint services and applicable agencies. He is also the Navy's representative to the Joint Directors of Laboratories Manufacturing Science and Technology Panel. Mr. Linder holds a B.S. degree in electrical engineering from Youngstown University.

Leo Plonsky

Mr. Plonsky supports the Navy Manufacturing Technology Program as a program officer. In this capacity, he is currently the Navy's program manager for the Institute for Manufacturing and Sustainment Technologies (iMAST) at ARL Penn State.

Mr. Plonsky is primarily responsible for coordinating Navy manufacturing technology programs. He serves as chairman of the Manufacturing and Engineering Systems Sub-Panel of the Joint Defense ManTech Panel. Mr. Plonsky manages, or has managed, several Navy contracts, and is the Navy's liaison to the NIST manufacturing technology programs. He was also the DoD representative on the industry-led team that developed the Agile Manufacturing concept. He previously served as Chairman of the Best Manufacturing Practices (BMP) non-electronics survey team. In that capacity, he received the Navy's prestigious Reliability and Maintainability Award.

Mr. Plonsky holds a B.S. degree in industrial engineering from Lehigh University as well as an M.S. degree in Management Science from Stevens Institute of Technology.

Amy Rideout

Ms. Rideout is the manager of the Marine Corps Systems Command Manufacturing Technology (ManTech) Program. Additionally, she serves as the Independent Research & Development (IR&D) and Dual Use Applications Programs (DUAP) coordinator.

Prior to her assignment with the MARCORSYSCOM, Ms. Rideout served as a program manager with the U.S. Army in their night vision and thermal weapon systems programs.

Ms. Rideout holds a bachelor of science degree in mechanical engineering from Stevens Institute of Technology as well as a master of science degree in industrial engineering from Texas A&M University.

FY 98 PAPERS AND PRESENTATIONS (abridged)

M. F. Amateau, D. S. Lee; “A Tribological Properties of Spray Cast Aluminum-Silicon Alloys,” Proceedings of the Third International Conference on Spray Metal Forming, 1997, pp 321-327.

M. F. Amateau, T. J. Eden, J. M. Galbraith, and M. J. Kaufman; “Microstructure and Mechanical Properties of Spray Formed Al-Fe-V-Si Alloy” at TMS Advanced Materials and Processing – PRICM 3 Symposium July 1998 Honolulu, HI

M. F. Amateau; “SSM Forming of High Temperature Spray Formed Aluminum Alloys” by at Sixth Semi-Solid Metalworking Users’ Group Meeting – March 24–25, 1998 at Concurrent Technologies Corp., Johnstown, PA

R. B. Bhagat, M. F. Amateau, J. C. Conway, Jr., B. Stutzman, B. Jones, and A. N. Papyrin; “A Deposition of Ni-Al-Bronze Powder by Cold Gas-Dynamic Spray Method on 2618 Al for Developing Wear Resistance Coatings,” to be published in the proceedings of the United Thermal Spray Conference and Exposition, September 15–18, 1997, Indianapolis, IN.

R. B. Bhagat (presentor), D. Agrawal, H. P. Cheng, G. Wright, B. Jones, and M. F. Amateau; “Reduction of Grain Growth in WC-Co Cermets” October 12–15, 1998, ASM Annual Meeting at Rosemont, IL

R. B. Bhagat, G. Wright, B. Jones, and M. F. Amateau; “An Ultrahard and Tough Nanocermet” February 15–19, 1998, TMS Annual Meeting, San Antonio, TX

J. C. Conway, D. S. Lee, M. F. Amateau and J. C. Conway, Jr.; “A Wear Mechanisms in Spray Formed Aluminum-Silicon Alloys,” accepted for publication, Proceedings of Conference on Advanced Material Processing, TMS, Orlando, FL, February 9–13, 1997.

J. M. Galbraith, A. E. Segall, A. N. Papyrin, J. C. Conway, D. Shapiro, M. F. Amateau , and T. J. Eden; “Utilization of the Cold Gas Spray Coating Process for the Improvement of Sliding and Abrasive Wear Performance,” ASM International Materials Solutions Conference and Exposition 1998, Chicago, IL, October 12–13, 1998.

W. D. Mark, “Statistical Characterization of Heat-Treatment Distortion of Gears,” Manufacturing Science and Advanced Materials Processing Institute Quarterly, Issue No. 1, 1998.

W. D. Mark, “Recent Advances in Gear Metrology,” presented to the American Society of Mechanical Engineers Committee on Gear Metrology, Detroit, Michigan, October 21, 1997.

W. D. Mark, “Prediction Method for Transmission Error Contributions from Measurements Made on Gear Teeth,” presented to the American Society of Mechanical Engineers Committee on Gear Metrology, Chicago, Illinois, March 20, 1998.

A. E. Segall, A. N. Papyrin, J. C. Conway, Jr., and M. F. Amateau; “A Development of a Cold Gas Spray Manufacturing Method for Component Wear Reduction,” poster presentation at the Defense Manufacturing Conference ’97, Palm Springs, CA, December 1–4, 1997.

A. E. Segall, J. C. Conway, Jr., D. H. Stiver III, C. A. Moose, and S. Hershman; “Elevated Temperature Fretting Evaluation Using a Flat-On-Flat Configuration” Paper/Presentation, STLE ’98 53rd Annual Meeting, Detroit, MI May 18–20, 1998

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2001 Jefferson Davis Highway
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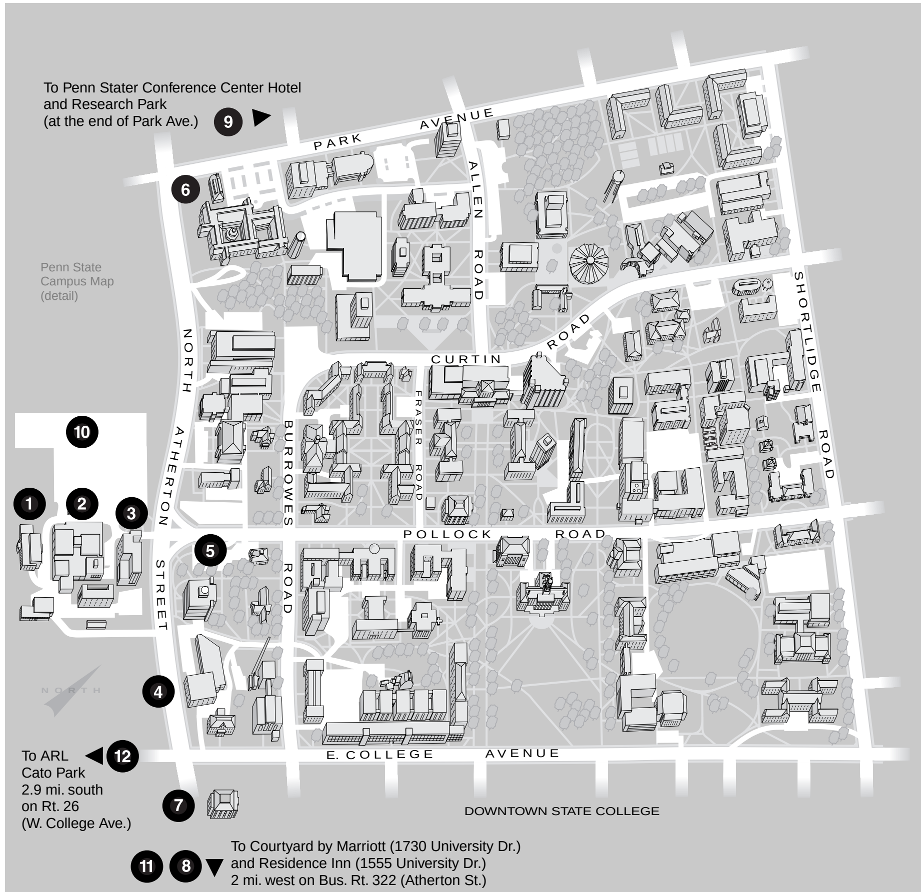
(703) 415-0112
(703) 415-0116 fax

TRAVELING TO ARL PENN STATE

Area Code (814)

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



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 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 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, and Baltimore 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

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 information:
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
(In the PSU Research Park, shuttle, car/cab)
(800) 893-4602
(814) 863-5000

The Atherton *(walk to campus)*
(800) 445-8667
(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
(car/cab, shuttle)
(800) 331-3131
(814) 235-6960

Sleep Inn
(car/cab)
(814) 235-1020

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.

iMAST on the World Wide Web

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

The iMAST web site is located at

www.arl.psu/core/imast/imast.html

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