

2003
BIENNIAL REPORT

Applied Physics Laboratory

COLLEGE OF OCEAN AND FISHERY SCIENCES
UNIVERSITY OF WASHINGTON

THIS YEAR THE APPLIED PHYSICS
LABORATORY AT THE UNIVERSITY
OF WASHINGTON CELEBRATES
60 YEARS OF SERVICE TO
ITS MISSION OF RESEARCH,
DEVELOPMENT, ENGINEERING,
AND EDUCATION FOR SCIENCE,
INDUSTRY, AND NATIONAL DEFENSE.

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Laboratory's home
on the University of
Washington campus.*

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Director's Message



Director Jeffrey Simmen

This year the Applied Physics Laboratory of the University of Washington celebrates its 60th year as a premier center for research, development, and advanced education in science and engineering. The Laboratory now is different from what it was many years ago, having moved away from its original focus, direction, and style. Through this evolution a superb organization, adapted to today's needs, has developed—an organization fueled and guided by a tight assemblage of innovative, rigorous, and experienced individuals; integrated across disciplines and across campus; and truly productive, in both scientific discovery and in the practical application of science and engineering. Today the Laboratory has a national and international reputation as a world leader in research and development related to polar science, ocean physics and engineering, acoustical and remote sensing, medical and industrial ultrasound, and environmental, information, and electronic systems.

While at the Office of Naval Research I was always impressed by the Laboratory's valuable and unique niche as a Department of Defense University Affiliated Research Center. I was a strong advocate of its extraordinary commitment to mixing basic and applied research, to balancing between

theory, experiment, and instrument development, to developing international cooperation, and to training the next generation of scientists and engineers. Since joining the Laboratory as Director in July 2003, I am even more impressed by the breadth and depth of the expertise, the pervasive entrepreneurial spirit, and the loyalty to "physics-based" approaches in practical applications that I have found here. The Laboratory has found a healthy balance between short-term (applied) pursuits and long-term (basic) research, and its commitment to excellence in emerging areas of importance to our nation's defense and well-being is stronger than ever.

Robert Spindel, who has guided the Laboratory's course magnificently for sixteen years, and other members of the management team have turned over to me an exemplary laboratory. I inherit a well-running organization—fiscally sound, well equipped, and having a first-rate staff. I inherit an organization that knows its mission well and that has consistently achieved excellence in scientific and technological achievement for six decades. The staff and I are committed to continuing this tradition of excellence as we move the Applied Physics Laboratory into the next era. We look forward to research and development opportunities and to serving the generous sponsors of our programs, especially our special partner the U.S. Navy, and our nation.

Jeff

OUR COMMITMENT
TO EXCELLENCE IN
EMERGING AREAS OF
IMPORTANCE TO OUR
NATION'S DEFENSE
AND WELL-BEING IS
STRONGER THAN EVER.

From Director Emeritus Robert Spindel

Since the last Biennial Report in 2001, we have witnessed events that have forced us to ask ourselves if America will be secure, and if our future will be safe. Can we depend on our past to inform our future, or has the world become too chaotic and unpredictable? How do we cope with such radical changes, such nonlinearities, in the mathematician's parlance? What should we do to assure a secure future for our country? We ask how our research can help provide answers. We have asked questions like this before. Times and crises have changed since the Laboratory was established to help the U.S. Navy solve problems with torpedo exploders. APL-UW has changed with them.

In 1987 when I came to APL-UW, we were in a Cold War with the Soviet Union. Over ninety percent of our research was sponsored by the U.S. Navy, almost all of it related to deep-sea and under-ice antisubmarine warfare. Since the Soviet collapse new and different security threats have emerged, and as a result the Navy has embraced a new doctrine, *Forward... From the Sea*, which anticipates more extensive and frequent near-shore operations. We responded by focusing research programs on littoral oceanography and shallow-water sonars. We developed programs to help the Navy cope with fire-hose doses of information enabled by the World Wide Web and by the Navy's adoption of "Information Technology-21" and today's "Force Net." And we developed new programs in medical ultrasound, for quicker, more effective battlefield casualty care. During this period our research embraced non-military threats as well, such as climate change, and we led national and international climate research programs in the Arctic.

As has been true in the past, the technologies we are working on today, the research horizons we are exploring, and the international research partnerships we continue to develop will help keep America strong. Some of these are highlighted in this report. They include research to enable high speed, error-free underwater acoustic data transmission and to develop mine hunting sonars that can produce two- and three-dimensional images so mines can be detected and classified by remotely operated, autonomous systems. The Asian Seas International Acoustics Experiment (ASIAEX) is illustrative of programs that not only produce first-rate research, but also foster international partnerships. Environmental sensing in the Arctic will continue to inform us about critical climate changes, and will characterize parameters central to the predictive skill of climate models. Our ultrasound research is moving beyond the battlefield to space, and has a component investigating the use of high intensity focused sound for non-operative remediation of cancer tumors.

The Laboratory's budgets for the last two years have been at record highs. Investments in facilities—expansion and improvement—have resulted in new, modern laboratories and a physical plant that is larger and in better shape than it has ever been.

I am pleased that as the Laboratory's command is changed it is strong intellectually and at an all-time financial high. I am grateful for having had the wisdom of the APL-UW Advisory Board, the generosity of our sponsors, and the privilege of working with our principal partner, the U.S. Navy. I am proud we have been part of making our country safe and secure, militarily and economically. I am confident that the Laboratory's future is bright, and that it will continue to contribute to a secure America.



FOR THE LAST
SIXTEEN YEARS
I HAVE ENJOYED
SHARING WITH YOU
THE CONTRIBUTIONS
OUR TALENTED
STAFF HAS MADE
TO SCIENCE AND
DEFENSE. IT
HAS BEEN A JOY
TO WORK WITH
WONDERFULLY
LOYAL, CREATIVE,
AND PATRIOTIC
PEOPLE.



Director Emeritus Robert Spindel

The Laboratory

SIX DECADES
OF RESEARCH
EXCELLENCE

FUNDAMENTAL AND APPLIED RESEARCH

The Applied Physics Laboratory of the University of Washington was formed 60 years ago at the request of the U.S. Navy to bring university resources to bear on urgent WWII defense problems. From a wartime beginning focused on effective torpedo exploders, APL-UW initiated acoustic studies and oceanographic research programs to understand how variations in the ocean environment affected the performance of Navy systems.

Decades of acoustic and oceanographic studies yielded an understanding of the world's deep oceans, and today APL-UW scientists are developing expertise in coastal and small-scale oceanography and the new physics required for tactical superiority in shallow water environments. Laboratory scientists and engineers make important contributions to understanding the earth's climate cycles—from satellite and *in situ* sensing of ocean winds, currents, and air-sea fluxes to observations of arctic sea ice, its

variations and effects on mid-latitude oceans. APL-UW continues to lead research in the physics of sound—from sonars used to probe the geology of the deep ocean floor to hand-held high frequency focused ultrasound devices to image and stop internal bleeding without surgery. The articles in this report are a selective sampling of the Laboratory's basic and applied research program that comprises hundreds of individual projects.

DIRECTOR, APPLIED PHYSICS LABORATORY—UW J. Simmen

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AIR-SEA INTERACTION & REMOTE SENSING K. Kelly, Chair

CENTER FOR INDUSTRIAL & MEDICAL ULTRASOUND L. Crum, Director

ELECTRONIC SYSTEMS DEPARTMENT G. Harkins, Head

ENVIRONMENTAL & INFORMATION SYSTEMS DEPARTMENT J. Pitton, Head

OCEAN ACOUSTICS DEPARTMENT K. Williams, Chair

OCEAN ENGINEERING DEPARTMENT R. Light, Head

OCEAN PHYSICS DEPARTMENT T. Sanford, Chair

POLAR SCIENCE CENTER R. Moritz, Chair

FACILITIES AND FUNDING

A research unit of the College of Ocean and Fishery Sciences at the University of Washington, the Laboratory is a Department of Defense University Affiliated Research Center and part of the national defense strategic infrastructure. Situated in Henderson Hall and other locations on the university campus, the Laboratory is equipped with specialized facilities for

physical and medical acoustics research, microwave and other remote sensing, image processing, electronic systems development, transducer development, and pressure testing, as well as a machine shop and a library. The Laboratory owns and operates three research vessels.

Research and development at APL-UW is funded almost entirely by grants and contracts, primarily with government mission agencies including the U.S. Navy, National Science Foundation, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and National Institutes of Health.



A new ocean sciences research vessel

FINANCES

The Applied Physics Laboratory remained financially strong through Federal Fiscal Years 2001 and 2002. Grant and contract awards totaled \$32.5M in 2001 and \$43M in 2002—a new record high. In 2002 APL-UW received funds to build a new Research, Development, Test and Evaluation vessel that will be transitioned to APL-UW for Navy ocean sciences research. This vessel represents an important new ocean research platform for the Laboratory and the University of Washington. Research project funding from the U.S. Navy accounted for about 62% of the 2002 total; the continuing strength of the Laboratory's basic research programs accounted for 54% of the 2002 total.



Associate Director William Bakamis

APL-UW discretionary resources, which are derived mostly from contract fees, represent approximately 2.5% of total income and are used to support a variety of strategic initiatives and business expenses not covered by grants and contracts. The largest portion of these funds is used to support independent research and new program

development efforts, which are currently focused on building additional Navy-related expertise. Other Laboratory discretionary expenditures include graduate student support, staff fellowships, and general-use equipment.

We remain committed to ensuring that the Navy's 60-year investment in APL-UW continues to be applied to national technical needs, and to preserving our ability to respond effectively and efficiently to present and future Navy and national defense requirements. While continuing to pursue opportunities with other government agencies and industry, we expect that the Navy will remain our principal sponsor.

APL-UW's Department of Defense grant and contract funding exceeds that of all other units at the University of Washington combined. The Laboratory's overall research and development budget continues to be among the largest on the UW campus.

GRANT AND
CONTRACT
AWARDS SET A
RECORD HIGH IN
FFY 2002.

SPONSOR	FFY 2001	FFY 2002
Office of Naval Research	\$ 13,320,000	\$ 14,706,000
Naval Sea Systems Command	\$ 1,292,000	\$ 5,284,000
Office of Naval Intelligence	\$ 1,810,000	\$ 2,963,000
Naval Surface Warfare Center	\$ 955,000	\$ 1,035,000
Space and Naval Warfare Systems Command	\$ 620,000	\$ 762,000
Naval Air Systems Command	\$ 557,000	\$ 552,000
Other Navy	\$ 213,000	\$ 1,328,000
National Science Foundation	\$ 7,220,000	\$ 8,564,000
National Institutes of Health	\$ 2,461,000	\$ 1,684,000
University of Mississippi		\$ 1,400,000
National Aeronautics and Space Administration	\$ 1,755,000	\$ 1,261,000
Jet Propulsion Laboratory	\$ 418,000	\$ 374,000
Scripps Institution of Oceanography		\$ 362,000
Indiana University		\$ 302,000
National Oceanic and Atmospheric Administration	\$ 293,000	\$ 313,000
U.S. Forest Service	\$ 237,000	
U.S. Geological Survey	\$ 177,000	
Other	\$ 606,000	\$ 2,123,000
TOTAL	\$ 32,519,000	\$ 43,013,000



TriSoarus on the R/V Knorr

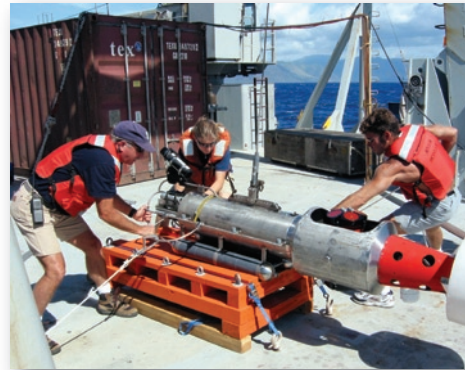
A HALLMARK OF
THE LABORATORY
IS ITS ABILITY TO
DESIGN, BUILD,
STAGE, AND
FIELD DEPLOY
THE TECHNOLOGY
REQUIRED TO
PURSUE AMBITIOUS
RESEARCH
PROGRAMS.

FIELD OPERATIONS: HIGHLIGHTS

The autonomous underwater vehicle **Seaglider** was deployed at Neah Bay, Washington, and sent out over the continental shelf to conduct profiling surveys for several weeks during spring 2002. Data were relayed back to Seattle and mission control commands were sent to the vehicle by satellite telemetry in near-real time.

In a field exercise that took scientists to the East Pacific Ocean near the Galapagos Islands, an APL-UW team used the **Modular Microstructure Profiler** to measure small-scale turbulence in the upper 300 m of the ocean at the Intertropical Convergence Zone.

As a follow-up to an extensive survey mission, a research team returned to the Hawaiian Islands in September 2002 for the final component of the Hawaii Ocean Mixing Experiment. In areas pinpointed as sites of intense mixing and internal wave generation, the recently modified **Shallow Water Integrated Mapping System (SWIMSII)** was deployed to make high-resolution maps of currents, conductivity, and temperature close to the rugged bottom and steep banks.



SWIMSII recovery during the Hawaii Ocean Mixing Experiment

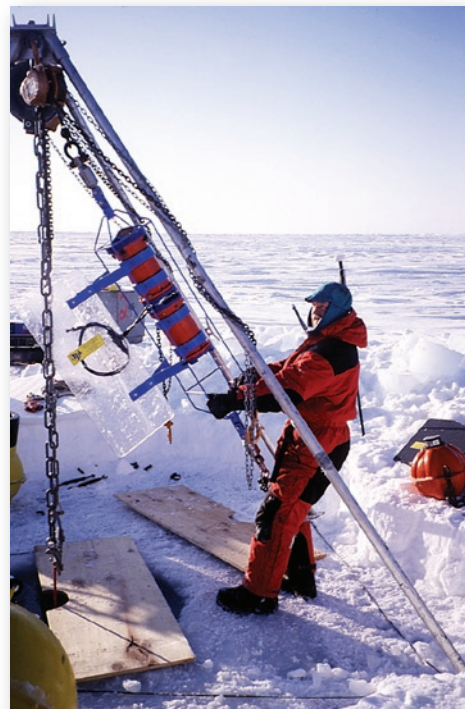
In the Adriatic Sea the new towed profiler **TriSoarus** was deployed during two cruises in 2003 to collect physical, optical, biological, and chemical data. These data allow oceanographers to study the sea's communication with atmospheric forcing events—winter storm winds and spring freshwater flows—at small lateral scales.

Laboratory polar scientists and ocean engineers established an ice camp in the Beaufort Sea for several weeks in spring 2003 to support U.S. Navy submarine under-ice capabilities testing.

Each spring since 2000 an APL-UW team has operated the **North Pole Environmental Observatory**. The observatory's mammoth logistical task of retrieving an oceanographic mooring through a hole in the ice and deploying a 2.5-mile-long replacement to the ocean floor at the North Pole has proceeded according to plan for several years.



Mike Gregg and the Modular Microstructure Profiler aboard the R/V Roger Revelle



Jim Johnson recovers the mooring at the North Pole Environmental Observatory.

Departments

OCEAN PHYSICS

The Ocean Physics Department focuses on research in small- to medium-scale physical oceanography and ocean acoustics. Scientists, engineers, and graduate students design and fabricate instruments, collect and analyze data, develop and test theory, and apply numerical modeling to further their understanding of heat fluxes, ocean currents, waves, turbulence, mixing, and acoustic propagation and scattering. The department is active in field programs along coastlines, in estuaries, straits, and the oceans of the world. As part of a Laboratory strategic planning effort the department has recruited several young scientists; new research thrusts augment the established ones.

A unique, highly sensitive refractometer is being developed to measure turbulent density/salinity in the ocean to provide a more complete understanding of global ocean circulation. A new towed, undulating vehicle, TriSoarus, has been used to study the dynamics and bio-optics of mid-basin fronts in the Adriatic Sea. Another undulating towed vehicle, the Shallow Water Integrated Mapping System (SWIMS), now carries upward- and downward-looking Acoustic Doppler Current Profilers (ADCPs) and has been operated as deep as 400 m to examine currents not accessible to shipboard ADCPs. Lagrangian floats, used to study the movement of water parcels along coastlines and in hurricanes, are being modified to incorporate newly available sensors that measure gas flux to improve knowledge of air-sea interaction.

A continuing effort uses theory and numerical models to study the electrodynamic of the ocean as it flows through the Earth's magnetic field. One instrument developed, the Electro-Magnetic Vorticity Meter, measures the electric fields produced by the flow. Another, funded by the U.S. Navy, is a free-drifting, neutrally buoyant electric field instrument. Other ocean electrodynamic studies are designed to understand the impact of environmental electromagnetic fields on undersea navigation and communication, including the study of the oceans' electromagnetic fields produced by oceanic, atmospheric, ionospheric, magnetospheric, and artificial sources.

By coupling their expertise in internal wave oceanography and acoustic propagation through random fluctuations in the ocean, department researchers are at the forefront of understanding the effects of internal waves on the propagation of sound through the ocean. The fundamental knowledge gained from the ongoing synthetic aperture sonar (SAS) primer research can be applied to the Navy's development of SAS systems for use at ranges to a target on the order of one to a few kilometers.

Theoretical and numerical modeling studies are linked directly to observation programs or to issues related to the interpretation of data obtained using new instrumentation or measurement techniques. Recent studies have focused on internal wave energy transfers, turbulent exchange flows in straits and estuaries, and interpretation of data obtained along near-Lagrangian trajectories.

The department's future is full of promise. The National Science Foundation has provided funds to obtain direct observations of entrainment flux in the Pacific equatorial cold tongue, which, when understood, will provide the missing ingredient to understand the heat budget of that area. Another NSF-funded program will measure Davis Strait—the point where Atlantic and Arctic oceans meet—year-round with Seagliders and other instruments. Locally, the Washington Sea Grant Program is providing funds for studies of mixing in the Hood Canal.



An Ocean Physics Department team prepares the Absolute Velocity Profiler for deployment.

AS MOUNTING
EVIDENCE POINTS TO
THE ARCTIC'S MAJOR
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ARCTIC PHYSICAL
SYSTEMS.

POLAR SCIENCE CENTER

Polar Science Center researchers observe and model the physical processes that control the nature and distribution of sea ice and polar ice sheets, the structure and movement of high-latitude oceans, and the interactions between air, sea, and ice. The center has contributed to an understanding that the arctic system has undergone major changes during the past two decades.

Center scientists are leaders of large-scale observation and process study programs including the Surface Heat Budget of the Arctic Ocean (SHEBA) project, the Study of Environmental Arctic Change (SEARCH), and the North Pole Environmental Observatory (NPEO). NPEO has been deployed each April for the past four years. Aerial hydrographic surveys are made across the Arctic Basin and buoys are deployed on the drifting ice. A mooring, consisting of 2.5 miles of cable outfitted with over a dozen instruments that monitor the upper 400 m of the ocean at the North Pole, is located, recovered through a hole in the ice, and replaced anew each year.

Instruments are invented to support field research. An autonomous underwater vehicle that runs fixed-depth, horizontal courses beneath the ice and open-water leads measures variations in the temperature, conductivity, and heat and salt fluxes. Bottom-moored, upward-looking sonars that measure the draft of the ice above are monitoring ice thickness at various locations to provide statistics on ice mass for the Arctic Basin. To monitor the transport of freshwater through Davis Strait, an improved upward-looking sonar will be deployed simultaneously with arctic-capable Seagliders and current profilers. They will collect measurements of ice draft, water temperature, salinity, and current and ice velocity.

Because of logistics and expense, satellite remote sensing is an important research tool in the polar regions. Data collected by satellite instrumentation are used to identify sea ice features and track ice motion, to estimate ice thickness and temperature, to measure surface and atmospheric heat budgets, and to estimate surface temperature and accumulation rates over polar ice sheets.

Physical-mathematical models are crucial to the study of ocean circulation, sea-ice kinematics, dynamics and thermodynamics, boundary-layer processes in the atmosphere and ocean, atmospheric radiation, ocean convection, and time evolution of the coupled air-sea-ice-climate system. The Polar Science Center's development, testing, and application of predictive climate models is closely tied to *in situ* and satellite remote observations. These efforts provide a greater understanding of how the polar regions function within the global climate system, as well as confidence in climate predictions.



Mike Steele measures temperature and salinity in the Arctic Ocean Boundary Current.

AIR-SEA INTERACTION & REMOTE SENSING

Air-Sea Interaction and Remote Sensing (AIRS) Department researchers study a wide range of atmospheric and oceanographic topics, all involving the use of remote sensing measurements. Field and laboratory experiments, in-house-designed, state-of-the-art instrumentation, numerical modeling, and data analyses are used to study diverse physical processes.

Several AIRS researchers are involved in the Coupled Boundary Layer Air-Sea Transfer program to improve coupled ocean-atmosphere models for the extremes of wind conditions—very low and hurricane force. An ongoing field program to monitor ambient sound from deep ocean moorings in the tropical Pacific Ocean has expanded to include the eastern South Pacific near Chile and the Gulf of Alaska. Acoustic rain gauges, which measure rainfall rate and type at sea, have been added to the Laboratory's Mixed Layer Floats and were deployed near Hurricane Isidore in September 2002. For the Polarimetric Emissivity of Whitecaps Experiment (POEWEX) conducted in fall

2002 at the OHMSETT wave basin at Naval Weapons Station Earle, AIRS scientists participated in the first detailed measurements of the azimuthal dependence of polarimetric microwave emissivities of large-scale breaking waves.

RiverRad is a pulsed Doppler radar capable of measuring the surface velocity vectors across a river. It has been deployed with the U.S. Geological Survey on riverbanks and on helicopters. RiverScat, a cheaper alternative that measures a single component of the surface velocity at a given location, has been deployed for many months on a river in western Washington; a hand-held version is planned.

An autonomous infrared radiometer system—Calibrated, InfraRed, In situ Measurement System (CIRIMS)—is used to validate satellite sea surface temperature products. Installed on the R/V *Ronald H. Brown* the innovative through-the-hull temperature and pressure sensors provide continuous near-surface bulk water temperature while underway.

Interannual fluctuations in oceanic heat transport are studied using TOPEX/Poseidon altimeter data; scientists and graduate students have demonstrated how advection and heat storage in western boundary currents contribute to atmosphere-ocean coupling through surface heat fluxes (see “Student Profiles” on page 29). A study of air-sea interaction in the California Current system is evaluating the performance of satellite-derived flux products and modeling the atmospheric response to the strong sea surface temperature fronts in this biologically important region.

A department oceanographer is analyzing measurements of barotropic tidal pressure and currents, and the radiation of low-mode internal tides from the Hawaiian Ridge as part of the Hawaii Ocean Mixing Experiment. He has also taken a leading role in the analysis of Acoustic Thermometry of Ocean Climate project data. Time series of large-scale temperature in the North Pacific are now acquired at APL-UW and posted in a nearly operational fashion on the World Wide Web.

The department’s airborne measurement program involves optical, infrared, and microwave technology. Phased-Doppler anemometry is used to investigate aerosols, infrared imagery is used to study spatial variability of sea surface temperature, and microwave radars are used to measure directional wave spectra and currents. The infrared and microwave measurements provide complementary information about the ocean surface dynamics.



AIRS scientists participated in the Polarimetric Emissivity of Whitecaps Experiment (POEWEX) at the OHMSETT wave basin at Naval Weapons Station Earle. During POEWEX AIRS scientists used a lift crane to mount three fully polarimetric microwave radiometers above the wave basin. Waves were made to break at a fixed location so that measurements could be taken of fractional area foam coverage in the radiometer footprint, aqueous-phase turbulence, void fraction, wave height, water surface roughness, and bubble size spectra.

CENTER FOR INDUSTRIAL & MEDICAL ULTRASOUND

The Center for Medical Ultrasound (CIMU) became a new APL-UW department in November 2000 and received sanction as an official University of Washington center two months later. It is a world-class leader in ultrasound research and development, and is an active participant in the tremendous expansion of the medical ultrasound industry. CIMU brings together the foremost government, industry, and research organizations to explore and develop new uses for ultrasonics through a four-fold mission:

- to foster research collaboration between UW faculty and their industrial partners on industrial and medical ultrasound projects
- to develop techniques, ideas, and products that have value to our society

CIMU IS A
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RESEARCH AND
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- to form partnerships with industry that enable this technology to be transferred to the commercial sector
- to educate and train students and technical professionals working in the fields of industrial and medical ultrasound

A major research effort is acoustic hemostasis, in which high intensity focused ultrasound (HIFU) therapy is applied to stop bleeding. This technology is being adapted for both surgical use in the operating room and to treat combat and civilian trauma prior to hospitalization. The ultimate vision is to treat patients noninvasively through the skin; NASA has funded an initiative to develop a HIFU system for critical care during space missions (see "Ultrasonic Medicine in Space" on page 18). Accurate detection and targeting are essential to the success of noninvasive HIFU treatment, so CIMU is investigating novel imaging techniques such as harmonic vector Doppler, pulsatility and integrated real-time ultrasound monitoring.

Efforts to better understand and control cavitation in extracorporeal shock-wave lithotripsy (ESWL)—a technique used to destroy kidney stones and gallstones—increases treatment effectiveness while reducing collateral damage to the kidney. Center scientists also investigate therapies that include ultrasound assisted drug delivery and gene transfection, and HIFU tumor treatment. Other research focuses on sonoluminescence, sonochemistry, and development of bioacoustic models.

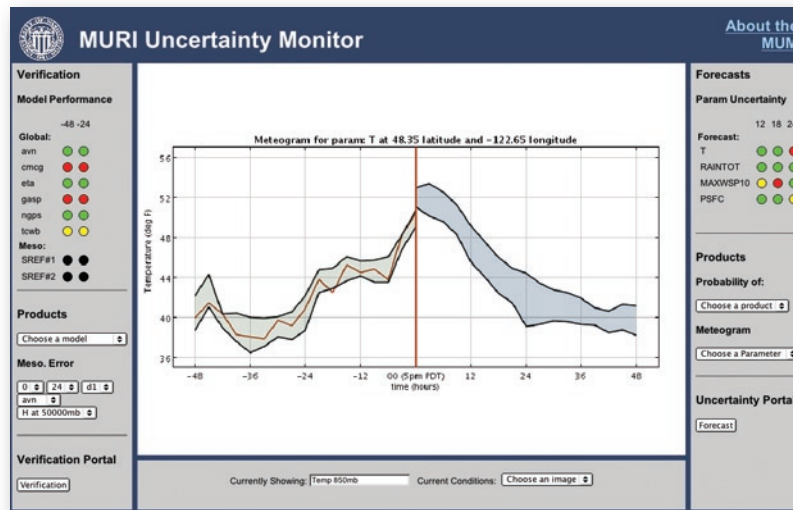
For several days in summer 2002, CIMU hosted the Second International Symposium on Therapeutic Ultrasound. The conference brought to Seattle 200 scientists and clinicians from 14 countries to share expertise across a range of topics from instrument engineering to clinical studies.

CIMU depends upon a talented, multi-disciplinary staff of physicists, engineers, technicians, and undergraduate and graduate students, as well as collaborations with other University of Washington researchers and medical professionals in the departments of Bioengineering, Electrical Engineering, Chemistry, Gastroenterology, Surgery, and Radiology. Its interest in developing paths to commercialization has led to strong collaborative ties with industry, from small companies in the Puget Sound region to global ultrasound manufacturers.

ENVIRONMENTAL & INFORMATION SYSTEMS

The Environmental and Information Systems Department is a multidisciplinary group focused on the creative application of new technologies to Department of Defense needs. Our group of physicists, earth scientists, electrical engineers, computer scientists, and interface designers team with scientists from universities, DoD laboratories, and industry to create systems and system components to solve critical problems for national security.

Expertise in meteorology, oceanography, modeling, and signal and information processing is applied to sonar systems used in antisubmarine warfare, torpedo defense, and mine countermeasure systems to enhance performance and identify performance limitations. Experimental arrays and data acquisition



Work for the Multidisciplinary University Research Initiative (MURI) on uncertainty in mesoscale meteorology has produced the MURI Uncertainty Monitor (MUM). This interface brings together multiple sources of information in order to improve the speed in which Navy forecasters assess the potential for uncertainty. The MUM presents the information in ways compatible with the forecasters' cognitive workflow.

systems acquire target, propagation, reverberation, and clutter data. Signal processing techniques are used to reduce interference, enhance signals, and improve classification across a broad range of applications including sonar, radar, navigation, and speech.

The department works directly with the fleet, most recently with the Air ASW community, to enhance and measure performance of current fleet systems, especially the impact of uncertainty in sensor performance prediction on both tracking and decision making.

Novel approaches to sonar control have been developed using computationally intelligent techniques to provide for optimum sensor effectiveness. Sonar control systems, though, are built on basic physics. For example, the analytic version of our Generalized Acoustic Bottom Interaction Model (GABIM) has been added to the Sonar Environmental Parameters Estimation System (SEPES). GABIM imposes geophysical relationships between bottom loss and scattering behavior, thereby improving the system's ability to estimate bottom characteristics.

Our Sonar Simulation Toolset (SST) provides simulated sonar time series signals for active and passive sonar research, and is used by the Navy, its contractors, and university laboratories. The latest SST release features a range-dependent reverberation algorithm.

For mine warfare applications we are developing algorithms to identify mines and other underwater objects automatically using images from APL-UW's Dual frequency IDentification SONar (DIDSON). A DIDSON with these capabilities will obviate the need for divers to inspect dangerous underwater objects.

A new signal processing effort seeks to improve low-rate speech coding technology by making use of non-acoustic measurements associated with glottal function. Ongoing signal processing work includes GPS anti-jamming, classification, and blind demodulation of communications signals, and impulsive-source active sonar classification.

In an ONR-sponsored Multidisciplinary University Research Initiative (MURI), department computer scientists together with the university's departments of Atmospheric Sciences, Psychology, and Statistics are developing methods to estimate and present uncertainty in meteorological model predictions to weather forecasters. They are conducting cognitive task analysis to improve the human-computer interface. User-centered design principles have also aided the department's Multimedia Development Group in a redesign of a user interface for an Expeditionary Warfare Decision Support System.

Applying expertise in statistics to non-tactical research, department researchers are studying long-term atmospheric and oceanic patterns in the North Pacific to learn how climate changes have influenced declining sea lion populations.

ELECTRONIC SYSTEMS

The association between APL-UW and the U.S. Navy submarine force is now into its 34th year. Over the decades recording technology has made great strides from simple reel-to-reel recorders to tailored systems that make use of ever-improving commercial off-the-shelf (COTS) components. A submarine now records over ten times the data and uses less tape on a smaller machine. As long as the advances in recording technology continue, the department is committed to making these advances available to the submarine force.

The capability to analyze this data for tactical purposes is designed into the submarine's onboard equipment. But detailed shore side analysis is yet another matter. The shore side system must review, analyze, and catalogue all sources of acoustical information, including that from the entire U.S. submarine force. These systems also integrate the



The DIDSON can be used by divers to perform security sweeps. A commercial binocular, color display interfaces with the camera and produces a large virtual image at a comfortable viewing distance.

latest commercial processing, display, and fiber-optic network technology with custom hardware, all designed to meet the Navy's needs.

The department continues to pursue research in a class of high-definition sonars designed for inspection and identification of objects in turbid water where optical systems fail. The most recent sonar, the Dual frequency IDentification SONar (DIDSON), provides near-video quality images at ranges from 12 m to 30 m. Initially developed to identify underwater intruders as part of harbor security, it can also be used on remotely operated submersibles, where the vehicles are directed to a location to scan the area with DIDSON and bring back imagery with sufficient detail to identify objects of interest.

DIDSON customers also include fisheries scientists. The sonar is used by the Alaska Department of Fish and Game to size and count spawning adult salmon and by the Battelle Memorial Institute to monitor fish movement in the vicinity of deflectors designed to keep fish from being ingested during the production of hydroelectric power. Other DIDSON customers include the U.S. Army Corps of Engineers, Nez Perce Indian Fisheries, University of Idaho, National Oceanic and Atmospheric Administration, and the California Department of Water Resources.

The Laboratory's strength in developing new technologies for scientific and commercial applications, as well as its long-term and productive relationship with the U.S. Navy continue in the Electronic Systems Department.

OCEAN ACOUSTICS

The Ocean Acoustics Department focuses on the propagation and scattering of sound in the ocean using theory and numerical modeling backed by ocean experiments. We study the effects of variability in the ocean environment on sound—the “forward” ocean acoustics problem—and we exploit our understanding to solve the “inverse” acoustic oceanography problem—where sound is used as a probe to study the ocean environment itself. Research spans the frequency range from a few Hz to hundreds of kHz.

At the lowest frequencies (a few Hz) we use coupled mode theory to examine acoustic/elastic wave propagation within the ocean and seabed to understand how seismic wave energy originating in the seabed is converted to acoustic energy that then propagates in the ocean. As low-frequency sound travels through the ocean it is altered by changes in ocean temperature, currents, and bottom and surface characteristics. Understanding these effects is part of North Pacific Acoustic Laboratory (NPAL) activities being conducted in collaboration with several other institutions.

At higher frequencies of hundreds of Hz to several kHz, enhancing U.S. Navy mid-frequency sonar operation in shallow water is of particular interest. We are involved in theoretical and experimental efforts to better understand and model the physics of propagation and scattering at these frequencies. Improved research models have been developed for ocean surface and seafloor scattering; these, in turn, improve U.S. Navy standard models that must balance fidelity against computational speed.

At still higher frequencies (tens of kHz) the Ocean Acoustics Department is involved in a variety of projects. We are exploring the limits of a new technique for underwater communication—passive phase conjugation (see “Undersea Wireless Communication” on page 16). This technique compensates for multipath propagation and scattering, thus enabling reliable, high-data-rate communication. Predicting the capability of sonar to detect buried mines at shallow grazing angles requires a mechanistic understanding of scattering from the seabed, penetration into the seabed, and propagation within the seabed. Recent sediment acoustics studies have shown that diffraction due to sand ripples is the main mechanism of penetration at shallow grazing angles.

Finally, at hundreds of kHz, multibeam sonars are being designed in-house for both basic and applied research. One system will be used to image and quantify hydrothermal flow on the Juan de Fuca Ridge. Another one is designed to operate in very shallow water and aid in the detection and classification of surf zone mines.

THEORETICAL AND
EXPERIMENTAL
EFFORTS SEEK
TO UNDERSTAND
THE PHYSICS
OF ACOUSTIC
PROPAGATION AND
SCATTERING OF
MID-FREQUENCY
SONARS OPERATING
IN SHALLOW
WATER.

OCEAN ENGINEERING

Ocean-going capability is a hallmark of APL-UW. The Ocean Engineering Department, where much of this expertise resides, is a resource for the Laboratory, the College of Ocean and Fishery Sciences, and the U.S. Navy. Department engineers design, fabricate, and deploy complex systems in the deep ocean, coastal waters, and the Arctic.



APL-UW provided dive support for U.S. Navy research operations in the Arctic, including under-ice retrieval of unarmed torpedoes after their test fires.

The Department is working to meet the 21st century trend toward autonomous oceanographic instrument systems that do not require expensive research vessel platforms. Drifting profilers, gliding autonomous underwater vehicles, cabled seafloor observatories, ocean moorings, and autonomous surface instruments fulfill research missions cost effectively. The Seaglider and Mixed Layer Float (MLF), both robotic oceanographic instruments, are deployed for months at a time to profile the water column while continuously taking measurements with their science payloads. Gliding or drifting, each uses a variable buoyancy system to move vertically in the water column or transit at a particular depth. Both are capable of surfacing maneuvers to obtain global positioning satellite (GPS) fixes of their location, send collected data via satellite data telemetry, and receive instructions from mission control.

Expertise in state-of-the-art underwater acoustic systems provides high-resolution imaging sonars, and research tools for experiments in sea surface acoustic scattering, underwater acoustic communications, rainfall measurement at sea, synthetic aperture sonar, and ocean sediment acoustics. The MOored Receiving ArraY (MORAY) and companion Broadband Acoustic Source System (BASS) were designed to study forward scattering of sound from the ocean surface over a broad frequency range—BASS provides the sound source to MORAY's vertical line array of hydrophones. The systems are linked by radio frequency and use GPS-based timing to synchronize the transmission and digitize the acoustic signal. The Sediment Transmission Measurement System, used to study the physics of sound propagation in ocean bottom sediments, will be modified with a department-designed and fabricated underwater rail system to allow the precise movement of a constellation of acoustic sources and receivers along the seafloor. New methods to study synthetic aperture sonar will rely on this system.



APL-UW team with TriSoarus in the Adriatic Sea

In spring 2003 department engineers constructed an ice camp that supported a staff of sixty U.S. Navy personnel, scientists, and engineers in the Beaufort Sea. The department provided all logistics including camp construction, infrastructure, and food services, as well as under-ice diving operations and technical services to support the science experiments and naval operations during the camp's month-long habitation.

Research Highlights



Three APL-UW-designed moorings were deployed in the Chukchi Borderland region at the beginning of the research cruise and retrieved five weeks later at the end.

A JOURNEY TO THE ARCTIC CROSSROADS

Rebecca Woodgate



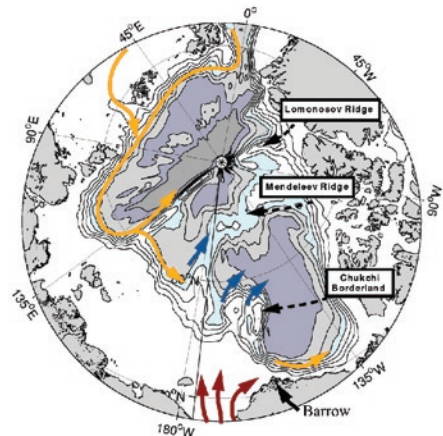
We have crunched our way through 600 miles of ice from Barrow, AK, aboard the USCGC Polar Star. And now, on a calm midnight in August at 80°N in the high Arctic Ocean, we stop to cast a CTD in the large lead we've followed for the last few hours. In a region typically devoid of open water, there's almost no ice in sight. What is happening up here in the Arctic?

A conductivity-temperature-depth cast returns to the surface in the Chukchi Sea.

CHUKCHI BORDERLAND CRUISE

Some 600 miles north of the Bering Strait and 800 miles south of the North Pole, a complex area of tortuous seafloor bathymetry known as the Chukchi Borderland marks the Pacific Ocean's entrance to the Arctic Ocean. This region of slopes, ridges, and deep-sea plateaus is also where waters from the Pacific and Atlantic oceans meet. The Atlantic waters are warmer, saltier, and reside deeper in the water column. They make their way to the Arctic Ocean Boundary Current from their entrance at the Greenland Sea. Traveling in an anticlockwise direction around the Arctic Ocean, they hug the continental slope and submarine ridges on a circumnavigating journey that takes five to ten years. The Pacific waters, having entered the Arctic by traversing the broad Bering and Chukchi shelves, are colder, fresher, and richer in nutrients than their Atlantic counterparts, and reside higher in the water column.

The interplay of these water masses and their fate in the Arctic Ocean, both of which depend on the motion of ice, seafloor topography, and winds, are matters of scientific debate. When the water masses meet in the Chukchi Borderland region, some continue east along the north coast of Alaska, and some are turned into the high Arctic. Although submarine transects have gathered data through the Borderland region in the last decade, the complexity of the region has defied analysis. The Atlantic waters carry heat, which could thin or melt the ice, and the Pacific waters carry nutrients, which are the mainstay of arctic biological systems. Together they influence local climate, biological systems, and nearby human communities, as well as global climate through their connections to global ocean circulation.



Atlantic waters Pacific waters
Transfer out into the deep basin?

As part of a three-year National Science Foundation Arctic Natural Sciences project, scientists from APL-UW, Scripps Institution of Oceanography, Oregon State University,

and the Lamont-Doherty Earth Observatory (Columbia University) are studying the interplay and fate of waters in the Borderland. During a five-week research cruise in summer 2002, the U.S. Coast Guard Cutter *Polar Star* crossed and recrossed the boundaries between the shelves, ridges, and deeps of the region. Three oceanographic moorings were deployed across the core of the boundary current at the beginning of the cruise and recovered at the end. An extensive hydrographic survey of 126 conductivity-temperature-depth (CTD) rosette casts included profiles of salinity, temperature, dissolved oxygen, water velocity (via L-ADCP, lowered acoustic doppler current profiler), water clarity, and water sample analysis. In the 24-hr daylight a large number of samples were collected. Bottle samples were taken for nutrients (2662 samples), dissolved oxygen (2999 samples), salinity (3066 samples), tracer chlorofluorocarbons (2500 samples), ^{18}O isotopes (1000 samples), barium (1000 samples), helium (108 samples), iodine-129 (96 samples), cesium-137 (27 samples), and denitrification N:Ar ratio (21 samples). The sampling regime meant bringing 30 tons of water aboard ship for analysis, and lowering and raising the CTD the round-trip distance from Seattle to Vancouver, B.C.



A CTD team: Knut Aagaard, Jim Johnson, Gail Grimes, Ron Patrick (Scripps Institution of Oceanography), Wendy Ermold, and (kneeling) Sarah Zimmerman (Lamont-Doherty Earth Observatory)

The combination of temperature, salinity, and chemical tracers tracks the different water masses. Nutrients mark the Pacific water; iodine and cesium, waste products from the European reprocessing plants, tag the Atlantic waters; chlorofluorocarbons reveal the “age” of the water (i.e., the time since it was last at the surface); and ^{18}O and barium mark the water as originating from the low-salinity sources of rivers and melted ice.

TEACHER AT SEA

While our heads were in the Arctic and our hands in the cold, cold water samples during the cruise, our feet were kept in the real world by our teacher at sea. Gail Grimes of Lake Stevens, WA, brought the Arctic and oceanographic research to students in Seattle and Barrow. To teach the concept of water pressure, she asked students to consider the fate of Cindy the styrofoam head, which was very effectively shrunk when lowered down to 3000 m depth on a CTD profile. Students were taught how to distinguish between the Pacific, Atlantic, and riverine waters with their sensitive “human salinometers” — their tongues.

As a member of the CTD team, she painted an ungilded picture of the life of oceanographers and crew aboard a research ship through daily updates on the cruise’s Web site. She translated the methods, hopes, and practicalities of the research, as well as basic oceanographic principles to student visitors. Over the two-month cruise, more than 3000 people visited the Web site to learn about the Arctic by looking over our shoulders as we worked.

EARLY RESULTS

Although analysis of the data is still in its heady, initial stages, some exciting results are already apparent. The intricate structure in the Atlantic water warm core and the large variability over small spatial scales is astounding. Some deep stations show evidence of sill flows crossing between the main basin and the isolated plateaus in the region. The most prominent result so far is the continued spreading of the warmer Atlantic water into the Chukchi Borderland. In the 1990s scientists measured the propagation of this anomalous core into the Arctic Ocean from the European side. Over the past decade it has traveled with the boundary current and during the summer of 2002 was finally exiting the Borderland region.

Team members: Knut Aagaard, Kellie Balster (UW School of Oceanography), Wendy Ermold, Gail Grimes, Marlene Jeffries, Jim Johnson, and Rebecca Woodgate



High school teacher Gail Grimes received National Science Foundation support to join the research crew of the expedition and to provide educational outreach to students in Barrow, AK, and Seattle, WA, before, during, and after the cruise.

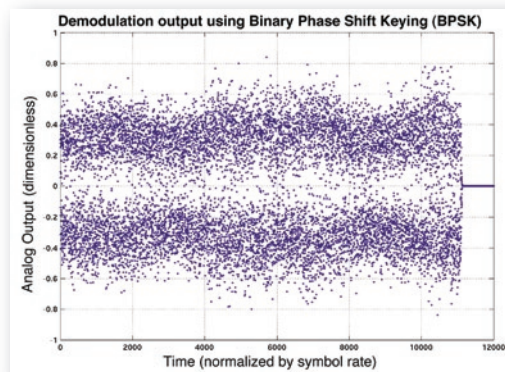
UNDERSEA WIRELESS COMMUNICATION

Dan Rouseff

From radios to cellular phones to Wi-Fi connections in your favorite coffee shop, wireless communications permeate our everyday life. All of these systems transmit digitally encoded electromagnetic energy through the atmosphere. Comparable communication systems in the undersea environment would allow transmission of data, commands, and even images among submarines, autonomous underwater vehicles, and divers. Unfortunately, electromagnetic energy does not propagate well through water. Another means of transfer is needed.

ACOUSTIC TRANSMISSIONS

Acoustic energy propagates well through water and holds promise as a means for undersea wireless communication. The physics of acoustic propagation, however, conspire with the undersea geometry to present unique challenges. The ocean acts like an echo chamber with sound bouncing repeatedly off both the sea surface and the seabed. For undersea communications these echoes are distorted, time-delayed versions of the original transmission that then interfere with subsequent transmissions. In practical applications it is not unusual to have over one hundred echoes competing with the data stream of interest, producing what is called inter-symbol interference (ISI).



A binary-coded data stream was processed at a fourteen-hydrophone array to determine if a "one" or a "zero" was transmitted. During a one-week experiment in Puget Sound, we found that the two clusters of scatter-plotted ones and zeros remained well separated, and the communication was unambiguous and error-free at a transmission rate of 2.1 kilosymbols/s.

SIGNAL EQUALIZERS

Equalizers can be built into a receiver's software to compensate for ISI by combining time-delayed versions of the received signal into one. But because the ocean environment is ever changing, especially the sea surface due to wave action, the equalizer must adjust continuously to changing components of the time-delayed versions of the signal. This increases computational complexity—possibly beyond acceptable levels for desired communication applications.

We have explored a method called passive phase conjugation that uses the ocean itself as an equalizer. Here, an array of hydrophones is deployed at the receiver. Each hydrophone gives a unique view of the path a sound signal travels between source and receiver. By constantly combining the different versions of the signal recorded by the hydrophones in the array, ISI is reduced. Software equalizers of reduced complexity can then mitigate ISI further.

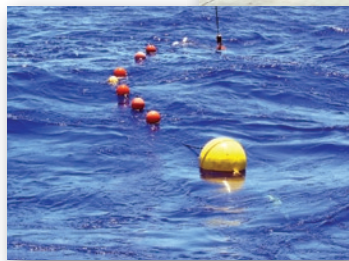
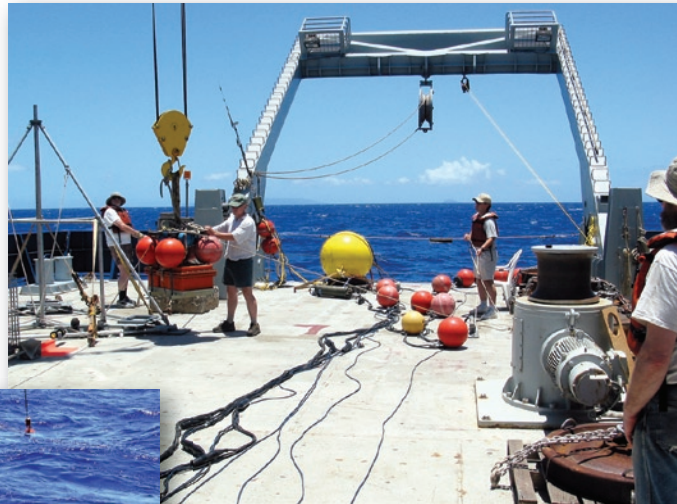
PASSIVE PHASE
CONJUGATION
USES THE OCEAN
ITSELF AS AN
EQUALIZER.



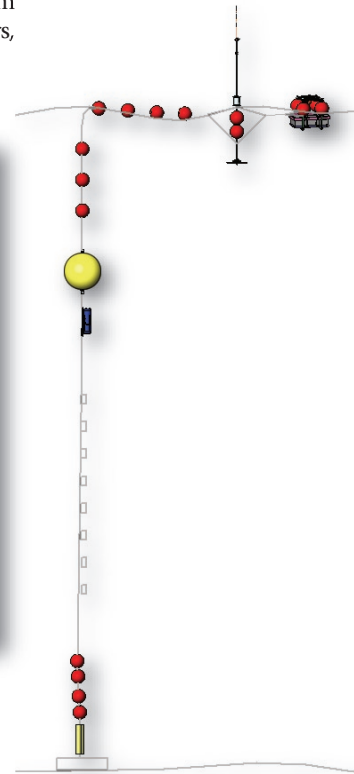
Receiving array recovery in Puget Sound. The radio frequency antenna is at the left and the battery pack is near the boat.

FIELD OPERATIONS

During experiments in Puget Sound we deployed a fourteen-hydrophone receiving array from the R/V *Henderson* and a source transmitter from the R/V *Miller*. The source was moved to different locations, ranging from 10 m to 120 m depth and at distances from 0.5 km to 5 km from the receivers. The source was allowed to drift relative to the receivers, and the shape of the receiving array and the inter-hydrophone spacing were varied.



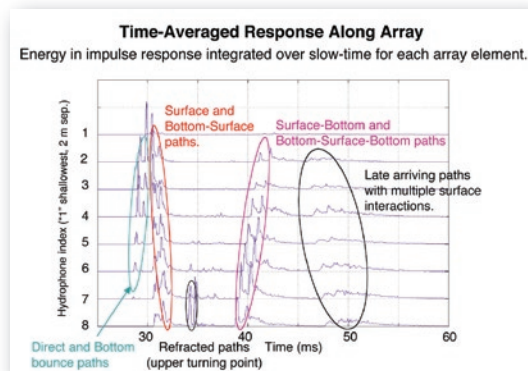
Photos from the Kauai-Ex experiment show the deployment of an eight-hydrophone array. Schematic shows the array in position with floating battery pack and radio antenna at the sea surface.



During this initial experiment we used all fourteen hydrophones at the receiving array and the full transmission bandwidth. However, bandwidth is expensive in a practical communication system. Decreasing the bandwidth increases the data transmission efficiency and allows multiple users to send data at the same time. The need to examine the trade-offs among bandwidth, coding schemes, and the number of hydrophones as a function of the signal-to-noise ratio motivated further fieldwork.

For two weeks during the summer of 2003, we conducted experiments off the island of Kauai as part of the ONR-sponsored, multi-institution Kauai-Ex experiment. These included tests with reduced bandwidth and fewer hydrophones on the array. We deployed an untethered eight-hydrophone receiving array with a radio link back to the ship that allowed us to monitor the data quality as experiments progressed and to adjust the receiver parameters as necessary. Detailed oceanographic measurements of the sea surface and the water column were conducted concurrent with the acoustic experiments. While still in the very early stages of analysis, data look promising. Our goal is to quantify algorithm performance and ISI reduction as a function of environmental conditions.

Team members: Warren Fox, Vern Miller, Dan Rouseff, Pete Sabin



Measurements made along the array during Kauai-Ex were related to the number of surface and bottom bounces for the various acoustic paths.

ULTRASONIC MEDICINE IN SPACE

Marilee Andrew

Consider the importance of the new automatic defibrillator to the airline passenger suffering a mid-air heart attack, and you can begin to imagine the value of automated devices for diagnosis and treatment of medical emergencies in long-term space flight. For astronauts on an interplanetary mission, there would be no turning back to Earth,



NSBRI team members (from left to right): Peter Kaczkowski, Justin Reed, Ajay Anand, Jim Hossack, Neil Owen, Mike Bailey, Erin Graf, Tonya Khokhlova, and Fran Olson. The portable HIFU system loads into the case held by Hossack and Bailey. Not pictured: Stephen Carter (UW Dept. of Radiology) and Larry Crum.

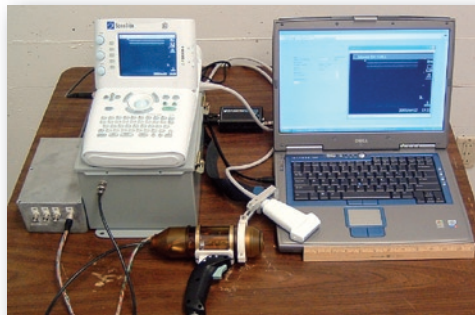
even in the case of life-threatening illness or injury. Thus the National Space Biomedical Research Institute (NSBRI) has initiated research efforts to develop sophisticated devices, or “smart medical systems,” to treat potential health crises on a long-term mission.

The zero-gravity and compact environment associated with space travel puts special constraints on the development of smart medical systems. Some traditional treatments are of little use in a weightless environment. And while gravity is reduced in space, inertia is not; thus collisions with heavy objects can result in traumatic injury and internal bleeding. While a physician will likely be part of the crew, the treatment system will need to be simple enough for any astronaut to use, and use quickly. High intensity focused ultrasound (HIFU) is a unique treatment modality that could allow a fairly inexperienced operator to perform “point and shoot” bloodless surgery.

PERFORMING SURGERY WITH SOUND

HIFU provides the unique capability to induce a biological effect deep within the body without surgical intervention. Focusing allows ultrasound waves to pass through intervening tissue without causing damage while delivering a therapeutic dose (4–5 orders of magnitude greater than the intensities used in diagnostic ultrasound) to a

region as small as a grain of rice. Treatment produces localized heating and, at sufficient pressures, mechanical effects including cavitation, which is the growth, oscillation and, in some cases, violent collapse of bubbles. These effects produce tissue denaturation and coagulation, which lead to the cessation of blood flow—inducing what is known as acoustic hemostasis.



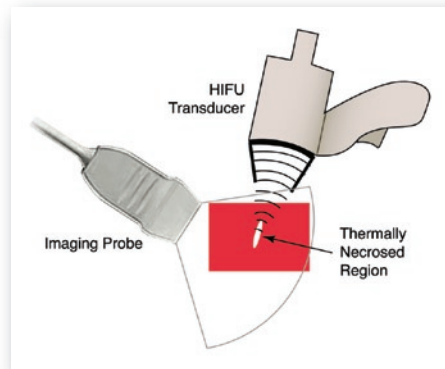
NSBRI Smart Medical System image-guided HIFU therapy prototype consists of a Sonosite hand-held imager, notebook computer/controller, imaging probe, HIFU transducer, and driving electronics.

Through initial research efforts funded by the Defense Advanced Research Projects Agency (DARPA), the Office of Naval Research, and the U.S. Army Medical Research and Materiel Command in support of combat casualty applications, investigators at the Center for Industrial and Medical Ultrasound (CIMU) have demonstrated that HIFU can stop bleeding from penetrating traumatic injuries such as cuts in organs and punctured or lacerated vessels, as well as blunt traumatic injuries such as a fractured liver or spleen. Treated vessels can be occluded

or kept patent, depending on the medical need, and the cauterized area is highly localized. Leveraging on this work, CIMU is now involved in an effort supported by NSBRI to take advanced trauma care into space. Investigators have coupled a commercial hand-held ultrasound imager with HIFU therapy and computer control to create a prototype image-guided therapy system. The goal now is to transform these technologies into a portable, lightweight, integrated, and user-friendly device that can image, monitor, and stop bleeding without breaking the skin.

MAKING HIFU SMART AND SPACEWORTHY

Integrated imaging is key to successful noninvasive HIFU treatment and presents several challenges. Diagnostic ultrasound imaging is used to see where therapy is being applied and to assess treatment effectiveness, but simultaneous ultrasound therapy causes interference. CIMU investigators have developed a technique to synchronize interfering HIFU treatment bursts with the imaging pulses of the diagnostic ultrasound probe so that the therapy zone can be observed clearly in the ultrasound image during the entire treatment. With the interference eliminated, HIFU treatment can be visualized, because it produces a bright, hyperechoic spot at the therapy zone in the ultrasound image. For treatment times greater than one second, this hyperechoic spot shows excellent agreement with the size, shape and position of the HIFU lesion, i.e., the area of denatured tissue. At shorter exposures, a hyperechoic spot appears, but no lesion is formed. These two features allow an operator to locate and target treatment precisely, as well as monitor treatment success.

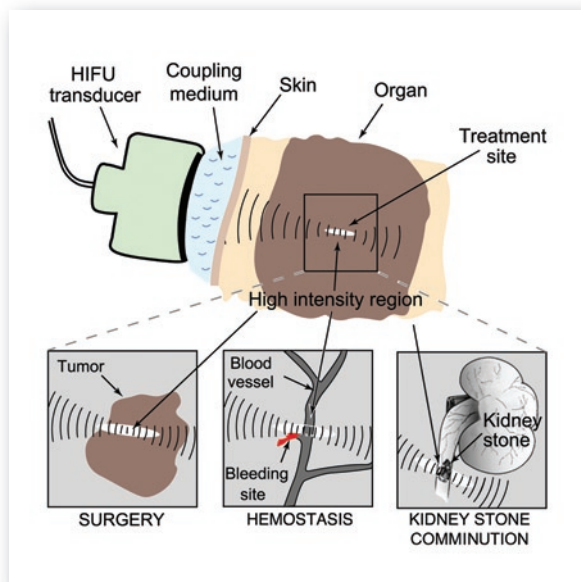


CIMU investigators have developed a technique to synchronize interfering HIFU treatment bursts with the imaging pulses of the diagnostic ultrasound probe so that the therapy zone can be observed clearly in the ultrasound image during the entire treatment.

Flexibility and portability are also important factors in system design. To deliver therapy to different depths within the body, the operator mechanically moves the single-element therapy transducer of the existing prototype system to vary treatment depth. Current research efforts will take advantage of phased-array transducer technology to adjust treatment depth electronically. Significant research also has been directed at miniaturization technologies for the electronics that drive both imaging and therapy. This work includes the development of amplifiers that are small, efficient, high-powered, and compatible with voltages on NASA vehicles.

FRONTIERS

NSBRI brings together the resources of the nation's leading biomedical research institutions to solve problems associated with human space travel. In addition to mission critical care, it is hoped that the smart ultrasound system could be used to image cardiac tissue, break kidney stones with shock waves, stimulate bone growth, and diagnose decompression sickness. A device that can perform multiple medical uses will be an essential tool on NASA space vehicles, and could be adapted to provide important new treatment capabilities in ambulances, emergency rooms, and operating theaters here on Earth.



A well-designed HIFU system could provide multimodal treatment to kill tumors, stop bleeding, and break up kidney stones.

OUR GOAL IS
TO DEVELOP A
PORTABLE, LIGHT-
WEIGHT, AND
USER-FRIENDLY
THERAPEUTIC
ULTRASOUND DEVICE
THAT WILL BE AN
ESSENTIAL MEDICAL
TOOL ON NASA
SPACE VEHICLES.

PACIFIC RIM NATIONS SYNCHRONIZE SHALLOW WATER ACOUSTICS STUDIES

The fifty-mile trip up the Huangpu River—a tributary of the Yangtze—from the East China Sea to the port at Shanghai is a marvelous experience. APL-UW scientists and engineers looked on as the 170-ft R/V *Melville* was piloted amid the surges and flows of huge cargo vessels, fishing boats, and small live-aboard barges. After making their berth, a six-person uniformed contingent from the State Oceanic Administration of the People's Republic of China boarded to conduct an inquiry with the experiment's Chief Scientist Peter Dahl concerning the cruise's scientific measurements made during the preceding two weeks. After an initial misunderstanding about required documentation, the contingent's lead person and Dahl zeroed in on their common rudimentary knowledge of Japanese language and appreciation of haiku. Mutual compliments led to an efficient business exchange and thus the Asian Seas International Acoustics Experiment (ASIAEX) in the East China Sea was ended officially.



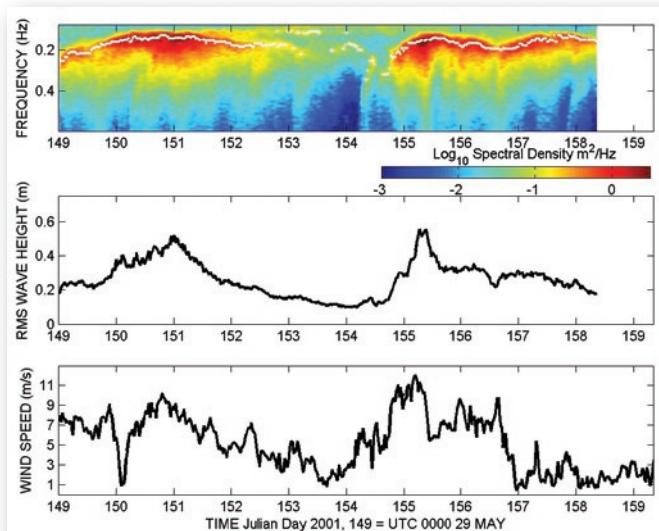
The APL-UW team aboard the R/V *Melville* at Shanghai (from left to right): Russ Light, Eric Boget, Peter Dahl, Pete Sabin, Vern Miller, and DJ Tang

The success of the ASIAEX field program, comprised of the experiments in the East China Sea and those of one month earlier in the South China Sea led by the Woods Hole Oceanographic Institution, was the culmination of five years of planning overseen by Jeffrey Simmen while he was the ocean acoustics program manager at the Office of Naval Research. The Asian marginal seas offer a unique shallow water laboratory in the world because their depth of a few hundred meters extends for hundreds of

kilometers across the continental shelf. Scientists from eight Asian institutions from Korea to Singapore and eleven institutions from across the U.S. joined together to collect ocean acoustic, oceanographic, and geophysical data. This coordinated effort enabled underwater acoustics to be understood and modeled within the proper environmental context.

For ten days in May and June 2001, the APL-UW crew aboard the R/V *Melville* conducted ocean acoustic propagation and scattering experiments to understand the acoustic interaction with ocean boundaries as influenced by seabed properties and variable sea surface conditions. Sea surface data showed three-day periods of significant winds and seas alternating with calm balmy conditions during the ten-day observation window.

Dahl measured the influence of the changing sea surface on shallow water acoustic propagation using the APL-UW-engineered MORAY (MOored Receiving ArraY). The instrument received acoustic signals in the frequency range 2–20 kHz transmitted from the R/V *Melville* at a distance of 0.5–1 km from the MORAY. Upon receiving and



Surface wave properties and wind speed recorded in the East China Sea during ASIAEX. The top shows contour of wave frequency spectra measured every one-half hour between 29 May and 8 June. The red areas show the wave frequencies of the most energetic waves, with the peak frequency tracked by the white dots. (A peak frequency of 0.2 Hz corresponds to a wavelength on the sea surface of 39 m.) The middle shows the average waveheight, and the bottom shows the wind speed. Between 29 May and 7 June, wind speed varied from near 1 m/s to 13 m/s and RMS waveheight varied between about 0.1 m and 0.6 m, thus providing a wide range of sea state conditions for the ocean acoustic experiments. In this open-sea environment wind speed and waveheight show correlation, with maximum waveheight developing a few hours after maximum wind speed.



Deploying the IMP2 in the East China Sea

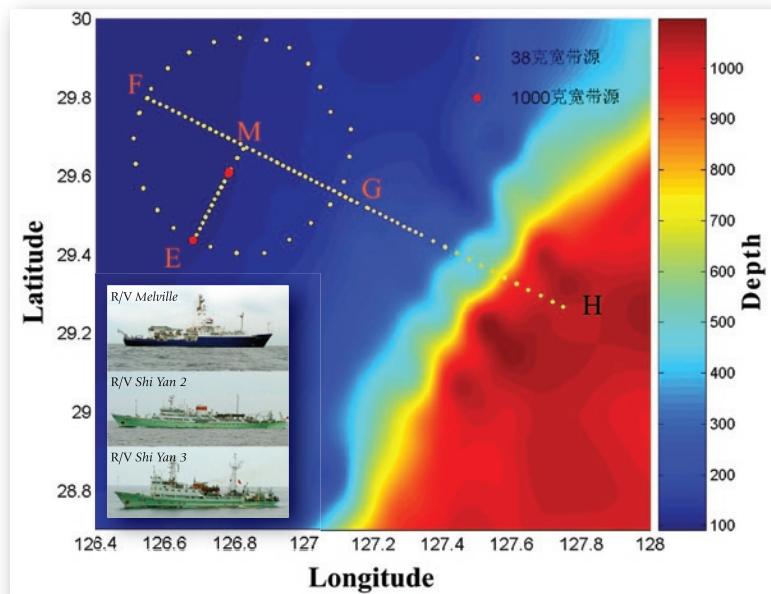
recording the signals, data were sent back to the *Melville* through an RF modem. Acoustic data obtained by the MORAY were used to study shallow water, short-range propagation and forward scattering from the seabed. Continuous measurements over two 24-hr periods were made to capture variability in environmental effects. The measurements in this frequency range are crucial to understanding underwater acoustic communication, detection, and imaging in littoral seas.

Senior Oceanographer DJ Tang collected seabed measurements in the study area with the IMP2 (In situ Measurement of Porosity, 2nd generation). This instrument, also engineered by APL-UW, resembles a 5-m-long sawhorse; it measures seafloor roughness at centimeter scales and seabed density at centimeter depth resolution. A conductivity probe is mounted on the IMP2 A-frame, which is equipped with horizontal and vertical motor systems. After each vertical measurement cycle is finished, the probe retracts to the starting position and the horizontal motor moves the probe to the next designated horizontal position, where the next vertical measurement cycle commences. Data collected by IMP2 are used as input for bottom acoustic scattering models.

A key phase of the cruise was the coordination of activities with two Chinese research vessels over five days. The service of three vessels covering a large geographic area was needed to study the mechanisms responsible for low-frequency reverberation in shallow water and how sound propagates across boundaries separating sediments of differing composition. The *Shi Yan 2* deployed 38-g and 1000-g explosive charges at 50-m depth along a set course up to 100 km away from the *Shi Yan 3* and *Melville*, which were recording the data on vertical line arrays.

ASIAEX collected an extraordinary set of synchronized acoustic, oceanographic, and marine geophysical data in Asian marginal seas. The work makes a significant contribution to understanding how variable seabed sediments and sea surface roughness in shallow water environments govern acoustic propagation and reverberation. Inverting acoustic propagation and reverberation field measurements across the frequency range of 10 Hz to 10 kHz has gone far to establish a unified geoacoustic description of the East China Sea's seabed.

The size and scope of the multinational effort created enormous logistical challenges, but all participants contributed to an increased understanding of the acoustic environment of the Asian littoral seas and appreciation of the people of the many Pacific Rim nations who came together to study it.



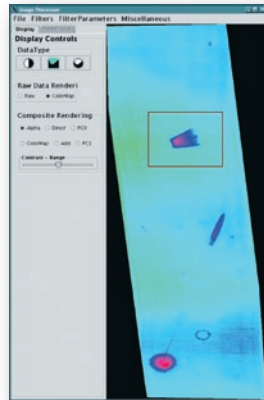
The large-scale experimental site for ASIAEX, East China Sea, was a circle of radius 30 km. The yellow dots (above) are waypoints visited by the R/V Shi Yan 2 for deployment of explosive sound sources. The R/V Melville and the R/V Shi Yan 3 held position at waypoint M and recorded acoustic transmissions from the deployed sources.

MINE COUNTERMEASURE RESEARCH

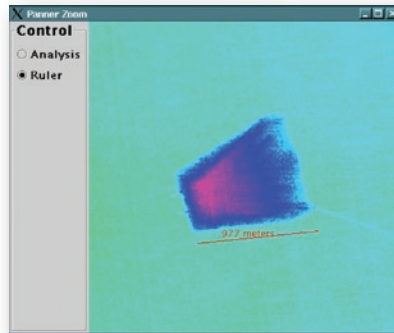
Recent Navy operations—notably, securing the port of Umm Qasr early in the Iraq war—underscore the urgent need to counter the threat of mines in shallow water regions. With support of the Office of Naval Research, APL-UW scientists and engineers are developing a range of technologies to outfit the U.S. Navy's tool chest of mine countermeasures. From software designed to enhance optical systems that detect

and identify mine-like objects to acoustic lenses that produce video-quality images covertly in dark and turbid water, the Laboratory is working to support the Navy's move toward organic mine countermeasures—the ability to detect, characterize, and neutralize mines quickly using a deployed unit's own resources rather than a dedicated force.

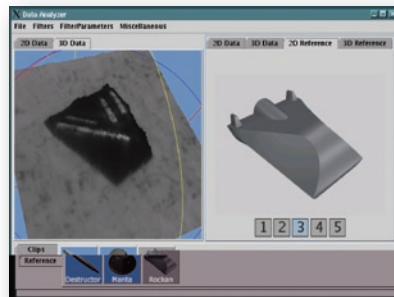
Image from a computer-aided mine detection exercise. The raw optical data is colorized to enhance contrast. The region of interest is bounded by a box.



A pan-zoomed display of the region of interest shows how a ruler tool is applied to a mine-like object for size determination.



The selected region of interest is converted to a three-dimensional rendering, then rotated and compared to a high-resolution rendering of a reference mine from the electronic library.



A new sonar system was deployed on a crawler platform at the Coastal Systems Station in Panama City, Florida, where it identified mine-like objects in very rigorous surf zone conditions.



IMPROVED IMAGING ALGORITHMS

Mines are especially difficult to detect in shallow water and in the surf and beach zones because they are easily obscured by the sediments and the rapidly changing environment. If naval forces are to project power ashore, they must cross these environments.

To search large areas quickly and improve the detection and identification of mine-like objects, Laboratory engineers have developed image processing and automatic target recognition algorithms to rapidly classify and identify mine-like objects. Capabilities include smoothing, sharpening, edge-detection, morphological determination (size and shape information), and wavelet denoising filters.

A triage feature allows operators to quickly tag regions of interest, save the data temporarily to a thumbnail gallery, and move on in their search. Tagged areas can be revisited at any time. Candidate mine objects from the data can then be compared to high-quality renderings of known mines in both two and three dimensions from a library of known mines.

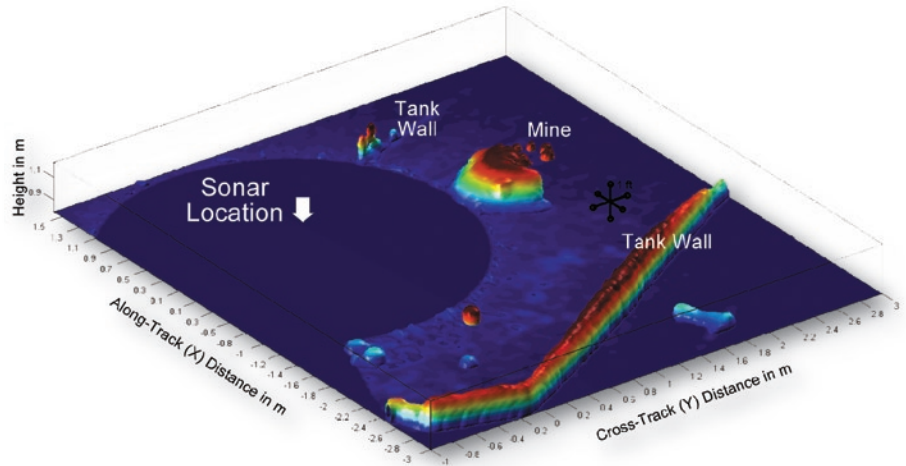
MINE HUNTING DEVICES

To put new sonar technology into the surf zone on a reconnaissance task, APL-UW has developed a scanning sonar that can be deployed on a crawler platform to generate three-dimensional volumetric data sets of mine-like objects within its field of view.

Effective, high-resolution imaging systems have traditionally used an array of acoustic sensors to form and steer sonar beams. These typically require that each stave of the array be sampled as a separate hardware channel, requiring significant amounts of support electronics. Putting imaging sonars on a small platform with modest power availability required a new sonar design.

By encoding angular imaging information into the bandwidth of broadband signals, hardware requirements are reduced. These new sonars use specific array design techniques and broadband pulses to map angular imaging information into the frequency domain. The beamformer for such a system

is designed around a time-frequency (i.e., spectrogram, Wigner) or time-scale (wavelets) decomposition allowing multiple independent beams to be formed simultaneously from a single hardware channel. Sonar imaging is thus achieved in a two-dimensional forward-looking configuration or in combination with conventional real or synthetic aperture techniques to provide a three-dimensional volumetric image.



PORT AND VESSEL SECURITY SWEEPS

Efficient and effective sweeps of ships' hulls and berths has become a high priority since 9/11. Whereas the U.S. Navy previously performed security swims with divers on a case-by-case basis, now regimented and routine security swims of vessels are conducted throughout the fleet. In clear water and sufficient ambient light, divers can use video cameras and their eyes to detect and identify underwater threats. And while existing sonar technology can be used in dark and turbid water, it is constrained by resolution and refresh rates.

Two acoustic lens-based cameras—the Limpet Mine Imaging Sonar (LIMIS) and the Dual frequency IDentification SONar (DIDSON)—were designed by APL-UW engineers to produce photographic-quality images with sound, even in dark, murky water. To obviate the divers' dangerous and time-consuming task of tactile object examination, the cameras have now been adapted for easy use by divers on security sweeps.

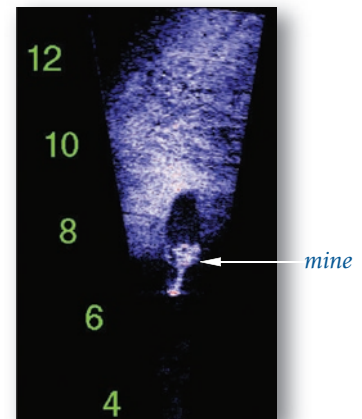
The dive team at the Shore Intermediate Maintenance Activity, Mayport Naval Station, was outfitted with LIMIS cameras and display systems to conduct security patrols of piers, bottom areas, and vessels in support of the U.S. Navy's Ft. Lauderdale, Florida, Fleet Week 2003. Divers cleared about 2500 ft of pier area in less than two hours of dive time—less than one-half that needed without the assistance of the cameras. Hull searches of support vessels—tug boats, pilot boats, and barges—were often completed in the darkness of the early morning hours. Each large tug was cleared by a diver in less than 10 min with no ancillary lights. Increased speed notwithstanding, the most important result of the exercise was that divers had increased confidence that bottom areas, vessels, and structures were clear of hazards after “seeing” them with the camera-display system.

DIDSON is also being used on untethered underwater vehicle (UUV) platforms where it can operate as a gap-filler for the UUV's side-scan sonars during a reconnaissance mission. It collects data at a constant frame rate and stores it with minimal energy requirements. At the mission's end an operator has a list of targets and their exact location. The operator may then direct the vehicle to take the DIDSON to the coordinates of each location to view the object at close range and at multiple aspects.

Laboratory scientists are working toward a more autonomous system in which DIDSON would use classification and identification algorithms in tandem with an on-board mine library to solidify decisions about detected mine-like objects. At a certain threshold DIDSON would direct the UUV to move so that it could look at particular features (bolt patterns, fins, etc.) and compare these spatial distributions with references from the library.

Team members: Ed Belcher, Pete Brodsky, Joe Burch, Matt Carpenter, Robert Carr, Andy Ganse, Bill Hanot, Julia Hsieh, Jim Luby, Fran Olson, Janet Olsonbaker, Jason Seawall, Troy Tanner, and Lee Thompson

The Laboratory has demonstrated in test tank experiments that the three-dimensional scanning blazed array sonar can image a mine-simulator target with high resolution.



A LIMIS image shows a limpet mine on the hull of a ship 7 ft (2.1 m) from the sonar in water with 6-in (15-cm) visibility. The diver stored the image and later downloaded it for analysis and display on a topside computer. The camera can store up to 50 images.

CHARTING THERMOHALINE INTRUSIONS IN FOUR DIMENSIONS

For several days during summer 2002, an Ocean Physics Department team led by Oceanographer Matthew Alford and Professor Mike Gregg mapped a thermohaline intrusion in Puget Sound. Before the team could deploy their instruments from two research vessels and begin their high tech choreography of four-dimensional mapping, they had to first find an intrusion. After one day of survey efforts, an intrusion of cold, fresh water was located sliding southward out of Possession Sound toward the Puget Sound shipping lane.

A Lagrangian float was thrown overboard to maintain position on the intrusion's interior and act as an acoustic beacon while microstructure profiles and towed-body surveys were dropped and run into and through the water mass. As it slid out and back from the head of Possession Sound on the tide, changes in structure and temperature were recorded at the intrusion's leading edge in near-real time.

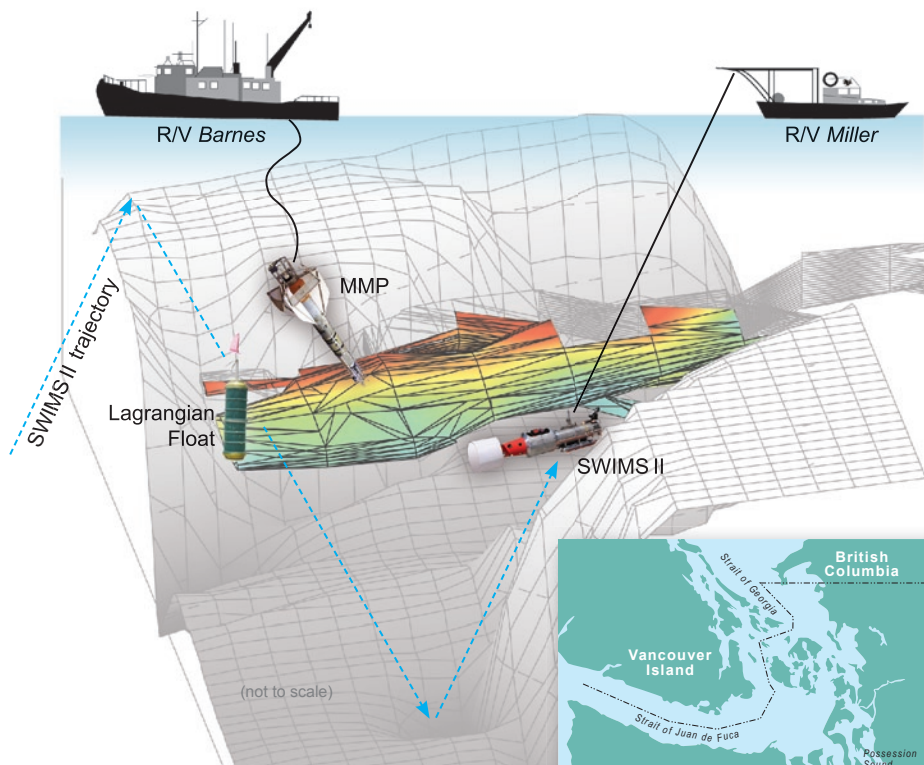
Ocean flows are spatially complex and can evolve rapidly over time. Oceanographic instrument systems resolve spatial and temporal dimensions with varying degrees of success. Moorings, anchored in place over long periods of time, have excellent temporal but single-point spatial coverage; shipboard surveys can cover a large area, but only one transect at a time; and single-point profiles have very good vertical resolution but poor temporal and horizontal coverage.

Intrusions, which are complex, small-scale processes involving fresh, cold or warm, salty water masses interacting with ocean flows, are known to exist, but they

are not adequately observed or explained. Are they shaped like 'tongues' or 'lenses', and how does their three-dimensional structure change over time? The technique developed by Alford and colleagues used here combines the strength of several observation strategies to resolve spatial and temporal scales simultaneously, providing a four-dimensional map.

Puget Sound is a natural 'ocean like' laboratory not far from APL-UW's back door; because intrusions had been detected on many previous research cruises in the sound, scientists were sure they would find one there. Oceanographers have known of thermohaline intrusions' ubiquity in the world oceans because they register on conductivity-temperature-depth surveys as inversions in temperature or salinity. Until now, they have not been tracked as they interact with the surrounding waters.

Alford and colleagues are interested in these structures because they may be key to isopycnal mixing, especially near fronts. Mixing helps to redistribute ocean properties that settle into stratified layers, influencing circulation and heat transport, and thus climate. And because the physical processes that



Schematic (above) represents data collection maneuvers used to map a thermohaline intrusion (colored field) of cold, fresh, low oxygen water centered between 40 m and 100 m depth.



Matthew Alford prepares a Lagrangian float for deployment.

mix the world oceans are too small to be resolved by climate models they must be parameterized to improve the predictive capability.

The Ocean Physics Department team proved that industrious scientists can use available tools in new combinations to increase their utility. APL-UW pioneered the use of Lagrangian floats to measure ocean mixing rates in near-surface boundary layers, under storms and hurricanes, in deep convective layers in the polar regions, and in strong coastal flows. Here, by ballasting a float to follow the parcel of water in the leading edge of the intrusion, researchers were able to follow the three-dimensional movement of the water mass. While deployed the float was tracked acoustically by the vessels above so that they could keep an accurate account of the intrusion's location.



R/V Miller in Puget Sound

The Shallow Water Integrated Mapping System (SWIMSII), developed to study coastal and estuarine environments and equipped with instrumentation returning measures of fine-scale temperature, salinity, and density fields near topography, was towed on its sawtooth profiling pattern through the intrusion by the R/V Miller. The Modular Microstructure Profiler (MMP), a 1.2-m

long, free-falling, loosely tethered instrument, was deployed from the R/V Barnes as it kept station near the float's signal. As it was dropped and retrieved repeatedly through the water column and intrusion, vertical profiles of temperature, conductivity, and centimeter-scale vertical shear of horizontal currents and centimeter-scale vertical temperature gradients were transmitted up the cable and then to a computer for display and data logging.



Jack Miller, Matthew Alford, Paul Aguilar, and Glenn Carter on the R/V Barnes in Puget Sound

The choreographed data collection maneuvers revealed that the thermohaline intrusion was a cold, fresh, low oxygen water mass centered between 40 m and 100 m depth that flowed south out of Possession Sound at about 0.02 m s^{-1} . Jagged structures implying turbulence and mixing on its leading edge were observed. This inference was confirmed with an observation that the water parcel containing the Lagrangian float near the leading edge warmed by nearly 0.2°C in 24 hr. "Because measured vertical fluxes were too small to account for this, horizontal stirring at the feature's edge appeared responsible. This was supported by a lack of warming observed by a float deployed inside the intrusion's core, away from the edge," notes Alford.

The

Another intrusion mapping experiment is ongoing in Puget Sound. Additional instrumentation includes two moored profilers measuring water temperature, salinity, and velocity as they crawl up and down their mooring cables. This observation technique will supply Alford and colleagues an additive partial view and perhaps make possible the first complete story of an intrusion's entire life cycle.

Team members: Paul Aguilar, Matthew Alford, Stephen Bayer, Eric Boget, Glenn Carter, Mike Gregg, Earl Krauss, John Mickett, and Jack Miller

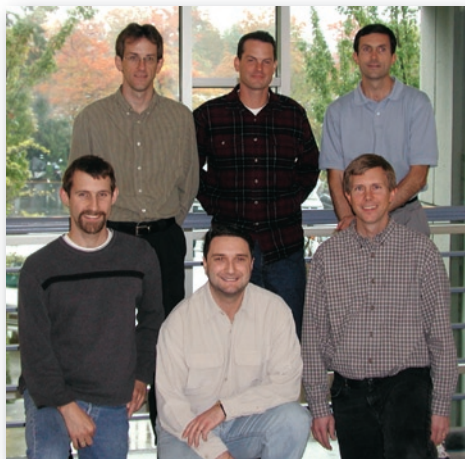
“THIS IS THE FIRST STUDY WHERE THE EVOLUTION AND STRUCTURE OF A MIXING WATER MASS HAVE BEEN OBSERVED DIRECTLY AND SIMULTANEOUSLY.”

— MATTHEW ALFORD

NEW DIRECTIONS IN SIGNAL PROCESSING

James Pitton

From defense applications such as radar and sonar to everyday commercial uses like cell phone communications, more and more people are benefiting from signal processing technologies. Touch-tone telephone menus are being replaced with speech recognition systems. Hikers use Global Positioning System (GPS) receivers as navigation aids. From Internet telephony and music and video streaming to intelligent systems that recognize sounds, images, and other patterns, signal processing surrounds us. As part of the widespread need for research in these areas, scientists and engineers in the Environmental and Information Systems Department are developing signal processing technologies to support national defense applications in such diverse fields as speech processing, sonar, and digital communications.



Team members: (standing, left to right) James Pitton, Clark Bodyfelt, Jack McLaughlin; (kneeling, left to right) Lane Owsley, Luca Cazzanti, and Bill Kooiman

COMPRESSING SPEECH, REDUCING NOISE

Our latest signal processing effort is in speech processing. Sponsored by the Defense Advanced Research Projects Agency (DARPA), we and the University of Washington Department of Electrical Engineering are collaborating to improve low-rate speech coding technology. Speech coding is widely used in cell phone communications, where speech is typically transmitted at 8000 bits per second (bps). Low-rate speech coding is used in military communications systems, reducing the data rate for speech to 2400 bps. The goal of this project is to further compress speech to bit rates between 200 and 800 bps, while producing speech quality at least as good as that produced by the current 2400-bps military standard speech coder.

Additional goals of the project include noise suppression to preserve the speech quality and low bit rate in militarily relevant noisy environments, and reliable authentication of the speaker's identity. These goals will be achieved by using new technology that directly

measures the vibrations produced by the vocal cords. We are investigating methods to combine these measurements with the information contained in the recorded speech to achieve speech coding at lower rates and in the presence of noise. Furthermore, direct measurement of the vocal excitation waveform potentially provides a unique physiological set of metrics that can be used for speaker authentication.

INTELLIGENT SONARS

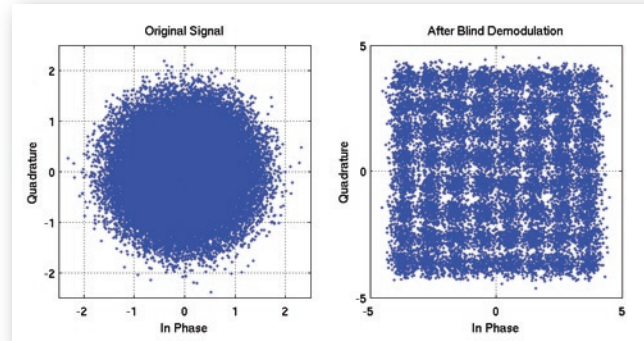
We are also investigating signal processing methods for active sonar systems, an area in which APL-UW has been involved for many years. The Office of Naval Research has tasked us to develop automatic target classification technology for active sonar systems by exploiting novel and conventional signal processing methods and knowledge of environmental physics and human auditory processing. Experienced sonar operators are able to recognize sonar target echoes by listening to the sound, even in shallow water, high-clutter environments where automated systems perform poorly. Understanding how sonar operators perform this task should lead to improvements in the performance of automatic classification systems.

A great deal is already known about how humans perform sound recognition in general. For example, many aural cues encode time-varying or "nonstationary" information, and these cues are very important for sound classification by humans. Our efforts have been directed at identifying such signal features in sonar echoes and incorporating them into an automatic classification system. We are also investigating methods to compensate for nonstationary propagation effects in the echoes, and incorporating the compensated features into an automatic classifier. We developed nonstationary feature extraction methods based on time-frequency templates and

efficient inverse-channel filters that account for propagation effects with minimal environmental knowledge. Our work has produced very positive results from incorporating various nonstationary signal features into an automatic classification system for active sonar data.

CLASSIFYING UNKNOWN SIGNALS

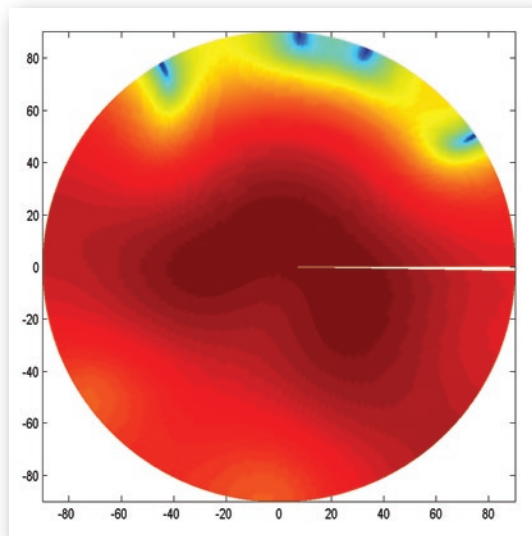
This experience in automatic classification is also being applied to digital communications signals for the Air Force Research Laboratory and the U.S. Army Communications Electronics Command (CECOM). We are developing methods to classify communications signals accurately across a wide range of modulation types. Once this modulation classification has been accomplished, the data can be demodulated from the received signal. Traditional commercial receiver techniques require that virtually all communications systems operating parameters, such as signaling constellations, carrier frequencies, symbol rates, and pulse shapes, be known. However, in some applications these operating parameters are not available and must be estimated “blindly,” that is, without knowledge of the signal being transmitted. Our goal in these efforts is to develop algorithms for combined recognition and demodulation of unknown communication signals.



A Quadrature Amplitude Modulation (QAM) signal before (left) and after (right) blind demodulation. Noise, channel distortion, residual carrier, and other unknown variables combine to make the received signal an unrecognizable blur. Blind demodulation methods make it possible to recover the undistorted signal “constellation” as shown, simplifying modulation recognition and making demodulation of the underlying data possible.

MITIGATING GPS VULNERABILITIES

Our efforts in signal processing for digital communications also extend to the Global Positioning System. GPS is a network of satellites that provides users with precise location information at an affordable cost. However, the GPS satellite signal is very low power, and hence is susceptible to jamming and interference. U.S. military systems, as well as commercial aviation, increasingly depend upon GPS for navigation. Hence, it is imperative that GPS receivers be able to operate effectively in the presence of jamming and other interference. Our research team has used adaptive signal processing techniques to cancel out jamming and other interference, preserving the use of GPS as a navigation aid.



These efforts have expanded APL-UW science and engineering expertise into new areas and served to foster collaboration with researchers at the University of Washington and elsewhere.

An “Azimuth-Elevation” plot of the response of an adaptive array in the presence of jamming. The rim of the circle corresponds to the horizon, while the center of the figure is directly overhead; the plot represents the upper hemisphere of the spatial response of the array. Red indicates regions where a GPS satellite signal would be received with high signal-to-noise ratio (SNR); blue indicates regions where the satellite signal would have low SNR. In this example, four interfering signal sources (jammers) are present at the locations where the response is blue. Satellites located anywhere in the sky other than these small blue areas would be received loud and clear despite the jamming.

Education



Associate Director Robert Odom

The Applied Physics Laboratory's level of involvement in the educational mission of the University of Washington has reached that of a large academic department. Forty APL-UW staff hold faculty appointments in twelve different departments ranging from Atmospheric Sciences to Neurological Surgery. Our greatest faculty presence continues to be in the School of Oceanography and the Department of Electrical Engineering with seventeen and thirteen APL-UW faculty, respectively. Seven of the forty APL-UW faculty hold appointments in more than one department.

The APL-UW faculty directed the research of thirty-eight graduate students, awarding eight doctorates and five masters degrees in the 2001–2002 biennium. Student research topics reflect the broad interests and diverse departments represented by the APL-UW faculty. Bioengineering student Tyrone Porter, working with his advisor Larry Crum, investigated the synergy between ultrasound and membrane-disruptive polymers and its effect on cell membranes. Elizabeth Steffen in the School of Oceanography, supervised by Principal Oceanographer Eric D'Asaro, studied convection in the Labrador Sea utilizing observations made by fully Lagrangian floats. Robb Contreras is

investigating rain effects on microwave backscatter from the sea surface with Principal Research Scientist Bill Plant.

The university has placed increasing emphasis on providing research experience for undergraduates. In 1993 there were three undergraduates participating in APL-UW research programs; there were twenty in 1997, and now over thirty undergraduates per year work with APL-UW scientists and engineers. Our contribution in this area equals that of the Physics Department, as well as an average over the ten departments making up the College of Engineering.

Undergraduates are given both freedom and responsibility by their APL-UW mentors. Engineer Mike Bailey commented casually to his lab that it would be useful to have a single trigger-operated device that would both image and produce high intensity focused ultrasound for therapeutic studies. While Mike was away at a scientific conference, undergraduates Stephanie Hoi Chung, Ryan Ollos, and Justin Reed bought a computer joystick at a local computer store, dismantled it, and rebuilt it, incorporating the ultrasonic transducers to perform exactly the functions Mike had suggested. This opportunity to take the initiative on an innovative project characterizes the undergraduate research experience at APL-UW.

Although our primary mission is research, ten individuals participated in classroom teaching in the previous biennium. A few of the courses taught by APL-UW faculty are

as replacements for colleagues on leave, but many of the courses represent specialties unique to the APL-UW faculty member. Examples include *Ocean Mixing* (Mike Gregg), *Combining Models and Data in Climate and Ocean Circulation Studies* (Kathie Kelly), *Corrosion and Surface Treatment of Materials* (Colin Sandwith), and *Ultrasound in Biology and Medicine* (Shahram Vaezy).

THE LABORATORY
IS A TOP
CONTRIBUTOR TO
THE EDUCATION
MISSION OF
THE UW BY
PROVIDING
RESEARCH
OPPORTUNITIES
TO GRADUATE
AND
UNDERGRADUATE
STUDENTS.

ADVANCED DEGREES AWARDED TO APL-UW STUDENTS AND STAFF AND FACULTY ADVISORS		
Alana Althaus	<i>Oceanography, M.S., 2001</i>	Kunze
Wen-Shiang Chen	<i>Bioengineering, Ph.D., 2002</i>	Matula
Peter Craigmile	<i>Statistics, Ph.D., 2001</i>	Percival
Eric Elsworth	<i>Oceanography, M.S., 2002</i>	D'Asaro
George Kapodistrias	<i>Mechanical Engineering, Ph.D., 2001</i>	Dahl
Floyd Karp	<i>Bioengineering, M.M.E., 2002</i>	Vaezy
Jody Klymak	<i>Oceanography, Ph.D., 2002</i>	Gregg
Jennifer MacKinnon	<i>Oceanography, Ph.D., 2002</i>	Gregg
Sandy Poliachik	<i>Bioengineering, Ph.D., 2001</i>	Crum
Adrian Prokop	<i>Bioengineering, M.S., 2002</i>	Vaezy
Dahlia Sokolov	<i>Bioengineering, Ph.D., 2002</i>	Crum & Bailey
Jonathan Yuen	<i>Bioengineering, M.S., 2001</i>	Vaezy

APL-UW's K-12 outreach program provides lab tours, demonstrations, and school visits by scientists and engineers, and had contact with over 450 members of the non-university public in 2002 alone. Principal Engineer Peter Dahl taught a short course on acoustics for middle school students participating in the GEAR-UP Program, a program for low-income middle schoolers. A highlight of his course was when he put a ringing cell phone in a bell jar. Using a vacuum pump to evacuate the jar, the ringing became fainter, finally fading away in a demonstration that sound cannot propagate in a vacuum like outer space—contemporary science fiction film special effects notwithstanding!

APL-UW is a popular destination with Pacific Northwest high school students participating in annual Math Day events sponsored by the UW Mathematics Department. The 2002 Math Day presentation by Oceanographer Rob Tyler was a real hit. He demonstrated the Monte Carlo integration technique for estimating the steady-state temperature distribution in a region using a large crate of oranges and the students themselves as nodes for the computation. Through our outreach programs we disseminate scientific knowledge and, hopefully, inspire future generations of scientists and engineers.

Student Profiles

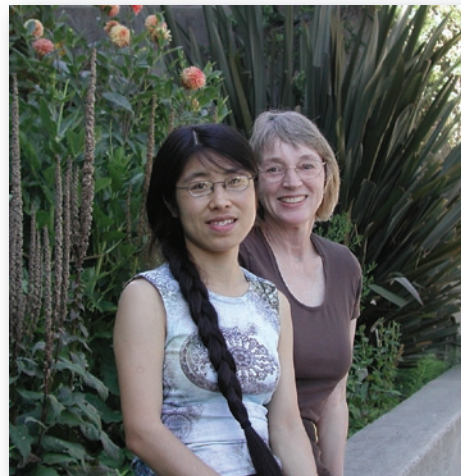
SHENFU DONG

Shenfu Dong knew the University of Washington School of Oceanography by reputation before deciding to come to the U.S. from China for graduate studies. When her application to the school's Ph.D. program was seen by Principal Oceanographer Kathie Kelly, she sent a few of her papers to Shenfu to begin the recruitment process. Shenfu was interested in using satellite data in oceanographic research—the core of Kelly's contributions to the field—and when Shenfu also remembered that she had cited one of Kelly's papers in her Master's thesis, her decision to come to APL-UW was made.

Shenfu is evaluating the role of ocean circulation in the variations of upper ocean heat content and temperature in the Gulf Stream. This region is important to climate because it is an essential component of the North Atlantic Ocean's 'conveyor belt' of heat poleward. This region makes the largest contribution to the net global annual flux of heat from the ocean to the atmosphere.

She has used satellite altimeter data to track changes in regional sea surface height. As water heats, it expands, and as it cools, it contracts, affecting the height of the sea surface. The TOPEX/Poseidon spacecraft's radar altimeters measure the precise distance between the satellite and sea surface. On its northward trek, some of the Gulf Stream flow is captured in a recirculation gyre. During the 1990s wintertime sea surface height in the gyre varied cyclically on a 4–8-year scale. Combined with hydrographic data and numerical modeling, Shenfu's research has demonstrated how the ocean is able to store excess heat and sustain sea surface temperature anomalies long enough to impact climate. The story constructed from these results is clearly one of excess heat stored in the ocean causing large fluxes to the atmosphere, rather than the ocean responding passively to atmospheric fluxes.

Shenfu notes that she has come to "... realize more and more how important it is to have a great mentor. I read a book recently about how to survive in a science career, and much of what I read had been taught to me by Kathie over the past several years. I believe my decision to come here and to study under her supervision is the smartest thing I have ever done."



Oceanography Ph.D. student Shenfu Dong, here with advisor Kathie Kelly, will complete her degree in early 2004.



Wendy Ermold prepares to 'drive the CTD' aboard the USCGC Polar Star in the Chukchi Sea.

WENDY ERMOLD

Wendy Ermold is a physicist in the Laboratory's Polar Science Center. She is also a graduate student in applied physics. What caught Senior Oceanographer Mike Steele's attention when he read her cover letter for the physicist position in 1999 was the enthusiasm she conveyed. "I love physics, and I'm a researcher at the core," she wrote. Wendy has excelled as a member of the center's science team and her dedication to physics and research has propelled her into the graduate program in the Physics Department. She has been able to work toward her graduate degree through the tuition exemption program offered to University of Washington staff.

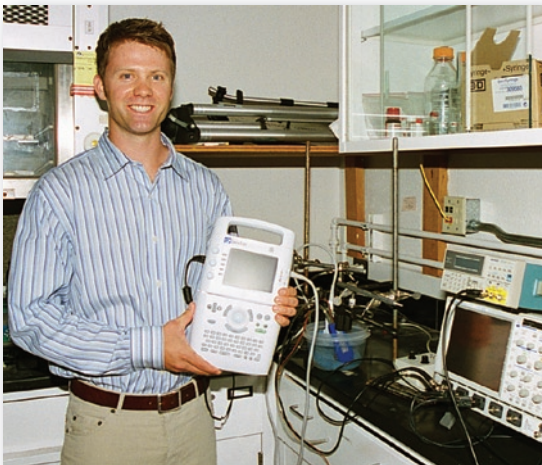
Wendy has been a team member on several field experiments—work that has been invaluable to her studies and thesis research. She was one of three graduate students with no sea-going experience (greenies) who were members of the science team aboard the *Polar Star* during the cruise to the Chukchi Borderland in summer 2002. Cruise Chief Scientist Rebecca Woodgate reported that "Wendy quickly and smoothly picked up the multitude of tasks thrown at her—water sampling, filing of protocols, preparing instruments, downloading data—and progressed to the highest responsibility of 'driving the CTD'."

Covering so many tasks on the cruise was a great opportunity, especially in that Wendy gained experience with the Lowered Acoustic Doppler Current Profiler, which measures upper ocean currents. This expertise led to an invitation to work with Lead Scientist Robin Muench at the ONR-sponsored Beaufort Sea ice camp. There, in spring 2003, she and colleagues lived and worked for two weeks at a camp on the frozen ocean 190 miles northeast of Prudhoe Bay, Alaska.

"My expeditions in the Arctic have been fantastic! It was really a lot of fun to be part of a group of scientists working toward the goal of figuring out what's actually going on up in the Arctic." Her enthusiasm for research has naturally led her to pursue data collection operations in the field. Wendy has completed the course work required for her M.S. degree in applied physics—focused toward physical oceanography—while working full time and traveling into the field several weeks at a stretch. Her combined determination to conduct research through direct observation and to expand her scientific expertise in the laboratory and classroom is the hallmark of a fine, young scientist and a great asset to the Laboratory.

NEIL OWEN

Devices resulting from electrical engineering student Neil Owen's work at the Center for Industrial and Medical Ultrasound may someday be found in orbiting space stations and speeding ambulances. Neil's path from a career in industry to graduate studies in electrical engineering and research at CIMU has been motivated by the "... chance to learn more and apply it to a cause that will ultimately save lives. This is a very exciting environment."



Neil Owen displays an ultrasound imager in his lab.

Neil is building a compact, self-contained, image-guided high intensity focused ultrasound (HIFU) hemostasis device to support a joint NASA and NIH project (see "Ultrasonic Medicine in Space" on page 18). He has collaborated with several Laboratory engineers to build a small, efficient power supply, develop a transducer that allows dynamic depth control, and an image-analysis algorithm that recognizes the HIFU-treated area—segmenting and sizing it. He has also devised methods to synchronize the HIFU system with any commercially available and unmodified ultrasound imager. His advisor, Engineer Mike Bailey, credits Neil with "... enabling us to dramatically reduce the size, weight, and complexity of an image-guided system and

move it toward a single, easy-to-use but multifunctional device.”

While engaged in important research, Neil is lauded as an outstanding student who contributes to the collegiality of CIMU labs. “Neil helps direct the work of undergraduates in the lab and is an expert aide on electrical engineering homework,” says Bailey. Neil notes that in return, because the students have such diverse backgrounds, he receives guidance on physics, mechanics, and acoustics.

Neil and Bailey are also effective forces in enhancing the Laboratory’s sharing of science through educational outreach. Their ultrasound demonstrations are favorites of the high school and college student groups that are frequent Laboratory visitors.

A highlight of Neil’s academic career was representing APL-UW at the fall 2002 Acoustical Society of America meeting where he presented his work on detecting and segmenting HIFU lesions in an ultrasound image. He is nominated to be a student council representative for the society’s physical acoustics technical committee as well.

Earning his M.S.E.E. degree in 2003, Neil is continuing studies toward a Ph.D. in Electrical Engineering and is working toward commercial development of the ultrasound image-guided HIFU hemostasis device.

DARIN SOUKUP

At the 2003 spring meeting of the Acoustical Society of America, Darin Soukup presented a poster on recent research results on acoustic scattering of low-frequency sound in shallow water environments—an especially challenging environment because of the acoustic interactions with rough sea surfaces, complex water volumes, and variable sediments on the sea bottom. Describing his research with advisor Bob Odom, Darin says, “Through theoretical and numerical work, we attempt to model seismo-acoustic wave propagation in a realistic shallow water environment where anisotropy, gradients, discontinuities, and random heterogeneities may be present.”

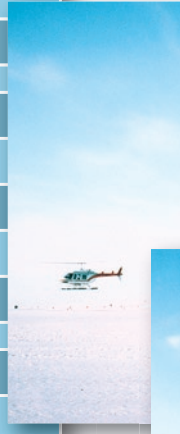
Seismic energy in the ocean—undersea earthquakes and volcanism, for example—is converted to acoustic energy that propagates efficiently across entire ocean basins. Several factors, including the rough sea bottom and low-velocity sediment covers, scatter the energy from high- to low-order modes, which have their maximum amplitudes in the SOFAR channel. Heterogeneous anisotropic media such as marine sediments are especially effective scatterers. Understanding the propagation of seismo-acoustic waves in shallow water environments then relies on treating the bottom and sub-bottom as elastic solids, and representing the ocean acoustic signal as a superposition of modes. Darin explains, “It is into this framework that we are able to incorporate the effects of rough surface scattering, anisotropy, and volume scattering.”

Bob Odom recruited Darin after seeing his graduate application because his background in physics and mathematics at California Polytechnical State University made him a good fit with Odom’s research programs. Not long after Darin arrived, Odom asked him to figure out how to run a program that computes the elastic modes of an anisotropic half-space. A colleague at another university wrote the program and published a paper on it, but because the tensor notation in the paper was very compact, Darin derived the results for himself and worked out all the elements of the tensors so he could compare them with the code. He found a number of bugs in the code, and then went on to add a section so that a realistic ocean model could be added to the upper layers. “When I saw the tenacity and careful attention to detail,” notes Odom, “I knew I had a truly first-rate graduate student!”

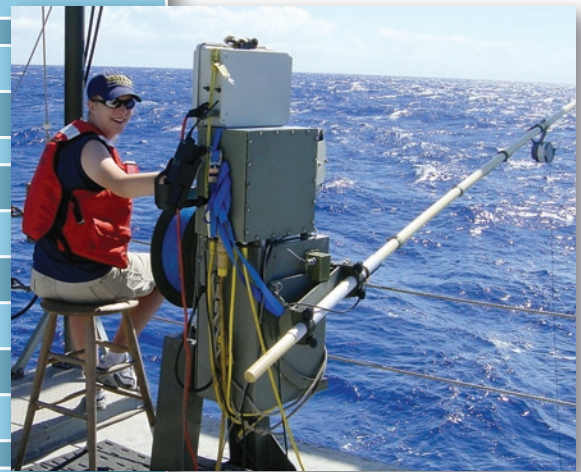


Darin Soukup earned a Ph.D. in Earth and Space Sciences in 2003.

GRADUATE STUDENTS, THEIR RESEARCH TOPICS AND ADVISORS		
Alana Althaus	<i>Internal tide radiation from Mendocino Escarpment</i>	Kunze
Ajay Anand	<i>Processing algorithms for ultrasound image-guided HIFU therapy</i>	Bailey & Kaczkowski
Oleg Babko	<i>Improving ice thickness distribution equations</i>	Rothrock
Abdullah Bamasoud	<i>Remote sensing of coastal filaments in the Arabian Sea</i>	Lee
Glenn Carter	<i>Turbulent mixing near rough topography</i>	Gregg
Arthur Chan	<i>Ultrasound image-guided HIFU treatment of uterine fibroids</i>	Vaezy
Wen-Shiang Chen	<i>Fragmentation thresholds, inertial cavitation, and bioeffects of ultrasound contrast agents</i>	Matula
Indranil Chowdhury	<i>Modeling of ice sound radar antenna characteristics</i>	Winebrenner
Robb Contreras	<i>Rain effects on microwave backscatter from the sea surface</i>	Plant
Shenfu Dong	<i>Upper ocean heat budget in the Gulf Stream region</i>	Kelly
Eric Ellsworth	<i>Internal waves in Knight Inlet</i>	D'Asaro & Henyey
John Flynn	<i>Array-based techniques for underwater acoustic communication</i>	Fox
Ruth Fogelberg	<i>Infrared and microwave measurements of ocean swell modulation of microbreaking</i>	Jessup
Jessica Foley	<i>Treatment of severe neural spasticity using HIFU</i>	Vaezy
Jing-Feng Guan	<i>Optical and acoustical imaging of small coated and uncoated bubbles</i>	Matula
Dan Hayes	<i>Heat and salt balance of the upper ocean beneath a melting ice cover</i>	Morison
Robert Huang	<i>Tissue pulsatility imaging and its application to prostate cancer detection</i>	Beach
Joo-Ha Hwang	<i>Ultrasound-induced vascular bioeffects</i>	Brayman & Crum
Marlene Jeffries	<i>Dynamics of fronts and filaments in the northern and central Adriatic Sea</i>	Lee
Chuanli Jiang	<i>Impact of scatterometer wind measurements on the tropical Pacific heat budget</i>	Kelly
Floyd Karp	<i>Ultrasound-assisted anesthesia</i>	Vaezy
Wayne Kreider	<i>Modeling and control of cavitation in therapeutic ultrasound</i>	Vaezy & Bailey
John Kucewicz	<i>Doppler ultrasound measurement of pulsatile strain in solid tissue due to perfusion</i>	Beach
Barry Ma	<i>Underwater acoustic signal of rainfall</i>	Nystuen
Joseph MacGregor	<i>Radar sounding of ice sheets</i>	Winebrenner
Jennifer MacKinnon	<i>Internal waves and mixing on the New England continental shelf</i>	Gregg
John Mickett	<i>Near-inertial internal waves in the East Pacific warm pool</i>	Gregg
Debashis Mondal	<i>Wavelet analysis of gappy time series</i>	Percival
Marie Nakazawa	<i>Characterization of lesions growing in time</i>	Bailey, Kaczkowski, & Crum
Neil Owen	<i>Ultrasound-guided HIFU therapy systems</i>	Bailey, Kaczkowski, & Crum
Kapil Phadnis	<i>Dynamics of microbreaking waves measured with infrared imagery</i>	Jessup
Sandy Poliachik	<i>Mechanisms of HIFU-induced platelet activity</i>	Crum
Tyrone Porter	<i>Effect of ultrasound and membrane-disruptive polymers on cell membranes</i>	Crum
Adrian Prokop	<i>Polyacrylamide hydrogel as a coupling medium for therapeutic ultrasound</i>	Vaezy
Dahlia Sokolov	<i>Cavitation control in lithotripsy</i>	Crum
Darin Soukup	<i>Seismo-acoustic wave propagation in shallow water</i>	Odom
Elizabeth Steffen	<i>Convection in the Labrador Sea observed with fully Lagrangian floats</i>	D'Asaro
Zolton Szuts	<i>Analysis of electric field measurements in the North Atlantic current</i>	Sanford
Juan Tu	<i>Cavitation from ultrasound contrast agents in vitro and in vivo</i>	Matula
Maya Whitmont	<i>A global characterization of internal-wave energy, energy flux, and mixing</i>	Alford
Eleanor Williams	<i>Signatures of internal wave parametric subharmonic instability</i>	Kunze
Mike Yargus	<i>Acoustics of porous media</i>	Jackson
Jonathan Yuen	<i>Characterization of lesion formation in a tissue-mimicking phantom</i>	Vaezy
Vesna Zderic	<i>Enhanced drug delivery to the eye using ultrasound</i>	Vaezy



Undergraduate student Dan Dyer documented research in the Arctic.



Oceanography graduate student Maya Whitmont

UNDERGRADUATE STUDENTS, THEIR RESEARCH TOPICS AND ADVISORS		
Thomas Anderl	<i>Visualizing environmental impacts of weather and uncertainty in weather forecasting</i>	Kerr
Brett Anderson	<i>Therapeutic application of HIFU in the brain</i>	Mourad
Joel Bolstad	<i>ATOC/NPAL data management and archiving</i>	Mercer
Jason Bush	<i>Thermal and lesion imaging of HIFU near vessels</i>	Bailey & Kaczkowski
Irene Chin	<i>Acoustic rain gauge and ARGO float</i>	Nystuen
Stephanie Hoi Ching Chung	<i>Attenuation imaging of HIFU in tissues</i>	Bailey & Kaczkowski
Elizabeth Dahl	<i>Therapeutic HIFU treatment of brain tumors</i>	Mourad
Peter Derrick	<i>Ultrasound imaging of organ displacement in micro-gravity</i>	Bailey
Zachary Frazier	<i>Theoretical, numerical and observational studies of coastal ocean electrodynamic</i>	Tyler & Winkel
Nick Fuller	<i>Upward looking sonar data analysis</i>	Moritz
Erin Graf	<i>Frequency sweeping to control cavitation in ultrasound therapy</i>	Bailey
Robyn Greaby	<i>Endoscopic HIFU and vascular flow phantoms for HIFU hemostasis</i>	Vaezy
David Halaas	<i>Medical applications of lithotripter</i>	Bailey & Kaczkowski
Jeffrey Harris	<i>Inverting SONAR data for sediment interface dynamics</i>	Williams
Eileen Hash	<i>Theoretical, numerical and observational studies of coastal ocean electrodynamic</i>	Tyler & Winkel
Robert Held	<i>Ultrasound image-guidance of HIFU therapy and transvaginal HIFU arrays</i>	Vaezy
Justin Huff	<i>Computer systems administration and data acquisition systems for environmental radars</i>	Plant
Grace Huynh	<i>Develop a water circulation system for transvaginal HIFU device</i>	Vaezy
Daniel Juarez	<i>Modeling effect of acoustic waveform on bubble oscillation</i>	Bailey
Jeong-In Kang	<i>Data analysis of HOME Nearfield Experiment</i>	Gregg & Winkel
Sanjeevani King	<i>Analysis and modeling of radar backscatter from the sea surface, system calibration</i>	Lettvin
Brian Lee	<i>Analysis of sea ice concentration from microwave satellite data</i>	Rigor
Melinda Lopez	<i>Ocean wave spectral modeling</i>	Lettvin
Brian MacConaghy	<i>Nuclear emissions from cavitation bubbles</i>	Matula
Kyle MacDonald	<i>Separating cavitation from acoustic nonlinearity in enhanced ultrasound</i>	Bailey
Nathan Miller	<i>In vivo cavitation detection in lithotripsy</i>	Bailey
Ben Monnahan	<i>Visualizing environmental impacts of weather and uncertainty in weather forecasting</i>	Kerr
Madhu Narayanan	<i>Computer programming and data analysis</i>	Yu
Lisa Nguyen	<i>Treatment of neurological disorders using therapeutic HIFU in the brain</i>	Mourad
Adrienne Noble	<i>Visualizing environmental impacts of weather and uncertainty in weather forecasting</i>	Kerr
Ryan Ollos	<i>Investigation of blood-brain barrier opening using HIFU</i>	Mourad
Cate Olson	<i>Analyze airborne measurements of radar backscatter and emission at high winds</i>	Lettvin
Eileen Peery	<i>Theoretical, numerical and observational studies of coastal ocean electrodynamic</i>	Tyler
Brian Piening	<i>Computer programming for the Sonar Environmental Parameter Estimation System</i>	Ganse
Nathan Ratliff	<i>Visualizing environmental impacts of weather and uncertainty in weather forecasting</i>	Kerr
Justin Reed	<i>Overpressure to suppress cavitation in ultrasound therapy for NASA</i>	Bailey & Kaczkowski
Casey Schneider-Mizell	<i>Climatology of ocean electrical conductivity</i>	Tyler
Alireza Shahrazad	<i>Mechanical focusing for HIFU</i>	Vaezy
Jason Shirley	<i>Environmental radar design and construction</i>	Plant
Chris Siani	<i>Environmental radar design and construction</i>	Plant
Matt Stumbaugh	<i>Puget Sound underwater ambient sound</i>	Nystuen
Laurence Tomsic	<i>Shear strength of tissue phantoms before and after HIFU</i>	Bailey & Kaczkowski
Thanh Tranh	<i>Radar backscatter statistics for non-Bragg sea surface scattering</i>	Lettvin
Sara Vaezy	<i>Blood-brain barrier opening with HIFU</i>	Mourad & Martin
Marcus Wallace	<i>Climate change data analysis</i>	Rigor
Kelly Yedinak	<i>Radar backscatter statistics for non-Bragg sea surface scattering</i>	Lettvin



Oceanography graduate student and Fulbright Fellow Abdullah Bamasoud



Bioengineering graduate student Vesna Zderic

Honors, Visitors and Events

2001

Director **Bob Spindel** received the Walter Munk Award, presented by The Oceanography Society, Office of Naval Research, and Office of the Oceanographer of the Navy. Principal Engineer **Darrell Jackson** (retired) was presented the Acoustical Society of America's Pioneers of Underwater Acoustics Medal. Principal Oceanographer **Scott Sandgathe** was named Fellow of the American Meteorological Society.

Senior Engineer **Warren Fox** was named a Senior Member of the IEEE. Senior Engineer **Dan Rouseff** was a Senior Visiting Fellow to the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge and was selected for the Scientific Advisory Board of International Acoustical Imaging Symposia.

Senior Engineer **Chris Jones** received a Special Research Grant for Entry Level Faculty and Research Associate **Todd Hefner** a Postdoctoral Fellowship, both from the Office of Naval Research.

The Laboratory hosted several distinguished visitors. They were:

- **Rear Admiral Jay M. Cohen**, Director, Test and Evaluation and Technology Requirements; Chief of Naval Research; Deputy Commandant Headquarters, USMC
- **Rear Admiral Michael A. Sharp**, Program Executive Office, Mine and Undersea Warfare
- **James C. Meng**, Executive Director, Naval Undersea Warfare Center Division, Keyport
- **Captain Douglas Roark**, Director of Acquisitions, Office of Naval Research
- **Robert Silverman** and **C.C. Everley** from the Office of Naval Research regional office
- **Penny Dalton**, Technical Director, Consortium for Oceanographic Research and Education
- Congressional Representative **Jim McDermott** and **Jane Saunders**

2001–2002 VISITORS, THEIR AFFILIATIONS AND APL-UW HOSTS

Mohamed Atmane	<i>Trinity College, Ireland</i>	Jessup
Cecilia Bitz	<i>Univ. Corp. for Atmospheric Research</i>	Moritz
Kevin Briggs	<i>Naval Research Laboratory, Stennis</i>	Thorsos
Sungwoon Choi	<i>Kyungwon Univ., South Korea</i>	Percival
Tim Fristedt	<i>Swedish Defense Research Agency</i>	Sanford
Martin Gade	<i>Institut für Meereskunde, Germany</i>	Plant
Anatoliy Ivakin	<i>N.N. Andreev Acoustics Institute, Russia</i>	Jackson
Muhammed Ilyas	<i>Baruna Jaya Technical Services, Indonesia</i>	Gregg
Rolf Käse	<i>Institut für Meereskunde, Germany</i>	Sanford
Vera Khokhlova	<i>Moscow State Univ., Russia</i>	Crum
Cyril LaFon	<i>INSERM, France</i>	Crum
Sophia Olhede	<i>Imperial College, United Kingdom</i>	Percival
Oleg Sapozhnikov	<i>Moscow State Univ., Russia</i>	Crum
A. Sulaiman	<i>Baruna Jaya Technical Services, Indonesia</i>	Gregg
Gail Ter Haar	<i>Royal Marsden Hospital, United Kingdom</i>	Crum
Ruo-Shan Tseng	<i>National Sun Yat-sen Univ., Taiwan</i>	Lien
Frédéric Vivier	<i>Univ. Pierre et Marie Curie, France</i>	Kelly
Grae Worster	<i>Univ. of Cambridge, United Kingdom</i>	Wettlaufer

APL-UW's research programs include collaborations with scientists from University of Washington departments and other national and international institutions.

APL-UW hosted the Navy Laboratory/Center Coordinating Group and University Affiliated Research Center Directors' Meeting.

Mathematician **Ignatius Rigor** received the Laboratory's Graduate Student Fellowship; physics student **Ryan Ollos** was the Hardisty Scholar and also received a University of Washington Mary Gates Endowment Research Training Grant. **Stephanie Chung** was a Mary Gates Endowment Fellowship recipient. Bioengineering student **Dahlia Sokolov** was honored with participation in the Christine Mirzayan Internship Program, National Academy of Sciences.

The APL-UW Director's Award was presented to Senior Research Scientist **Dale Winebrenner** and Innovative Technology Awards went to **Ed Belcher**, **Brad Bell**, **Joe Burch**, **Larry Crum**, **Bob Goddard**, **Bill Hanot**, **Darrell Jackson**, **Peter Kaczowski**, **Steve Kargl**, and **Pierre Mourad**.



Bob Spindel and Rear Admiral Charles H. Griffiths, Jr.



Seaglider demonstration for Admiral Vern Clark



Leo McGinnis

Electrical engineering student **Sanjeevani King** was named Hardisty Scholar and Mathematician **Ignatius Rigor** received the Laboratory's Graduate Fellowship.

There were three recipients of the APL-UW Director's Award: Engineer **Mike Bailey**, Administrator **Dian Gay**, and Instrument Maker Lead **Leo McGinnis**. Bob Spindel presented Innovative Technology Awards to **Mike Bailey**, **Larry Crum**, **Paul Hilmo**, **Roy Martin**, **Pierre Mourad**, **Misty Noble**, **Marla Paun**, **Andy Proctor**, **DJ Tang**, and **Shahram Vaezy**.

Principal Engineer **Peter Dahl** was elected Fellow of the Acoustical Society of America. Senior Physicist **Tom Matula** was named Chair of the society's Physical Acoustics Technical Committee, and Senior Engineer **Shahram Vaezy** won the society's Science Writing by a Professional Prize.

Center for Industrial and Medical Ultrasound Director **Larry Crum** was named Distinguished Visiting Professor, Moscow State University.

Oceanographer **Matthew Alford** won a Young Investigator Program Award from the Office of Naval Research and Physicist **Cecilia Bitz** received the Community Climate System Model Distinguished Achievement Award.

The Laboratory was honored with visits from **Admiral Vern Clark**, Chief of Naval Operations, and **Rear Admiral Charles H. Griffiths, Jr.**, Commander, Submarine Group Nine.

The National Society of Black Engineers named bioengineering student **Tyrone Porter** Graduate Student of the Year. The American Geophysical Union's Outstanding Student Poster Award was won by oceanography student **Glenn Carter** and bioengineering student **Arthur Chan** was nominated for the Prize Paper Award of the American Society for Reproductive Medicine. Oceanography student **Alana Althaus** was presented the UW School of Oceanography Dean A. McManus Excellence in Teaching Award.

Undergraduates **Erin Graf**, **Robyn Greaby**, and **Kyle MacDonald** were all UW Space Grant Scholars.

2002



Tyrone Porter

Personnel

DIRECTORATE

Jeffrey A. Simmen - Director

William T. Bakamis - Assoc. Director, Business and Finance

David L. Martin - Assoc. Director, Program Integration and Development; Principal Oceanographer

Robert T. Miyamoto - Assoc. Director, Applied Research and Technology; Affil. Assoc. Prof., Electrical Engineering

Robert I. Odom, Jr. - Assoc. Director, Education Programs; Principal Physicist; Res. Assoc. Prof., Earth and Space Sciences

Robert C. Spindel - Director Emeritus; Prof., Electrical Engineering; Adj. Prof., Oceanography

Staff

Dian L. Gay - Administrator - Program Operations

Jeanette Marr - Administrative Coordinator

Assigned outside Washington state

Kenneth W. Lackie - Manager

Ronald P. Radlinkski - Principal Physicist

Lilia L. Ramirez - Manager

Joseph M. Ruppert - Principal Physicist

Shelby F. Sullivan - Senior Engineer

OCEAN PHYSICS

Thomas B. Sanford - Chair, Scientific Committee; Principal Oceanographer; Prof., Oceanography

Matthew H. Alford - Oceanographer IV; Affil. Asst. Prof., Oceanography

Stephen J. Bayer - Senior Engineer

Glenn S. Carter - Predoctoral Res. Assoc.

Andrew C. Cookson - Field Engineer

Eric A. D'Asaro - Principal Oceanographer; Prof., Oceanography

John H. Dunlap - Senior Engineer

Jason I. Gobat - Oceanographer IV

Michael C. Gregg - Prof., Oceanography

Ramsey R. Harcourt - Oceanographer IV

Frank S. Henyey - Principal Physicist

Marlene A. Jeffries - Res. Asst.

Eric L. Kunze - Principal Oceanographer; Prof., Oceanography

Craig M. Lee - Senior Oceanographer; Affil. Asst. Prof., Oceanography

Shenghui Li - Res. Assoc.

Ren-Chieh Lien - Senior Oceanographer

John B. Mickett - Predoctoral Res. Assoc.

Jack B. Miller - Principal Engineer

Stephen A. Reynolds - Senior Oceanographer

Robert H. Tyler - Oceanographer IV; Affil. Asst. Prof., Earth and Space Sciences

Maya E. Whitmont - Res. Asst.

David P. Winkel - Oceanographer IV

Staff

Phyllis P. Adams - Fiscal Specialist I

Jeong-In Kang - Student Helper

Sheila S. Ocoma - Fiscal Specialist I

Nancy J. Sherman - Administrator



Tom Sanford

POLAR SCIENCE CENTER

Richard E. Mortiz - Chair, Principal Investigator Council; Principal Oceanographer

Knut Aagaard - Principal Oceanographer; Prof., Oceanography

Roger H. Andersen - Mathematician IV

Oleg Babko - Predoctoral Res. Assoc.

Cecilia Bitz - Physicist IV; Affil. Asst. Prof., Atmospheric Sciences

Indranil Chowdhury - Res. Asst.

Wendy S. Ermold - Physicist I

Andreas Heiberg - Principal Engineer

James M. Johnson - Senior Field Engineer

Christopher Krembs - Oceanographer III

Bonnie Light - Physicist IV

Ronald W. Lindsay - Senior Physicist

James H. Morison - Principal Oceanographer; Affil. Prof., Oceanography

Mark L. Ortmeier - Oceanographer II

Ignatius Rigor - Mathematician III

David A. Rothrock - Principal Res. Scientist; Assoc. Prof., Oceanography; Adj. Assoc. Prof., Atmospheric Sciences

Kay A. Runciman - Mathematician III

Francis J. Sawatzki - Data Control Technician III

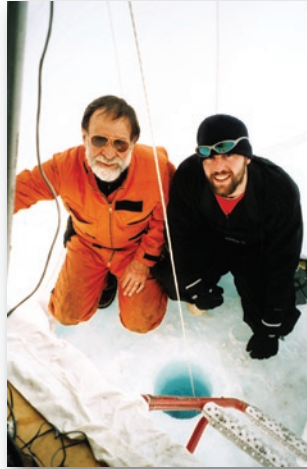
Axel J. Schweiger - Oceanographer IV

Michael Steele - Senior Oceanographer

Harry Stern - Mathematician IV

Dean J. Stewart - Field Engineer

Vadim L. Tsemekhman - Postdoctoral Scientist
 Mark R. Wensnahan - Physicist III
 Dale P. Winebrenner - Senior Res. Scientist; Res. Assoc. Prof., Electrical Engineering; Adj. Res. Assoc. Prof., Earth and Space Sciences
 Rebecca A. Woodgate - Res. Asst. Prof., Oceanography
 Yanling Yu - Oceanographer IV
 Jinlun Zhang - Oceanographer IV



Jamie Morison and Dan Dyer

Staff

Mari S. Forster - Program Coordinator
 Suzan V. Huney - Administrator
 Brian M. Lee - Student Helper
 Beverly A. Pelto - Manager

AIR-SEA INTERACTION & REMOTE SENSING

Kathryn A. Kelly - Chair; Principal Oceanographer; Affil. Prof., Oceanography
 William E. Asher - Senior Oceanographer
 Robert F. Contreras - Predoctoral Res. Assoc.
 Aseem D. Datar - Res. Asst.
 Suzanne Dickinson - Oceanographer III
 Shenfu Dong - Predoctoral Res. Assoc.
 Brian D. Dushaw - Senior Oceanographer; Affil. Asst. Prof., Oceanography
 Kathleen A. Edwards - Oceanographer III
 Ralph C. Foster - Physicist IV
 Kenneth O. Hayes - Engineer IV
 Andrew T. Jessup - Principal Oceanographer; Affil. Assoc. Prof., Civil Engineering and Mechanical Engineering
 Chuanli Jiang - Res. Asst.
 William C. Keller - Senior Physicist
 Ellen E. Lettvin - Oceanographer IV
 Trina Litchendorf - Res. Aide II
 Jeffrey A. Nystuen - Principal Oceanographer; Affil. Assoc. Prof., Oceanography
 Kapil R. Phadnis - Res. Asst.
 William J. Plant - Principal Res. Scientist; Affil. Prof., Atmospheric Sciences
 Michael R. Zarnetske - Predoctoral Res. Assoc.

CENTER FOR INDUSTRIAL & MEDICAL ULTRASOUND

Lawrence A. Crum - Assoc. Director; Res. Prof., Electrical Engineering and Bioengineering
 Ajay Anand - Predoctoral Res. Assoc.
 Marilee A. Andrew - Senior Engineer
 Michael R. Bailey - Engineer IV
 Bradley M. Bell - Principal Mathematician
 Andrew A. Brayman - Senior Res. Scientist
 Francesco Curra - Engineer IV
 Barbrina Dunmire - Engineer III
 Jingfeng Guan - Predoctoral Res. Assoc.
 Paul R. Hilmo - Physicist I
 James M. Hossack - Engineer III

Lingyun Huang - Predoctoral Res. Assoc.
 Peter J. Kaczkowski - Senior Engineer
 Steven G. Kargl - Senior Physicist
 Wayne Kreider - Predoctoral Res. Assoc.
 John C. Kucewicz - Predoctoral Res. Assoc.
 Roy W. Martin - Principal Engineer; Res. Prof., Anesthesiology
 Thomas J. Matula - Senior Physicist; Affil. Asst. Prof., Electrical Engineering
 Pierre D. Mourad - Senior Mathematician; Res. Assoc. Prof., Neurological Surgery
 Terrence W. Myntti - Electronics Technician II
 Neil R. Owen - Res. Asst.
 Marla Paun - Engineer IV
 Andrew H. Proctor - Senior Field Engineer
 Frank L. Starr - Res. Manager
 Juan Tu - Predoctoral Res. Assoc.
 Shahram Vaezy - Senior Engineer; Asst. Prof., Bioengineering

ELECTRONIC SYSTEMS DEPARTMENT

Gary L. Harkins - Department Head
 A. John Black - Software Engineer II
 John A. Blattenbauer - Engineer IV
 Clark A. Bodyfelt - Engineer IV
 Matthew R. Carpenter - Engineer III
 William H. Hanot - Senior Engineer
 Benjamin M. Henwood - Senior Engineer
 Robert E. Johnson - Principal Engineer
 William A. Jump - Senior Engineer
 Carl J. Larson, Jr. - Field Engineer
 James C. Luby - Principal Engineer; Affil. Asst. Prof., Electrical Engineering
 Larry D. Nielson - Field Engineer
 J. Aaron Nix-Gomez - Engineer III
 Steven E. Purcell - Engineer III
 Marcelino Soriano - Manager
 Eric W. Strenge - Field Engineer
 Marvin L. Strenge - Principal Engineer
 Robert E. Van Note - Senior Field Engineer



Lori Ferro

ENVIRONMENTAL & INFORMATION SYSTEMS

James W. Pitton - Department Head; Senior Engineer; Affil. Asst. Prof., Electrical Engineering
 Gregory M. Anderson - Senior Engineer
 Michael L. Boyd - Principal Physicist
 Peter M. Brodsky - Engineer IV
 Robert J. Carr - Senior Computer Specialist
 Luca G. Cazzanti - Engineer III
 Judith D. Ellingwood - Senior Engineer
 William J. Felton - Senior Field Engineer
 Warren L.J. Fox - Senior Engineer; Affil. Asst. Prof., Electrical Engineering
 Andrew A. Ganse - Engineer III
 Robert P. Goddard - Senior Physicist
 Edward C. Gough, Jr. - Principal Engineer
 Megan U. Hazen - Engineer III
 Leah Foechterle Heiss - Engineer III
 Julia B. Hsieh - Engineer III
 David W. Jones - Senior Oceanographer
 Richard K. Kerr - Senior Engineer
 Elizabeth Kirby - Engineer IV



Eric Boget and Mike Ohmart

William C. Kooiman - Engineer IV
 David W. Krout - Predoctoral Res. Assoc.
 Charlotte Leigh - Senior Physicist
 Michael Macaulay - Senior Oceanographer
 John J. McLaughlin - Senior Engineer
 Robert T. Miyamoto - Assoc. Director; Affil. Assoc. Prof.,
 Electrical Engineering
 Janet I. Olsonbaker - Engineer IV
 Lane M.D. Owsley - Engineer IV
 Donald B. Percival - Principal Mathematician; Affil. Assoc. Prof.,
 Statistics
 Scott A. Sandgathe - Principal Oceanographer
 Marc S. Stewart - Senior Physicist
 Gordon L. Swartzman - Senior Engineer; Res. Prof., Fisheries
 Troy T. Tanner - Senior Computer Specialist
 Patrick G. Tewson - Engineer III
 Joseph S. Wigton - Engineer IV
 Andreas G. Winter - Predoctoral Res. Assoc.
 Daniel J. Wolkenstorfer - Principal Engineer

OCEAN ACOUSTICS

Kevin L. Williams - Department Chair; Principal Physicist;
 Assoc. Prof., Oceanography
 Rex K. Andrew - Engineer IV
 Catherine Bader - Mathematician IV
 Linda J. Buck - Systems Analyst/Programmer III
 Jee Woong Choi - Res. Assoc.
 Peter H. Dahl - Principal Engineer;
 Res. Assoc. Prof., Mechanical Engineering
 Wm. Timothy Elam - Senior Physicist
 Brian T. Hefner - Res. Assoc.
 Bruce M. Howe - Principal Oceanographer;
 Res. Assoc. Prof., Oceanography
 Anatoliy N. Ivakin - Senior Physicist
 Christopher Jones - Senior Engineer
 James A. Mercer - Principal Physicist; Res.
 Assoc. Prof., Earth and Space Sciences
 Robert I. Odom - Principal Physicist; Res.
 Assoc. Prof., Earth and Space Sciences
 Daniel Rouseff - Senior Engineer
 Darin Soukup - Predoctoral Res. Assoc.
 Dajun Tang - Senior Oceanographer
 R. Lee Thompson - Senior Engineer



Keith Magness

Eric I. Thorsos - Principal Physicist; Affil. Assoc. Prof., Electrical
 Engineering
 Emily A. Ward - Res. Asst.
 Michael A. Wolfson - Mathematician IV
 Ernest T. Young - Principal Engineer

OCEAN ENGINEERING

Russell D. Light - Department Head; Principal Engineer
 Paul A. Aguilar - Field Engineer
 Eric S. Boget - Engineer IV
 Joe A. Burch - Engineer IV
 John B. Elliott - Engineer IV
 Lyle F. Gullings - Senior Field Engineer
 Frederick Karig - Principal Engineer
 Michael F. Kenney - Oceanographer III
 Harold A. Kolve - Principal
 Engineer
 Keith E. Magness - Res. Aide II
 Timothy M. McGinnis - Senior
 Engineer
 Vernon W. Miller - Senior
 Engineer
 Michael A. Ohmart - Field
 Engineer
 Francis G. Olson - Senior Field
 Engineer
 Peter L. Sabin - Senior Field
 Engineer
 Colin J. Sandwith - Principal
 Engineer; Res. Assoc. Prof.,
 Mechanical Engineering
 Jason L. Seawall - Engineer III
 Daniel A. Stearns - Field
 Engineer
 Keith L. Van Thiel - Engineer III
 Michael L. Welch - Senior Engineer
 Timothy Wen - Senior Engineer



*Fran Olson at the ice camp
 on the Beaufort Sea*

APPLIED RESEARCH & TECHNOLOGY SUPPORT

Thomas Anderl - Student Helper (EIS)
 Caitlin K. Anderson - Student Helper (AR&T)
 Robert M. Bolstad - Res. Manager (OA/CIMU)
 Morgan K. Carter - Student Helper (ES)
 Irene Chin - Student Helper (AIRS)
 Lori J. Ferro - Administrative Specialist (CIMU)
 Erin Graf - Student Helper (CIMU)
 April J. Greenwell - Fiscal Specialist (OA/CIMU/OE)
 Sanjeevani King - Student Helper (AIRS)
 Nathan W. Kohagen - Student Helper (AIRS)
 Sanjay K. Lakkad - Student Helper (AIRS)
 Dorothy F. Lowell - Administrative Specialist
 (CIMU)
 Benjamin Monnahan - Student Helper (EIS)
 Adrienne Noble - Student Helper (EIS)
 Ryan Ollos - Student Helper (CIMU)
 Alisa P. Proctor - Helper (CIMU)
 John A. Pyles - Student Helper (EIS)
 Nathan D. Ratliff - Student Helper (EIS)
 Colin H. Saari - Res. Coordinator (OE)
 Laurence C. Tomsic - Student Helper
 Angela D. Van Valkenburg - Administrative
 Specialist (EIS)

Eric T. Walkingshaw - Student Helper (EIS)
 Keith A. Walls - Res. Coordinator (AIRS/OA)
 Timothy R. Whitcomb - Student Helper (EIS)
 William D. Woodman - Engineer IV (ES)
 Lan Yu - Fiscal Specialist (EIS)

ADMINISTRATIVE & TECHNICAL SERVICES

RESOURCES

Gordon K. Glass - Department Head, Resources

Building Services

Ponciano Austria - Maintenance Custodian I
 Jim Fahey - Manager
 O. Ray Hartman - Maintenance Supervisor I
 Stuart R. Woolfield - Maintenance Mechanic II



Jim Fahey

Distributed Computing Services

James S. Anderson - Student Helper
 Stefani P. Banerian - Senior Computer Specialist
 Dan C. Dyer - Student Helper
 David D. Fetrow - Senior Computer Specialist
 Adam L. Morehead - Senior Computer Specialist

Library

Jane M. Doggett - Library Specialist Supervisor
 Leslie A. Harding - Library Specialist I
 Christina Polwarth - Student Helper

Machine Shop

John P. Gutensohn - Instrument Maker III
 Timothy W. Jansen - Instrument Maker III
 Douglas S. Jordan - Instrument Maker III

Milford T. Knutson - Instrument Maker III
 Leo P. McGinnis - Instrument Maker Lead
 Robert L. Prong - Manager
 Richard W. Syverson - Maintenance Mechanic II

Publications

Ronald L. Carnell - Office Asst. III
 Brian S. Rasmussen - Manager
 Kim E. Reading - Graphic Designer

Purchasing & Property Control

John J. Albin - Fiscal Specialist I
 Samantha D. Auflick - Fiscal Technician III
 Peggy K. Buschmann - Manager
 Thomas F. Guthrie, Jr. - Truck Driver I
 Thomas A. Kerrigan - Fiscal Specialist I
 F. Ozan Mizrakli - Fiscal Specialist I
 Johnny W. Siu - Student Helper
 Susan L. Womack - Fiscal Specialist I

Security, Safety & Central Services

Charlotte Boynton - Program Support Supervisor I
 Chris L. Craig - Maintenance Mechanic I
 Mariann DomBek - Office Asst. III
 Kelley P. Knickerbocker - Manager
 Christian Smith - Office Asst. III

Shipping & Receiving

Daniel R. Gyll - Warehouse Worker II
 Michael G. Miller - Program Support Supervisor I

BUSINESS & ADMINISTRATION

William T. Bakamis - Assoc. Director, Business and Finance
 Peggy L. Hartman - Asst. to the Assoc. Director

Financial Information Systems

Larry C. West - Senior Computer Specialist

Financial Management

Kannie Cheung - Fiscal Technician III
 Cheuk Chhann - Program Asst.
 Anne L. Clark - Administrator
 Becky E. Harrison - Fiscal Specialist II
 Anthony J. Nice - Manager
 Tina M. Stremick - Office Asst. III
 Hien D. Tran - Accounting Supervisor

Grant and Contract Administration

Moira G. McCrory - Administrator

Human Resources/Personnel

Robert M. Bratager - Manager
 Linda M. Marsh - Coordinator

—personnel as of July 2003

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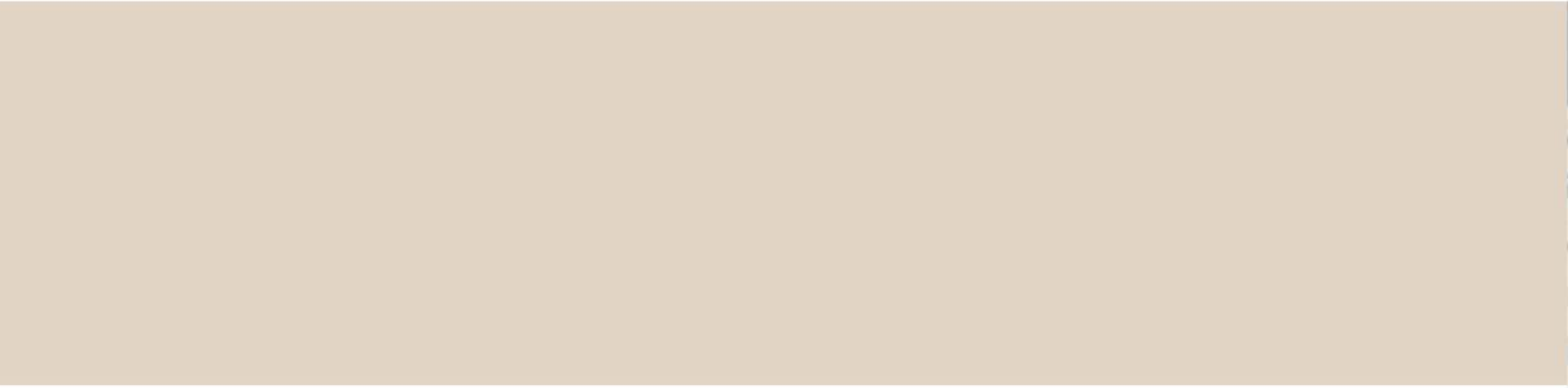
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