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Penn State University
ARL Business Office (814) 865-4275
State College, PA

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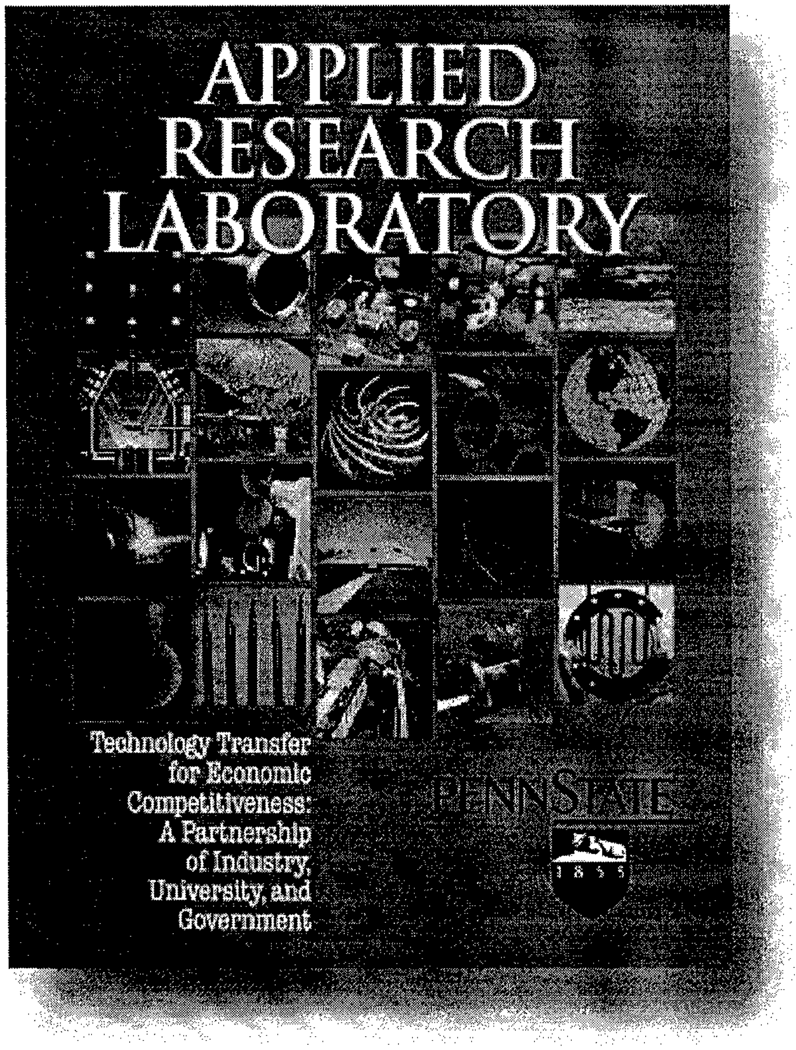

WE OFFER MANY THINGS TO MANY CLIENTS

The Applied Research Laboratory is a cost-effective, diversified, project-oriented research facility. As the largest of the affiliated laboratories, centers, and institutes that make up the University's Intercollege Research Programs, ARL draws on the intellectual, economic development, and technology transfer resources of Penn State. Ours is a client-focused R&D environment serving large and small businesses and governmental agencies. Projects can range between both ends of the technology transfer spectrum: from providing off-the-shelf technology implementation assistance for productivity enhancement to implementation of advanced technologies for new product or process development. ARL offers clients a "can-do" responsiveness, delivering timely solutions to real-world scientific and technical problems.

TECHNOLOGY TRANSFER MECHANISMS

- Cooperative R&D agreements

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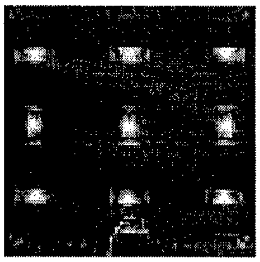
- Licensing agreements
- Industrial R&D consortia
- Test bed demonstrations and prototyping
- Teleconferencing and remote instruction
- Faculty and staff exchanges
- Concurrent engineering
- Teaching factories and training
- Proprietary contract R&D

INTELLECTUAL PROPERTY CONSIDERATIONS

Successful technology transfer requires flexibility in addressing intellectual property concerns. ARL utilizes the Intellectual Property Office at Penn State and transfers resident technologies through individualized proprietary agreements and intellectual property licensing arrangements. The University recognizes the importance of transferring this technology to the commercial sector where it can benefit the public. Therefore, it usually grants sponsors the first option to negotiate licensing rights to new technologies arising from sponsored research programs. It is flexible in negotiating intellectual property issues. Additionally, the University develops a significant number of technologies under federal projects and nonsponsored departmental research. Technologies that are owned by the University are made available to industry through Penn State's Technology Licensing Program.

Acoustics



ARL conducts a full-spectrum acoustics program that ranges from basic research to practical applications. Its fundamental work focuses on such topics as the basic physical mechanisms that govern vibrating structures, high-performance sensors, acoustical radiation, acoustic refrigeration methods, and the propagation and fluctuations of acoustic energy through air and water. This work yields new approaches to noise and vibration control, structural tailoring, undersea environmental change, and active and passive sound and vibration control. Through combined analytical, numerical, and experimental means, the program develops methods to translate these findings into practical use.

Recent developments at ARL demonstrate this resident capability in acoustics and vibration. Among its most important achievements, the program has produced new, noninvasive methods to measure vibration power flow and acoustic intensity and has developed improved algorithms for actively controlling vibration in a structure.

The program's research facilities include a flow-through anechoic chamber ideally suited for measuring fans and blowers, a large physical acoustics laboratory focused on acoustic refrigeration techniques, and a structural acoustics laboratory that has a fabrication facility for unsteady pressure and force instrumentation and a large tank for in-water testing. The program also makes use of ARL's optics laboratory, which allows for laser vibrometry studies of large structures, and its facility for testing and calibrating underwater transducers. These facilities are coupled with the Laboratory's signal-processing equipment to provide comprehensive data collection and analysis.

These unique acoustics and vibration capabilities are available to meet the needs of government and industry. They can be employed in efforts ranging from basic studies to management and completion of major design and development projects.

Potential Applications

Structural damping

Heating, ventilation, and air-conditioning system silencing

Vehicle noise reduction

Aircraft powerplant noise attenuation

Models for sound-field propagation

Machinery condition monitoring

Weld-quality monitoring

Environmental modeling and monitoring

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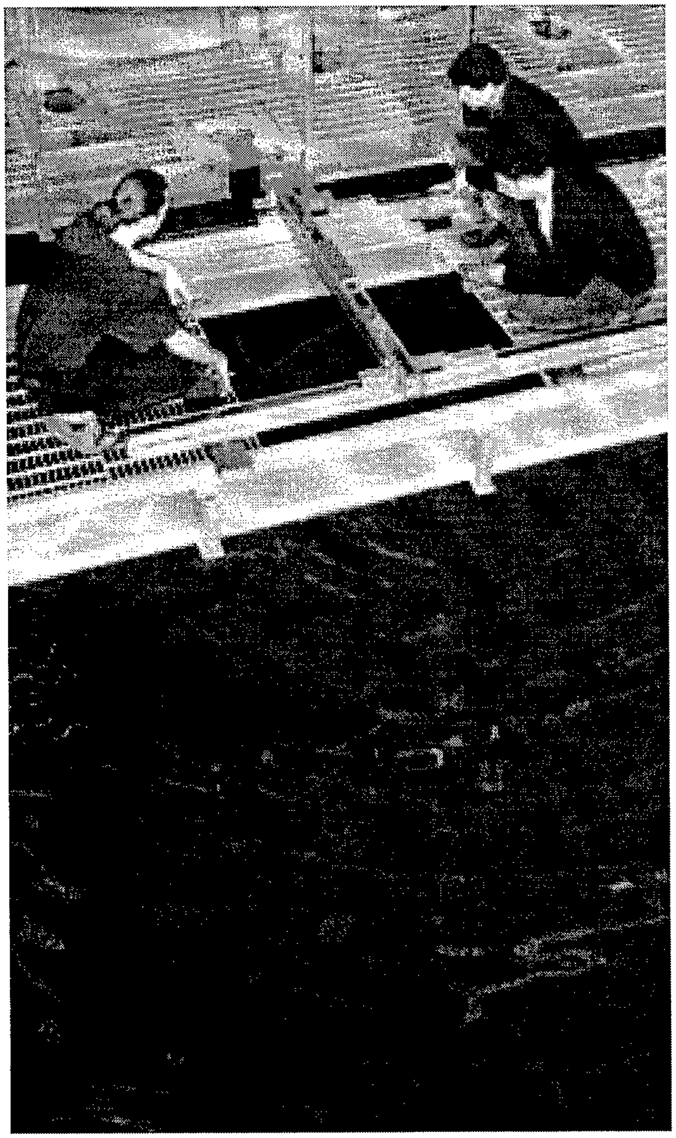
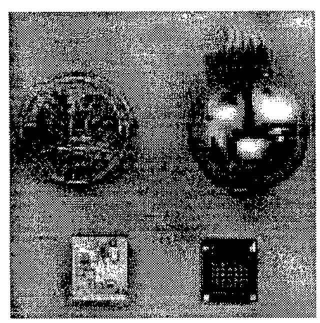
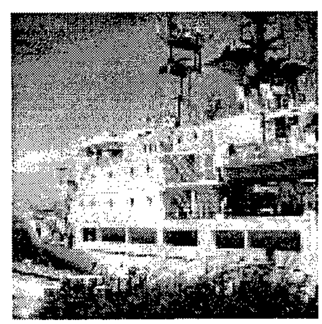


Resident Expertise and Technologies

Active vibration and acoustic control
Computer modeling of machinery vibration and noise
Nondestructive testing
Process control and diagnostics
Advanced sensor design and applications
Sound propagation and radiation in air and water
Structural acoustics
Environmental acoustics
Physical acoustics

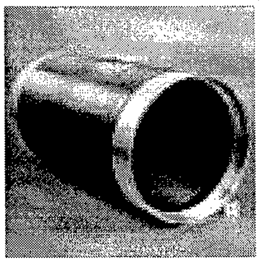




Facilities

Large Flow-Through Anechoic Chamber
Underwater Anechoic Tank
Underwater Vibration Testing Facility
Quiet-Wall Jet Facility
Structural Acoustics Laboratory
Underwater Reverberation Tank
Physical Acoustics Laboratory
Unique Sensor Laboratory

Advanced Composite Materials



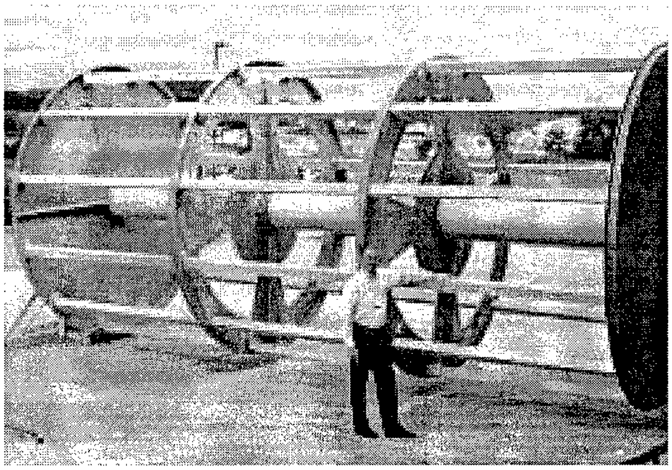
ARL has earned a leadership role in the development of composite technology for applications in marine vehicles. To support this role, ARL has assembled an experienced technical staff, established complete in-house design/analysis, fabrication, and testing facilities, and has developed an extensive network of proven subcontractors.

ARL utilizes a concurrent engineering approach in developing composite structural applications. This approach requires a close and continuous interaction between all key technology disciplines including structures, acoustics, materials, manufacturing, and quality control to ensure that the delicate balance between structural integrity, performance, producibility, and cost is maintained. This concurrent engineering approach has been demonstrated successfully by designing, fabricating, and testing full-scale composite structures in a variety of U.S. Navy and industrial programs.

Technology thrusts include active and passive noise and vibration control using advanced composite materials, development of fabrication techniques capable of producing laminated composite structural components greater than eight inches thick, development of both strength-based and fracture mechanics-based fatigue test methodologies and life prediction models for complex geometry composite hardware, optimization of low-cost fabrication techniques such as filament winding and resin transfer molding for marine and industrial composite structures, and the development of advanced ultrasonic inspection and in situ acoustic emission monitoring techniques.

Potential Applications

Noise reduction
Marine vehicles
Infrastructure
Lightweight structures
Ballistic protection and physical security
Smart structures



Resident Expertise and Technologies

DESIGN AND ANALYSIS
- Acoustic tailoring
- Structural life prediction

MATERIALS CHARACTERIZATION
- Environmental effects
- ASTM standard and custom test development

FABRICATION
- Low-cost process development
- Sub- and full-scale prototyping

STRUCTURAL TESTING
- Prototype and element testing
- Experimental and analytical correlation

ULTRASONIC NONDESTRUCTIVE EVALUATION
- Advanced signal processing
- Acoustic emission diagnostics

Facilities and Equipment

COMPUTING

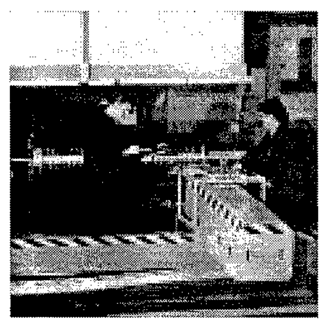
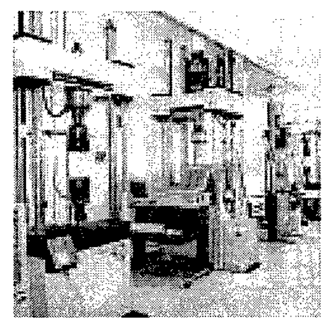
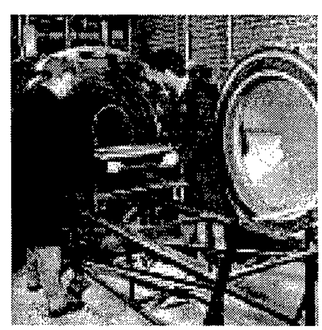
Four workstations, supercomputer access, Unigraphics CAD, I-DEAS pre- and post-processing software, MSC NASTRAN, ABAQUS, POWER, and DYNA FEA solvers

FABRICATION

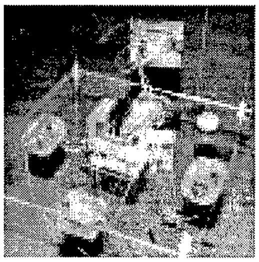
Large-Capacity Filament Winding Facility, Hand Lay-up and Autoclave Cure Facility, resin transfer molding equipment, laminating presses, Century Design tube rolling equipment, pultrusion equipment

TESTING

33-Kip Universal test machine, ten servo-hydraulic test frames (5-Kip to 100-Kip capacity), instrumented impact tester, High-Pressure Hydrostatic Test Facility, Cavitation Erosion Facility, small and large ultrasonic test tanks


Advanced Sensing and System Monitoring



ARL is a leader in the research, development, prototyping, and evaluation of high-performance acoustic and vibration sensors. The focus is on very-low-self-noise sensors, self-calibrating sensors, microfabricated sensors, optical sensors, and sensor data transfer and networking in harsh environments.

Current research includes design and prototyping of self-calibrating, active-vibration-canceling sensors and fiber-optic vibration sensors; development of microfabricated directional hydrophones; precision calibration techniques for acoustic and vibration sensors and; noise floor and stability of microfabricated sensors for inertial navigation applications.

ARL maintains a Sensors Laboratory at the University Park campus and an Inertial Navigation Laboratory in southeastern Pennsylvania. The Sensors Laboratory contains an isolation test chamber in which measurements of sensor noise far below normal ambient acoustic and vibration levels are possible; three reciprocity calibration fixtures for absolute, primary calibration of microphones, accelerometers, and rotational-rate sensors (such as gyroscopes); and a heterodyne laser interferometric imaging system for the analysis of the dynamic behavior of microsensor structures. In addition, there are several laboratory areas for the fabrication of sensors and associated electronics. The Inertial Navigation Laboratory is the Navy's premier facility for test and evaluation of high-end inertial navigation components and systems.

Potential Applications

High-performance active and passive sonar systems
Condition-based maintenance
Unattended sensing systems
Inertial navigation for personnel or remotely piloted vehicles
Flow-noise canceling sensors
Monitoring of complex systems
Local- and wide-area monitoring of the environment

Resident Expertise and Technologies

Very-low-noise sensor and electronics design

Sensor noise-floor measurement

Primary calibration of acoustic and vibration sensors

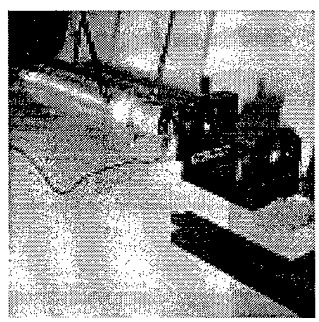
Design of self-calibrating and self-diagnosing sensors

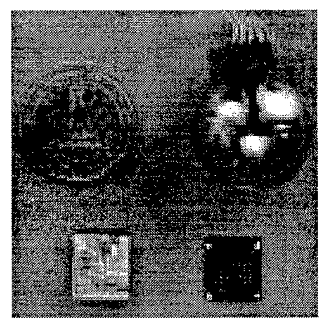
Wireless sensor data links

Optical and fiber-optic sensors

Design of fault-tolerant networks of sensors for harsh environments

Application of microfabrication to acoustic and vibration sensing





Facilities and Equipment

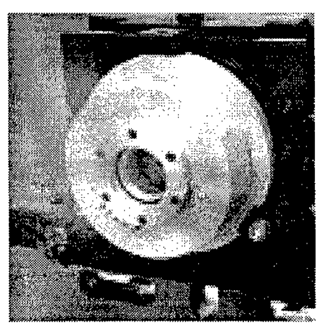
Low-Noise Sensor Isolation Test Chamber

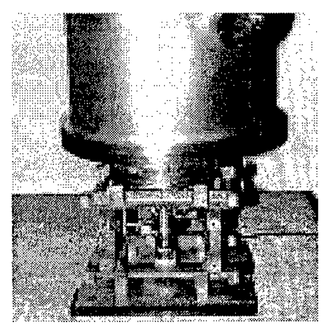
Precision reciprocity calibration apparatus for microphones, accelerometers, and gyroscopes

Heterodyne laser system for dynamic imaging of sensor structures

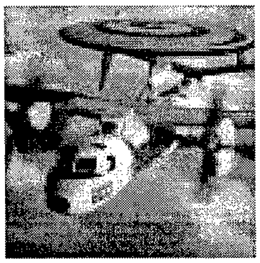
Inertial Navigation Laboratory

Nanofabrication Facility for implementation of MEMS sensor/processor systems





Communications



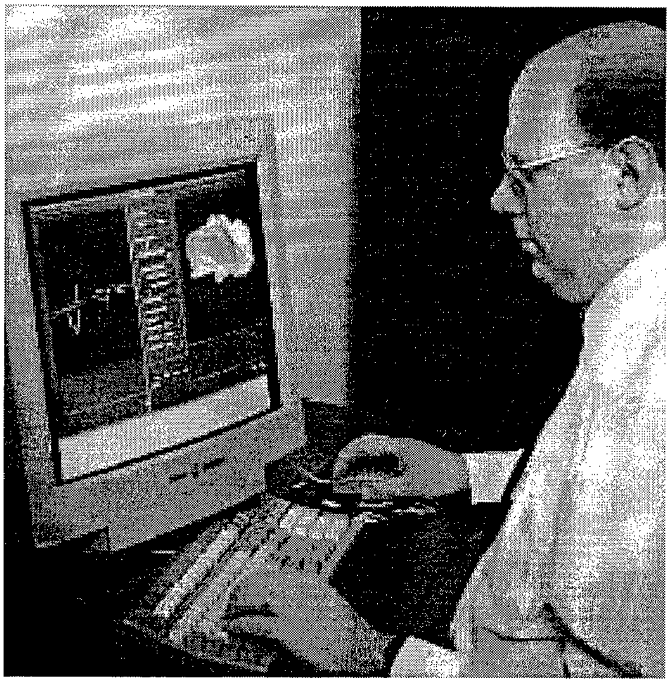
Through the maturing of a range of technologies, wireless communication is becoming pervasive. Virtually every existing communications application, whether it is the LAN or video-conferencing, is being developed using wireless access. Characterizing new and evolving communication systems requires accurate, high-fidelity, physics-based models. ARL has been a key player in the development of design and analysis tools for applications as diverse as cellular and PCS to virtual environments for the design and analysis of communication systems.

Presently, ARL is using time-stepped and event-driven techniques to create a virtual softbench for the design of advanced communication systems. Simulation-based design techniques can greatly reduce the development cycle and time to market. Having a validated virtual design readily facilitates the design of product enhancements and updates.

ARL has also been actively conducting basic and applied research in such diverse areas as electromagnetic absorbing techniques, computational electromagnetics, genetic optimization methods, conformal antennas, cellular/PCS radiowave propagation models, and communication node/network analysis.

Potential Applications

Simulation-based design
Communication system design/optimization
Virtual system characterization
Cellular/PCS modeling
GPS antennas
EMI/EMC issues



Resident Expertise and Technologies

Virtual electronic order of battle

Communication system design

Multi-fidelity simulation tools

Information operations

Signal analysis workstation

Electromagnetic analysis

Electromagnetic propagation server

High-fidelity electromagnetic analysis workstation

Genetic algorithm development

Higher-order spectral processing

Emitter localization

Antenna engineering

Cellular/PCS models

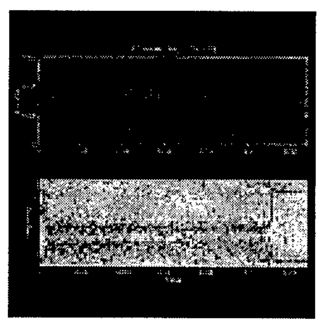
Facilities and Equipment

Signal Analysis Laboratory

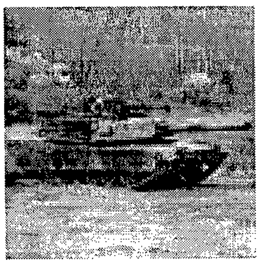
Multi-platform design environment (SUN, DEC Alpha, Silicon Graphics, TAC-N)

Radiowave propagation

Secure Processing Facility



Condition-Based Maintenance



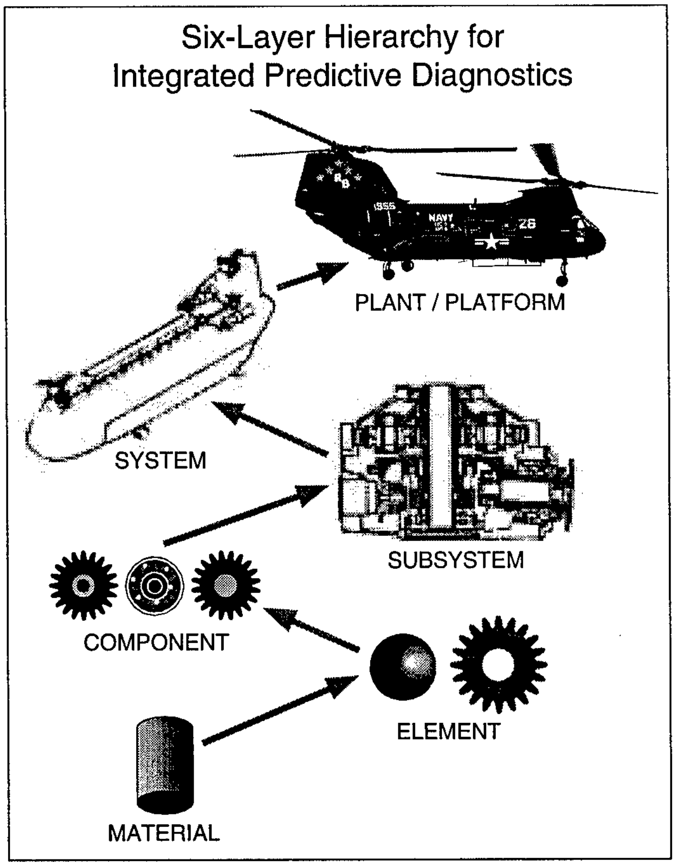
The emerging technology of condition-based maintenance (CBM) of mechanical equipment is aimed at developing systems that are capable of monitoring the operation of a complex piece of machinery and providing an accurate characterization of the current system state and an accurate prediction of the remaining useful life. This approach is a departure from two traditional maintenance approaches: 1) run until mechanical failure occurs, then repair; and 2) schedule maintenance and inspection based on probabilistic failure models. CBM offers a significant savings in life cycle maintenance costs, improved system reliability, and increased safety.

An extensive research program at ARL is focused on key components of CBM. Our research spans the complete hierarchy of understanding and predicting failure phenomena at the material's level to higher levels of mechanical components, subsystems, systems, and platforms (e.g., aircraft, ships, etc.). Recent research accomplishments include: 1) advanced, intelligent, self-calibrating sensors; 2) a complete tool set for digital signal processing of sensor data and multi-sensor fusion techniques to combine information from multiple sensors; 3) test beds and models to observe and track the evolution of mechanical failure phenomena such as wear, crack growth, fatigue, etc; 4) a fundamental theoretical framework and practical models for predicting accurately the evolution of failure phenomena; and 5) new hybrid methods for automated reasoning that incorporate the features of fuzzy logic, rule-based systems, neural networks, and decision-level fusion.

Our program includes fundamental research as well as applications to systems such as turbine engines, rotorcraft power systems, shipboard equipment, powerplants, and large-scale systems such as wind tunnels. ARL's researchers are working in collaboration with a consortium of industrial partners to create commercial intelligent component health monitoring systems (ICHMs). Our government collaborators include researchers from the Office of Naval Research, NASA, and the U.S. Army.

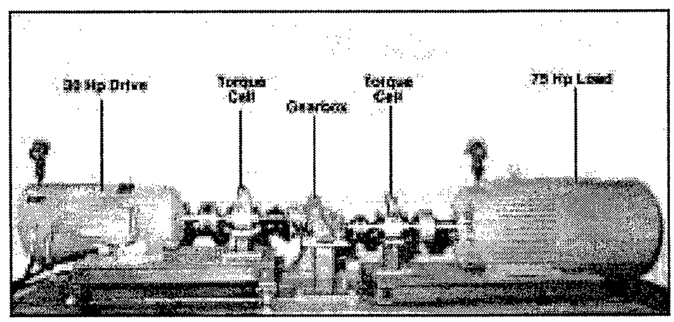
Potential Applications

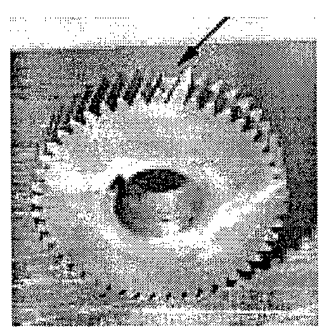
Medical monitoring systems
Automated manufacturing systems
Monitoring of complex mechanical systems
Transportation infrastructure monitoring
Intelligent buildings

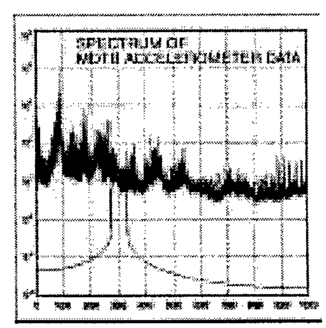


Resident Expertise and Technologies

Multi-sensor data fusion
Digital signal processing
Approximate reasoning
Materials characterization
Mechanical modeling and simulation
Nondestructive test and evaluation
Mechanical failure testing
Data analysis and visualization
Microelectronic and mechanical systems (MEMS)
Nonlinear dynamic modeling



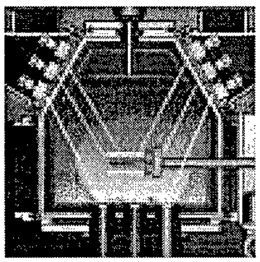




Facilities and Equipment

Systems Integration and Technology Transfer (SITT) Facility
Mechanical Diagnostics Test Bed
Multi-sensor data fusion toolkit
Digital signal processing and toolkit
Scientific Visualization Laboratory
Nanofabrication Facility
Nonlinear Dynamics Computing Facility
Hydrogenization Test Laboratory
Gear Research Institute
Drivetrain Technology Center
NASA Rotorcraft Center at Penn State

Electron Beam – Physical Vapor Deposition



ARL conducts substantial research and development in materials and materials processing. This work addresses performance issues for power transmission, thermo-power systems, and structures. The program's extensive facilities are equipped to characterize materials for their mechanical and thermal properties, as well as corrosion and wear resistance.

Materials science efforts at ARL focus on advanced materials such as high hot-hardness steels and advanced processes, including thermomechanical net shape forming (ausform finishing), spray metal forming, and electron beam–physical vapor deposition (EB-PVD).

A new technology thrust, electron beam–physical vapor deposition (EB-PVD), is being implemented at ARL. Research and development in coatings for thermal control in turbine jet engines will address wear-resistant surfaces and other applications where special surface conditions are required. The cornerstone of this activity is the acquisition of a large, industrial-class facility developed at the Paton Welding Institute in Kiev, Ukraine. ARL's acquisition of this facility will bring substantial benefits to the U.S. industries that are participating with ARL in this program's development. It is anticipated that the developed coatings will greatly enhance cutting tool life, make possible substantial increases in engine performance, and provide numerous opportunities for reducing life cycle costs in applications where durability is limited due to surface wear and abrasion.

Potential Applications

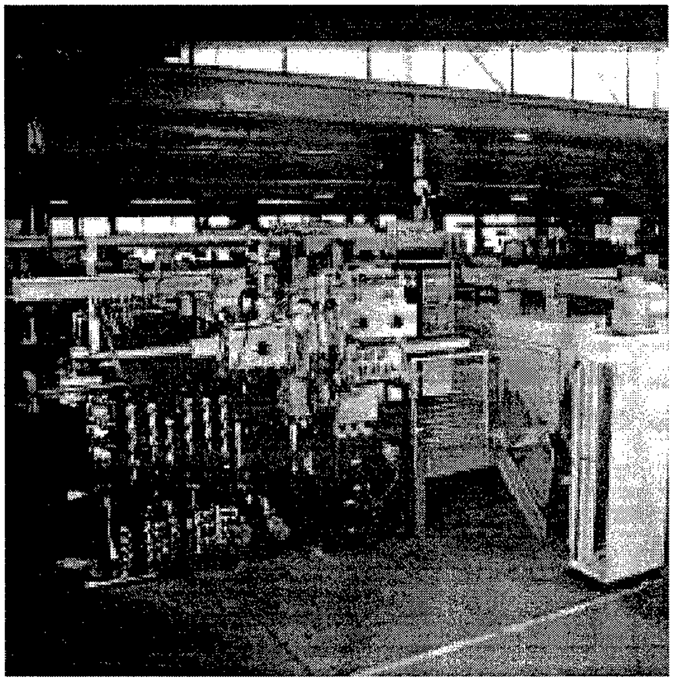
Wear components

Gas turbine engines (high-temperature, discontinuously-reinforced aluminum alloys)

Computer disk head actuators (Al 4% Li alloys)

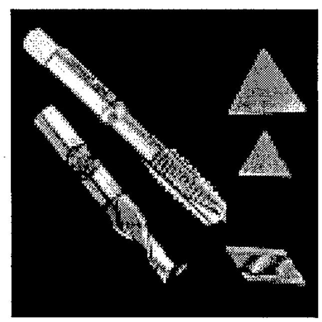
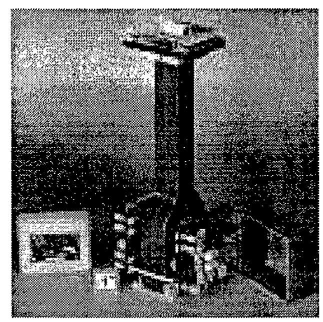
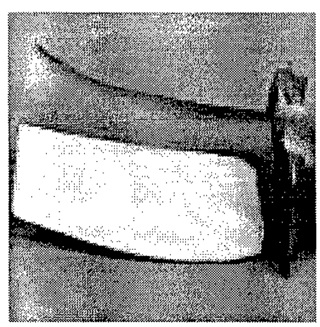
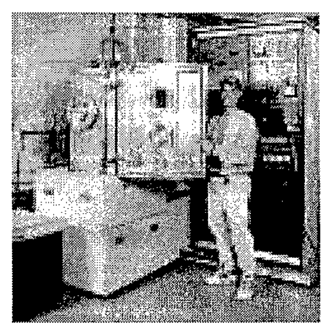
Thermal barrier coatings

Wear-resistant coatings



Resident Expertise and Technologies

Wear and corrosion amelioration and testing
Surface processing
Thermal and surface barrier coating technology
Nanophase material development and synthesis

Environmental Compliance and Monitoring

Environmental constraints are an ever-growing issue to commercial and military-use sectors. New procedures for compliance monitoring and new methods for environmentally benign manufacturing and repair operations are a development challenge to all involved. Environmentally sound remediation of problems and practices of the past requires new approaches to compliance monitoring. ARL is bringing technology to bear on a range of compliance and monitoring problems. A major effort has produced a mobile laser radar system (lidar) that profiles atmospheric properties from the ground to the stratosphere. The system proved effective in a shipboard trial, in which it measured atmospheric constituents over the Atlantic Ocean across both northern and southern hemispheres. ARL is now exploiting the system's sensitivity to measure trace levels of pollutants in the atmosphere.

Another environmental thrust is within the Air and Water Quality Laboratory where improvements in monitoring and oxidative destruction of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) are under study. The fully instrumented laboratory has a 2,500 scfm pilot-scale pollutant treatment system employing hybrid destruction technology. The latter consists of ozone UV photocatalysis, ozone/peroxide water oxidation, and ozone-based in situ activated carbon regeneration. This facility is actively involved in both commercial and military R&D efforts.

ARL uses laser-based methods for the neutralization, incineration, and removal of toxic materials. Work is in progress, for example, to find electromagnetic wavelengths most effective for breaking down VOCs, HAPs, and PCBs. Combining the latest laser and electro-optics technology, ARL is developing hand-held, real-time instruments for toxic metals monitoring. Further thrusts are towards developing alternatives to chemical coating and joining processes that require highly toxic materials. The laser welding of electronic components is an effective replacement for standard soldering practices. Laser cladding has the potential to replace standard cladding processes.

The range of environmental compliance and monitoring problems that ARL successfully addresses is enhanced by its strong partnership with other research components of the University, such as the Environmental Resources Research Institute (ERRI) and the College of Engineering.

Potential Applications

Global monitoring

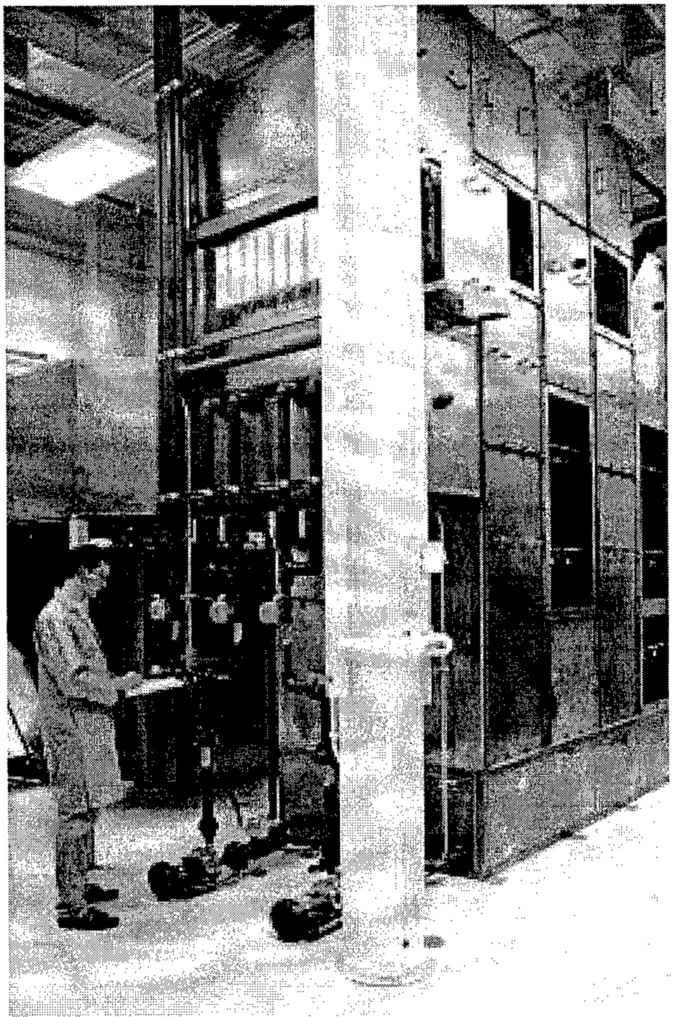
Environmentally more effective control processes

Improved and more effective environmental monitoring techniques

Hazardous material monitoring and disposal

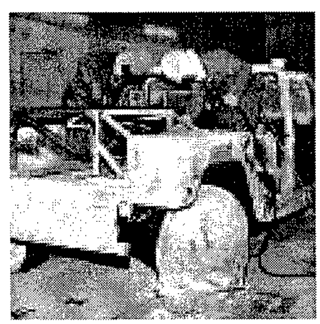
Military base compliance and remediation

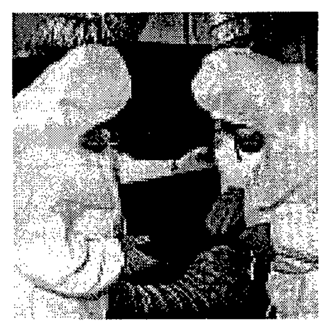
Environmentally safe manufacturing and repair methods

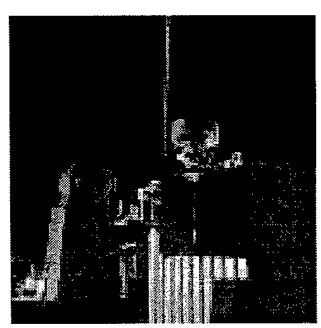


Resident Expertise and Technologies

Laser-based remote and specialized sensing
Control, destruction, and monitoring of VOCs and HAPs
Laser-based hazardous material waste treatment
Laser-based alternatives to plating and lead soldering
Site assessment
Environmental acoustics
Solvent substitutes – Supercritical carbon dioxide applications
Environmentally benign paint application and removal technologies



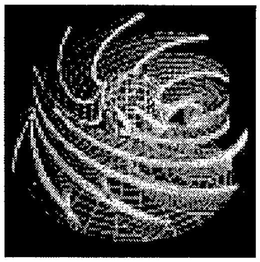




Facilities

Lidar Laboratory
Air and Water Quality Laboratory
Laser Processing Laboratory
Electro-Optics Laboratory
Facility design and modernization group

Fluid Dynamics and Turbomachinery



ARL has a long history of research in the areas of fluid dynamics and turbomachinery. With its excellent test facilities, ARL has traditionally focused on experimental fluid dynamics, where fundamental and exploratory research is conducted into the physical phenomena governing boundary layer flows, cavitation, flow control, and the hydrodynamics of marine vehicles. To enhance this research, ARL has developed unique state-of-the-art facilities, instrumentation, and a methodology for the experimental study of fluid dynamic phenomena.

In addition, ARL has designed and tested advanced propulsors for all types of marine vehicles, as well as axial-flow pumps, centrifugal pumps, and low-speed fans. In an attempt to develop advanced propulsors as an integrated element of a total vehicle, ARL has developed and implemented concurrent engineering practices—incorporating the hydrodynamic, hydroacoustic, and mechanical design aspects into a design team approach.

ARL also performs experimental and theoretical research in the areas of flow acoustics, structural acoustics, noise control, and active noise cancellation. Researchers in these areas have access to excellent facilities that provide opportunity to research many of the areas of the physics of flow-generated acoustic forcing functions and the structural response to these forcing functions. These facilities include two acoustic water tank facilities, a flow-through anechoic chamber, as well as the Garfield Thomas Water Tunnel. These facilities are instrumented with state-of-the-art instrumentation, including a scanning laser vibrometer.

The computational mechanics activities at ARL encompass a broad range of disciplines with a major connection to the methodology of computational fluid dynamics (CFD). There are ongoing computational modeling efforts in the areas of propulsor and turbomachinery design, unsteady vehicle maneuvering, materials processing, and cavitation. Turbomachinery analysis using CFD codes has a strong influence on the design of propulsors for both submarines and torpedoes. Turbomachinery analysis codes are being further developed at ARL and integrated into the propulsor design process to reduce both design risk and the number of iterations in the design cycle.

Potential Applications

Fluid dynamics of materials processing

Fluid dynamics of automotive components

Machinery noise reduction

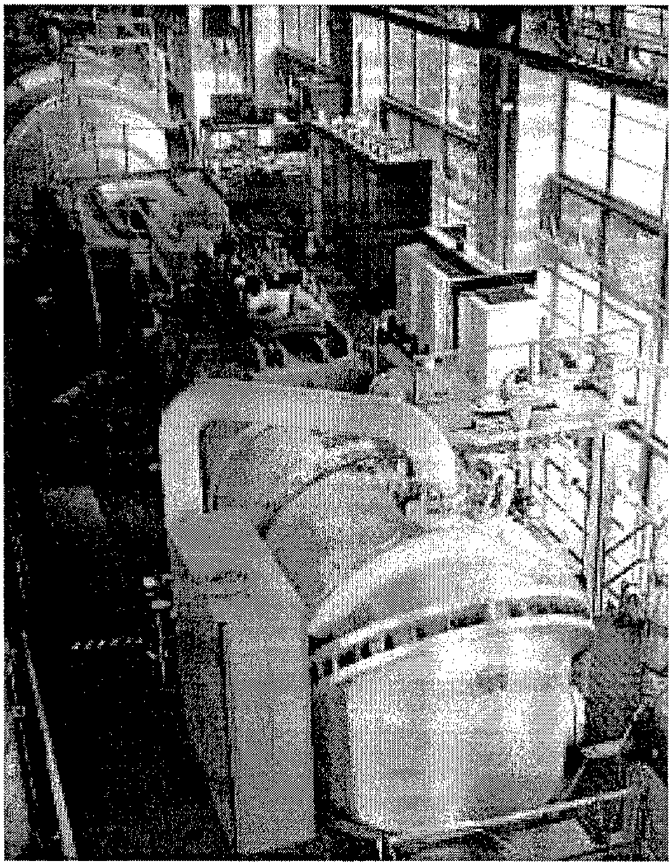
Rotary equipment efficiency

Commercial seacraft propulsion

Acoustics of automotive components

Aircraft turboprop mechanics

Improved pump and fan designs



Facilities

48-inch-diameter Water Tunnel
- High Reynolds Number Pump Facility (HIREP)
- Large Flat Plate Facility

12-inch-diameter Water Tunnel
- Centrifugal Pump Facility

6-inch-diameter Water Tunnel

1.5-inch-diameter, High-Speed Cavitation Tunnels

Boundary Layer Research Facility (glycerin tunnel)

Subsonic Cascade Tunnel

Axial-Flow Fan Air Facility

Flow-Through Anechoic Chamber
- Axial Flow Research Fan
- Cascade (quiet, open-jet) Facility
- Quiet Wall Jet Facility

Prototype Numerically-Controlled Manufacturing and Inspection Facility

Resident Expertise and Technologies

Active control of turbomachinery flows

Advanced fluid-dynamic and aero-/hydroacoustic measurement techniques

Boundary-layer flows and drag reduction

Centrifugal/axial flow pump analysis, design, and testing

Computational fluid dynamics

Inspection technology

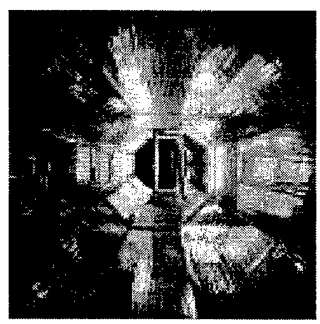
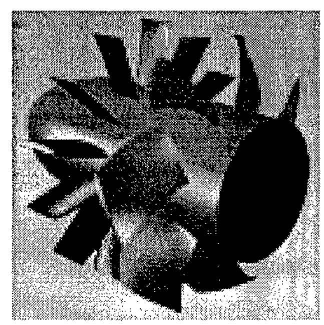
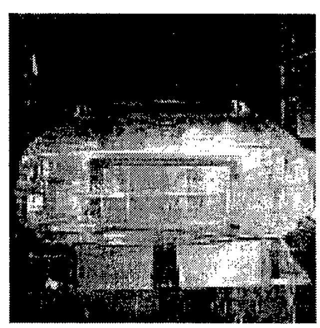
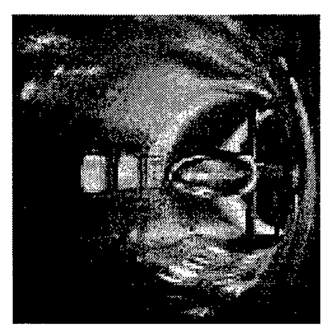
Propeller design

Structural testing with laser vibrometer and accelerometers

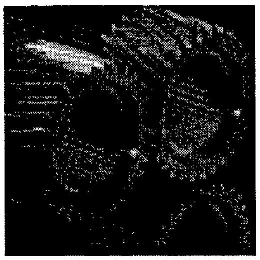
Turbomachinery and propeller CAD/CAM, inspection, and testing

Unsteady flows and flow control

Ventilating fan design

Gear and Transmission Technologies



ARL conducts extensive research, development, design, manufacturing processing, inspection, and testing of transmission dynamic components and structural housings. Current projects address important technological objectives such as affordable, improved high-power density and low-noise power transmission gearing; high-temperature and lightweight lubrication systems; and advanced high-temperature gear, bearing, and housing materials and designs. The development of these technologies focuses on lowering costs over the drivetrain's lifecycle (design, manufacturing, and maintenance).

Current efforts are focused on the following technologies:

- advanced gear, bearing, and shaft materials testing and evaluation for mechanical and chemical properties, thermal properties, lower-cost processing development, and bending and surface fatigue performance
- advanced high-temperature housing materials that permit fabrication by an ARL low-cost, robotic cutting/welding crash-resistant and corrosion-resistant method
- net shape finishing of gears and bearings by ausform finishing that addresses reduced production times and improved fatigue strength and surface finish
- noncontacting workpiece (gear and housing components, etc.) positioning systems that address the cost reduction of precision CNC machining operations by eliminating the need for physical machined datum reference surfaces on the workpiece
- noncontacting, high-precision/high-speed inspection systems for gears and other components that address a major cost reduction (orders of magnitude) in component inspection time and production control time
- gear metrology and performance prediction that addresses full qualitative and quantitative understanding of relationships between gear design parameters, tooth elastic deformations, tooth modifications, gear manufacturing/processing errors, capability for computing elastic deformation contributions to transmission error via finite-element capability and advanced gear system modeling capability.

Potential Applications

Net shape finishing (gears, bearings, ball screws, and other machine elements)

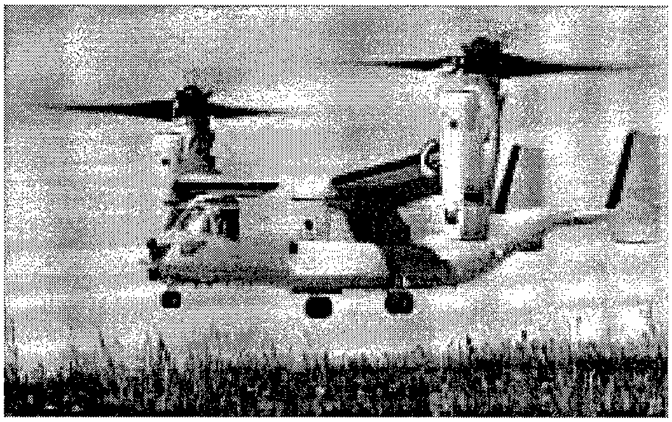
Cutting tool technology

Powder metal gear densification (increased load capacity)

Precision transmissions (increased power density)

High-temperature hot hardness materials (gears, bearings, and shafts)

Lightweight, high-temperature transmission housings and structures (permitting mini-lube systems, increasing power density, and reducing manufacturing lead times)



Facilities and Equipment

Advanced Manufacturing Facility

- World's first production-capable double-die ausform gear/ bearing finishing machine
- Single-die ausform finishing machine for cylindrical specimens

Drive System Component Performance Testing Facility

- Electrohydraulic closed-loop single-tooth bending fatigue testing machines
- Rolling-contact fatigue (RCF) testing machines
- Dynamic 6-inch center distance (150 hp) four-square double-set gear test rig
- Dynamic 3.5-inch four-square gear test rigs
- Worm gear dynometers
- X-ray diffraction machine

Gear Dimensional Inspection (Metrology) Facility

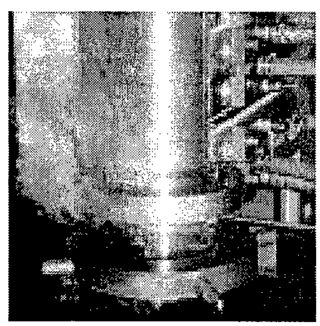
- M&M precision 3000QC gear-measurement machine
- MAAG SP-130 precision base-circle gear-measuring machine (with artifacts)
- MAAG SP-160 precision base-circle gear-measuring machine (with artifacts)
- Zeiss UPMC 550 precision coordinate-measuring machine

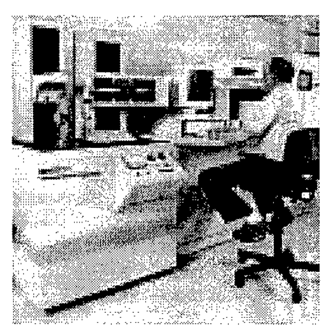
Diagnostics/Prognostics Gearbox and Component Testing Facility

- Mechanical Diagnostic Test Bed
- Single-ball v-ring test rig

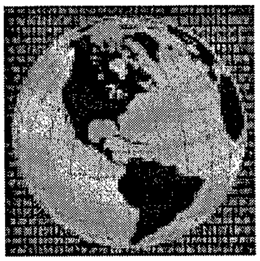
Resident Expertise and Technologies

Advanced gear technologies
Process characterization
Equipment characterization
Machine tool development
Metal removal through grinding
Noncontact inspection technology
Gear performance prediction
Advanced heat treatment
Powder metallurgy
Short- and long-duration dynamics
Thermomechanical processing of metals and contact machine elements
Tooling technology
Advanced measurement methodologies





Information Systems Technology



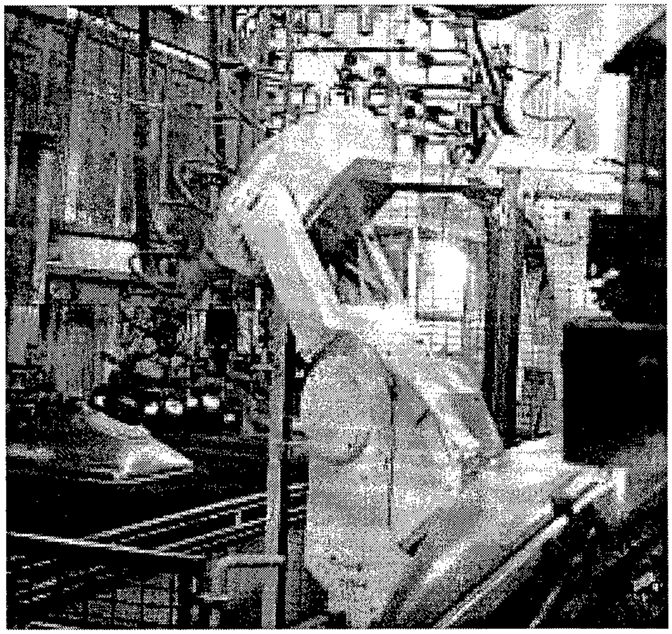
The Information Systems Department develops and applies advanced technologies to the organization, processing, fusion, and analysis of distributed information for rapid decision support and integration of system functions. Its current technology base supports Navy applications in Undersea engineering, C2/battle management, operations and logistics-information management, computer integrated manufacturing, human-factors engineering, computer-aided training, enterprise reengineering and medical, transportation and environmental information support systems for industry, government and DoD. The Department maintains expertise and conducts cutting-edge research in distributed processing and multi-database architectures, information fusion, discrete event control, decision sciences, cognitive science, and educational technology. The information systems collaboratory has active research programs in five major areas: interoperability, human performance technologies, enterprise modeling and integration, logistics, and distributed autonomous systems.

The interoperability of heterogeneous systems, distributed geographically and differing in content, access mechanisms, and local uses of language is being achieved through the modeling, organization, and integration of data sources in several domains. ARL's National Information Infrastructure (NII) test bed demonstrates the commercial potential of our innovative solutions by supporting real-time, remote diagnostics and prognostics of operating machinery.

Technological solutions integrating data and processes to provide decision support are integrated into complex work environments through careful user-centered system design and computer-assisted training of personnel whose jobs are changing as information becomes a primary workplace resource. ARL Human Performance Technologies group approaches the optimization of human performance through both design and training in areas including information-based maintenance, logistics planning and decision making, and complex system maintenance and operations.

The ability to plan operational strategies, foresee ramifications of actions, and make intelligent decisions based on enterprise data requires an integrated information infrastructure providing visualization, fusion, and intelligent, timely retrieval couched in user context and language. Innovations from the NII test bed and ARL-designed configuration-based technical information management system have established our expertise in important aspects of enterprise modeling and integration.

Improving control and interaction in complex systems of cooperative or semiautonomous agents provides a multidisciplinary area of research bringing together distributed system design, dynamic process control, and distributed coordination. ARL's innovations in automata-based distributed hierarchical control have been applied to the control of hierarchies of autonomous underwater vehicles, integrating theoretical areas including formal-language theory and discrete-event dynamic-systems theory.

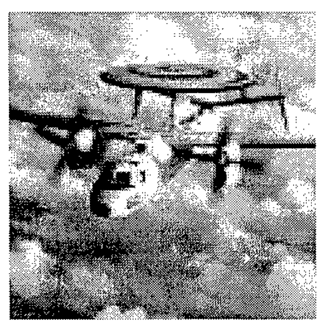


Resident Expertise and Technologies

Information systems design and integration
Database and network performance management
Hierarchical command and control architectures
Human-performance technologies
Computer-based training
Intelligent inferencing technologies
Distributed interactive simulations
Simulation-based design
Scientific visualization

Potential Applications

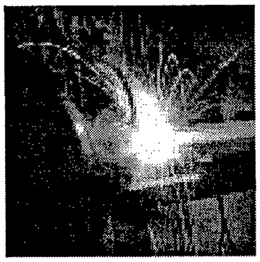
Metasystems integration
Next-generation information-based engineering services
Human-performance management and technologies
Technical skills, knowledge training, and performance support
Mobile networks of unmanned vehicles
Process/workflow design and implementation
Intelligent, interactive maintenance assistance tools



Facilities and Equipment

Information Systems Collaboratory
Scientific Visualization Laboratory
Distributed simulation environment
Secure computing and network facilities
Networked UNIX, DOS/Windows, Windows NT, and Macintosh platforms
Large-scale demonstration capabilities

Laser Processing and Manufacturing



ARL is a world leader in the development of applications of lasers to both the manufacturing and the repair of metallic components of many systems. Applications include naval vessels, aircraft, heavy equipment, railroad cars, and even bicycles. The Navy recognized this outstanding capability by establishing the Navy Laser Applications Research Center of Excellence within ARL's laser laboratories in 1995.

Experienced and accomplished technical staff in combination with state-of-the-art laser processing facilities form the cornerstone of ARL's success in exploiting the laser for manufacturing and repair industries. A large number of applications have been transferred to both the Navy and private industry, thus improving the affordability and effectiveness of manufactured components for the Navy and the Department of Defense.

Technologies of interest include laser welding, cladding, cutting, surface transformation hardening and modifications, creation of near-net shape components, stripping of coatings, and remediation of hazardous materials. Of these technologies, ARL is using its expertise to meet specific manufacturing needs in several key areas.

Potential Applications

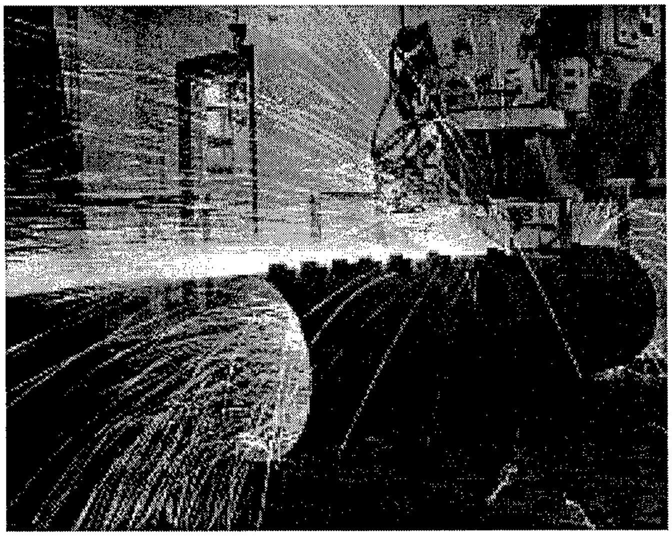
High-speed laser beam welding of corrugated-core structural components called LASCOR

Laser beam welding of aluminum alloys for cost-effective fabrication and assembly of aerospace and automotive structures

Laser cladding for wear and corrosion resistance to replace environmentally unfavorable chromium electroplating

Utilization of high-power Nd:YAG lasers with fiber-optic beam delivery for reducing costs and increasing the flexibility of laser welding and cutting systems

Fabrication of titanium alloy components in near-net shape by the computer-controlled laser melting of powdered starting material



Facilities and Equipment

25-kW and 14-kW CO_2 lasers with articulating robotic systems (300 cu. ft. working volume)

3-kW (CW) Nd:YAG laser with fiber-optic beam delivery

1.5-kW CO_2 lasers

400-W (avg.) Nd:YAG laser

100-W Cu vapor laser

100-W (avg.) Q-switched Nd:YAG laser

Resident Expertise and Technologies

Successful processes include:

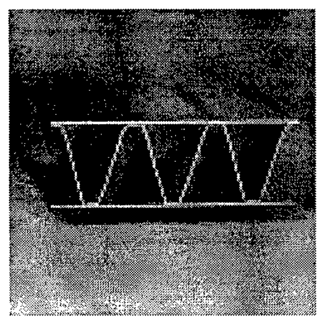
- Welding, cutting, and cladding
- Surface hardening and modi•cations
- Creating net shape components
- Stripping coatings
- Remediating hazardous materials

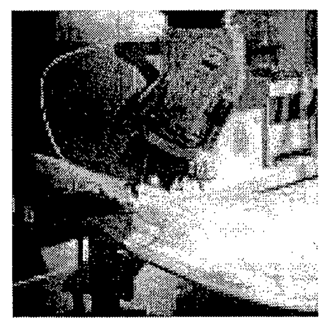
Materials processed successfully include:

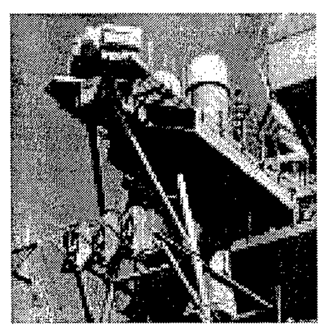
- Specialty stainless steel and nickel alloys
- Titanium alloys
- Aluminum alloys
- Copper alloys
- Ship hull materials

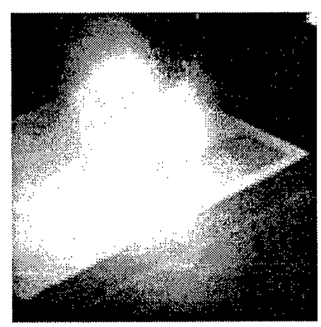
Demonstrated capabilities include:

- Lightweight structure fabrication (LASCOR)
- Repair/refurbishment techniques
- Paint and hazardous coating removal
- Process monitoring via spectroscopy
- Real-time process inspection via acoustic monitoring
- Preproduction prototype manufacturing via technology partners

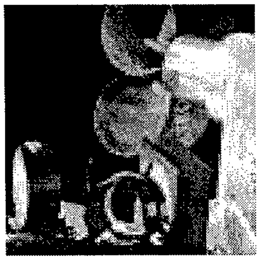








Manufacturing Technologies



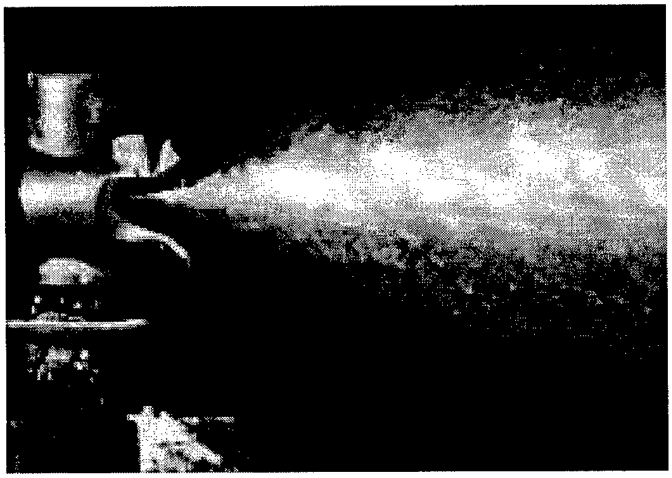
ARL serves a wide range of manufacturing businesses, naval aviation and Marine Corps depots, Navy and private shipyards, and other DoD facilities and agencies. ARL has assembled a unique mix of facilities and experienced technical staff to help bring our clients into the era of "green" manufacturing and repair, while keeping them on the leading edge of computer-integrated manufacturing, simulation-based design, management information systems, and electro-optic technologies for inspection and measurement systems.

ARL develops solutions to manufacturing and repair problems brought to us by our clients. Multidisciplinary teams are the norm as most of the challenges include environmental, health, and safety issues as well as productivity, quality, and cost issues. While there is no proscribed team structure, it is not unusual to find chemists, mechanical engineers, physicists, and computer scientists on a project team. Multidisciplinary teams seek solutions to such challenges as spectroscopy for paint characterization, environmentally compliant methods for turbine blade coating removal, numerous reverse engineering issues, and shearography for the nondestructive inspection of composite and honeycomb structures.

Under the manufacturing technology umbrella, ARL has grown significant thrust areas in electro-optics, simulation-based design, computer-integrated manufacturing, management information system design, and manufacturing waste stream reduction and treatment while maintaining our foundation capability for the design and delivery of prototype manufacturing and repair work cells.

Potential Applications

Manufacturing efficiency
Structural welding
Flexible manufacturing systems
Industrial modernization
Precision inspection systems
Life cycle management
Robotic manufacturing and inspection
Process monitoring and control



Resident Expertise and Technologies

ENVIRONMENTAL

- Air and water treatment
- Coatings application and removal
- Supercritical CO_2 cleaning and extraction

ELECTRO-OPTICS

- Shearography
- Spectroscopy
- Noncontact gauging

COMPUTER-INTEGRATED MANUFACTURING

- Machine, workcell, and factory simulation
- Concurrent engineering
- Knowledge-based engineering
- Manufacturing and repair process planning

SOFTWARE SYSTEMS

- Management information systems development
- Web site development

SIMULATION-BASED DESIGN

- Knowledge-based engineering
- CAD/CAE/CAM
- Distributed programming and applications integration
- Simulation and visualization
- Information management technologies
- Lifecycle cost estimating

Facilities and Equipment

Two laser articulating robotic systems (LARS)

Computer-controlled laser workstations

1.5-, 14-, and 25-kW CO_2 laser systems

400-W, 3.0-kW Nd:YAG lasers

Integrated robotic weld cell with computer-controlled welding positioner and off-line simulation/programming workstation

Gas metal arc and gas tungsten arc welders

CAD/CAM workstations interfaced with 4-axis and 5-axis computer numerically controlled milling machines

Computers and vision/sensor systems

Imaging spectrometer (UV-NIR, .2-nm resolution)

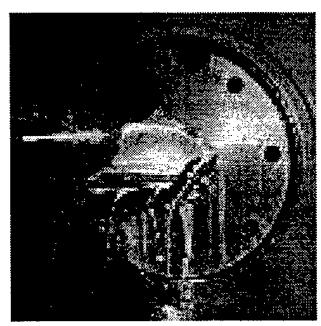
Tunable Ti-sapphire laser

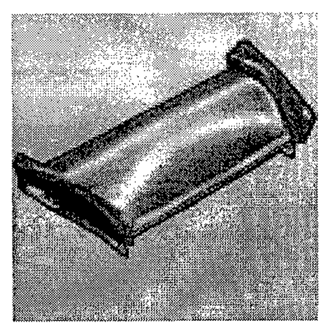
CCD cameras (12-bit, 1,500 ∞ 1,000 pixel)

Vibration-isolated optical tables

Photon counting system

Air and Water Quality Laboratory





Navigation Technologies

ARL conducts navigation research, development, testing and evaluation for new technology navigation sensors and systems for application in air, marine, and land vehicles at its Navigation Research and Development Center located in Warminster, Pennsylvania. Product areas include gyroscopes, accelerometers, gravimeters, gradiometers, speed sensors, inertial navigators, geophysical navigation, radio and satellite navigation systems, celestial navigation systems, and integrated navigation systems.

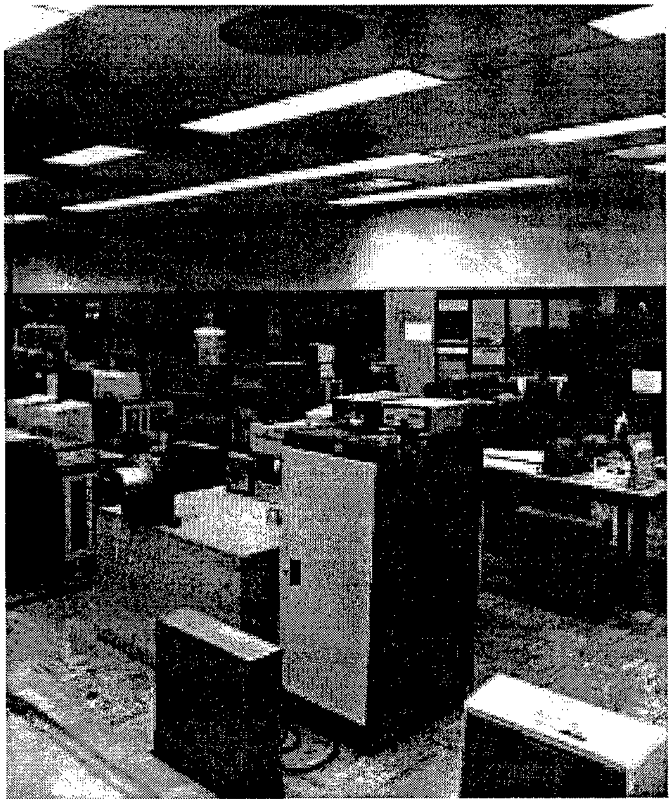
ARL's navigation research efforts are focused on exploring and investigating new sensor and navigation concepts and advancing new technology through experimentation and assessment of performance. ARL acts as the technologist in the transition and insertion of these new technologies in next-generation navigation systems and develops advanced navigation system capabilities by conducting: system mechanization and design studies; analyses utilizing computer simulations and modeling techniques; algorithm development; and the testing and evaluation of sensor and system navigation products under laboratory and dynamic operational conditions. Consultation and technical support services are also provided by ARL for the development of product improvements for fielded navigation equipment and for international technology transfer including analyses of export cases.

Extensive use is made of the Navigation Facility and the capacity for research and testing for the most precise navigation sensors and equipment. The Warminster location was selected based on an exhaustive survey, which determined that this site was the most seismically and environmentally quiet spot in the continental United States and has the best bedrock. The test piers are bonded directly to the bedrock and are isolated from the rest of the building. The building was designed and constructed specifificaally for this function and maintains the very quiet test environment. There is no known comparable facility.

ARL's navigation efforts are conducted in close association with industry for both military and commercial applications. ARL also provides navigation education, which includes course instruction.

Potential Applications

Positioning, steering, and maneuvering of vehicles
Tracking and location of vehicles and targets
Stabilization of vehicles and weapons and missile systems
Initialization and alignment of fire control, weapons, and missile systems
Support to command, and control and decision aid systems



Resident Expertise and Technologies

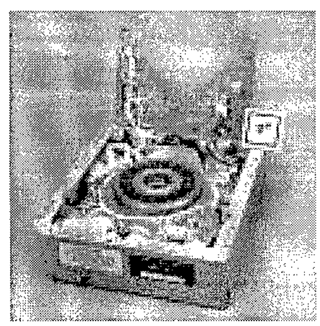
Inertial Sensors and Systems

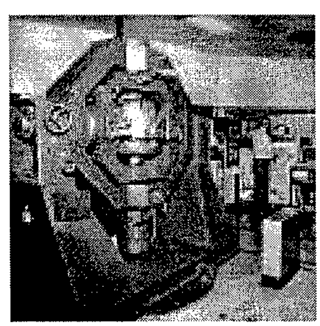
- Conventional mechanical
- Electrically suspended
- Ring laser
- Fiber optic
- Micro-machined
- Passive navigation
- Bathymetric, gravity, and magnetic navigation
- Terrain estimation

Global Positioning System

Geographic information systems

Navigation test vehicle operations





Facilities and Equipment

Quiet Test Laboratory

- 12 test piers bonded directly to bedrock
- State-of-the-art sensor test tables mounted on the test piers
- Test chambers for investigating environmental sensitivities
- Power backup system to fully support long-term testing
- North Star sighting windows for precise test table alignment
- Seismograph to record seismic disturbances

Navigation Data Processing, Computer Simulation, and Analysis Laboratory

Navigation Library

Classroom

Signal and Image Processing

ARL has been transferring actively its expertise in signal and image processing to the government and the defense industrial base for several decades. The Laboratory is a leader in applying state-of-the-art signal-processing techniques to such complex problems as the guidance and control of autonomous vehicles and has been training personnel in signal-processing technology through the University's summer program, short courses, and customized training seminars. This experience has given ARL a complete capability to conceive, specify, develop, simulate, design, implement, and test signal- and image-processing techniques for creative applications.

ARL's expertise in signal and image processing includes traditional narrowband (FFT) processing, wideband (wavelet) processing, image processing and classification, adaptive signal processing, data fusion, neural networks, and detailed background estimation and smoothing techniques for dealing with random noise. Other research thrusts include waveform design, high-resolution imaging, and higher-order spectrum analysis. Associated with this capability is ARL's resident expertise in the theory and development of parallel processing architectures and real-time algorithm implementation using modern DSP chips. ARL's recent work includes the application of multidimensional wavelet transforms to the design and implementation of optimum wideband detection and classification systems.

Sophisticated facilities exist to support the research thrusts in multidimensional signal and image processing. ARL can apply its complete capabilities to any system requiring signal synthesis, signal analysis, or signal processing and can assist with product upgrades and new product development. ARL's capabilities in signal- and image-processing range from basic research and algorithm development to the implementation of real-time experimental systems.

Potential Applications

Intelligent vehicle systems

Voice recognition

Medical diagnostics

Computer-aided data compression/decision making

Machine diagnostics

Remote sensing

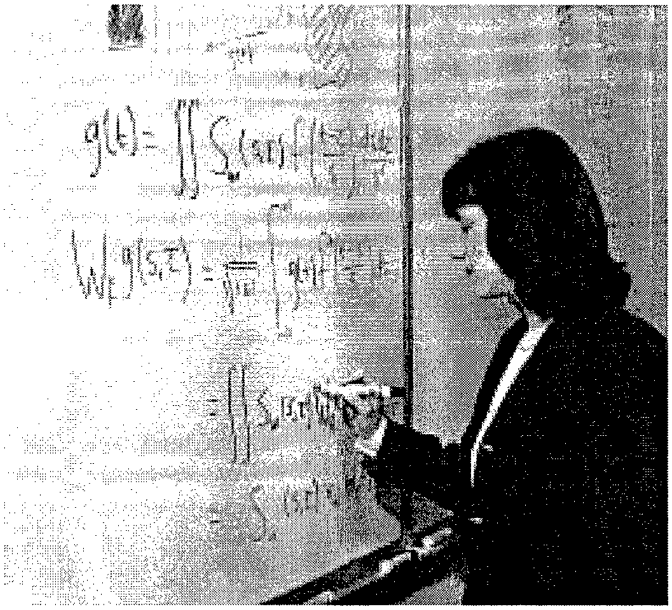
Guidance and control

Communication

Radar/sonar

Nondestructive testing

Machine vision

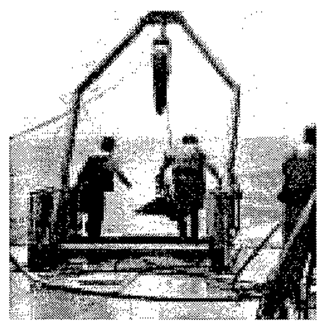


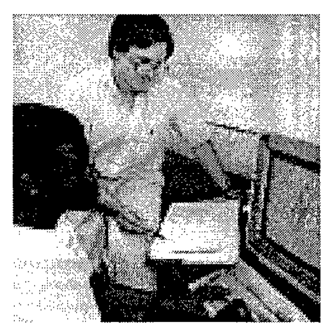
Facilities and Equipment

25 highly qualified signal-processing experts
Signal-Processing Laboratory
Network of Sun workstations
Silicon Graphics workstation
DSP software and development systems
Digital and optical record and data archival systems
MATLAB signal-processing toolboxes

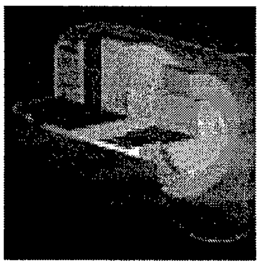
Resident Expertise and Technologies

Multidimensional signal processing
Adaptive signal processing
Data fusion
Transmit waveform design
High-resolution image processing
Pattern recognition and classification
Fuzzy logic/inference networks
Neural networks
Real-time DSP implementation
Parallel processing
Detection theory
Statistical parameter estimation
Embedded system software
Wavelet transforms
Time-frequency transforms
Algorithm design and implementation





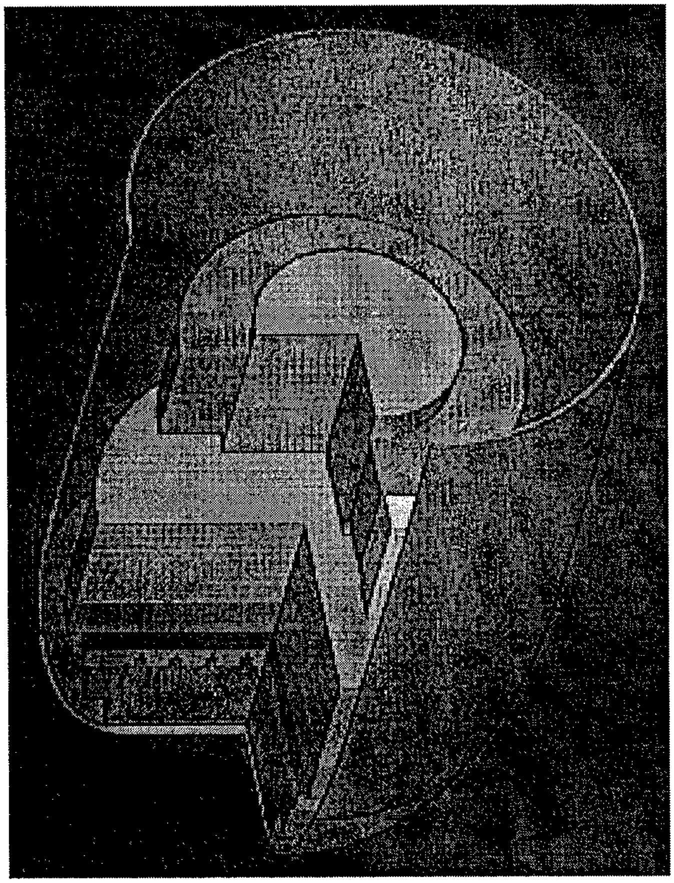
Simulation-Based Design



Simulation-based design is a key enabling technology for affordable product development, acquisition, and operation as well as for the efficient exploration of the advanced system concept design space. This process, and the resulting virtual prototypes, provide efficient technology transfer as well as early and accurate assessment of cost effectiveness and integrated life cycle support requirements. ARL has employed simulation-assisted design to achieve these objectives for over 20 years. The development of computer-aided design tools and object-oriented, open software architectures, together with the conversion of model libraries to HLA-compliant formats, has made the integration of design, performance prediction, and cost-estimation toolsets possible. This integration in turn, allows the construction of virtual prototypes of advanced systems and new system concepts using a simulation-based design (SBD) process. The resulting virtual prototypes are used to evaluate the cost effectiveness of new technologies in operationally realistic synthetic war games. The use of advanced engineering toolkits for engineering analysis helps achieve designs that are right the first time. The expected development costs and time should be reduced by 30–50 percent, as documented in numerous industry studies. High-fidelity results are achieved through the use of validated models and assessed by the application to existing systems as test cases. ONR is supporting this development as a major mechanism for technology transfer as a component of the Navy modeling and simulation initiative.

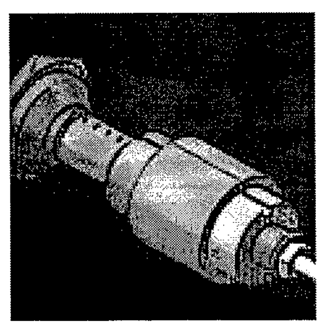
Development of the SBD process at ARL is a Laboratory-wide effort, which is led by the Manufacturing Technology Department. The program is supported by the computer-integrated manufacturing (CIM) test bed assets, manufacturing process models and databases for cost estimation, parametric CAD tools, extensive libraries of physics-based analysis models, simulation and visualization tools, and by Laboratory information management capabilities in networking (such as the National Information Infrastructure test bed and the information broker technology of the Information-Based Systems Department). An SBD environment based on the Common Object Request Broker Architecture (CORBA) has been developed that emulates the acquisition process, from operational requirement development through detailed design, simulation analysis, and manufacturing and product support assessment. The system provides efficient integration of legacy codes and CAD models, exports and imports model and analysis toolkit services, and supports geographically distributed development and end user teams.

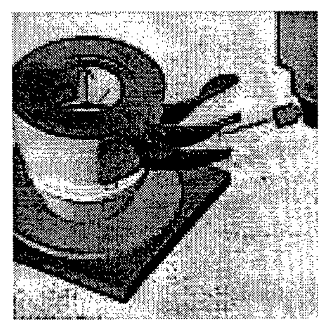
The pilot application of this new technology is for torpedoes and autonomous undersea vehicles. Specifically, the cost effectiveness of wideband technology in torpedo guidance was evaluated in FY97. SBD plans for FY98 include the lightweight hybrid torpedo, torpedo defense counterweapon, and offboard source applications. Also, plans have been initiated in FY97 and will be implemented in FY98 to develop an SBD system for use in the development of the multifunction information distribution system (MIDS), the successor to the current Link 16 JTIDS. In addition, plans are underway to use the SBD process to support the rapid design and manufacturing of propulsors for both undersea and surface vessels.

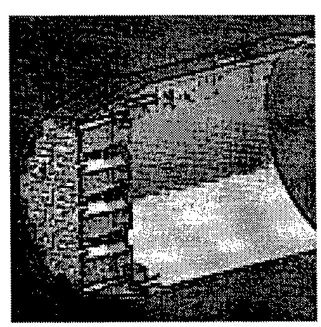


Resident Expertise and Technologies

Object-oriented networking and database design
Knowledge-based engineering
AI-based optimization
Expert systems design
Virtual prototyping
Information-based systems technology
Simulation, modeling, and virtual reality
Signal and image processing
Manufacturing process analysis and modeling
Cost modeling
Concurrent engineering







Potential Applications

Broadband advanced sonar systems
Undersea weapons systems
Offboard acoustic source
Communication systems
Power and propulsion systems
Environmental control systems

Facilities

Computer-Integrated Manufacturing Test Bed
CORBA Test Bed
Simulation and Visualization Laboratory
National Information Infrastructure Test Bed
Computational Fluid Dynamics Laboratory
Parametric CAD (Unigraphics) Network
IGES/STEP Test Bed

Spray Metal Forming

Spray metal forming is a rapid solidification process that can significantly enhance the properties and microstructure of engineering alloys as well as create new alloy compositions not possible by conventional processes. The process consists of the atomization of a metal stream with inert gas, which is deposited onto a collection plate or mandrel. The deposited preform is sufficiently void free so that it can be used in the as-sprayed condition, or can be further processed by forging, extrusion, or rolling.

Spray metal forming can be used to improve the performance of conventional aluminum alloys and produce new alloys for commercial and military applications. The spray-forming plant at ARL is capable of producing aluminum billets up to 70 pounds as well as tube and plate products. The following spray-formed aluminum alloys are being developed and/or validated at ARL:

High-Temperature Aluminum Alloys. Aluminum alloys with temperature capabilities extending to 300°F for up to 8,000 hours.

Ultrahigh-Temperature Aluminum Alloys. High-volume fraction, ultrafine dispersoid alloys capable of operation to 700°F that can be used as a substitute for titanium alloys in some applications.

Ultralow-Density Aluminum Alloys. Formulations of Al-High Li, with density reductions exceeding 20 percent which exhibit performance improvements competitive with graphite/epoxy materials.

High-Strength, Corrosion-Resistant Aluminum Alloys. Al-Zn-Mg-Cu alloys that can be processed and heat treated to display excellent corrosion resistance as well as high strength.

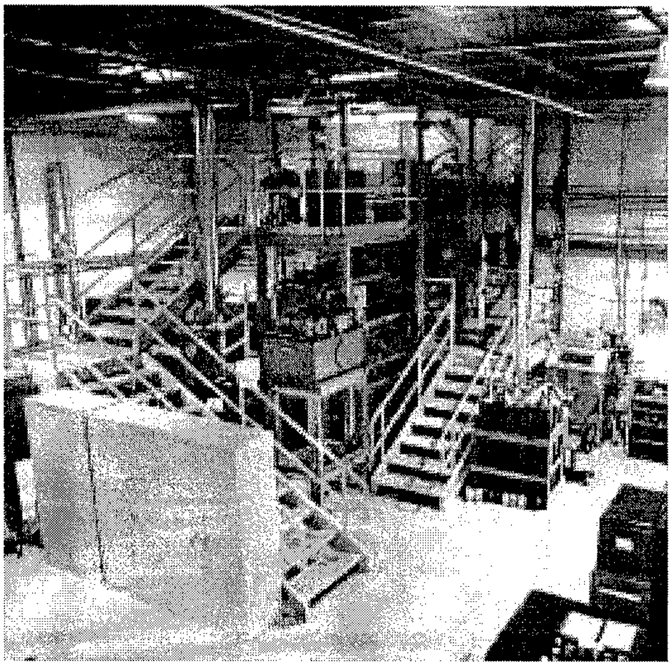
Ultrahigh-Strength Aluminum Alloys. Ultrahigh strength has been achieved in aluminum alloys that have a high solute content and ultrafine microstructure. Some of these alloys have a strength approaching 850 MPa with reasonable ductility, fracture toughness, and thermal stability.

Wear-Resistant Alloys. Aluminum silicon alloys are used in a variety of wear-resistant applications such as engine pistons, cylinder heads, block liners, and compressor and transmission components.

Metal-Matrix Composites. Spray metal forming can produce a variety of MMC products with high-volume fraction uniformly dispersed reinforcement particles.

The specific benefits of spray metal forming include:

- Economical application of new material concepts to advanced alloy systems or products by permitting compositions and structures not possible by conventional ingot or powder metallurgy fabrication techniques
- Lower material and manufacturing costs by the elimination of a number of processing steps
- Improved reliability, performance (e.g., increased strength, lower weight, increased corrosion resistance, etc.) and lifecycle costs through superior metallurgical properties



Resident Expertise and Technologies

Aluminum metallurgy

Design and testing for wear resistance

Fatigue and fracture mechanics testing and analysis

Aluminum metal matrix composites

Potential Applications

High-performance turbine engine components

Lightweight armored vehicle track components

Automobile engine and brake components

Aircraft wheel and brake assemblies

Consumer sporting goods

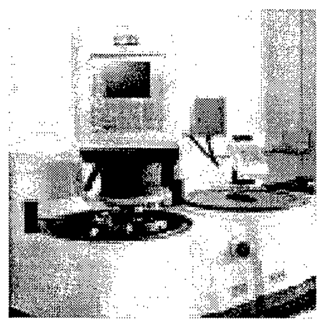
Airframe structures

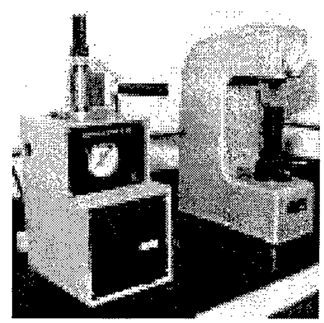
Non-heat-treatable high-strength automotive body/chassis parts

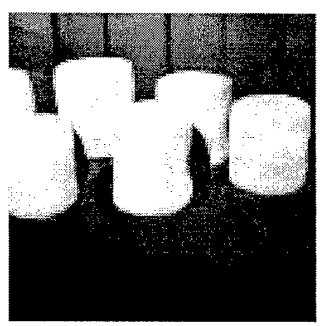
Gas turbine engine components

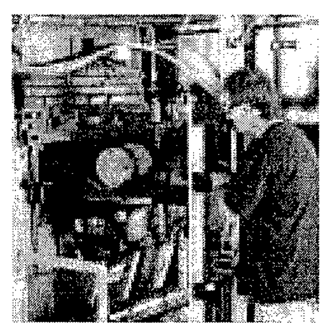
Computer hard disk components

Cryogenic tanks







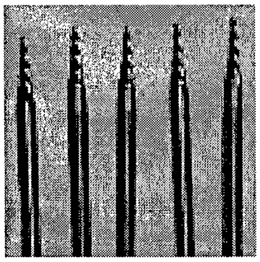


Facility

A 6,000 sq. ft. Aluminum Spray Metal Facility that includes:

- A pilot production plant
- Alloy preparation and refining equipment
- Extrusion equipment
- Microstructural analysis capability
- Mechanical characterization capabilities
- Surface characterization capabilities

Surface Technology



ARL's capabilities in materials science and material surface modification encompass a number of traditional and innovative material processes. Among them are nanophase material technology, lightweight laminate composite armor, cold gas dynamic spraying and fretting, and fatigue amelioration through material and/or coating development.

Nanophase material technology is focusing on the application of materials that can be manufactured with particle sizes below .5 microns. Research has proven that materials with particles of this size can be used to improve the material performance of a number of components including: cutting tools, bearings, and drill bits.

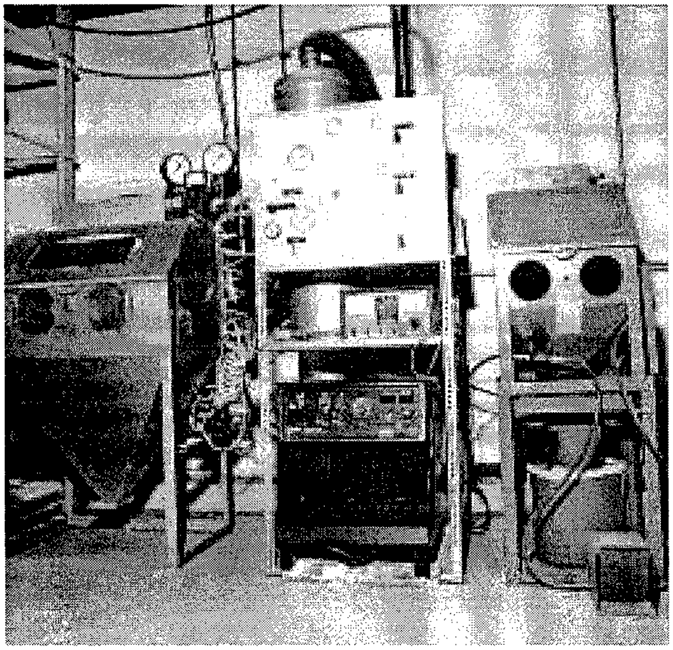
ARL initiatives in lightweight laminate composite armor are focusing on unique applications of layered laminate composites for which reinforcing material are tailored and oriented to defeat a host of munitions more effectively than conventional armor systems.

Cold gas dynamic spraying is a coating process that uses high-velocity, low-temperature gas to carry a variety of coatings powders to metal, ceramic, glass, or polymer substrates. This process provides a simple and inexpensive alternate to provide wear and corrosion resistance without excessive heating of the substrate.

Coupled with the fatigue and wear capabilities of Penn State, ARL has the capability to measure, evaluate, and implement corrective measures to eliminate/minimize adverse fatigue and fretting mechanisms in a variety of systems. Using advanced materials and/or coatings, ARL has been quite successful in solving adverse wear and corrosion in components ranging from aircraft catapult systems to high-performance turbine engines.

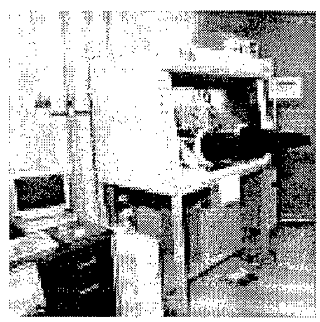
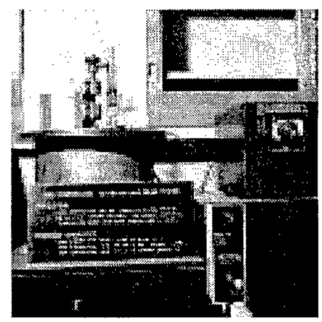
Potential Applications

Cutting tools
Engine bearings
Drill bits
Armored vehicles and blast deflectors
Engine fuel injectors
Compressor blades



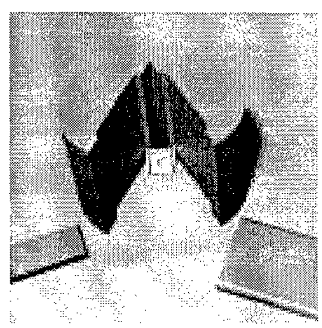
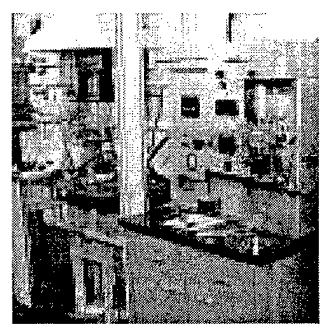
Resident Expertise and Technologies

Nanophase material technology
Lightweight armor design
Cold gas dynamic spraying
Fatigue, wear, and corrosion amelioration
Lubrication development

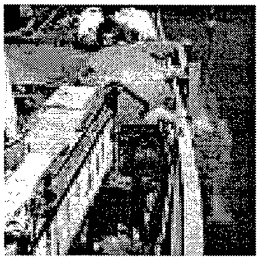



Facilities

Powder Metallurgy Laboratory
Ceramic Hot Press and Ceramic Tape Casting Facility
Cold Gas Dynamic Spraying Facility
Wear, Fatigue, and Corrosion Testing Facility

Systems Engineering

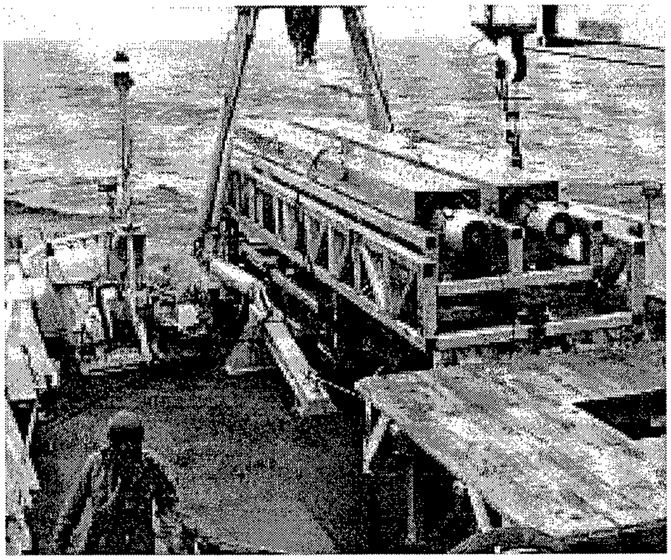


At ARL, systems engineering includes the functions of system simulation, system analysis, system integration, and system demonstration. Models are constructed and exercised in simulations to evaluate concept candidates and to define the most promising conceptual systems. Models have been developed for items and processes as diverse as undersea vehicles, electromagnetic and acoustic propagation, and microelectronic and micromechanical devices. Proof of principle frequently requires the demonstration of a functional system and analysis of data acquired in the demonstration. ARL engineers and technicians are skilled in converting conceptual designs into operational prototypes. The process involves design, fabrication, debugging, and testing, all of which can usually be accomplished within the Laboratory. Design and simulation function iteratively and interactively in that encountering design limits requires the modification of the model, and then the new set of alternatives are evaluated. Programs utilizing this process can truly claim to practice simulation-supported development.

Although many feasibility demonstrations involve undersea test vehicles employed to evaluate propulsors, powerplants, control systems, sonar signal processing, and transducer arrays. However, land-based instruments such as a lidar-based atmospheric profiling system, ground vehicle-based systems such as a tank noise cancellation system, special-purpose instruments such as acoustic propagation test buoys, and dedicated systems such as those used in control of thermal powerplants have been produced. The integrated systems needed for these demonstrations are developed by interdepartmental teams. Commercially available components and subsystems are used to the greatest extent possible and, where feasible, existing subsystems are adapted to new applications to leverage available funding.

Full design and fabrication capability, which can include the design, development, and testing of electronics, mechanical hardware, and software/firmware, is maintained within ARL. Computer-based machine shop services are provided in-house for prototype fabrication. Specialized test equipment supports the core technologies assigned to the Laboratory.

ARL prides itself on being able to take a program from a needs statement through concept identification to full feasibility demonstration. The Laboratory has also participated in design transition to industry for production. This capability has grown in importance with the emerging need for closer cooperation between research and development organizations and private industry.



Facilities and Equipment

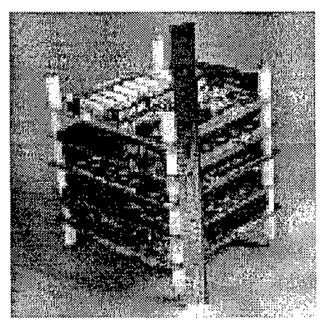
In-house and networked high-speed computational capabilities
Navy-standard undersea weapons simulations
Library of simulation, analysis, and visualization software
Signal Analysis Laboratory
Transducer development and test facilities
Sonar system in-water acoustic test installation
Autonomous undersea test vehicles
Specialty operations (etching, plating, silk screening) facility
Full machine shop
Computer-assisted drafting
Electronics assembly and test areas

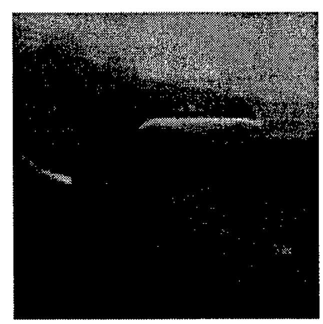
Potential Applications

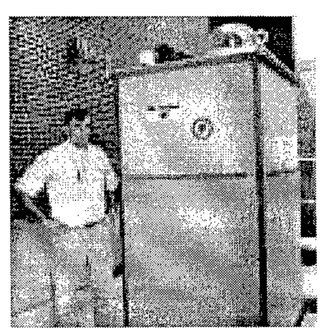
Undersea vehicle system and subsystem development
Sensor analysis and development
Bottom sounders and obstacle avoidance systems
Control system development
Conceptual system analysis
Special-purpose instrumentation
Special-purpose communication equipment
Simulation-assisted design
Active noise cancellation

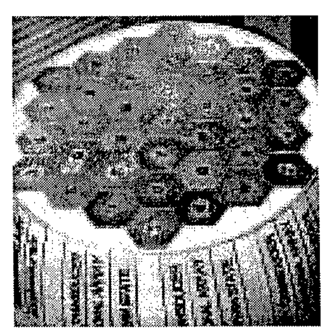
Resident Expertise and Technologies

Advanced computer graphics
Digital system simulation
Advanced signal processing
Data handling, reduction, and analysis
Advanced transducer design, development, and fabrication
Electronics hardware design, fabrication, and testing
Embedded software design
Application of microprocessors, microcontrollers, and digital signal processors
Mechanical system design, fabrication, and assembly
Full-system development
Systems integration and testing
Field measurement and testing programs
Design transition to industry









Thermal Energy Sources and Power Generation

ARL is a national leader in the research, development, testing, and evaluation of high-power and high-energy-density systems. This program focuses on thermodynamic processes, thermochemical energy sources, internal computational fluid dynamics, and magnetohydrodynamic propulsion.

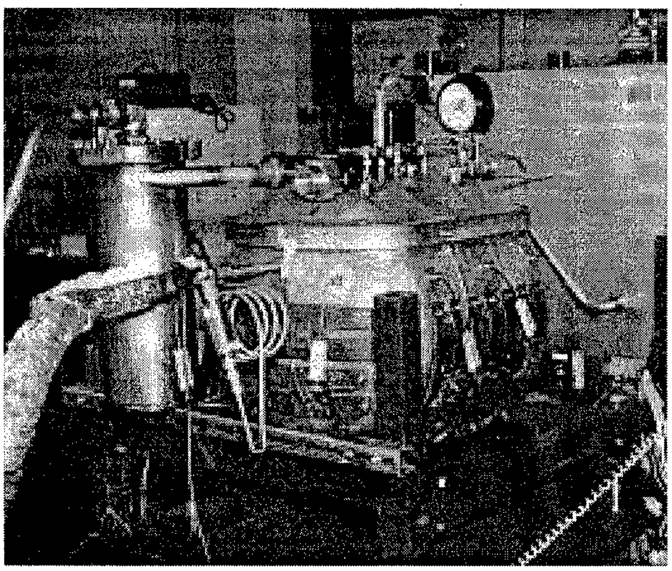
Among our most significant achievements, ARL researchers created the Stored Chemical Energy Propulsion System (SCEPS), a revolutionary propulsion technology. Currently, we are conducting basic research studies in thermal power to characterize and model the complex thermal-chemical reactions of SCEPS-type systems. In these reactions, a gaseous oxidant is injected into a molten-metal reactor. The resulting reaction is highly energetic and creates a complex, multiphase flowfield in the reactor.

A new area of ARL leadership is magnetohydrodynamic (MHD) pumping, a concept that has the potential for providing a pump or propulsor with no moving parts. Groundbreaking work by ARL has been conducted with the largest magnetic field strength yet employed for such research in the United States.

ARL maintains two remote test sites for preparing and testing experimental powerplants. One site is used to prepare experimental powerplants, conduct turbine-gearbox tests, and perform small-scale propulsion experiments. The other site tests SCEPS propulsion systems across a range of power levels. The facilities house a test control room supported by instrumentation systems for control and data acquisition, a propulsion component preparation and assembly area, a high-temperature, low-pressure steam facility, a water cooling system, a calibration area, and several test cells.

Potential Applications

High-energy-density power systems
MHD propulsion
Compact fuel-cell reactant storage
Rankine/Stirling applications
Nonpolluting power systems

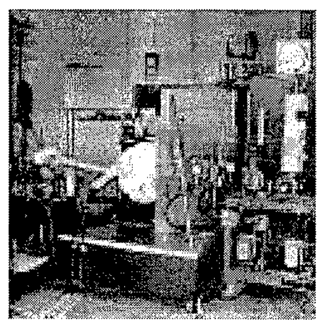


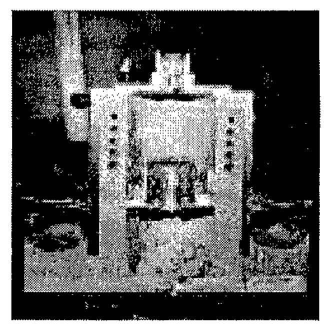
Resident Expertise and Technologies

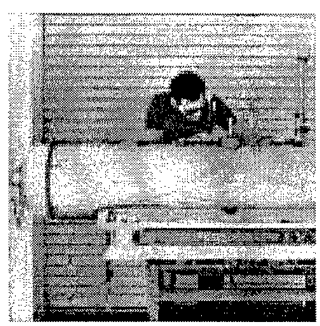
Combustion simulation
Compact heat exchanger analysis, design, and testing
Digital thermochemical process control
Energy systems design, analysis, and testing
Hazardous material and liquid metal handling and processing
Internal computational fluid dynamics
Nuclear reactor simulations, e.g., loss of coolant analysis
Thermochemical energy source analysis, design, and testing
Thermodynamics and thermal process analysis

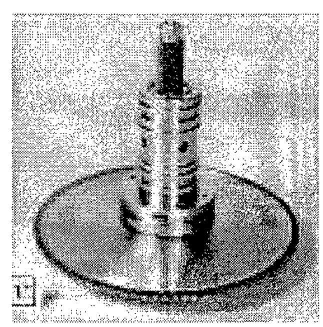
Facilities and Equipment

Computer-controlled powerplant test facilities
Thermal Propulsion Research Facility
Engine dynamometers and test stands
High-energy system test facilities
High-temperature system instrumentation









Thermoacoustic Engines and Refrigerators

Glassblowers have known for several hundred years that differences in temperature can create sound. It has only been during the last decade that the reverse process—the use of sound to produce cooling—has been observed and controlled. These efforts expanded rapidly in the late 1980s when it became apparent that chlorofluorocarbons (CFCs) caused serious damage to the earth's stratospheric ozone layer. This realization has led to severe problems for the refrigeration industry since the substitute refrigerants (HFCs and HCFCs) have now raised concerns that include toxicity to humans, contributions to global warming, and generation of acid rain as well as practical problems associated with retrofit compatibility and lubrication. Thermoacoustic coolers have the advantage in that they use only inert gases as the thermodynamic working fluid. These gases are nontoxic, odorless, and inflammable. They are harmless to the stratospheric ozone layer, have no global warming potential, and are cheap, uncontrolled, and readily available. Thermoacoustic engines have only one moving part, which does not require maintenance or lubrication.

ARL staff has expertise in the development and testing of both thermoacoustic refrigerators (heat pumps) and thermoacoustic sound sources (prime movers). The Space ThermoAcoustic Refrigerator (STAR) was flown on the space shuttle Discovery (STS-42) in January 1992. That design has produced a maximum single-stage temperature difference of 118°C—sufficient to turn steam into ice! We have also built a more powerful thermoacoustic chiller that was used to provide cooling for two racks of radar electronics on board the USS Deyo (DD-989) in March 1995. The Shipboard Electronics ThermoAcoustic Chiller (SETAC) produced 420 watts of useful cooling power. A follow-on three-ton (10-kW thermal) air-conditioning unit for shipboard applications is under development at ARL.

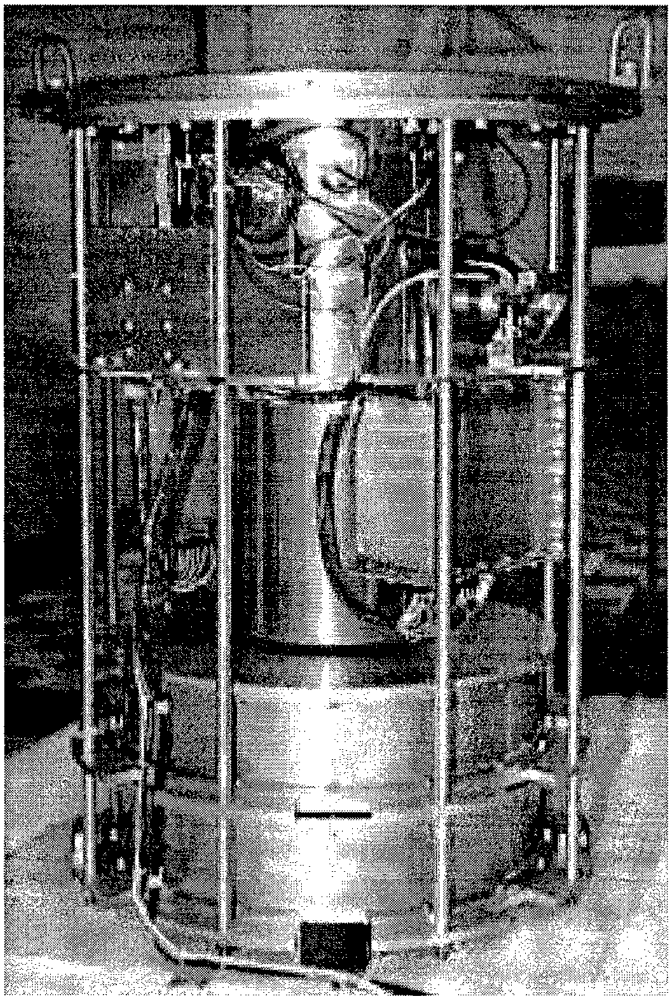
In addition to our ability to produce the prototype thermoacoustic systems, ARL's close association with Penn State's Graduate Program in Acoustics puts ARL in a unique position to educate the scientists and engineers who can support industrial production and provide new thermoacoustic designs for a variety of other refrigeration and power-generation applications.

Potential Applications

Residential and commercial food refrigerator/freezers

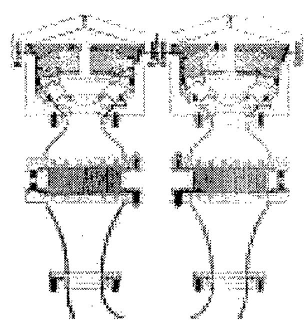
Electronics or computer thermal control

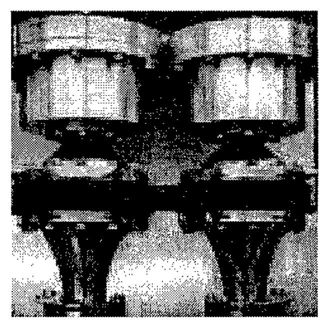
Thermal or solar electrical generation

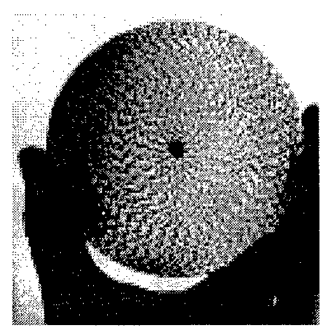


Resident Expertise and Technologies

Compact heat exchanger analysis, design, and testing
Custom transducer signal-conditioning electronics
DELTAE thermoacoustic computer design codes
Precision acoustic power flow measurement
Heat flow calibration and measurement
Shock-suppressing resonator design
Analog and digital control systems



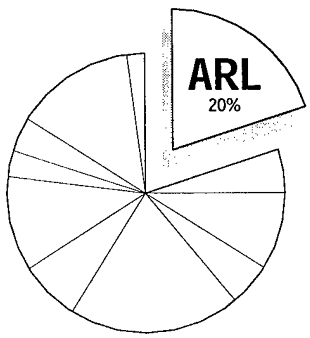




Facilities

Gas mixture analysis
Pressure testing
Rapid prototyping machines
Primary standard transducer calibration

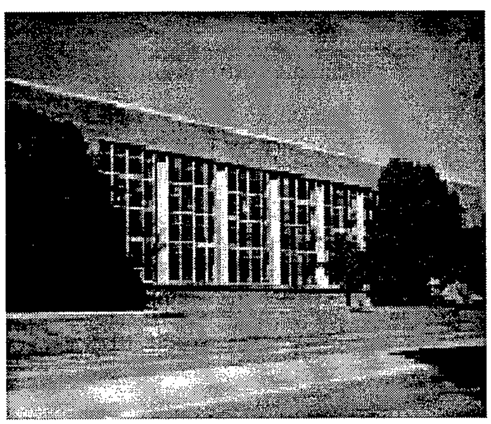
ARL's Resources: Penn State and Beyond

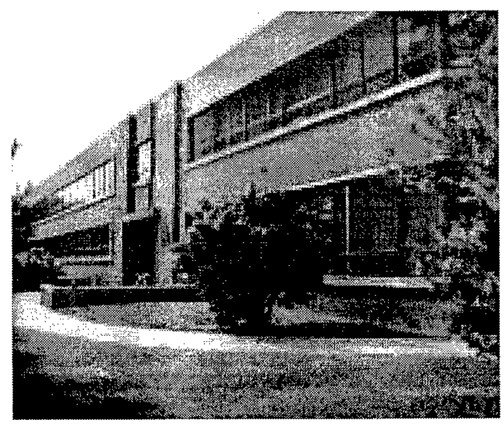


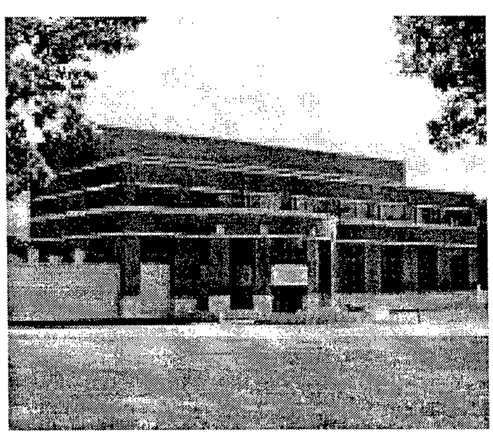
Penn State's research expenditures

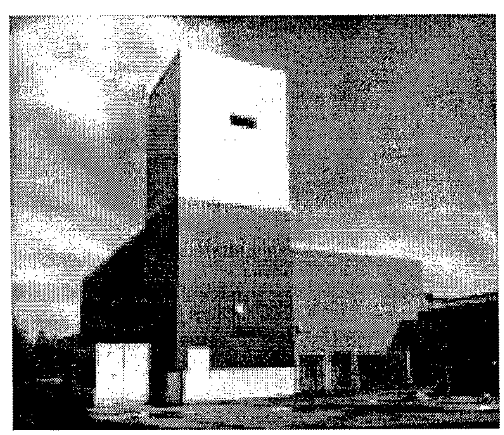
ARL—the largest of the interdisciplinary centers at Penn State—brings together real-world research problems and the University's vast resources. Located at University Park, the central campus of Penn State, ARL comprises a main laboratory and several satellite facilities. ARL occupies the Applied Research Laboratory Building, the Garfield Thomas Water Tunnel Building, a portion of Research Building West, and the Applied Science Building on the main campus; it devotes more than 200,000 square feet to engineering and testing facilities. The Laboratory maintains several remote test sites adjacent to the campus. In addition, ARL has offices in Keyport, Washington; Warminster, Pennsylvania; and in Washington, D.C.

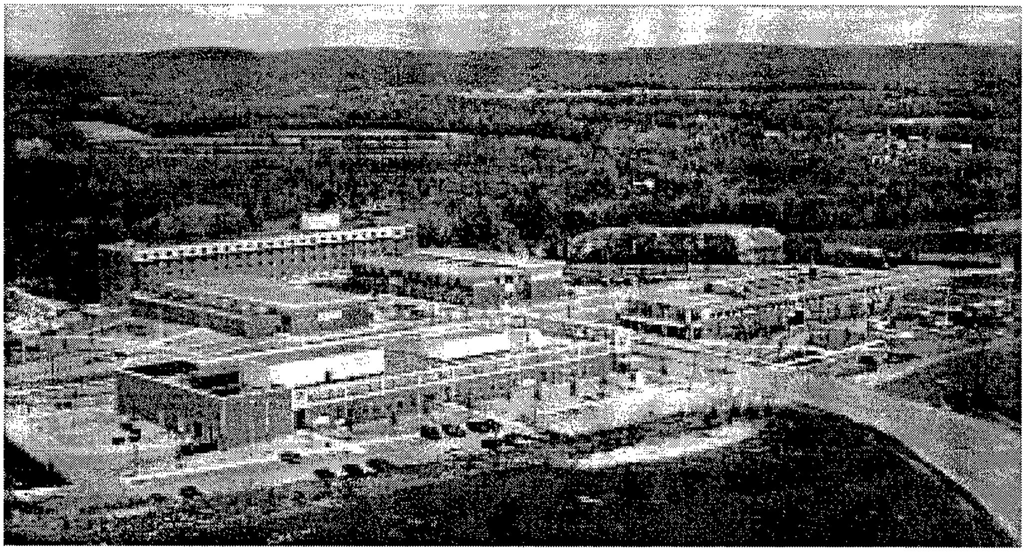
As a major research university with expert faculty specializing in applied science and engineering, Penn State is well-qualified to support broad research initiatives. ARL collaborates with research faculty in the Colleges of Engineering, Science, Earth and Mineral Sciences, and others, taking advantage of numerous facilities in the Penn State system. Penn State serves more than 54,000 undergraduate and 8,000 graduate students. Its academic community produces numerous patents and inventions each year and publishes 2,500 technical papers and books and 850 theses.











The Penn State Research Park, designed to stimulate industry-based technology, makes use of the University's extensive science and engineering research facilities. This $360 million research park offers study and research arrangements that fuel so many of today's technologies. Overall, the expansion of the University's technical facilities will benefit ARL.

Penn State is a multicampus system with facilities valued at $2.1 billion and an operating budget in 1998 approaching $1.4 billion. The research and graduate studies program receives nearly $264 million in state, federal, and private-sector funds. Penn State is second only to MIT in industry-sponsored research and development and, at $348 million in total R&D expenditures, ranks tenth among U.S. universities.

Penn State's Network

ARL is a part of Penn State's economic development thrust, which responds to short-term and long-range needs. This thrust, led by the Penn State Research and Technology Transfer Network, includes a wide range of services for industry, such as the University Cooperative Extension and Continuing Education programs, the Commonwealth Educational System, PENNTAP, the Institute of State and Regional Affairs, the Small Business Development Center, and the Center for Regional Business Analysis.

Pennsylvania Industrial Support Programs

The Commonwealth of Pennsylvania and Penn State co-sponsors three Industrial Resource Centers. These centers, staffed by specialists in manufacturing management, factory automation, bioprocessing, and other fields, provide information to small- and medium-sized companies to help them stay on the cutting edge of manufacturing techniques. Through the innovative Ben Franklin Partnership programs, state, private, and educational resources are linked to develop new technology-based business opportunities.

A partial listing of Penn State's Collaborative Research Centers, Laboratories, and Institutes

Center for Acoustics and Vibration

Center for Advanced Materials

Center for Electronic Materials and Processing

Center for Engineering of Electronic and Acoustic Materials

Composites Manufacturing Technology Center

Computational Fluid Dynamics Studies

Environmental Resources Research Institute

Laser Metalworking Technology Transfer Facility

Manufacturing Research Center

Materials Research Institute

Drivetrain Technology Center

Spatial and Temporal Signal Processing Center

Turbomachinery Laboratory

Gear Research Institute

Surface Engineering Center

Getting Your Project Started

The first step in starting a project with the Applied Research Laboratory is to contact ARL's Business Office. Following an initial consultation on the details of the project, ARL will follow up with a formal proposal that will identify the scope of work, cost, personnel needed, project time line, and contract details. All discussions and correspondence will be held in confidence.

A Proven Track Record

Based on a long-standing research and development relationship with the DoD and other federal agencies, ARL has gained comprehensive leadership, management, and business experience. This success has produced a team of focused, results-oriented researchers and managers experienced in completing complex tasks on time and achieving high-quality results. ARL's experience reflects years of administering diverse research contracts. These include a variety of government sponsors, contracts as small as $10,000 and as large as $300 million, and contracts involving numerous subcontract awards. The complexity has ranged from simple research projects to multitask omnibus contracts.

Security

Because of the sensitivity of the programs ARL conducts for the federal government, it is ideally suited to conduct other governmental or proprietary research and to offer clients unmatched project security. All industrial projects will be afforded company proprietary protection. Publications related to project research will be shared with the sponsor for review and comment to ensure protection of the sponsor's competitive position and intellectual property.

Costs

Project fees are charged solely to cover costs associated with the research services performed, including direct costs, such as staff salaries, supplies, and materials, and indirect costs and fee. ARL is a self-sustaining organization within the University, and we afford sponsors the same rates provided to our most favored customer, the U.S. Navy. Neither the Laboratory nor the University profits financially from its operation. Pennsylvania companies developing new products may be eligible for a Ben Franklin Partnership grant to enhance their research investment.

Contact ARL's Business Office

To further explore sponsored research opportunities at the Laboratory and to arrange a project-specific discussion at no obligation, call (814) 865-6343

Applied Research Laboratory
The Pennsylvania State University
P.O. Box 30
State College, PA 16804