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PENNSTATE



# iMAST

Applied Research Laboratory  
Institute for Manufacturing and  
Sustainment Technologies



## Report Documentation Page

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# A Message from the Program Manager

*"We have to remember that even as wonderful as this leading-edge technology is, it will still depend on great people to drive, fix and support it. And that's the real strength of our team, the people who make it possible."*

—Admiral Jay Johnson  
Chief of Naval Operations

The Institute for Manufacturing and Sustainment Technologies (iMAST) at The Pennsylvania State University's Applied Research Laboratory (ARL) continues to enhance manufacturing practices that will reduce risk in the fielding of reliable high-quality Navy and Marine Corps weapon systems. Our customers are the warriors of the fleet who serve above and below the sea, in the air, and on land, both at home and abroad. We are committed to leveraging the Navy's Manufacturing Technology (ManTech) Program in support of our nation's premier guardians—the sea service warriors who will encounter many unique battlefield challenges as a changing world order tries to sort itself out.

During fiscal year 1999, 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. One institute highlight of the year that is worthy of noting was a survey of iMAST by the Best Manufacturing Practices (BMP) Center of Excellence. The survey found approximately 50 best practices associated with our core technologies. This report has been published and is available upon request. You can also find it on BMP's home page which is <<http://www.bmpcoe.org>>.

As we acquire fewer weapon systems at ever-increasing cost, we are becoming obliged to ensure that these weapons last well into the new century we are about to enter. Repair technologies will play an increasingly important role in the sustainment and readiness equation. Investments will need to be made in carefully selected repair technology projects. With research, development and acquisition funding restrictions, many are (rightly) concerned that the Navy and Marine Corps are both being compelled to rob their future procurement accounts to pay for the

numerous contingency operations that have developed recently. While this is a valid concern, it should be pointed out that some previous forward thinking is bringing the Navy-Marine Corps team to a vanguard position in terms of leading-edge warfighting systems. It was a personal highlight for me to attend the Marine Corps' recent Amphibious Triad ceremony at Quantico, Virginia where the Advanced Amphibious Assault Vehicle (AAAV) was rolled out by General Dynamics Land Systems, Inc. Not alone, the AAAV shared the stage with two complementing weapon systems, the MV-22 Osprey tiltrotor aircraft, and the Landing Craft Air Cushion (LCAC). These marvelous applications of technology will provide the Navy-Marine Corps team a highly desired full-scale over-the-horizon (OTH) operational maneuver from the sea (OMFTS) capability. Other acquisitions, either underway or on the drawing board, that will join this triad in the 21st Century include the Joint Strike Fighter (JSF), new attack submarine, DD-21 destroyer, LHX amphibious ship, JCC joint command ship, ADCX cargo ship, and new generation aircraft carrier (CVX).

As we power up for year 2000, 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 direct government acquisition and support infrastructures, or through 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.

*"...we have long had a saying in the Marine Corps that the guiding principle of our transformation strategy must be 'Equip the man, not man the equipment.' That is to say, as important as changes in technology might be, one thing is certain: it will be the young men and women in our armed forces who will continue to make the critical difference on tomorrow's battlefields. Technology will matter, but only if it is used to empower the young men and women of our armed forces to prevail against the new adversaries and in the new lethal operating environments we see just over the horizon."*

—Lieutenant General Martin Steele, USMC  
Deputy Chief of Staff for Plans, Policies and Operations  
Headquarters, U.S. Marine Corps

As always, I invite you to learn more about our program. This annual report details our fiscal year 1999 accomplishments and provides insight into our capabilities and resident expertise. Please give us feedback and let us know how we can support you. I look forward to hearing from you and extend an offer to visit us at any time.



HENRY WATSON

ManTech Program Manager

ARL Penn State

# iMAST FY1999 Annual Report



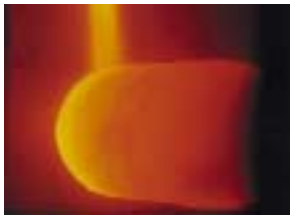
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# The Institute for Manufacturing and Sustainment Technologies

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.

# 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)

An increasing proportion of industrial dual-use sponsored research, both in terms of total dollars and number of projects, has been a significant and promising trend for The Drivetrain Technology Center this year. The increased industrial support has resulted from the expanded component testing capability at the Drivetrain Technology Laboratory, which now includes a comprehensive range of machines for rolling/sliding contact fatigue, gear single tooth bending fatigue, power circulating gear tooth bending fatigue, power circulating gear tooth surface fatigue, and spline testing. The transmission component testing and metrology capability facilitates research in new technology development and evaluation for a variety of applications such as air and ground vehicles, automotive and industrial gearing, powder metal gearing, etc.

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.

## Performance Testing of Ausformed Finished Gears

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

## iMAST Technical Thrust Areas

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.

Evaluation of surface durability of ausform finished RCF test specimens was completed, and has demonstrated over 650% increase in rolling/sliding contact fatigue life (L10 life) of ausformed cylindrical specimens. Manufacture, testing and calibration of power circulating gear test rigs required for the program was completed, and quality evaluation and testing of baseline gears was carried out. During the past year, ausform finishing experiments to optimize the rolling dies tooth profiles was initiated, and is currently in process. Design and manufacture of the tooling and test gears required for the root/fillet ausforming of spur gears has also been initiated.

*Project Leader: Dr. Nagesh Sonti*

## Ausform Finishing of Bearing Races

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 AAV main transmission.

During the past year, design and manufacture of the tooling required for ausforming of Rexnord cylindrical bearing inner races was completed. Induction heating experiments on inner races furnished by Rexnord were completed for

establishing the preform size required for ausform finishing. Preliminary coating experiments on cylindrical specimens have been successfully completed, and metallurgical evaluation has demonstrated that the low temperature coating process has produced good adhesion with no change in the microstructure or surface hardness. Manufacture of cylindrical RCF test specimens for further coating trials is in process. Development and evaluation of two bearing endurance test rigs was completed at Rexnord Corporation, and testing of standard bearings made by conventional process is in process.

*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

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. Steps are currently underway to install the Non-Contact Workpiece Positioning System on the manufacturing floor of a major aerospace manufacturer.

*Project Leader: Dr. Suren Rao*

## In-Situ Gear Error Measurement

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 x 10<sup>-6</sup>). 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.

*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)

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*

## 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

(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. Karl Reichard*

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

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.

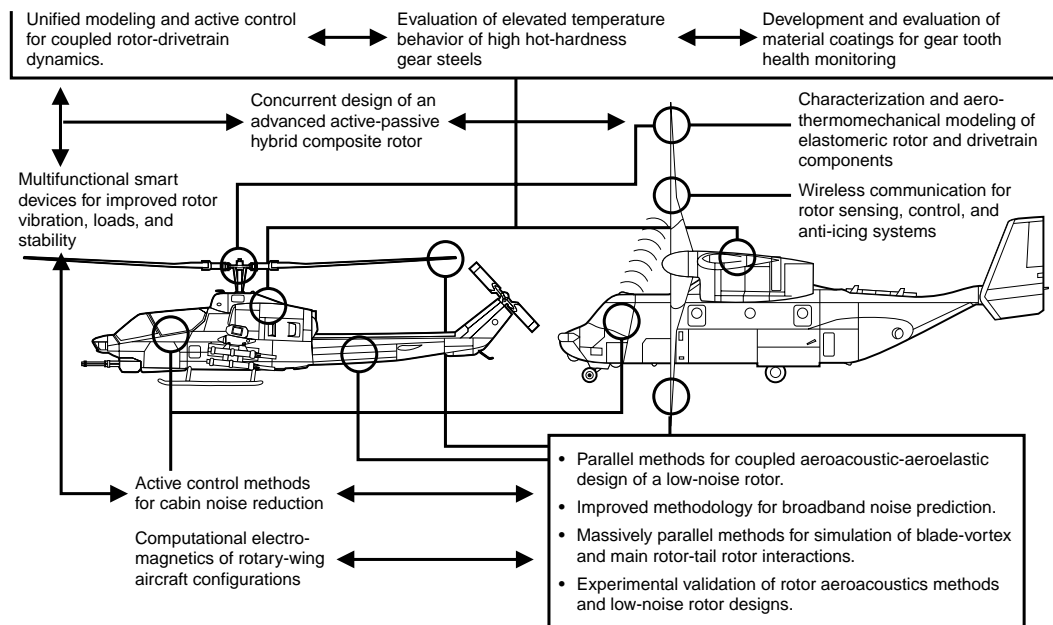
This program will develop affordable improved fatigue- and scoring-resistant materials for high-performance drive system components including gears, bearings, and shafts. Reliable materials manufacturing processing data will be established, as well as fatigue and scoring resistance data which is required 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.

*Project Leader: Mr. Al Lemanski*

### Penn State Rotorcraft Center of Excellence

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*





# 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

Allison Engines  
AlliedSignal  
Boeing Helicopters  
Pratt & Whitney  
The Timken Company

### ■ VEHICLE/INDUSTRY RESEARCH BLOC

Eaton Corporation  
General Motors  
New Venture Gear  
The Timken Company

### ■ INDUCTION HARDENING GROUP

Allison Transmissions  
Bison Gear & Engineering  
Caterpillar  
Contour Hardening  
Deere & Company  
Eaton Corporation  
Harley-Davidson  
Mack Trucks  
The Timken Company

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

## Trustees and Committees

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.

*POC: Dr. Suren Rao*

# 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.

The Materials Science Division had eight 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. On all 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 Joint Strike Fighter and the AAV, where new technology or materials were involved, all aspects of the program starting with material selection, followed by processing, testing, and final fabrication of the components were either performed or directed by members of the division. Components are then delivered to the sponsor for evaluation.

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)

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, Patuxent 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

Current manufacturing methods require 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 cutting tool (ball end mill) can not be used to fabricate a complete compressor section. The ball mills must be changed frequently which increases the manufacturing cost of component and adversely affects the machining tolerances.

This project is applying a novel consolidation technology to manufacture prototype machine tools using nanocrystalline powder. Fully dense, nanograined cemented carbide cutting tools have been fabricated. The developed materials are much superior in hardness and fracture toughness in comparison with conventional fine grained cemented carbides. Machining results have shown that the prototype nanograined cutting tools (inserts for lathe turning and ball end mills for

milling operations) have up to 40 times the longevity of conventional cutting tools in machining titanium alloys (Ti-6Al-4V and Ti-17).

*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

### 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) Roadwheels

This project is evaluating manufacturing technologies to provide component weight savings and improve maintainability on the roadwheel system of the AAAV.

Cold Gas Dynamic Spraying (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.

## 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.

## 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.

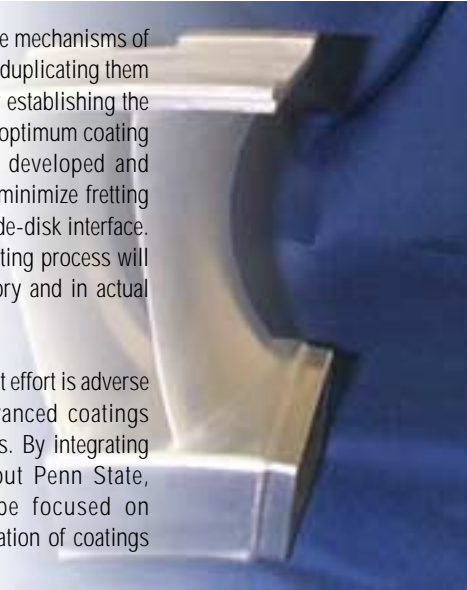
## F/A-18 F404 Fretting and Low-Cycle Fatigue Amelioration

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 Leader: Dr. Joseph Conway*



# 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

The EB–PVD facility produced over 60 successful runs, depositing a number of new coatings, all tailored to Navy needs. Among these was a thermal barrier coating with a markedly improved thermal insulation property, making it very attractive for turbine blade application. This improved thermal insulation was achieved by an innovative application of the EB–PVD process which was used to control the porosity of the coating. In tool coating applications of EB–PVD, the deposition of titanium boro-carbo-nitride has been demonstrated. This very hard coating has the potential of increasing machine tool wear life by an order of magnitude. In addition, the potential for EB–PVD fabrication of rhenium parts has been demonstrated by depositing rhenium on a molybdenum mandrel, which can then be chemically removed, leaving a freestanding, thin-walled rhenium tube.

Laser processing activities included a number of major milestones during the fiscal year. A prototype for a hand-held semi-automatic laser paint stripper was demonstrated. Rhenium processing was also pursued in the laser area, with the demonstration of clean, crack-free cutting of slab rhenium. Laser technology transfer was highly successful during this fiscal year, both with the establishment of a facility for the laser repair of aluminum torpedo parts at Naval Underwater Warfare Center, Keyport, Washington and with the arrival of the prototype propulsor laser welding robot at ARL for checkout; the full robot will be installed at Norfolk Naval Shipyard Foundry and Propeller Center at Philadelphia. The laser facility at ARL was also extended to include ultraviolet laser light, with the bringing on line of a 200-watt excimer laser, (originally acquired at no cost from a completed Air Force project).

## Ukraine Joint R&D

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.

Recent significant accomplishments include: 1) The Ukraine International Center for Electron Beam Technology (ICEBT) successfully produced a thick alloy plate (12 x 12 x 1.5 in) composed of Cu- 10% Cr-4%Nb alloy by the co-evaporation of three ingots (Cr, Nb, and Cu) as an alternative cost effective technology in the manufacturing of such items as combustion chamber liners. 2) At the PSU facility low conductivity thermal barrier coatings were produced by modifying the composition and microstructure of conventional thermal barrier coating material (ZrO<sub>2</sub> -8 wt. %Y<sub>2</sub>O<sub>3</sub>). Additional testing and evaluation of these low conductivity TBC's are underway. 3) High temperature refractory metals including tungsten and rhenium were deposited successfully on molybdenum mandrels as a proof of concept for producing tubes of refractory metals.

*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

Several major accomplishments have been achieved within the past year in the development of hard carbide and boride coatings synthesized by ion beam assisted, electron beam physical vapor deposition (IBA, EB-PVD). The hardness of titanium carbide (TiC) coatings produced by reactive IBA, EB-PVD was increased up to 3500 VHN. This 15 % hardness improvement is largely attributed to the addition of an ion beam which was used to densify and texture the coating microstructure. TiC coating is commonly used as the bond coat for a subsequent TiB<sub>2</sub> coating on WC-Co cutting inserts. TiB<sub>2</sub> cannot be directly deposited on to the inserts as it reacts forming an unstable compound. In addition, the adhesion of various coatings deposited by IBA, EB-PVD has been increased from ~5-10 N to over 50 N; the average adhesion value for most PVD coatings is approximately 40 N. Applying multilayered coatings of TiC/TiB<sub>2</sub> and Cr<sub>3</sub>C<sub>2</sub>/TiB<sub>2</sub> can further increase hardness of the coatings. Also, titanium carbide was successfully deposited by the co-evaporation of titanium and carbon through a molten slug of tungsten. Lastly, significant progress has been made in the formation of a super hard, metastable TiBCN coating by the co-evaporation of three ingots: titanium, carbon through molten tungsten, and TiB<sub>2</sub> and simultaneously bombarding the surface with a mixture of ionized nitrogen and argon gas.

The adhesion of the TiBCN coating is >50N and has the hardness equal to a soft diamond-like coating. An integral part of this project is transferring this technology to at least one tool company-at no cost to the project. Coated samples are being evaluated by Portsmouth Naval Shipyard (the sponsor) and interested leading tool manufacturers (Valenite Co., Richter Precision Inc., and Kennametal Inc.).

*Project Leader: Dr. Jogender Singh*

## Surface Removal by Optically-Delivered Lasers

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. As FY 1999 wraps up, a hand-held prototype system has been designed, built and tested, and has proven effective in removing a variety of coatings.

*Project Leader: Mr. Ted Reutzel*

## Repair and Refurbishment of Fatigue-Limited Structures

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

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*

## Laser Processing of Nickel Aluminum Bronze

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.

*Project Leader: Mr. Ken Meinert*

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

Catapult trough covers on aircraft carriers require substantial refurbishment due to the severe operating environment typically encountered. There are usually 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 nasty 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 between the wheels and the tracks causing accelerated wear of the 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 excess heat input with laser processing enables the channels to be resurfaced with clad metal. New replacement cost is approximately \$25K/trough cover and there are currently approximately 1900 trough covers in need of repair.

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. Present estimates of laser repair are of the order of 50 to 60% of replacement costs. Laser welding repair of trough covers is a feasible solution previously demonstrated with CO<sub>2</sub> laser technology. The purpose of this project is to demonstrate that the ND:YAG laser with a fiberoptically delivered laser beam can successfully deposit Inconel 625 clad material onto the worn channel surfaces of the catapult trough covers to extend their service life in accordance with the approved NAWC/NAVAIR acceptance standards. This will require the modification of existing equipment to handle the linear motion and geometry of the trough covers. Parameter and procedure development, NAWC and NAVAIR approvals along with component testing will be part of this program. Also hardening and testing the equipment for reliability/repeatability, as required for transition into production, will be addressed. The repairs will be coordinated with the cognizant technical authority (NAWC) and the potential customer (AIRPAC).

*Project Leader: Dr. Thomas Schriempf*

# 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

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

*POC: Clark Moose*

## 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

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

*POC: Dr. Robert Keay*

## Evaluation and Application for Polymer Coatings for Rudder Treatment

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

*POC: Dan Metrey*

## Barstow Air Treatment Enhancements

Provide ongoing technology assessments and analytical and process/system design support to assure improved and more cost effective VOC/HAP treatment and control for paint booth exhausts.

CUSTOMER:  
Marine Corps Logistics Base Barstow

SOLUTION:  
The existing Air Pollution Control System at Barstow has measurable performance limitations. Enhancements to the existing treatment system are under examination. Modifications to the current operating procedures have been recommended as a short-term solution. Engineering changes to incorporate a VOC capacitor and biofilter system for improved system efficiency are being evaluated.

BENEFITS:

- Improved understanding of APCS technology.
- Restored VOC treatment capacity.
- Improved treatment system cost performance.
- Ensure environmental compliance.

*POCs: Dr. Robert Keay and Ms. Janice Schneider*

## Improved Paint Stripping and Blast Media Technologies

Develop an approval process and 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

*POC: John Merenich*

## Diagnostic Technique Qualification and Validation Using Fleet Data

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

*POC: Carl Byington*

## Spectroscopic Paint Characterization

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

*POC: Ted Reutzel*

## Phase-Stepping Shearography for Noncontact NDI

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

*POC: Karl Reichard*

## Environmentally-Friendly NiAl Coating Stripping

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

*POC: Dennis Wess*

## 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 require toxic or flammable solvents
- Reduces solvent costs
- Enhances cleaning performance
- Remains the only available option developed to date

*POC: Robert Keay*

## 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

*POC: Charlie Tricou*

## LAV Heater Exhaust

Increase the reliability of the heater assembly located in the crew compartment of the Marine Corps' Light Armored Vehicle (LAV). A malfunctioning heater directly impacts vehicle readiness when employed in a frigid environment.

### CUSTOMER:

Marine Corps Systems Command (Marine Corps Detachment, U.S. Army Tank-automotive Armaments Command

### SOLUTION:

Increase heater reliability by performing analyses and developing recommended design improvements for implementation on the heater assembly and the vehicle. Retrofit fielded units via kits and modification instructions.

### BENEFITS:

The benefits from this project include reduced operating costs for the vehicle due to decreased maintenance requirements for the crew heater assembly. In addition, higher system reliability will provide increased uptime and enhanced readiness for the Light Armored Vehicle.

*POC: Mr. Dennis Wess*

## Automated Paint Application, Containment and Treatment System (APACTS) Design and Prototype Support

Provide support to the NAVSEA effort to deliver an (APACTS) system for more efficient and compliant hull painting operations.

**CUSTOMER:**  
Naval Surface Warfare Center, Carderock Division

**SOLUTION:**  
As one of many sponsors of this effort provide R&D and design expertise and follow on technical support in the areas of overspray capture shroud design and VOC/HAP treatment system design.

**BENEFITS:**

- Improved understanding of overspray capture technology.
- Develop active VOC/HAP treatment capabilities for hull painting operations.
- Ensure environmental compliance.

*POC: Dr. Robert Keay*

## FlashLamp Paint Removal Improvement

Compliance with existing and anticipated future environmental regulations have compelled the Jacksonville Naval Aviation Depot (NADEP JAX) to investigate alternate ways to safely and effectively strip paint from aircraft surfaces. Permissible exposure limits (PELs) to Methylene Chloride (now used for paint removal), and to heavy metals such as Chromium and Cadmium (which exist in many primer paints) are being significantly reduced. This requires NADEP JAX to identify and implement new approaches to paint removal.

**CUSTOMER:**  
Naval Aviation Depot Jacksonville

**SOLUTION:**  
Employing Flashjet technology is an economically and environmentally viable method of safely removing paint from the exterior of aircraft. A prototype system has been developed. The lessons learned during the prototype proof of concept trial provided the information to design, and field a production ready

tool. The specification of that production Flashlamp tool was completed under this effort.

**BENEFITS**

- Reduce PELs to acceptable and safe levels.
- Establish environmentally responsible approach to paint removal.
- Achieve payback for entire system via cost reduction within 5 years.

*POC: William Sabol*

## Enhanced Sustainment for Heavy Equipment

Determine the age related failure modes which increase the total ownership cost and reduce service readiness for the Marine Corps combat support logistic equipment.

**Customer:** Marine Corps Systems Command  
**Solution:** Collect data from Marine Corps facilities to establish systems impacted by age related deterioration and develop alternative procedures/materials to address these issues .

**Benefits:**  
\*Reduced total cost of ownership  
\*Increased service readiness

*POC: John Merenich*

## Acoustic Tile Removal

Develop induction heating system to remove acoustic tile and contaminated paint from decommissioned submarines prior to disposal.

**CUSTOMER:**  
Puget Sound Naval Shipyard

**SOLUTION:**  
Determine operating parameters of induction heating device for removal of acoustic tile and contaminated paint to minimize environmental impact.

**BENEFITS:**

- Increased productivity
- Minimize environmental impact
- Reduced injuries

*POC: John Merenich*

# 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 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

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 chills 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 HFC's or CFC's are 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.

*POC: Robert Johnson*



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

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.

*POCs: Dr. Rich Martukanitz and Al Lemanski*



## Noncontact High-Speed Gear Inspection

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 reflectivity 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.

*POC: Dr. Karl Reichard*



## LASCOR: Lightweight Structural Panels

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.

*POC: Ted Reutzel*



## Pericyclic Transmission

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.

*POC: Al Lemanski*

# 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

## 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

## Airframe System Technologies

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

## 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

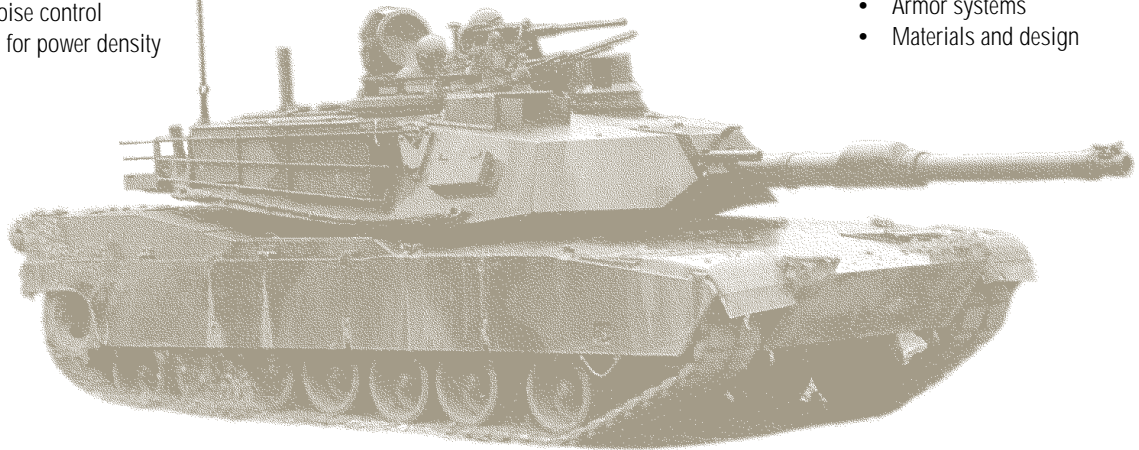
- Condition-Based Maintenance
- Distributed diagnostic system architectures
- Embedded engine predictive diagnostics
- MMI for troubleshooting and diagnosis

## 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

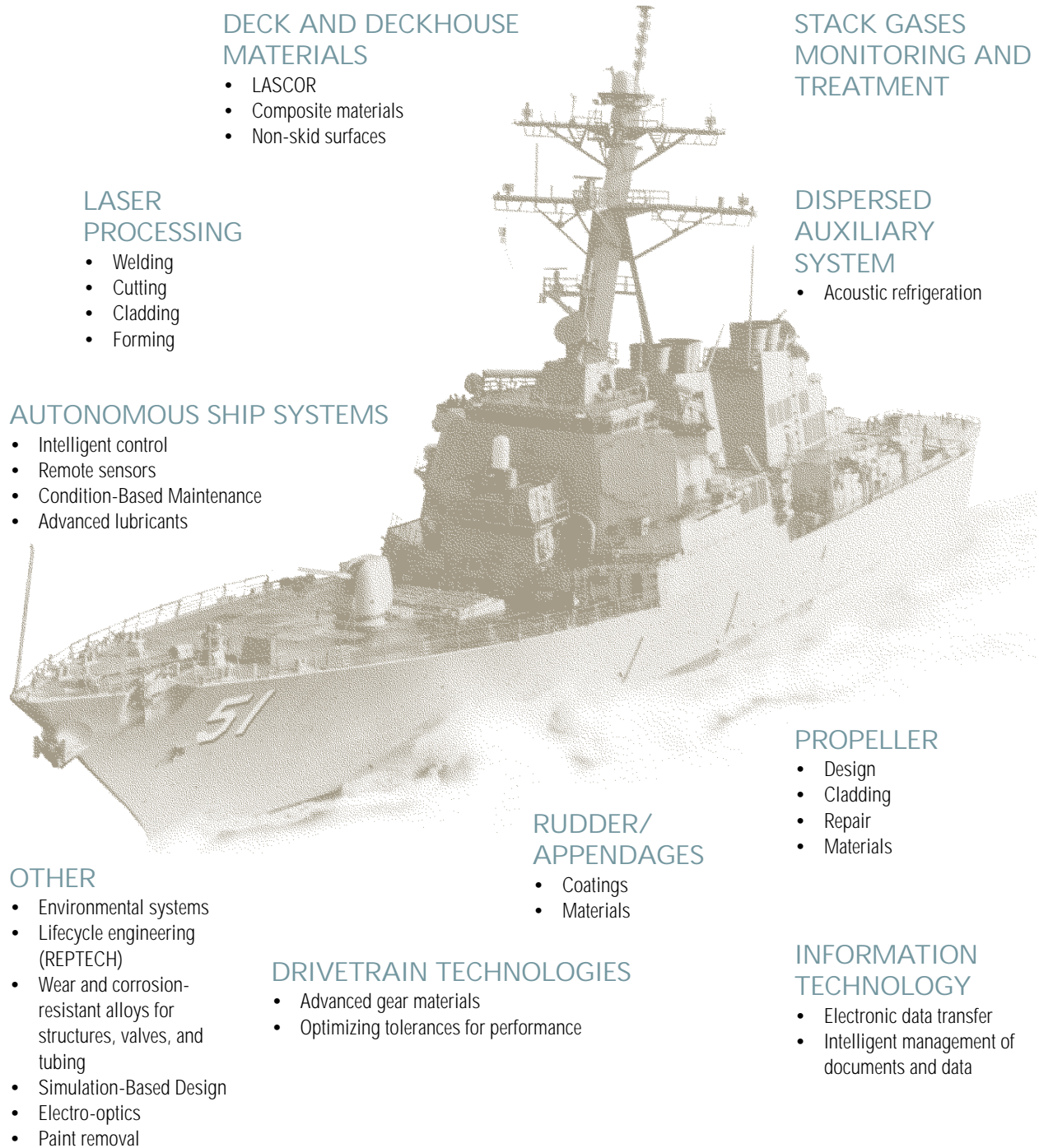
- Performance prediction
- Rapid prototyping
- Drive shaft laser balancing
- Condition monitoring
- Wear-resistant coatings via cold gas dynamic spraying and EB-PVD
- Spray formed HT aluminum alloys
- Localized laser HT and cladding for wear and corrosion resistance

## 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.



## DECK AND DECKHOUSE MATERIALS

- LASCOR
- Composite materials
- Non-skid surfaces

## STACK GASES MONITORING AND TREATMENT

## DISPERSED AUXILIARY SYSTEM

- Acoustic refrigeration

## LASER PROCESSING

- Welding
- Cutting
- Cladding
- Forming

## 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



## Mechanical Drive Transmission Facilities and Equipment



### 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 Facilities and Equipment



### Spray Metal Forming

- 5,000 sq. ft. facility
- Full metallography and surface characterization capabilities
- Research scale/pilot plant equipment
  - melts up to 65kg of aluminum
  - produces billets (16" x 10"), strip/plate (12" x 6" x .8"), tubes (12" x 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 ceramics

## High Energy Processing Facilities and Equipment

### Manufacturing Science Research Facility

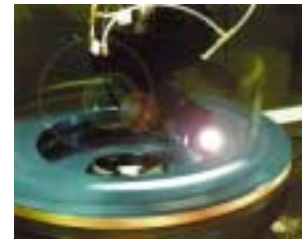
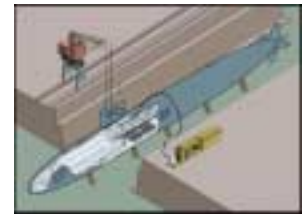
- 14-kW cw CO<sub>2</sub> laser system
- Two 1.5-kW cw and pulsed CO<sub>2</sub> laser systems
- 3-kW cw Nd:YAG
- 400-W pulsed Nd:YAG
- 10-W Q-Switch Nd:YAG
- 200-W excimer laser
- Laser Articulating Robotic System (LARS)
- Large-scale gantry
- Support equipment (e.g., robotic, linear and rotary workstations, etc.)

### Technology Transfer Facilities

- 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

### EB-PVD Facility

- 100 to 150 microns per minute deposition rate
- 1m<sup>3</sup> 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 Manufacturing 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 (Drivetrain Technologies)

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 acting director for the Drivetrain Technology Center.



### Maurice F. Amateau (Materials Science Technologies)

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 (High Energy Processing Technologies)

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.



## 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 (photo not available)

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.





### Ted Hicks

Mr. Hicks supports the Navy Manufacturing Program as a program officer for the Manufacturing Technology Detachment in Philadelphia. In this capacity he is currently the Navy's program manager for the Institute for Manufacturing and Sustainment Technologies (iMAST) at ARL Penn State, as well as the Navy Joining Center (NJC) and Manufacturing Technology Transfer Center (MTTC). Mr. Hicks also serves on the Joint Defense Manufacturing Technology Program (JDMTP) sustainment working group and the JDMT metals panel.

Mr. Hicks hold a B.S. degree in mechanical engineering from Drexel University.



### MARINE CORPS SYSTEMS COMMAND

#### BGen James M. Feigley, USMC

Brigadier General Feigley is the Commander, Marine Corps Systems Command at Quantico, VA. The Marine Corps Systems Command (MARCORSYSCOM) serves as the lead systems command for the Institute for Manufacturing and Sustainment Technologies (iMAST) Navy ManTech Program at ARL Penn State.

General Feigley's distinguished military career has spanned 28 years and includes duty at sea, overseas, and ashore in executive and command positions within the FMF (Fleet Marine Force), Headquarters, U. S. Marine Corps, and other joint service commands. A graduate of the University of Wisconsin-Oshkosh (B.S.), General Feigley's FMF military occupational specialty centered on amphibious tracked vehicle operations. A designated acquisition professional, General Feigley served as Direct Reporting Program Manager (DRPM) for the Advanced Amphibious Assault Vehicle (AAAV) program prior to his selection to flag rank and subsequent current command. Brigadier General Feigley is a graduate of the Marine Corps Command and Staff College as well as the Defense Systems Management College (DSMC).



#### 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.

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## iMAST

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P.O. Box 30  
State College, PA 16804-0030  
Telephone: (814) 863-3207 (Carol Ott – cvo1@psu.edu)  
Fax: (814) 865-0865  
[www.arl.psu.edu/core/imast/imast.html](http://www.arl.psu.edu/core/imast/imast.html)

## 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.edu/core/imast/imast.html](http://www.arl.psu.edu/core/imast/imast.html)

# 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 State 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

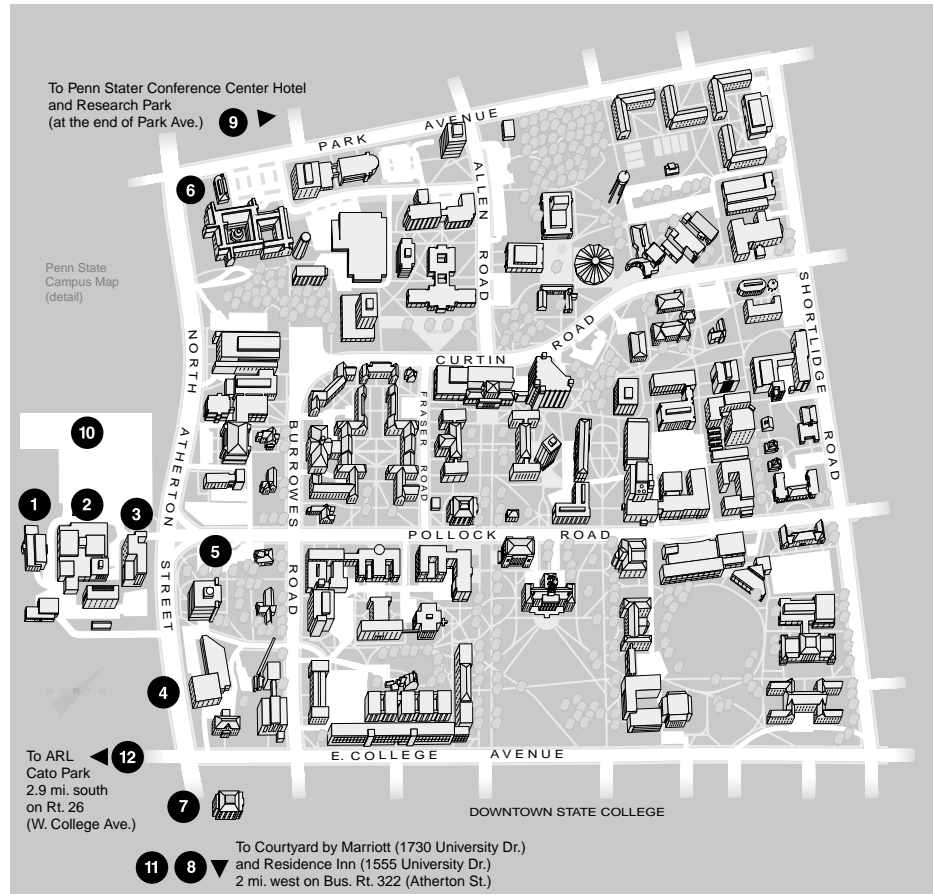
There are two routes. (1) Take the Northeast extension of the Pennsylvania Turnpike (I-76) to I-80. From I-80, exit at Exit 24 (Bellefonte). Follow Route 26 to State College; or (2) take the Schuylkill Expressway to the Pennsylvania Turnpike (I-76). Use Exit 19 (Harrisburg East) follow I-283 to I-83 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 State Conference Center Hotel (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.



## ARL Washington D.C. Office

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



# ARL Organization by Core Competency

## Undersea Systems



### CORE COMPETENCIES

- Autonomous Control and Intelligent Systems
- Systems Engineering and Analysis
- Energy Science and Power Systems
- Acoustics
- Institute for Non-Lethal 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

## Communications and Information



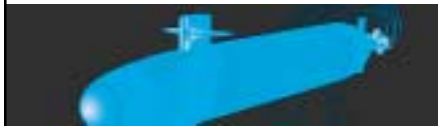
### CORE COMPETENCIES

- Information Science and Technology
- Navigation Research and Development Center
- Systems and Operations Automation
- 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

## Submarine and Ship Technology



### CORE COMPETENCIES

- Engineering Mechanics
- Flow and Structural Acoustics
- Computational Mechanics
- Water Tunnel Operations

### 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 Science
- High-Energy Processing
- Drivetrain Technology Center
- Electro-Optics Center

### MAJOR PROGRAMS

- Ausforming Finished Bearing Races
- Ausform Gear Qualification (DUST)
- Spray Metal Forming (JSF)
- Gold Gas Dynamic Coating (AAAV)
- Laser Free Forming
- Femtosecond Laser Processing

## Presentations and Publications (Abridged)

- T. E. Eden, "Aluminum Alloys Produced by Spray Metal Forming," 1999, No. 2, iMAST Quarterly, pp. 3-7.
- W. D. Mark, "Method for Precision Calibration of Rotary Scale Errors and Precision Determination of Gear Tooth Index Errors," November 1998, Mechanical Systems and Signal Processing, Volume 12, Number 6, pp 723-752.
- W. D. Mark, "Characterization and Measurement of Heat-Treatment Distortion of Gears," 1999, No. 1, iMAST Quarterly, pp. 3-8.
- J. T. Schriempf, P. E. Denney, "Preliminary Investigation into Materials Processing by High Power Diode Pumped Nd:YAG Lasers" ICALEO '98, Orlando, FL, 11/98.
- J. Singh, D. Poondi, R. Subramaniam, and M. Ottoni, "Synthesis of Silver Nanoparticles by Laser-Liquid-Solid Interaction Technique." 1998, Journal of Materials Synthesis and Processing, pp. 89-104.
- J. Singh and D. Wolfe, "Microstructural Evolution of Titanium Nitride (TiN) Coatings Produced by Reactive Ion Beam-Assisted Electron Beam Physical Vapor Deposition (RIBA, EB-PVD)," 1999, Journal of Materials Science, Volume 34, pages 2997-3006.
- J. Singh, F. Quli, D. E. Wolfe, J. T. Schriempf and J. Singh, "An Overview: Electron Beam-Physical Vapor Deposition Technology- Present and Future Applications Proceedings of "Surface Engineering: Science and Technology", at TMS Annual Meeting at San Diego, edited by A. Kumar, J. J. Moore, published by TMS, 1999, page 100.
- J. Singh and D.E. Wolfe, "Titanium carbide coatings by reactive ion beam assisted, electron beam- physical vapor deposition (EB-PVD)," International Conference for Metallurgical Coatings and Thin Films, San Diego, 1999.
- J. Singh, Nam Hyun Kang, and P. Howell, "Preliminary investigation on the effect of gravity on welding behavior of a 304 stainless steel," NASA Microgravity Materials Science Conference, edited by D.C. Gillies and D.E. McCauley (1998) 575-580.
- J. Singh, T. A. Mahank, and A. Kulkarni, "A Numerical Model of Laser-Glazing Process Applied To Stainless Steel," 13th International Conference on Surface Modification Technologies (SMT XIII) and 8th International Conference on Processing and fabrication of Advanced Material (PFAM VIII), Singapore (September 8-10, 1999).
- B. A. Striebig, R.W. Regan, and H. -K Son. 1999. "Enhanced odor destruction for municipal sludge disposal at sanitary landfills". 31st Mid-Atlantic Industrial and Hazardous Waste Conference, Storrs, CT. June 20-23, 1999.
- B.A. Striebig and J.P. Showman. 1999. "Photo-oxidation of ethylbenzene: Consequences of reactor design and scale-up". 31st Mid-Atlantic Industrial and Hazardous Waste Conference, Storrs, CT. June 20-23, 1999.
- B. A. Striebig, R. W. Regan, and H. -K. Son. 1999. "Odor evaluation and alternative sludge stabilization methods for solid waste disposal facilities". Air and Waste Management's 92nd Annual Meeting and Exhibition, St Louis, MO. June 20-24, 1999.
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# FY-99 Technology Transfer Event Participation



Defense Manufacturing Conference '98

Navy League Sea-Air-Space Expo '99

American Helicopter Society Forum 55

Showcase for Commerce-Johnstown, PA

ManTech Day on the Hill

NDIA Tech 2000

Society for Military History

Marine Corps League Modern Day Marine Expo '99

Penn State Northeast Industrial Showcase '99

Focal Spot '99

ICALEO '99

Photonics East '99

Showcase for Commerce-Kittanny, Pa.





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