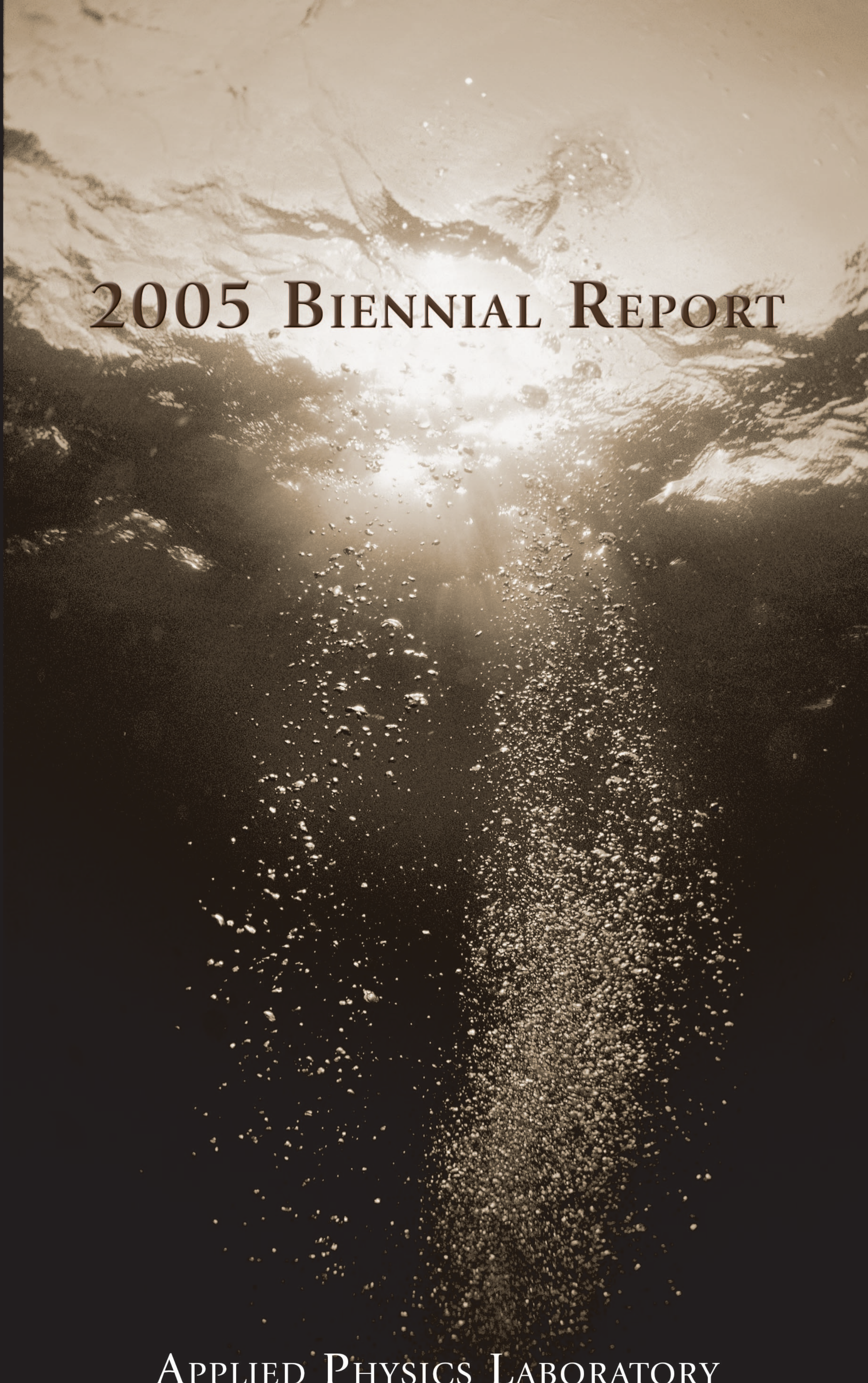
APL-UW

2005 Biennial Report



Applied Physics Laboratory

College of Ocean and Fishery Sciences
University of Washington

From the Director


Mary Levin

In my first two years as the Director of the Applied Physics Laboratory of the University of Washington, my appreciation has deepened for the unique attributes of this extraordinary organization. This Laboratory is an integrated community of talented individuals, whose collective efforts produce remarkable insights and accomplishments. A small sampling of these from the past two years is highlighted in this report.

APL-UW continues to advance its leadership role in the core research areas upon which it has built an outstanding reputation—polar science, ocean physics and engineering, acoustical and remote sensing, medical and industrial ultrasound, and environmental information and electronic systems. Increasing success is reflected in research funding, which has risen to a notably higher level from just a few years ago. Our researchers' ability to collect observations in laboratory settings and in the field, especially their successful and superb performance at sea, continues to be one of our most noteworthy strengths.

APL-UW finishes this biennium as a partner in several exciting new areas that will expand directions for future research and development—high-performance photonics technology, networked (fixed and mobile) undersea systems, techniques to counter improvised explosive devices, and solutions to environmental and health challenges. Several strategic initiatives inaugurated over the past biennium will enhance Laboratory performance. We plan to build up our physical infrastructure and to foster greater integration and interaction with our parent institution, and our regional and national peers and partners.

As we move ahead in service of our generous research sponsors—especially the U.S. Navy—I am certain that APL-UW will continue to make exceptional contributions to the security and prosperity of our nation.

Jeff Simmen

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The Laboratory

At a Glance

Over six decades ago the Applied Physics Laboratory of the University of Washington was founded by the U.S. Navy as one of four university laboratories to serve the Navy and federal government. From this beginning during WWII, the Laboratory initiated acoustic studies and oceanographic research programs to understand how variations in the ocean environment affected the performance of Navy systems.

Today APL-UW enjoys a reputation as a world leader in the areas of polar science, ocean physics and engineering, acoustical and remote sensing, medical and industrial ultrasound, and environmental information and electronic systems. Our success is due to a commitment to mix basic and applied research, to balance among theory, experiment, and instrument development, to foster international cooperation, and to train the next generation of scientists and engineers.

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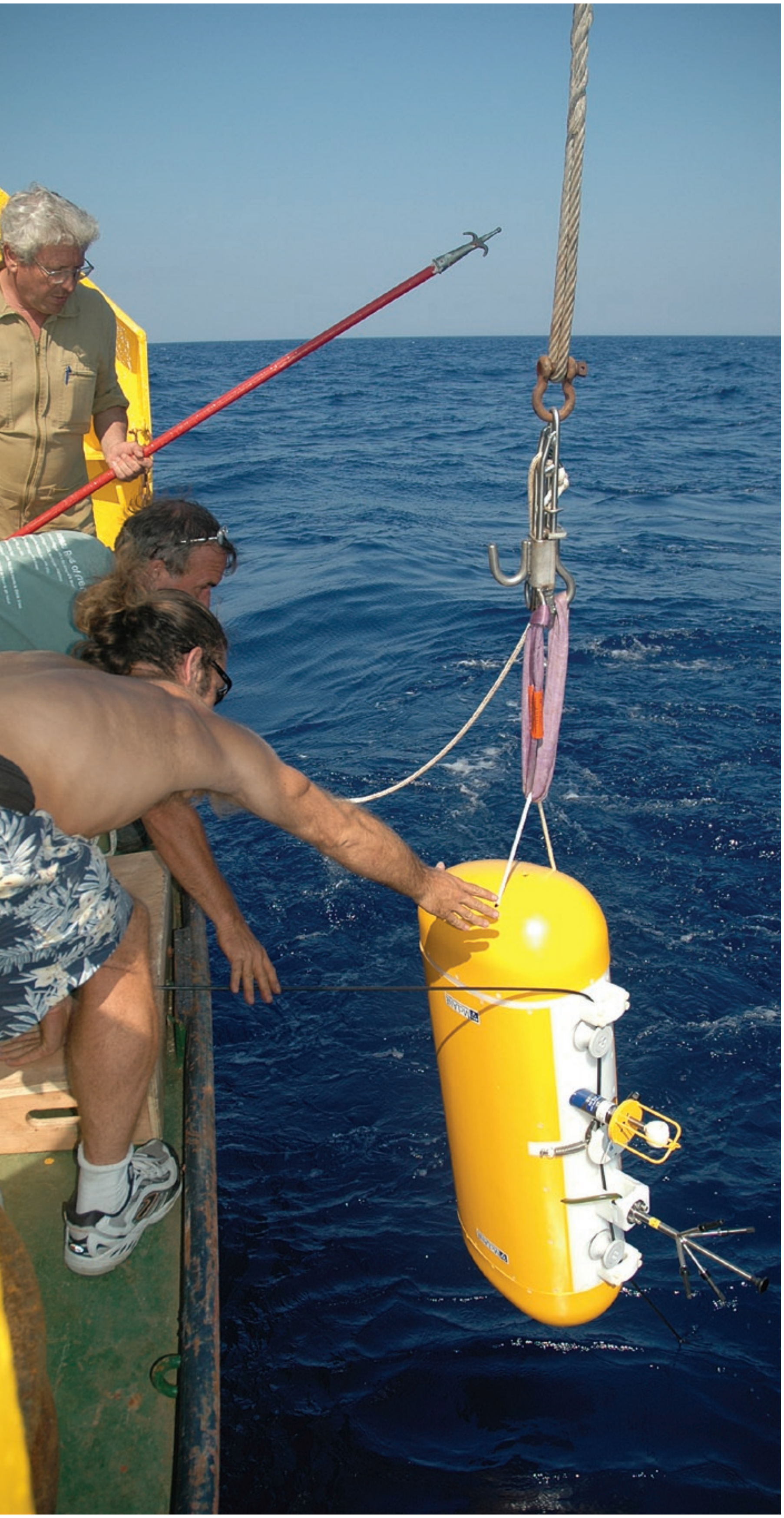
In the Field

A hallmark of the Laboratory is its ability to design, build, stage, and field deploy the technology required to pursue advanced research projects. Several long-term programs observe ocean climate in the Arctic. For the fifth year researchers at the North Pole Environmental Observatory made aerial hydrographic surveys across the Arctic Basin and deployed buoys on the drifting ice. A mooring, consisting of 2.5 miles of cable outfitted with over one dozen instruments at the North Pole, is recovered and replaced anew each April. The observatory is funded through 2008.

The freshwater flux out from the Arctic Ocean modulates deepwater formation in the Labrador Sea, which drives global ocean circulation. One research program focused on this freshwater flux is collecting hydrographic samples at a critical 'switchyard' north of Ellesmere Island, and another is taking measurements with moored instruments and the autonomous undersea vehicle Seaglider in Davis Strait.



The Seagliders deployed in Davis Strait were at sea for nearly 200 days, and a pair sent on a mission across a portion of the Pacific Ocean as part of the North Pacific Acoustic Laboratory program covered 1,860 miles—both are new endurance records for autonomous undersea vehicles. The Pacific deployment was in conjunction with a month-long cruise on the R/V *Melville*, on which an APL-UW team suspended a low-frequency acoustic source from the ship at stations spanning over 3000 km across the North Pacific. Signals were received on several assets, including a U.S. Navy system of hydrophone arrays. Scientists are examining the data to learn more about the effects of ocean internal waves on long-range acoustic propagation.

A team collected at-sea data in the Aegean Sea in fall 2004 that will be used to improve models of coastal internal waves and mixing processes. Measurements were taken over several months by moored instruments including those that crawl up and down the mooring cable to record data throughout the water column. Another successful mooring deployment, this time in the Ionian Sea, placed hydrophones at several depths to listen for ambient noise, including the sound of raindrops on the ocean surface. The rainfall can be quantified (drizzle is distinct from large drops) from these recorded sounds and then compared to radar and rain gauge measurements from nearby land stations.

An underwater rail structure and acoustic transmission tower were placed on the seafloor just off the Florida coast to test how sonars can detect mine-like objects buried in the sandy sediments. Laboratory divers spent hours setting and retrieving targets and instruments in the research area. Even though operations during the Sediment Acoustics Experiment 2004 (SAX04) were interrupted several times during the hurricane season of 2004, the data promise a tremendous return of scientific insight.

Honors

APL-UW was honored with distinguished visitors during the past biennium. The **Honorable Norm Dicks**, Congressman of Washington's sixth district, paid a special visit to the Laboratory in August 2005. He was apprised of several ongoing programs, especially those of relevance to naval operations. The University of Washington's new president, **Dr. Mark Emmert,** was given a tour and briefed on current research and development efforts. Similarly briefed during their visits were **Robert Winokur**, Technical Director, Office of the Oceanographer of the Navy, and **Dr. Stephen Lubard**, Technical Director, Office of Naval Research. The Laboratory also hosted the Chief of Naval Operations Strategic Studies Group; they visited to assess technologies for future transition to the fleet.

Our newly renovated Hardisty Conference Center hosted the 2004 Department of Defense University Affiliated Research Centers (UARC) Directors' Meeting; Jeffrey Simmen and the other directors met to share science and technology developments and to plan UARC strategies to meet future DoD needs. Since then several science workshops and meetings sponsored by the Office of Naval Research, National Science Foundation, and other federal mission agencies have been held in the state-of-the-art facility.

Awards

Several Laboratory scientists and engineers received prestigious accolades over the past two years. The Acoustical Society of America presented its Medwin Prize in Acoustical Oceanography to **Jeffrey Nystuen**, and its R. Bruce Lindsay Award to **Michael Bailey**; **Nystuen**, **Steven Kargl**, and **Thomas Matula** were named fellows of the society. **Fred Karig** received the Meritorious Public Service Award from the Department of the Navy for his unparalleled expertise and leadership in establishing ice camps for arctic research operations. The U.S. Geological Survey presented their John Wesley Powell Award to **William Plant** for his work monitoring river discharge with radars (see *Radars Above Rivers* on p. 20).

Research Highlights

The Life of Sea Ice

In an environment that supports a thick cover of sea ice, it is hard to imagine life within the ice. But there is. Christopher Krembs, Oceanographer at the APL-UW Polar Science Center, studies how microscopic organisms that use sea ice as habitat affect the physical properties of the ice and are critical to the marine food web in the Arctic. His research, funded by grants from the National Science Foundation, is the first in this inherently interdisciplinary field.

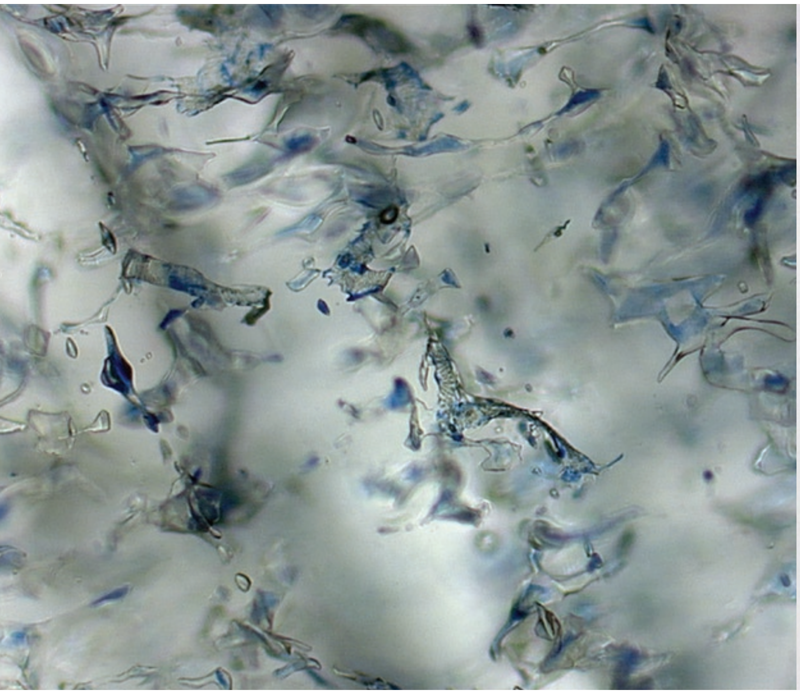
When sea ice forms, the salt from the water is not incorporated into the ice crystals. Instead, pores or pockets of highly concentrated salty water are engulfed into the matrix. Under the influence of gravity, these brine pockets tend to drain downwards toward the underlying ocean, creating channels that grow in width over time. Microbial life thrives in these small, nutrient-rich brine pockets and channels.

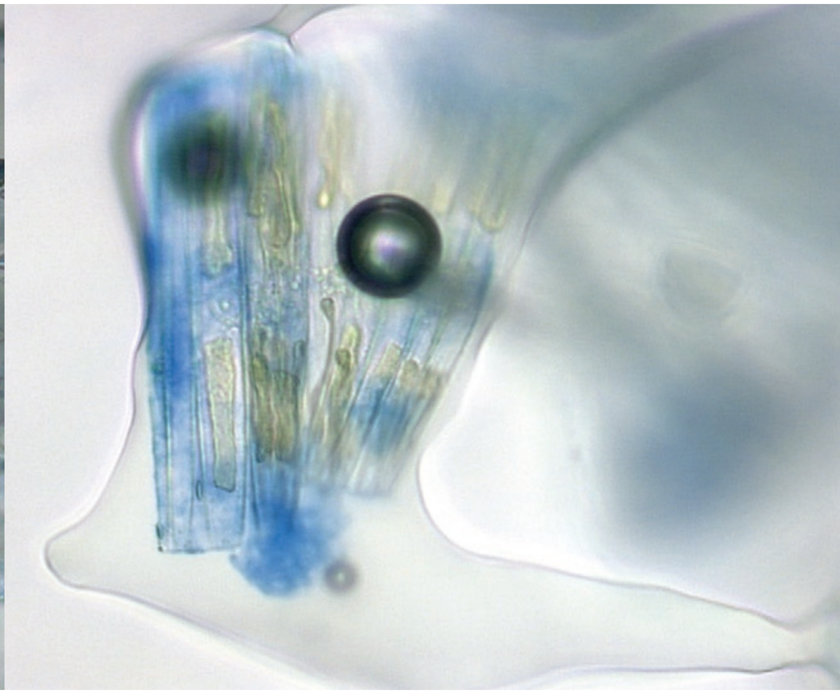
Microbial communities include bacteria, fungi, and protozoa, but Krembs has focused on single and chain-forming diatom species of algae. Naturally, and in particular under the stress of subfreezing conditions, the diatoms produce slime, an exopolymeric substance (EPS) actually, which protects them from the elements and cushions them in the ice–brine channels. EPS retains brine in the ice, which maintains a larger liquid habitat, and increases ice porosity. This change in sea ice microstructure alters its mechanical properties, such that the ice goes from brittle to malleable. "Slimy sea ice is actually mushy when you hold it in your hand," says Krembs.

In the spring, as early as February when the first arctic sunlight shines on the ice pack for short periods each day, the diatoms begin to grow near the ice–water interface at the bottom of the ice. The algae filaments can grow to a meter or more in length, waving into the water below.

Their cryoprotective slime also attaches the algae to the ice sheet, but not directly. Diatoms and their EPS adjust to and modify ice crystal growth and melting, and achieve attachment by entanglement in the ice crystal lattice. The slime cushion, too, sustains the lengthening algae filaments against the shear forces of the ocean currents.

Microphotographs of natural sea ice with blue-stained EPS and diatom cells





In April 2005 Christopher Krembs took students to Barrow, Alaska, to document his field experiments on the landfast ice. Paul Mandeville (video) and Zach Martin (audio), from the Art Institute of Seattle, were part of the collaborative project between APL-UW and the art institute to produce a multimedia presentation on the research. This product of the Laboratory's educational outreach vision is also an important curriculum enhancement for ongoing outreach efforts.

Biofilms like EPS are known to inhibit the flux of heat. Because EPS is found in greatest concentrations at the bottom of the sea ice, the site of most growth and melt, Krembs has questioned whether microorganisms and their slime may retard melting. This could imply that the algae are able to prolong the stability of their habitat as their biomass reaches its maximum in spring and the onset of the melt season.

Sea ice algae account for about one-half of the primary production (photosynthesis) in the Arctic Ocean. Attached to the ice bottom, algae are easily accessible to winter-starved organisms; remaining entangled in the ice effectively prolongs the productive season by about four months. During summer the surface of the ice melts, becoming mostly fresh water. This warmer melt water percolates downward through the ice into one brine pocket, then another, and runs through the channels. They run together, lengthen, and open at the bottom of the ice sheet flushing nutrients and microorganisms into the ocean.

Krembs notes that his research subject has required integration of several disciplines, saying, "Understanding interactions between sea ice microorganisms and their habitat has created a nexus of interdisciplinary research combining organismal physiology, behavior, and ecology with condensed matter and polymer physics—all in the context of climatic change."

A NEW CRYOSCIENCE LABORATORY at APL-UW will maintain temperatures between –30°C and 0°C and house state-of-the-art instrumentation to study physics, chemistry, and biology in low environmental temperatures. The lab's controlled conditions will allow Krembs to isolate the various mechanisms affecting ice algae attachment to the sea ice, as well as the environmental processes that initiate the algae flux from the ice.

Physicist Bonnie Light and Principal Oceanographer Richard Moritz plan to conduct experiments in the new lab on the optical and physical properties of melting sea ice. These will further our understanding of the ice–albedo feedback that modulates how much solar energy is absorbed by or reflected from the ice surface. The lab is a unique experimental and observational system that will make possible major advances for cyroscientists at APL-UW, the University of Washington, and throughout the country.

Atmospheric & Oceanic Factors in Hurricane Ferocity

The 2004 Atlantic hurricane season was historically severe for the state of Florida. In late August, several days before Hurricane Frances made landfall on the eastern Florida coast, APL-UW researchers aimed for a window of opportunity to take atmospheric and oceanic measurements during a hurricane that had never been carried out before. Robotic ocean profiling floats were parachuted from an aircraft in front of the approaching storm and another mission flew researchers and their instruments aboard a NOAA plane through Frances's rain bands and eye wall.

Observations and model simulations predict a hurricane's path reasonably well, but forecasts of hurricane intensity are much less accurate. Frances's intensity fluctuated during her last days at sea and there was concern that the slow moving storm would gain strength as it crossed the warm waters of the Gulf Stream.

Current numerical models of hurricane intensity incorporate wind speed, drag on the ocean surface, and heat flux between the water and air. Sea spray is critical because it transfers heat and momentum from the ocean to the atmosphere, stoking the hurricane's engine. Small calculation errors in the energy transfer from spray can lead to large errors in predicted intensity.

Principal Oceanographer Bill Asher and Researcher Trina Litchendorf fitted a phase Doppler particle analyzer (PDPA) on a NOAA aircraft that is routinely used by the agency to fly reconnaissance and research flights into hurricanes. The PDPA lasers were pointed out a window to measure the size and velocity of spray and raindrops. While a standard device in a lab setting, the instrument had never before been used in an aircraft while flying through a hurricane.

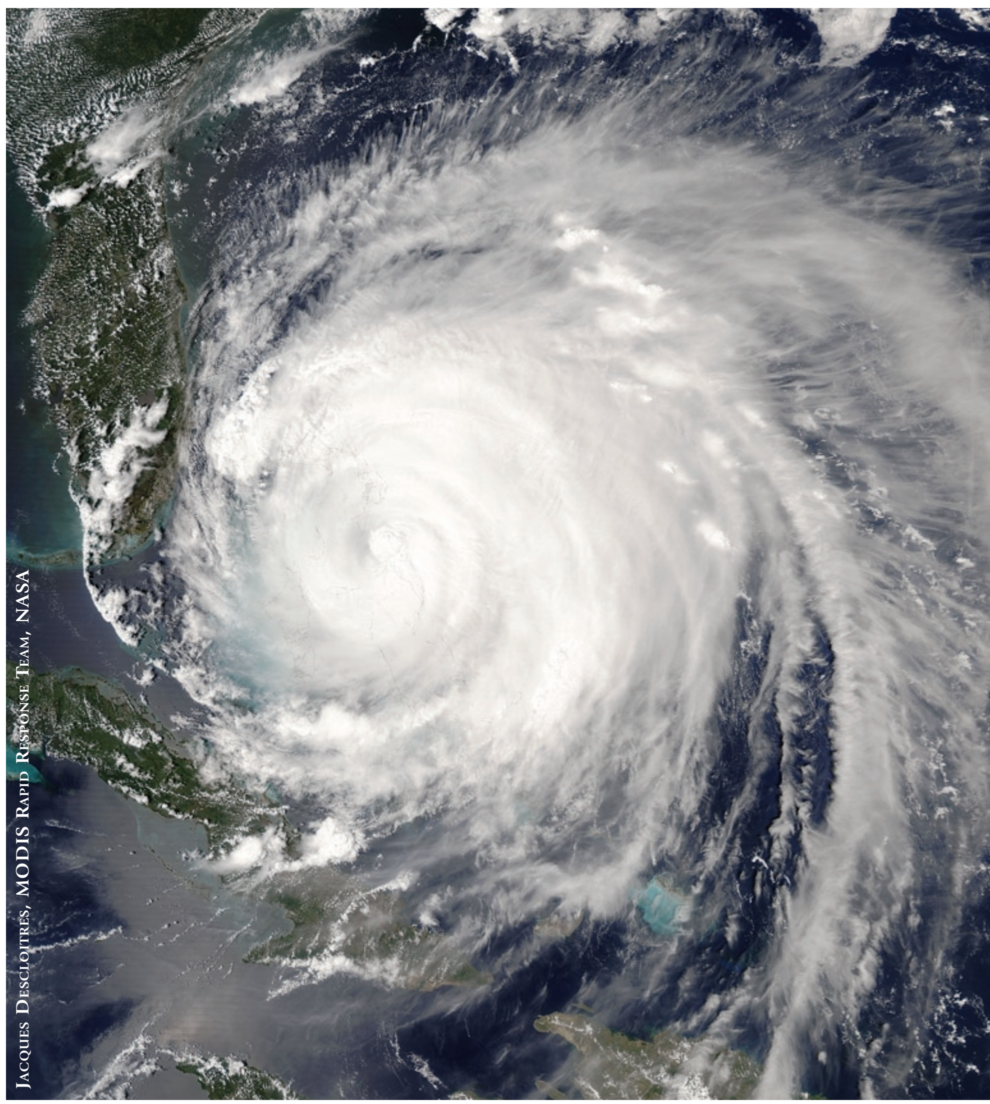
Trina was tasked to be aboard with the instrument. "I kept the PDPA running, and it looks like the data demonstrate the feasibility of using it to make measurements of droplets within hurricanes," she reported. The data, along with those recorded several weeks later during Hurricane Jeanne, show that there are consistent variations in the distribution of droplet sizes as a function of position in the hurricane. Droplets in the eye wall clouds are smaller on average than those in clouds farther from the storm's center. In cloudless areas of the hurricane, the instrument also measured a vertical gradient in sea spray droplets. This gradient can be used to estimate the rate of droplet production, a critical parameter in calculating the heat flux due to sea spray.

Until now, only fortuitous encounters with moorings or buoys provided oceanic observations of hurricanes. Researchers from the Ocean Physics Department (Principal Oceanographers Tom Sanford and Eric D'Asaro, and Engineers John Dunlap and Jim Carlson) deployed two types of autonomous and robust floats to collect undersea data from Frances. Standard Webb Research Corp. Autonomous Profiling Explorer (APEX) floats were modified with an APL-UW subsystem to measure ocean current velocity around the instrument as it profiled between programmed depths—a long-proven expertise at APL-UW. The velocity observations, along with the conventional measures of temperature and salinity that are standard for the floats, allow researchers to distinguish among various possible dynamic processes involved with hurricanes. Lagrangian floats, developed at the Laboratory, are engineered with active buoyancy controls and compressible hulls that match the surrounding water's density and follow its three-dimensional motions.

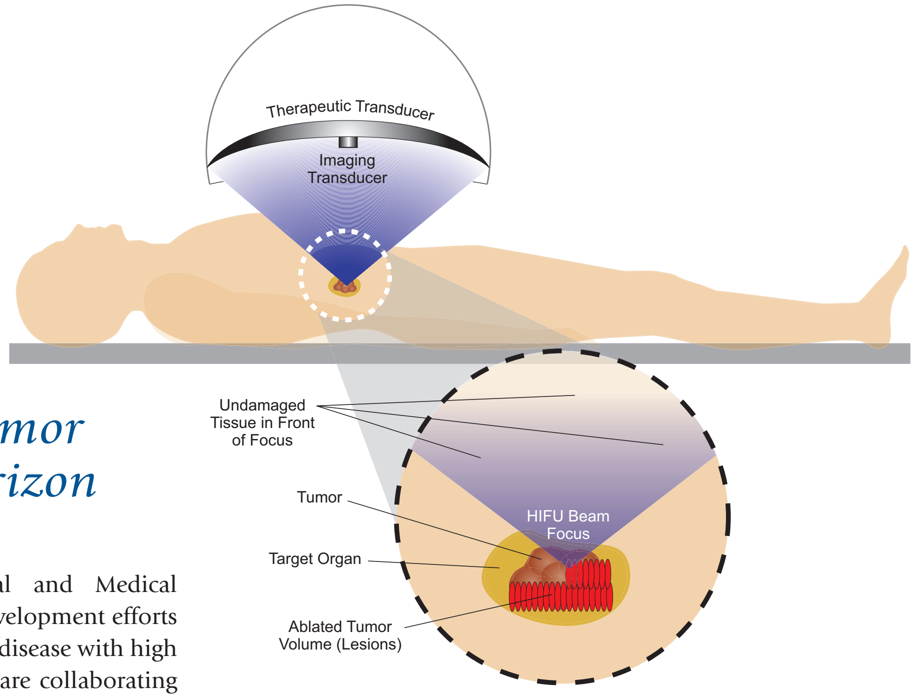
Three APEX and two Lagrangian floats were parachuted in front of Frances. After completing their programmed missions they surfaced and transmitted data by satellite communications. As the category 4 storm passed, the turbulent eddies carried the Lagrangian floats through the evolving surface mixed layer, and the APEXs recorded the strong shear instabilities within and across the layer's bottom boundary caused by the extreme wind stress and strong currents. The storm deepened the mixed layer from 25 meters to 120 meters and cooled it by about 2°C by entraining colder water from below. The Lagrangian floats, also fitted with dissolved oxygen sensors, recorded a flux of gas into the already supersaturated ocean; the foam from the breaking waves was injected by the strong turbulent eddies.

The APL-UW research missions were two components of the Office of Naval Research initiative CBLAST (Coupled Boundary Layers Air–Sea Transfer) that is tapping expertise from universities and government agencies to improve understanding of air–sea interactions; ocean mixing, sea swell and spray, and circulations in the lower 100 m of the atmosphere all play a role in the extreme physical environment of hurricanes. New observations may ultimately improve the prediction accuracy of hurricane intensity. APL-UW researchers are also involved in CBLAST efforts covering the opposite end of the spectrum—understanding air–sea coupling at very low wind speeds.

Team members: Bill Asher, Jim Carlson, Eric D'Asaro, John Dunlap, Trina Litchendorf, and Tom Sanford



Jacques Descloitres, MODIS Rapid Response Team, NASA



Therapeutic Ultrasound—Tumor Ablation on the Horizon

The Laboratory's Center for Industrial and Medical Ultrasound (CIMU) leads research and development efforts to treat severe trauma injuries and human disease with high intensity focused ultrasound (HIFU). We are collaborating with scientists and physicians at the University of Washington Departments of Radiology, Medicine, and Surgery to acquire an integrated ultrasound-guided HIFU patient treatment system. After initial device characterization studies and *in vivo* studies with animal models, we anticipate performing clinical trials to test the efficacy of tumor treatment with HIFU.

HIFU provides the unique capability to induce a biological effect deep within the body without surgical intervention. Focusing permits the passage of ultrasound waves through intervening tissue without damage. At CIMU we have explored HIFU's utility to arrest hemorrhage, to induce drug delivery, to open the blood–brain barrier, and to alleviate neurological pain and spasticity (see *Education, Graduate Student Profiles: Jessica Foley* on p. 25).

A HIFU treatment and monitoring system installed recently at the University of Washington incorporates an ultrasound imaging system and two large-aperture transducer arrays, one above and one below the treatment bed. This device and others like it have been used to treat a variety of conditions, particularly benign and malignant tumors, in over 20,000 patients abroad.

Our first step is to characterize the system, to assure that treatment effects can be applied consistently. One component is to demonstrate the robust registration of the ultrasound-guided treatment target area to the focus of the HIFU transducers; this will show how the system's robotics maintain focusing accuracy even during the patient's regular breathing. Further studies in animal models will assess the short- and long-term effects of therapy. Results from these and other studies will be used to petition the U.S. Food and Drug Administration (FDA) for an investigational device exemption, which will allow us to pursue a clinical pilot study.

The FDA has approved one HIFU medical device that targets and ablates uterine fibroids—benign tumors of the uterus. It uses magnetic resonance imaging to visualize patient anatomy, map the fibroid tissue to be treated, and monitor HIFU therapy by measuring the temperature of the treated region. Our system differs in that it will use real-time ultrasound monitoring, which represents a significant cost savings, and we will seek authorization to treat malignant cancer tumors.

Our group determined that pancreatic cancer will be the first indication for which treatment approval is sought. This pernicious disease is the fourth leading cause of cancer death in the U.S.; approximately 32,000 Americans die from cancer of the pancreas each year with an average survival from diagnosis of five months. Surgical resection of the tumor provides the only potential for cure; only about 10 percent of those diagnosed, however, are candidates for surgical treatment. For all others diagnosed with locally advanced or metastatic pancreatic cancer, chemotherapy and radiation are the only treatment options, but many patients can only be given supportive care and pain control.

HIFU treatment—noninvasive and having no local or systemic toxicities—has benefits over the standard non-surgical therapies. Tumor ablation by HIFU begins with targeting; then heating and mechanical effects are directed to the tumor tissue to kill it, thus arresting its growth without damage to surrounding tissue. For pancreatic cancer patients a growing tumor can cause several complications—bowel and bile duct obstruction, progression of pain, and weight loss.

A pilot clinical study will likely be completed by late 2006 or early 2007. FDA approval will be sought to recruit patients

into a larger study. This phase will necessitate the addition of several HIFU treatment systems at medical research centers across the country. Throughout these studies we expect to demonstrate that HIFU treatment can ablate the tumor noninvasively, reduce patients' pain, improve quality of life, decrease their reliance on pain medication, and improve overall survival.

Separately, the National Institutes of Health has funded CIMU to conduct a five-year study of basic research into treating cancer tumors with HIFU. The confluence of these programs demonstrates a great strength of a research center like APL-UW. Here, the vertical integration of basic science, engineering, and medical research along with technology transfer will hopefully result in a new medical device that can be applied to treat human disease.

CIMU research on ultrasound-guided HIFU tumor treatment and autonomous acoustic hemostasis is funded by the National Institutes of Health and the Defense Advanced Research Projects Agency, respectively.

Team Members: Marilee Andrew, Kirk Beach, Andrew Brayman, Stephen Carter, Larry Crum, Brian Cunitz, Francesco Curra, Barbrina Dunmire, Joo Ha Hwang, Peter Kaczkowski, Steve Kargl, John Kucewicz, Stuart Mitchell, and Vesna Zderic

HIFU research team at APL-UW's Center for Industrial and Medical Ultrasound

Undersea Glider Science Applied to Naval Operations

The Laboratory leads in the research and development of autonomous oceanographic instrument systems that lessen the need for expensive research vessel platforms. The autonomous undersea vehicle (AUV) Seaglider, developed by APL-UW and the UW School of Oceanography between 1995 and 2001, can be deployed for months at a time to profile the water column during dive cycles controlled by a variable buoyancy system. Measurements are taken at frequent intervals by Seaglider's sensors. During surfacing maneuvers the glider obtains global positioning satellite fixes, sends collected data via satellite data telemetry, and receives operator instructions. The real-time progress of Seagliders on research missions operating in oceans around the world can be viewed by the public through a website hosted at the Laboratory. The vehicle has proven itself as a cost-effective solution for long-endurance, robotic monitoring of oceanographic quantities including temperature, salinity, dissolved oxygen, fluorometry, and optical backscatter. Other sensors may be integrated in the future.

The Office of Naval Research funded the vehicle's development and has continued to support the technology's application to U.S. Navy operations. The oceanographic quantities measured by the glider are valuable to the Navy. Real-time data on undersea environmental variability can lead to informed decisions on, for example, tactical sensor optimization. Twice in 2004 the glider provided convincing evidence of its ability to serve as a persistent, long-range, distributed undersea sensor. It relieves personnel of mundane, singular, and expensive bathythermograph casts and provides sampling automation, precision, and frequency never before seen by the fleet.

A Seaglider team participated in RIMPAC04—a U.S. Navy joint exercise with naval assets from eight other nations in deep water near Hawaii. For the four weeks after the glider's launch, Senior Physicist Marc Stewart worked continuously with Navy meteorological and oceanographic personnel at both Pearl Harbor and San Diego to analyze and process the returning data. As information was fed from the field, he worked with Navy personnel to evaluate the effects that the real-time glider data were having on their numerical models of the ocean environment and acoustic propagation. Principal Engineer Jim Luby piloted the glider from his office at APL-UW during this first mission in which a Seaglider was operating to support Navy antisubmarine warfare exercises.

Later in the year Senior Engineer Tim Wen and a Seaglider went to the East China Sea to participate in TASWEX04. This was the first time for a Seaglider to probe this oceanographically dynamic shelf-break environment. As a typhoon moved through the area of operations, the Seaglider continued to sample the environment, recording a deepening surface mixed layer as the storm passed.

Closer to home in Puget Sound, a Seaglider was launched last June in an ONR-sponsored demonstration exercise (AUVFest) of several different autonomous undersea vehicles. Seaglider profiled continuously over 40 horizontal nautical miles during six days in a shallow water mine warfare simulation. Upon reaching the surface in each dive cycle, the glider telemetered data ashore and received waypoint and command file updates. The shore server immediately formatted temperature, salinity, and ocean current data into standard Navy-formatted messages and e-mailed them to the Naval Oceanographic Office where they were forwarded in real time back to the AUVFest command center to be assimilated into a numerical model of tidal flow. During the demonstration Seaglider also collected oxygen data to support the Laboratory's Hood Canal Dissolved Oxygen Program.

Because of the Laboratory's proven expertise, APL-UW scientists and engineers were asked to collaborate with the Marine Physical Laboratory of the Scripps Institution of Oceanography on an ONR-sponsored program to develop a flying wing undersea glider. A wing is the most efficient hydrodynamic glider shape because most of the vehicle's surface provides lift. With a span of 20 feet, the new glider is not as portable and easily deployed as the Seaglider, but it will be capable of carrying larger sensor payloads at higher speeds than any ocean glider currently flying through the sea.

Team members: Neil Bogue, Jason Gobat, Craig Lee, Russ Light, Jim Luby, Keith Magness, Marc Stewart, Keith Van Thiel, and Tim Wen

Listening for Whales and Tuning In to Their Soundscapes

Monitoring marine mammal populations is critical for regulatory and conservation efforts. Our expertise in undersea acoustics is being applied to studies where passive listening methods are used to detect whales and to understand the complexities of the soundscapes in which they live.

Principal Oceanographer Jeff Nystuen has used Passive Aquatic Listeners (PALs), moored acoustic instruments designed and built at APL-UW, to monitor ambient underwater sound at sea. His principal interest has been the sound of rainfall at sea, but other sounds are detected including whales and ships. In shallow water environments sounds made by humans, especially shipping traffic, are often most prevalent.

With Nystuen, Senior Engineer Christopher Jones and Mathematician Mike Wolfson used a PAL to collect ambient noise data in Haro Strait, a busy international shipping channel that is also a preferred foraging location for the three pods of southern resident killer whales. Killer whales' echolocation capabilities are powerful and sensitive—scientists believe a whale can perceive a single salmon from as far as 100 meters away. Is it possible that persistent background noise or sudden loud sounds impair the whales' ability to hunt?


David Truzinski

The team is collocating the PAL data with shipping traffic logs to determine specific sound sources. They are using a numerical model of the undersea environment of Haro Strait—a deep canyon off the coast of San Juan Island dropping to about 300 meters—to predict sound levels incident on whales as they move through the area. The acoustic results agree favorably with the observations. The environment is nearly infinitely variable and cannot be duplicated exactly by the model. Nevertheless, the researchers are studying oceanographic variables such as water temperature, sea surface roughness, and topography to determine what underwater sounds are both possible and probable in Haro Strait given certain acoustic sources.

Traditional whale conservation methods that rely on visual sightings are constrained by seasonal migration patterns and by the short periods that most cetaceans spend on the surface. For example, southern resident killer whales are often observed in summer when they are in Puget Sound to hunt seasonal salmon runs, but in the winter they leave for the Pacific Ocean and scientists have almost no information on their activities and whereabouts.


NOAA

Modified PALs have been placed strategically in the Pacific off the Washington coast to listen for the whales — two off Cape Flattery, one near Westport, and on one of the moorings deployed by the Scripps Institution of Oceanography near the Olympic Coast National Marine Sanctuary. Principal Oceanographer Sue Moore, who joined the Laboratory on a two-year appointment from her position as Director of NOAA's National Marine Mammal Laboratory, is partnering with the Scripps researchers to determine the seasonal occurrence of the whales near the sanctuary and proximate to a naval underwater training range.

Fortunately, scientists recognize killer whale vocalizations: communication whistles in one frequency range and echolocation clicks at another. Beaked whales, which also occur off the Washington coast, generally produce sounds at somewhat higher frequencies. The call detections recorded by the PALs are collocated with satellite data of sea surface temperature and nutrients, allowing Moore and colleagues to predict the whales' use of and movement through the habitat. The goal is to provide enough information to make informed decisions regarding human use of the sanctuary.

Moore and Oceanographer Kate Stafford have used similar passive listening techniques to monitor large whales in the North Pacific including the Gulf of Alaska and Bering Sea. For nearly a decade the U.S. Navy Sound Surveillance System (SOSUS) and other long-term hydrophone arrays have been used to describe seasonal blue whale call patterns throughout the North Pacific Ocean. Whale calls have been correlated with satellite data to show that sea surface temperature gradients or fronts often correspond to high zooplankton productivity and blue whale call locations.

In the summer of 2004, NOAA scientists photographed a blue whale in the Gulf of Alaska, the first sighting there in three decades. The sighting was mere confirmation for Stafford. Based on years of hydrophone recordings, she documented that a distinct group of animals range the eastern North Pacific from the equator to at least 55°N during feeding and calving migrations. Furthermore, recordings in the Gulf of Alaska reveal that, "There are primarily two call types in the North Pacific, which can be roughly divided on an east–west basis… the differences might be representative of population-level differences in blue whales," says Stafford. Both the eastern and western call types have been recorded during early fall in the Gulf of Alaska, suggesting that this is a region of overlap and potential interaction between whales from different sides of the ocean.

APL-UW marine mammal research is sponsored by the NOAA Northwest Fisheries Science Center, and the Office of Naval Research.
Team members: Eric Boget, Bruce Howe, Chris Jones, Keith Magness, Sue Moore, Jeff Nystuen, Kate Stafford, Tim Wen, and Mike Wolfson

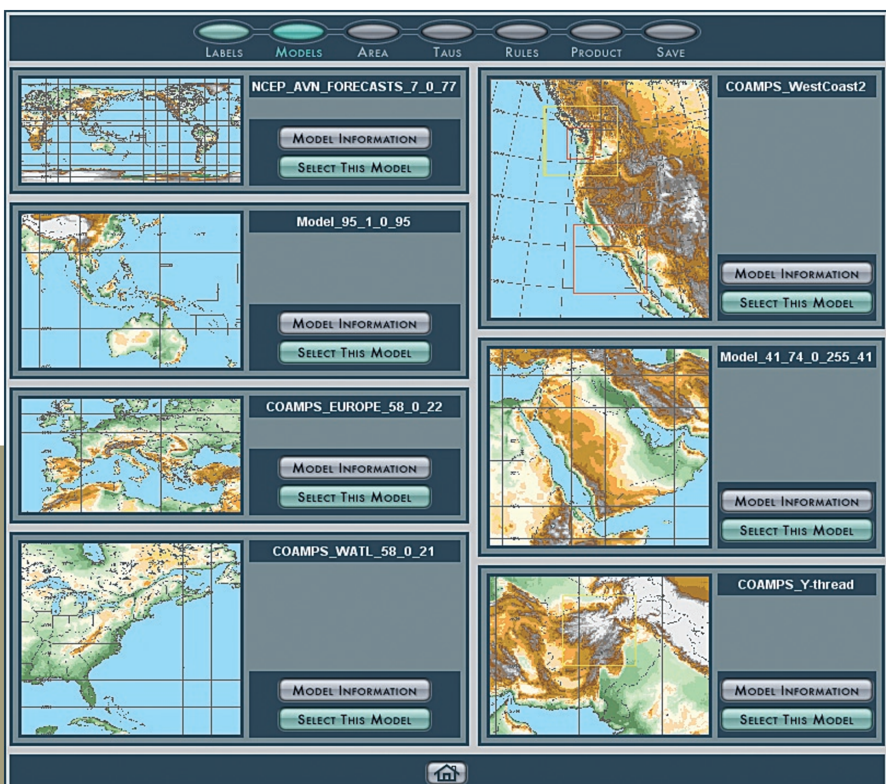
Human Factors Research—*Improving People's Ability to Make Decisions*

Janet Olsonbaker

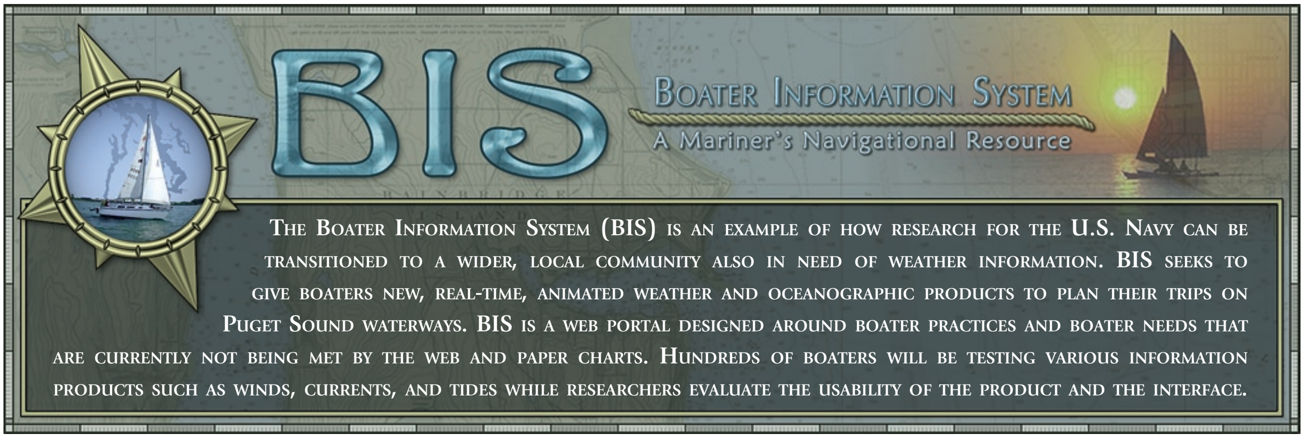
APL-UW is addressing the U.S. Navy's need to understand how personnel use computer-derived information and how they could improve the decisions they make based on that information. Navy weather forecasters, for example, confront massive quantities of meteorological and oceanographic information, often in dissimilar formats, and without enough time to assess the meaning of it all. These forecasters work in cramped conditions and are often interrupted to do other tasks while trying to put out a forecast. Their responsibility is to give war fighters accurate information about clouds, fog, or dust that can obscure targets, and wind that could divert an unguided weapon. Our team of researchers asked: Can we package the needed information in such a way as to help Navy personnel make better decisions more easily?

Human factors is a discipline dedicated to designing systems that accomplish work within the limits and benefits of human operators. The emphasis is not on training the person to overcome design shortfalls nor is it sufficient merely to develop a very capable system. Rather, human factors requires that researchers have a thorough knowledge of specific users and how they currently accomplish work. The full range of tasks, the cognitive operations a person must remember to solve the problems that arise, and each level of decision the person must make all come into play. Whether the system seeks to establish new behavior or change the user's current practices, the person must be comfortable with the system in order to use it to complete a task.

Two current projects are showing promise in helping the Navy meet its goal of improved decision making for weather forecasters. EVIS is a tool used by planners and analysts to evaluate the impact of weather on military missions. Researchers collected data during several field experiments and at-sea operations. They documented forecasters at work, noting a heavy reliance on their own mental image of large-scale weather conditions based on past experience rather than actual model data. EVIS allows forecasters to choose models and the time resolution of the weather impacts. EVIS then assesses the models and integrates the essential information to tell them the impact of weather on the mission of interest.



EVIS model selection interface

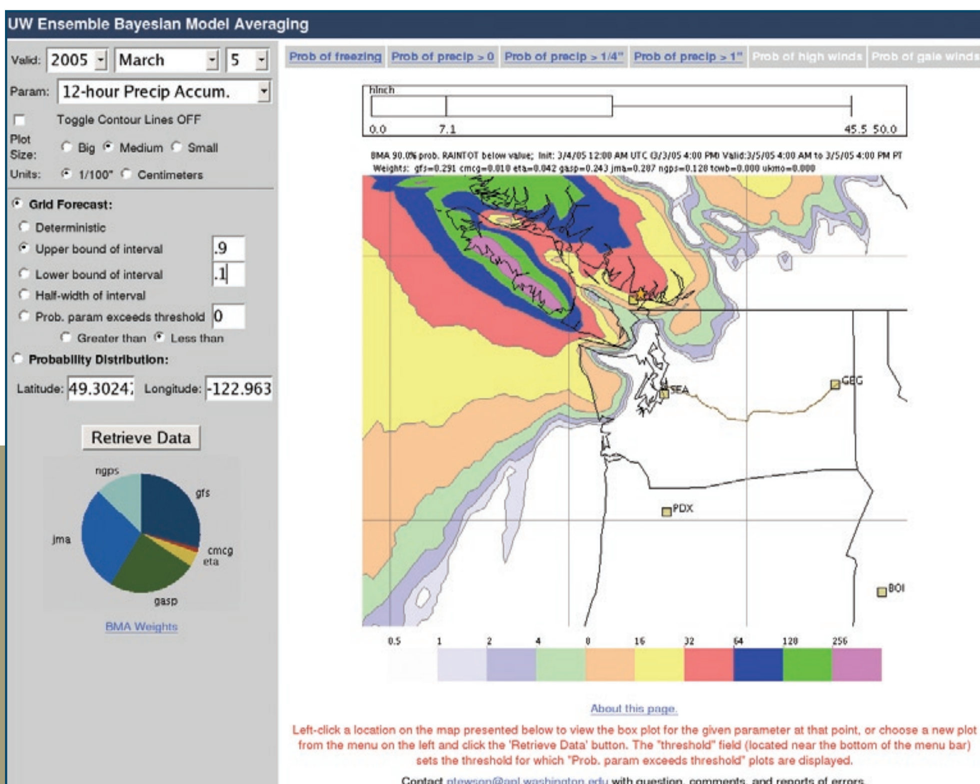


Unlike EVIS, a MURI project is developing methods to assess the accuracy of the predicted weather impacts. Current methods of meteorological forecasting produce predictions with unknown levels of uncertainty. The BMA (UW Ensemble Baysian Model Averaging) speeds the process by which a forecaster can assess the potential or probability as well as the degree of uncertainty about the likelihood of a storm. BMA is an implementation of an algorithm developed by the UW Department of Statistics using visualizations from the MM5 (UW Mesoscale Ensemble of Forecasts) model, developed by the UW Department of Atmospheric Sciences. APL-UW integrated access to the model with the algorithm to make it run in real time.

Environmental Visualization (EVIS) is an Office of Naval Research Future Naval Capability Project that was selected for the Office of the Secretary of Defense's Horizontal Fusion project. Researchers are: *David Jones, Robert Carr, Keith Kerr, Beth Kirby, Janet Olsonbaker, and Troy Tanner*

The Multidisciplinary University Research Initiative (MURI) is titled "Integration and Visualization of Multi-Source Information for Mesoscale Meteorology: Statistical and Cognitive Approaches to Visualizing Uncertainty," and is sponsored by the Secretary of Defense under the Office of Naval Research. Researchers are: *David Jones, Patrick Tewson, and Keith Kerr; Adrian Raftery, UW Department of Statistics; Cliff Mass, UW Department of Atmospheric Sciences; Buz Hunt and Susan Joslyn, UW Department of Psychology*

The Boater Information System (BIS) is sponsored by the Washington Sea Grant Program. Researchers are: *David Jones, Janet Olsonbaker, Troy Tanner, Robert Carr, and Patrick Tewson*



BMA shows the highest likely amount of accumulated precipitation during the 12 hours before 4 p.m., 5 March 2005

Above the Flow—
Gaging River Discharge with Radars

William Plant

The volume of water flowing in over 7000 streams across the country is monitored by the U.S. Geological Survey (USGS). Technicians measure stream velocity and depth with current meters and sounding weights in order to calibrate continuous water height measurements and determine discharge rates. This is a time-consuming and sometimes hazardous procedure, and because instruments are in the water, maintaining them against the effects of fouling and debris damage is costly. Furthermore, the measurements cannot usually be made under flood conditions, precisely when they are needed most.

For the past six years our group at APL-UW has worked with the USGS to improve these measurement techniques using instruments that do not contact the water. When fully tested, our methods will allow more accurate prediction of flooding conditions and better estimates of water usage for industrial, agricultural, residential, and recreational purposes.

The basis for our measurements is the Doppler shift produced in microwaves scattered from the moving water surface. Microwaves do not penetrate water so our instruments measure velocities in the top few millimeters of the stream. Used in tandem with USGS ground-penetrating radars (GPR) that determine a stream's depth, we can calculate accurate discharge values in many streams, without ever putting an instrument or boat in the water.

One of our microwave systems, RiverScat, focuses on a few-square-meter spot to measure the stream's surface velocity moving toward the antenna. All calculations required to produce velocity values are made in a six-inch-cubed, battery-powered module that can host up to four antennas. Processed data are stored here and recovered on site or accessed via Internet connection.

A second instrument, RiverRad, is a Doppler radar that is less portable but more powerful than RiverScat. It measures horizontal surface velocity at a range of locations across a stream and processes data on board to obtain real-time surface velocities. RiverRad can measure velocities at distances over one kilometer away from the antenna,

whereas RiverScat measurements are made at distances up to about 50 m.

Many streams and rivers have stable beds that change little over time. We measured discharges on such a river with our non-contact instruments continuously over a 10-month period while the USGS measured water depth and current velocity with their standard methods intermittently over the same period. The results were in good agreement, but a single discharge value computed from in-water measurements took about two hours, while those from RiverScat, RiverRad, and GPR took about five minutes.

Continuous surface velocity measurements are especially important on streams with unstable beds where depth cannot be monitored frequently enough to account for topographic changes. For example, RiverScat was deployed under a bridge crossing a northwestern Washington river over a period that included a high-flow event on 11 December 2004. The stage readings were nearly the same for two measurements made before and after the event, but the surface velocity decreased by more than a factor of two. This showed that the bed of the stream had been changed by the high flow so that a single stage corresponded to two different discharges.

Continuous, direct measurements of stream depth and velocity from the bank are the ideal way to make discharge calculations. GPR depth measurements, however, have only been made with the antenna directly above the water using, for example, helicopters or light cableways. Our group and the USGS have begun a collaboration with the University of Michigan to see if a MHz radar developed there can overcome this limitation. The goal of bankside, non-contact streamgaging stations remains just out of reach but tantalizingly close.

Team members: Kenneth Hayes, Justin Huff, William Keller, Nathan Kohagen, William Plant, and Christopher Siani

Undergraduate researchers Justin Huff, Christopher Siani, and Nathan Kohagen were all University of Washington students seeking field research opportunities when they began working on the project to develop river radars.

Justin is now employed by Blue View Technologies (a Seattle company spun off from the Laboratory that specializes in high-definition imaging sonars), Christopher is an Engineer in the Laboratory's Ocean Engineering Department, and Nathan, who was the 2003 Hardisty Scholar, began graduate studies in Electrical Engineering this fall at the UW.

This research and development effort benefited greatly from the talents of these students while contributing to their educations.

Education

Robert Odom & Ellen Lettvin

The Applied Physics Laboratory makes substantial contributions to the educational mission of the University of Washington. During the past two years we had sixty-one undergraduates carrying out research with Laboratory scientists and engineers as mentors and supervisors. Student research covered topics as diverse as the projects of electrical engineering student Adam Maxwell, who works with Senior Engineer Michael Bailey on two-frequency enhancement of high intensity focused ultrasound heating, and oceanography student Marta Krynytzky, who works with Physicist Cecilia Bitz to analyze arctic climate models with regard to a changing climate's influence on indigenous peoples. Many of our undergraduate students will work year-round and become integral and significant contributors to the research projects; some have even given presentations at international science and engineering meetings.

New Scholarships

New developments in our undergraduate scholarship program are a result of generous grants from The Boeing Company. One, the Boeing Scholar Program for Women and Underrepresented Minorities, is modeled after our existing Hardisty Scholar Program; it provides a half-time research job for one calendar year and a book allowance for an undergraduate student. The first recipient is Rachel Sparks (see adjacent feature).

Funds were also provided to establish the Boeing Mentoring Program for Women and Underrepresented Minorities. Both are motivated to stem the substantial attrition of highly qualified and talented female and minority students at all levels in the educational process, particularly in the disciplines of science, mathematics, and engineering. The paucity of accomplished women and minorities serving as models or mentors is a frequently cited cause of attrition. Mentoring is a successful intervention strategy for at-risk students. This program puts motivated and capable students in touch with mentors, providing them with access to exemplary role models. Our first participants in the program are Gauri Sudame, who is majoring in mathematics and statistics and works with Principal Mathematician Don

Percival to develop geophysical software in R and Matlab, Joann Lin, who works with Senior Engineer Antao Chen on research using light to investigate blood and oxygen drug levels in the brain, and Marta Krynytzky (see above).

APL-UW Faculty

The APL-UW faculty of thirty-six represents nine campus departments from Oceanography to Neurological Surgery; members served as chairs on the committees of fifty-eight graduate students. Twenty-three graduate degrees were awarded among these students, with fourteen earning doctorates and nine earning masters degrees. See page 30 for a complete listing of students and degrees earned.

Last year the first meeting of an APL-UW faculty was convened. This group meets several important needs among our staff active in educational activities; it provides a group identity both within and outside the Laboratory for those involved in teaching, student supervision, and departmental service. A formalized group provides several opportunities: a supportive, in-house infrastructure linked specifically to our education mission and that of the university, and a forum for those who seek to participate more actively in the academic life of UW departments, colleges, and schools, as well as for those who seek to assist in developing curricula. This group is vital to our future as we continue to increase and formalize our academic role.

Educational Outreach

Outreach to the non-university public is an important part of our educational vision. We regularly give presentations and lab tours to students participating in Gaining Early Awareness and Readiness for Undergraduate Programs (GEAR UP), funded by the federal government to encourage students from low-income backgrounds to set educational goals beyond high school. We also participate in Math Day, sponsored annually by the university's mathematics department. A recent highlight was our hosting of secondary school science teachers who were in Seattle to attend the annual meeting of the National Association of Science Teachers.

The Hardisty Scholar Program was established to provide opportunities for undergraduate students who wish to pursue research projects under the direction of APL-UW faculty scientists. Evan Gander, now a senior electrical engineering student, was the 2004 Hardisty Scholar. He is assisting Senior Engineer Tim McGinnis with the development and testing of a power supply system to be used in a prototype ocean observatory 60 km offshore in Monterey Bay. Evan notes that his horizons were broadened by learning how much work there was for an electrical engineer doing ocean science. Describing his APL-UW experience, Evan says, ***"While many of my classmates complain that they have never experienced engineering work, I have seen both realistic problems and innovative solutions. I've learned how old voltmeters (twice as old as I am) are still useful. I've seen ground loops happen, and have fixed them. I've reverse engineered a time delay reflectometer. I've built and tested the physical channel for an underwater Ethernet system and learned how to build connectors onto optical fiber. The experiences I've had are simply invaluable."***

The Boeing Scholar Program at APL-UW was established in 2004; the first recipient is bioengineering student Rachel Sparks. With her advisor, Principal Physicist Pierre Mourad, she is studying methods to increase drug delivery to the brain—a difficult task as the brain has a natural barrier to guard it against foreign molecules. Her studies have focused on getting cancer drugs and antibiotics into the brain by disrupting sections of the blood–brain barrier with high intensity focused ultrasound. Now a senior, Rachel describes her goals saying, ***"I plan to continue my work in Dr. Mourad's lab for my senior research project—a requirement for the bioengineering department. Then I will pursue a doctoral degree, with research focusing on medical imaging devices. I want to be a primary investigator in biomedical research, where my findings can be used to improve the quality of medicine that patients receive."***

The research programs of both students demonstrate the wedding of visionary science to state-of-the-art engineering. Their experiences build insight into the increasingly complex and interdisciplinary problems faced by researchers.

Graduate Student Profiles

Glenn Carter

Glenn Carter's experience at APL-UW exemplifies the Laboratory's ability to offer research programs that are tailored to students' science objectives and distinguished by the opportunities for hands-on field experience. Glenn's career as an oceanography student encompassed all aspects of the research enterprise—theoretical analysis, field deployment of novel instrumentation, data collection and analysis, and the publication of results.

This year Glenn defended his Ph.D. dissertation on turbulent ocean mixing near extreme seafloor topography. His research considered the turbulence resulting from the interaction of internal waves and tidal flow with topography at two sites: the Monterey submarine canyon and the Hawaiian ridge. Near Hawaii, for example, ocean mixing rates over the undersea ridges were thousands of times more intense than typically found in the open ocean.

"I have been very lucky to have had so much time at sea," says Glenn. "This sea time has given me a great education into the specialty instrumentation that makes the Laboratory a leader in small scale oceanography." His advisor, Professor Mike Gregg, praises Glenn's dedication to mastering the instrumentation because maximizing performance and data quality drive good science.

Carter's experience on one-dozen-plus research cruises included two out of Honolulu, which yielded data for his dissertation research, one that ended in the Galapagos Islands, one based from Istanbul, Turkey, and another from Athens, Greece. Glenn admits that, "Overall, I have spent over 200 days at sea as a student at APL-UW." Mike Gregg adds, "I experienced the most interesting ports of my career as an oceanographer on the cruises that included Glenn."

Glenn relates that, "On six long cruises we collected microstructure data around the clock utilizing two 12-hour watches. On two recent field experiments, one in the North Pacific Ocean and one in the Aegean Sea, I was the watch commander for one of those watches." As commander he was responsible for implementing the cruise's science plan and coordinating the efforts of the ship's captain and crew with the chief scientist and research team. He also served as deck boss, overseeing that the launch and recovery of all instruments proceeded according to plan.

Carter left APL-UW to begin a post-doctoral position at the University of Hawaii this past summer, but he and Gregg are certain that their research collaborations will continue.

Glenn Carter in foreground

Jessica Foley

Spasticity and pain are major complications of neurological disorders including multiple sclerosis, cerebral palsy, and the long-term effects of stroke or traumatic injury to the brain or spinal cord. Signified by uncontrollable muscle contractions, spasticity is difficult to treat effectively. Current treatments such as oral medications, intramuscular blocks, nerve blocks, and surgical interventions often provide only short-term or partial benefit and can be invasive and high risk. Bioengineering Ph.D. candidate Jessica Foley is pursuing research to use high intensity focused ultrasound (HIFU), guided by ultrasound imaging, to quiet overactive nerve reflexes that are involved in spasticity and pain.

In their early work she and her advisor, Senior Engineer and Associate Professor of Bioengineering Shahram Vaezy, developed ultrasound image-guided HIFU devices and treatment protocols to non-invasively target and block the sciatic nerves of animal models *in vivo*. Long-term studies indicate that the HIFU-induced conduction block persists at least 14 days after treatment. Future work will investigate the threshold HIFU dose for conduction block and whether HIFU of different doses could produce varying effects on the nerves ranging from temporary conduction block to permanent degeneration.

Jessica was accepted as a graduate student to the UW Department of Bioengineering in 2001, and during the recruitment weekend activities she visited with Vaezy. Her undergraduate research at Duke University on three-dimensional ultrasound imaging of the heart and her goal to advance medicine through bioengineering research made her a natural fit with the Center for Industrial and Medical Ultrasound (CIMU) and Vaezy's lab.

The idea to treat spasticity with HIFU originated through discussions among Jessica, Vaezy, and Dr. James Little, a neurologist who works with spinal cord injury patients at the Veterans Affairs Medical Center in Seattle. Jessica notes, "I had become interested in using HIFU to treat complications of neurological disorders, particularly those related to spinal cord injury, so I contacted Dr. Little after reading about his research and clinical experience."

Vaezy says that Jessica's thesis research topic opened up a new area of research at CIMU. "Although we didn't have an active project on nerves, she pursued her interest, assembled an expert team, did preliminary studies, and now is on her way to do some seminal experiments. She is a model student with ambition, vision, and persistence to take a project from inception to completion."

Now that the team has collected promising results from *in vivo* studies, they are preparing to seek approval for a small clinical study using HIFU to treat patients with spasticity resulting from spinal cord injury. Further, their ideas have resulted in a full patent application that has been filed by the UW.

Finances

William Bakamis

The Applied Physics Laboratory remained financially strong through Federal Fiscal Years 2003 and 2004, operating at a funding level about 25% higher than just three years ago. Grant and contract awards totaled $40.4M in 2003 and $39.5M in 2004. Research project funding from the U.S. Navy accounted for about 57% of the 2003 total; the continuing strength of the Laboratory's basic research programs accounted for 67% of the 2004 total.

APL-UW contract fees, which are discretionary resources, represent approximately 2.5% of total income and are used to support a variety of business expenses and strategic initiatives not covered by grants and contracts. The largest portion of these funds is used to support internal Independent Research and Development efforts, which are currently focused on building additional Navy-related expertise. Other Laboratory fee expenditures include graduate student support, staff fellowships, and general-use equipment.

We remain committed to ensuring that the Navy's 60-year investment 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 needs. While continuing to pursue opportunities with other government agencies and industry, we expect that the Navy will remain our principal sponsor.

APL-UW's grant and contract funding from the Department of Defense exceeds the combined DoD funds received by all other units at the University of Washington. The Laboratory's overall research and development budget continues to be among the largest of any single unit on the UW campus.

Funding

Sponsor	FFY03 (x $1,000)	FFY04 (x $1,000)
Office of Naval Research	12,358	11,214
National Science Foundation	9,666	9,306
Naval Surface Warfare Center	1,014	5,317
University of Mississippi	2,095	2,100
Office of Naval Intelligence	3,058	868
Naval Sea Systems Command	3,477	198
National Institutes of Health	1,597	897
National Aeronautics and Space Administration	929	1,264
Space and Naval Warfare Systems Command	685	798
Naval Research Lab	–	1,443
Naval Air Systems Command	731	568
National Oceanic and Atmospheric Administration	309	550
Baylor University	314	518
Indiana University	384	368
Monterey Bay Aquarium Research Institute	–	725
Jet Propulsion Laboratory	370	–
Other Navy	1,710	1,374
Other	1,729	1,969
TOTAL	**40,426**	**39,477**

Development

Ellen Lettvin

A strategic initiative introduced by Director Simmen in 2004 is to increase development efforts for the Laboratory. APL-UW development encompasses several important areas that fall primarily into two categories: corporate and foundation relations, and community relations. The former entails establishing stronger relationships with companies active in research and technology areas where APL-UW is an established leader — opportunities are being sought for research funding from non-traditional sources, technology transfer, and sponsorship of students. Early successes in this area include establishing the Boeing Mentoring Program for Women and Underrepresented Minorities, and the Boeing Scholar Program, now entering their second year. Several other corporate partnerships are underway. Community relations entail establishing stronger ties with our core communities defined geographically (e.g., from our home campus and throughout the Puget Sound region), by commonality of background (e.g., APL-UW alumni and retirees), and by interests (e.g., arctic climate change and medical device technologies).

A key component to our success in these endeavors will be to increase our visibility within each of these communities. We have taken several steps to accomplish this goal. Several articles have been printed in *APL News*, which is distributed to retirees, alumni, and campus administrators, on the topic of development, and the APL-UW website now includes a page devoted to development. We have established stronger ties with UW News and Information, resulting in significantly increased press coverage of Laboratory endeavors. We are active on university-wide committees such as the UW Earth Initiative, which seeks to foster innovative partnerships that address environmental and natural resource challenges.

We hosted our first community outreach and networking event at JM Cellars in Woodinville, WA. Researchers representing three APL-UW departments (Polar Science, Air–Sea Interaction and Remote Sensing, and Industrial and Medical Ultrasound) gave presentations highlighting Laboratory research and accomplishments in these areas. The event was a great success, attended by about 50 people representing each of our core communities. Plans are underway to host a second such event. The Laboratory also had a significant presence at the inaugural UW Open House held in spring 2005. Demonstrations and exhibits from eight research areas currently active at APL-UW were represented, and over 80 visitors attended.

Plans are in place to expand upon these efforts—hosting congressional staffers who are visiting the UW, partnering in developing exhibits and events to be held at the Pacific Science Center in Seattle, and modifying the format of the popular APL-UW Seminar Series. The 2005–2006 series is dedicated to issues relating to technology commercialization, and will focus on the areas of environmental monitoring and medical devices. Over 20 leading experts from academia,

government, industry, and the venture finance community are participating, increasing our visibility within all of these important groups.

Our development efforts are closely linked to our education mission. Because APL-UW does not receive any funding from the state of Washington, private gifts as well as corporate and foundation support help us to fund student fellowships and provide teaching support so that we can recruit and retain the best students, researchers, and teachers. Private support also enables us to expand our educational outreach programs to schools, to mentor undergraduate students throughout the UW, and to seed new research projects. As federal funding priorities shift, private support can serve a very important role in enabling APL-UW to remain at the forefront of scientific and engineering discovery and education. We are very enthusiastic about broadening our base of support to encompass this new area.

Student Achievements

Degrees Awarded

Student	Topic	Advisor
Arthur Chan	Bioengineering, Ph.D., 2003	Vaezy
Robb Contreras	Atmospheric Sciences, Ph.D., 2004	Plant
Shenfu Dong	Oceanography, Ph.D., 2004	Kelly
John Flynn	Electrical Engineering, Ph.D., 2004	Fox
Jing-Feng Guan	Electrical Engineering, Ph.D., 2004	Matula
Daniel Hayes	Oceanography, Ph.D., 2003	Morison
John Kucewicz	Bioengineering, Ph.D., 2004	Beach
Bin-Bing (Barry) Ma	Oceanography, Ph.D., 2004	Nystuen
Tyrone Porter	Bioengineering, Ph.D., 2003	Crum
Brian Rabkin	Bioengineering, Ph.D., 2004	Vaezy
Darin Soukup	Earth and Space Sciences, Ph.D., 2004	Odom
Elizabeth Steffen	Oceanography, Ph.D., 2003	D'Asaro
Mike Yargus	Electrical Engineering, Ph.D., 2003	Jackson
Vesna Zderic	Bioengineering, Ph.D., 2004	Vaezy
Ruth Branch	Civil Engineering, M.S., 2003	Jessup
Indranil Chowdhury	Electrical Engineering, M.S., 2004	Winebrenner
Marlene Jeffries	Oceanography, M.S., 2004	Lee
Chuanli Jiang	Oceanography, M.S., 2004	Kelly
Neil Owen	Electrical Engineering, M.S., 2003	Bailey & Crum
Kapil Phadnis	Mechanical Engineering, M.S., 2004	Jessup
Justin Reed	Physics, M.S., 2004	Bailey
Travis Sherwood	Materials Science and Engineering, M.S., 2004	Chen
Zolton Szuts	Oceanography, M.S., 2004	Sanford

Graduate Students

Student	Topic	Advisor
Ajay Anand	The determination of temperature using backscattered high-frequency ultrasound to monitor HIFU therapy	Kaczkowski & Crum
Oleg Babko	Analysis of CTD and XCP data taken north of Ellesmere Island	Rothrock & Steele
Abdullah Bamasoud	Dynamics of Arabian Sea coastal filaments	Lee
Nishant Prakash Bhatambrekar	Electro-optic polymer materials and devices for fiber optics	Chen
Ruth Branch	Microbreaking modulation by ocean swell using infrared and microwave techniques	Jessup
Michael Canney	Role of cavitation and nonlinear acoustics in HIFU therapy	Bailey & Crum
Glenn Carter	Mixing around the Hawaiian Ridge	Gregg
Arthur Chan	Image-guided HIFU treatment for uterine leiomyomata	Vaezy
Indranil Chowdhury	Far field radiation from dipole antennas above a lossy half space	Winebrenner
Robb Contreras	The effect of rain on microwave backscatter from the ocean: Measurements and modeling	Plant
Bryan Cunitz	Instrumentation to collect and analyze vector Doppler ultrasound (5 MHz) data to detect internal bleeding	Kaczkowski & Crum
Shenfu Dong	Interannual variations in upper ocean heat content and heat transport convergence in the western North Atlantic	Kelly
Wendy Ermold	Salinity trends on the Siberian shelves	Steele
John Flynn	Computation and architectures for array receivers in large delay Doppler spreading	Fox
Jessica Foley	Image-guided HIFU as a novel method to produce conduction blocks of peripheral nerves	Vaezy
Rei Furukawa	Sensors based on polymer optical fibers	Chen
Andrew Ganse	Nonlinear inversion from nonlinear filters for ocean acoustics	Odom
Tia Ghose	Role of cavitation and nonlinear acoustics in HIFU	Bailey & Crum
Robyn Greaby	Pulsatile flow phantoms	Vaezy
Jing-Feng Guan	Light scattering and imaging techniques applied to sonoluminescence and ultrasound contrast bubbles	Matula
Daniel Hayes	The heat and salt balances of the upper ocean beneath a spatially variable melting sea ice cover	Morison
Joo Ha Hwang	Ultrasound-mediated vascular bioeffects: Applications for hemostasis and sclerotherapy	Brayman & Crum
Marlene Jeffries	Filament dynamics and response to strong forcing in the Adriatic Sea	Lee
Chuanli Jiang	Evaluation of a hybrid air–sea flux product using satellite-derived fields	Kelly
Michael Keim	The statistical significance of arctic ice thickness distributions	Percival
Clark Kirkman	Greenland ice sheet mass balance	Bitz
Wayne Kreider	Effect of heat transfer to cavitation bubbles during therapeutic ultrasound	Bailey & Crum
John Kucewicz	Tissue pulsatility imaging: Ultrasonic measurement of strain due to perfusion	Beach
Wenbo Luo	Internal bleeding detection and development of an in-house ultrasound contrast agent	Vaezy

Graduate Students, continued next page

Graduate Students, continued

Student	Topic	Advisor
Bin-Bing Ma	Passive acoustic detection and measurement of rainfall at sea and an empirical ocean ambient sound model	Nystuen
Brian MacConaghy	Modeling waves generated by various lithotripters	Bailey
Joseph MacGregor	Measurement of englacial radar attenuation using several methods, principally bistatic radar, applied to measurement of ice sheet basal temperatures	Winebrenner
Kim Martini	Internal tides in Mamala Bay and the Oregon Shelf	Alford
John Mickett	Mixing in Puget Sound	Gregg
Marie Nakazawa	Ultrasound imaging identification of HIFU lesions	Bailey
Neil Owen	Ultrasonic image monitoring of kidney stone position and comminution in lithotripsy	Bailey & Crum
Anna Pyayt	Fiber optic wavelength selective optical switches based on electro-optic polymer waveguides	Chen
Kapil Phadnis	Infrared imagery velocity estimation using optical flow and particle image velocimetery algorithms	Jessup
Tyrone Porter	Synergy between ultrasound and membrane-disruptive polymers and its effect on cell membranes	Crum
Brian Rabkin	Cavitation and hyperecho in ultrasound image-guided HIFU	Vaezy
Justin Reed	Two-frequency mixing to control bubble dynamics	Bailey
Eric Rehm	Biophysical interactions using optics	D'Asaro
Travis Sherwood	Polymer ring resonator made by two-photon polymerization and vertically coupled to a side-polished optical fiber	Chen
Susan Soggs	Integration of polymer photonic devices with CMOS VLSI integrated circuits	Chen
Darin Soukup	A coupled local mode approach to laterally heterogeneous anisotropic media, volume scattering, and T-wave excitation	Odom
Haishan Sun	Integrated optical components for communications and sensor applications	Chen
Elizabeth Steffen	Observations of vertical and horizontal aspects of deep convection in the Labrador Sea by fully Lagrangian floats	D'Asaro
Zolton Szuts	Small-scale vorticity dynamics	Sanford
Juan Tu	To quantify cavitation generated during pulsed ultrasound in *ex vivo* and *in vivo* tissue	Matula & Brayman
Michael Volny	Reactive and soft landing of polyatomic ions on *in situ* plasma treated metal surfaces	Elam
James Westphal	Characterization and processing of poled electro-optical polymer materials	Chen
Maya Whitmont	Spatial patterns of near-inertial internal wave energy from historical moorings	Alford
Eleanor Williams	Internal wave–wave interactions	Kunze
Mike Yargus	Experimental study of sound waves in sandy sediment	Jackson
Jinfei Yu	Thin-profile HIFU transducer design with cooling	Vaezy
Michael Zarnetske	Ocean circulation in the North Pacific using acoustic tomography	Howe & Dushaw
Vesna Zderic	Ultrasound-enhanced ocular drug delivery	Vaezy

Undergraduate Students

Student	Topic	Advisor
Jeremy Anderl	Service oriented architecture for DoD horizontal fusion projects	Carr
Thomas Anderl	Visualizing uncertainty in weather forecasting	Kerr
Brett Anderson	Using ultrasound to permeabilize the blood–brain barrier	Mourad
Brandon Ballinger	Modeling the effects of ocean currents and temperature on air–sea coupling	Kelly
Dan Blizzard	Construction of an ultrasound device to monitor HIFU lesion formation in the brain	Mourad
Joel Bolstad	ATOC/NPAL data management and archiving	Mercer
Courtney Boynton	Electro-optic polymer optics	Chen
Sean Burgess	Device design for image-guided HIFU ablation of peripheral nerves	Vaezy
Shih-Chi (Kenny) Chen	Sea surface scattering statistics modeling	Lettvin
Kohen Chia	Projections of an ice-diminished Arctic Ocean	Zhang
Irene Chin	NOPP ARGO float project	Nystuen
Nathan Chin	Use of ultrasound to open the blood–brain barrier/Acoustics and safety of acoustic toothbrush	Mourad
Elizabeth Dahl	Using ultrasound to permeabilize the blood–brain barrier	Mourad
Carie Frantz	Biocompatible hydrogels for intraoperative acoustic hemostasis	Vaezy
Zach Frazier	Automatic differentiation	Bell
Evan Gander	Development, construction, and testing of prototype for the MARS power supply and ALOHA/MARS mooring	McGinnis
Erin Graf	High-frequency ultrasound fragmentation of kidney stones	Bailey
Robyn Greaby	Pulsatile flow phantoms for image-guided HIFU hemostasis	Vaezy & Hwang
Jeffrey Harris	Inverting sonar data for sediment interface dynamics	Williams
Robert Held	Control system for HIFU array	Vaezy
Erik Henne	Computer simulation to determine optimum cooling set-up for thin-plate transducer	Vaezy
Grace Huynh	Development of water circulation system for an ultrasound image-guided HIFU device	Vaezy
Tanya Ilnitskiy	QuikSCAT wind vector retrieval	Lettvin
Aminul Islam	QuikSCAT wind vector retrieval	Lettvin
Ilan Jen-La Plante	Analysis of visible satellite images to look for internal waves	Kelly
Jeong-In Kang	Data analysis of HOME Nearfield Experiment	Gregg & Winkel
Julian Kelly	Two-frequency ultrasound to erode kidney stones	Bailey
Tanya Khokhlova	Vibro-acoustography to track kidney stones and to assess comminution	Bailey
Sanjeevani King	Modeling of radar backscattering from the sea surface, system calibration, and analysis of backscatter measurements	Lettvin

Undergraduate Students, continued next page

Undergraduate Students, continued

Student	Topic	Advisor
Nathan Kohagen	River surface current sensors	Plant & Hayes
Marta Krynytzky	IPCC models, arctic climate, and the influence on indigenous peoples	Bitz
Jiro Kusnunose	Vertical-mount simple Schlieren systems	Vaezy
Leslie Kwor	Development of wavelet software in the R language	Percival
Brian Lee	Sea ice concentration from microwave satellite data	Rigor
JoAnn Lin	Medical diagnostic optics	Chen
Trina Litchendorf	Measuring spray droplets at high wind speeds	Asher
Kelvin Ma	Graphics for wavelet software in the R language to analyze multi-scale geophysical data	Percival
Brian MacConaghy	Modeling waves generated by various lithotripters	Bailey
Adam Maxwell	Two-frequency enhancement of HIFU heating	Bailey
Thomas Mera	Thin-profile intraoperative HIFU transducers	Vaezy
Ben Monnahan	Visualizing uncertainty in weather forecasting	Kerr
Madhu Narayanan	Computer programming and data analysis	Yu
Lisa Nguyen	Observation of HIFU 'prelesions' in the brain using diagnostic ultrasound	Mourad
Adrienne Noble	Visualizing uncertainty in weather forecasting	Kerr
Ryan Ollos	Investigation of blood–brain barrier opening using HIFU	Mourad
Kristin Pederson	Blood–brain barrier investigations and use of HIFU to increase the specificity of pain diagnosis	Mourad
Christina Polwarth	DIDSON autonomous identification	Fox
Nathan Ratliff	Visualizing uncertainty in weather forecasting	Kerr
Justin Reed	Two-frequency mixing to control bubble dynamics	Bailey
Blake Riebe	Focused ultrasound used to raise the temperature of the hypothalmus	Curra
Alireza Shahrazad	Mechanical focusing for HIFU	Vaezy
Jason Shirley	Environmental radar design and construction	Plant
Chris Siani	Environmental radar design and construction	Plant
Rachel Sparks	Using ultrasound to permeabilize the blood–brain barrier	Mourad
Gauri Sudame	Longitudinal analysis of data related to the menopausal transition	Percival
Kasha Touloei	Using ultrasound to permeabilize the blood–brain barrier	Mourad
Konstantin Voziyan	Non-Bragg/alpha stable modeling of the sea surface	Lettvin
Eric Walkingshaw	Horizontal Fusion and EVIS	Kerr
Ward Williams	Freshwater switchyard of the Arctic Ocean and an integrated assesment of the pan-arctic freshwater system	Steele

Personnel– by Department

Directorate

Jeffrey A. Simmen - Director

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

Ellen E. Lettvin - Asst. Director, Education & Development

David L. Martin - Assoc. Director, Science & Technology Integration; Principal Oceanographer

Robert T. Miyamoto - Assoc. Director, Science & Technology Transition; Affil. Assoc. Prof., Electrical Engineering

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

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

Dian L. Gay - Administrator, Program Operations

Air–Sea Interaction & Remote Sensing

William J. Plant - Chair; Principal Res. Scientist; Affil. Prof., Atmospheric Sciences

William E. Asher - Principal Oceanographer

Gene H. Chatham - Student Helper

Zachary N. Conrad - Student Helper

Lisa H. Couret - Helper

Suzanne Dickinson - Oceanographer III

Brian D. Dushaw - Senior Oceanographer; Affil. Asst. Prof., Oceanography

Kathleen A. Edwards - Oceanographer IV

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 - Predoctoral Res. Assoc.

H. Ryan Jones - Student Helper

William C. Keller - Senior Physicist

Kathryn A. Kelly - Principal Oceanographer; Affil. Prof., Oceanography

Ellen E. Lettvin - Senior Oceanographer

Hanzhuang Liang - Res. Assoc.

Trina Litchendorf - Res. Aide II

Jeffrey A. Nystuen - Principal Oceanographer; Affil. Assoc. Prof., Oceanography

Kapil R. Phadnis - Res. Asst.

Keith A. Walls - Administrator

Michael R. Zarnetske - Predoctoral Res. Assoc.

Researchers in our department seek to learn about the environment by monitoring conditions near air–water interfaces and to develop new remote sensing techniques for doing this. Most applications of this research deal with ocean conditions, though scientists also conduct studies in laboratory wind–wave tanks and on rivers.

Department investigators have demonstrated that ocean currents can be deduced from measurements of surface wind fields by satellite-borne scatterometers—microwave systems that monitor ocean surface roughness. This may lead to improved methods of measuring currents on a global scale. The transport and storage of heat by such currents has been shown to be a major factor in the transfer of heat between the ocean and atmosphere, which is of critical importance to climate processes.

Breaking waves also influence the transfer of heat and gases across the ocean surface. The most obvious breaking waves are whitecaps, but investigators here have shown that breaking may be much more prevalent because most breaking waves are not visible to the eye. They are, however, detected at microwave and infrared wavelengths, where their effects on sea surface temperatures can be measured.

Coordinated studies have produced novel insights into the complex environment of hurricanes. Some of our researchers flew on NOAA hurricane hunter aircraft through hurricanes to measure sea spray drop sizes with a phase Doppler laser (see *Hurricane Ferocity Predictions* on p. 10). Others have looked into whether normal hurricanes produce boundary layer rolls in the lower atmosphere. And we have taken part in studies showing that the drag of the ocean on the wind does not continue to increase at hurricane wind speeds, providing an explanation of how hurricane-force winds are sustained over the ocean.

Center for Industrial & Medical Ultrasound

Lawrence A. Crum - Director; Res. Prof., Electrical Engineering and Bioengineering

Ajay Anand - Predoctoral Res. Assoc.

Marilee A. Andrew - Senior Engineer

Michael R. Bailey - Senior Engineer

Bradley M. Bell - Principal Mathematician

Andrew A. Brayman - Senior Physicist

Michael S. Canney - Predoctoral Res. Assoc.

Bryan W. Cunitz - Res. Asst.

Francesco Curra - Engineer IV

Barbrina Dunmire - Engineer IV

Lori J. Ferro - Administrative Specialist

Tia Ghose - Predoctoral Res. Assoc.

Robyn Greaby - Predoctoral Res. Assoc.

Lingyun Huang - Predoctoral Res. Assoc.

Peter J. Kaczkowski - Senior Engineer

Steven G. Kargl - Senior Physicist

John C. Kucewicz - Engineer III

Wenbo Luo - Predoctoral Res. Assoc.

Brian E. MacConaghy - Res. Asst.

Thomas J. Matula - Senior Physicist; Affil. Asst. Prof., Electrical Engineering

Adam D. Maxwell - Student Helper

Lisa Day Mercer - Administrative Specialist

Blake P. Miller - Predoctoral Res. Assoc.

Stuart B. Mitchell - Res. Assoc.

Pierre D. Mourad - Principal Physicist; Res. Assoc. Prof., Neurological Surgery

Terrence W. Myntti - Field Engineer

Ryan Ollos - Physicist II

Neil R. Owen - Predoctoral Res. Assoc.

Marla Paun - Engineer IV

Andrew H. Proctor - Senior Field Engineer

Colin Reinhardt - Res. Asst.

Blake Riebe - Res. Aide

Rachel E. Sparks - Student Helper

Frank L. Starr - Res. Manager

Juan Tu - Predoctoral Res. Assoc.

Rowen E. Tych - Student Helper

Shahram Vaezy - Senior Engineer; Assoc. Prof., Bioengineering

Vesna Zderic - Res. Assoc

The Center for Industrial and Medical Ultrasound (CIMU) is a world-class leader in ultrasound research and development. Our talented, multidisciplinary staff of physicists, mathematicians, engineers, technicians, and students works with a wide variety of researchers and medical professionals around the world to advance the expansion of the field. These relationships are enhanced by many industry partnerships and help to foster CIMU's mission of research collaboration, development and commercialization of technology, and training and education of students and professionals.

We are working on a broad variety of challenges including a high intensity focused ultrasound (HIFU) system to destroy benign and malignant tumors (see *Therapeutic Ultrasound* on p. 12). It will utilize diagnostic ultrasound for real-time guidance and HIFU for tumor destruction, permitting totally non-invasive, as well as bloodless, surgery.

Tom Matula and the engineering staff at APL-UW are working to optimize the efficiency of industrial food processing equipment with hydrodynamic cavitation technology. Here solid ingredients are liquefied (to make fruit juices, soy milk, or mayonnaise, for example) when subjected to the shear forces resulting from the rapid creation and collapse of bubbles.

CIMU and Moscow State University collaborate with colleagues in the Consortium for Shock Waves in Medicine, and play an important role in engineering safer and more effective lithotripters (devices used to break kidney stones). CIMU is focusing in particular on developing new ultrasound monitoring to give useful feedback to the urologist, and on optimizing the acoustic and cavitation fields to aid lithotripter manufacturers. Leveraging on knowledge gained from years of shock-wave lithotripsy research, our scientists are working proactively to define safe protocols and devices for the treatment of plantar fasciitis and tendonitis.

Pierre Mourad and APL-UW staff are developing a non-invasive method to measure intracranial pressure (ICP) with ultrasound. Because elevated ICP is associated with a number of serious neurological conditions, rapid, non-invasive measurements of ICP are extremely useful. A newly funded NASA project will develop an ICP measurement device for astronauts in space, where there is high risk of brain edema.

Electronic Systems

Gary L. Harkins - Department Head
A. John Black - Software Engineer II
John A. Blattenbauer - Engineer IV
Clark A. Bodyfelt - Senior Engineer
Neil M. Bogue - Senior Engineer
Matthew R. Carpenter - Engineer III
Morgan K. Carter - Student Helper
Antao Chen - Senior Engineer;
Affil. Assoc. Prof., Electrical Engineering
Rei Furukawa - Res. Asst.
April J. Greenwell - Fiscal Specialist II
Benjamin M. Henwood - Senior Engineer
Robert E. Johnson - Principal Engineer
William A. Jump - Senior Engineer
Carl J. Larson, Jr. - Field Engineer
JoAnn M. Lin - Student Helper
James C. Luby - Principal Engineer
Matthew J. McCurdy - Student Helper
Larry D. Nielson - Field Engineer
J. Aaron Nix-Gomez - Engineer III
Steven E. Purcell - Engineer III
Justin J. Schultz - Field Engineer
Marcelino Soriano - Manager
Eric W. Strenge - Field Engineer
Marvin L. Strenge - Principal Engineer
Laurence C. Tomsic - Field Engineer
Robert E. Van Note - Senior Field Engineer
William D. Woodman - Engineer IV

For more than 35 years our department has provided state-of-the-art solutions to challenging problems faced by the U.S. Navy. A major focus of our work is special purpose data recording systems for submarines. Modern submarines host a wide range of sensors, each providing a critical capability to the overall mission. Data from these sensors are used for tactical purposes by the submarine crew, but are also collected for later detailed analysis such as mission reconstruction. It is in this latter role that systems designed by APL-UW have special importance.

Submarines leave port and stay at sea for months at a time. Throughout these missions the data from thousands of sensors must be collected, time stamped, and stored on high-density data storage devices. We develop custom recording systems for this purpose. These systems utilize the latest commercial off-the-shelf recording technology including solid state, disk drive, and magnetic tape-based devices. To interface the data recorders with the submarine sensors, department engineers design custom electronic and fiber optic interfaces using off-the-shelf electronic components or, when necessary, by designing custom electronic devices using field programmable gate arrays or application-specific integrated circuits. We also develop highly specialized signal processing tools used to analyze the collected data.

We have begun new initiatives in the areas of autonomous undersea gliders and microwave photonic devices. We are partnering to develop a new, large undersea flying wing glider for surveillance applications. This work is leveraging off the Laboratory's very successful Seaglider development program (see *Undersea Glider Science* on p. 14). In microwave photonics our engineers are developing new sensors, high-speed switches, and other devices using novel polymer photonics materials developed by the University of Washington's Chemistry and Material Sciences and Engineering departments. These devices operate directly with light, and are expected to replace electronic devices in future systems.

Environmental & Information Systems

James W. Pitton - Department Head; Principal Engineer; Affil. Asst. Prof., Electrical Engineering

Jeremy J. Anderl - Student Helper

Gregory M. Anderson - Senior Engineer

Michael L. Boyd - Principal Physicist

Peter M. Brodsky - Engineer IV

Robert J. Carr - Engineer III

Luca G. Cazzanti - Engineer III

Keith L. Davidson - Engineer IV

Christian Eggen - Principal Physicist

Judith D. Ellingwood - Senior Engineer

William J. Felton - Senior Field Engineer

Warren L.J. Fox - Senior Engineer; Affil. Assoc. Prof., Electrical Engineering

Andrew A. Ganse - Engineer III

Robert P. Goddard - Senior Physicist

Megan U. Hazen - Engineer III

Julia B. Hsieh - Engineer III

David W. Jones - Senior Oceanographer

Richard K. Kerr - Senior Engineer

Elizabeth Kirby - Engineer IV

William C. Kooiman - Engineer IV

David W. Krout - Predoctoral Res. Assoc.

Charlotte Leigh - Senior Physicist

Michael Macaulay - Senior Oceanographer

Stuart D. Maclean - Engineer IV

John J. McLaughlin - Senior Engineer

Robert T. Miyamoto - Assoc. Director; Affil. Assoc. Prof., Electrical Engineering

Benjamin P. Monnahan - Engineer III

Kou-Ying Moravan - Senior Physicist

Jan A. Newton - Principal Oceanographer; Affil. Asst. Prof., Oceanography

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

Gauri R. Sudame - Student Helper

Troy T. Tanner - Senior Computer Specialist

Patrick G. Tewson - Engineer III

Angela D. Van Valkenburg - Administrative Specialist

Joseph S. Wigton - Engineer IV

Daniel J. Wolkensdorfer - Principal Engineer

Lan Yu - Fiscal Specialist II

We are a multidisciplinary group focused on the creative application of new technologies to Department of Defense needs. Our group of electrical engineers, computer scientists, physicists, earth scientists, and other researchers teams with engineers and scientists from universities, DoD laboratories, and industry to solve critical problems for national security and environmental science.

Expertise in meteorology, oceanography, acoustic modeling, and signal and information processing is applied to sonar systems used in antisubmarine warfare, torpedo defense, and mine countermeasure systems to improve performance and identify performance limitations. Our researchers are automating analysis of U.S. Navy antisubmarine warfare exercises via a web-based data distribution and scenario reconstruction system. Another group is employing autonomous vehicles to perform environmental measurements in U.S. Navy exercises and sea trials (see *Undersea Glider Science* on p. 14). Our Human Systems Interaction program is expanding, adding new computer scientists (see *Improved Decision Making* on p. 18).

Our department has added new expertise in signal processing for several research and development efforts, including new work in mine countermeasures. One program focuses on automatically processing underwater imagery produced by the DIDSON (Dual-frequency IDentification SONar), a high-resolution imaging sonar developed at APL-UW. One application for the DIDSON is as a forward-looking sensor on an autonomous undersea vehicle; several large data sets have been collected recently by other institutions with the sonar deployed in this manner. Researchers designed and implemented algorithms that automatically screen these large data sets for objects of interest that the vehicle has encountered. This advance relieves human operators of the onerous task of screening the data manually. The eventual goal is to develop algorithms that will allow autonomous vehicles to independently detect, classify, and identify objects of interest in-stride.

Our basic and applied oceanographic research continues to grow with the recently funded Hood Canal Dissolved Oxygen Program. This program is bringing together local, state, federal, and tribal government policy makers to evaluate potential corrective actions to restore and maintain a level of dissolved oxygen that will reduce stress on marine life in Washington State's Hood Canal.

Ocean Acoustics

Kevin L. Williams - Department Chair; Principal Physicist; Assoc. Prof., Oceanography

Rex K. Andrew - Engineer IV

Robert M. Bolstad - Res. Manager

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

Jamie C. Griffith - Visiting Scientist

Brian T. Hefner - Physicist IV

Bruce M. Howe - Principal Oceanographer; Res. Assoc. Prof., Oceanography

Anatoliy N. Ivakin - Senior Physicist

Darrell R. Jackson - Principal Engineer Emeritus

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

Kathleen M. Stafford - Oceanographer IV

Dajun Tang - Senior Oceanographer

Eric I. Thorsos - Principal Physicist; Affil. Assoc. Prof., Electrical Engineering

Michael A. Wolfson - Mathematician IV

We study the effects of a variable ocean environment on the propagation and scattering of sound—the "forward" ocean acoustics problem. We also exploit our understanding of these effects to solve the "inverse" acoustic oceanography problem—where sound is used as a probe to study the ocean environment itself. Our studies span the frequency range from a few cycles per second (Hz) to hundreds of kHz (1 kHz = 1000 cycles per second).

As low-frequency (10–1000 Hz) 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 the North Pacific Acoustic Laboratory (NPAL). In the fall of 2004, NPAL researchers examined how ocean internal waves affect long-range acoustic propagation. We also 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 very low-frequency acoustic energy that then propagates in the ocean.

Enhancing U.S. Navy mid-frequency sonar (1–10 kHz) operation in shallow water involves theoretical and experimental efforts to better understand and model the physics of propagation and scattering. Ocean acoustics models are improved by including the influence of the rough ocean surface and variable seafloor. These models, which must balance fidelity against computational speed, will be tested in an at-sea experiment off the New Jersey coast in fall 2006.

Taking advantage of our knowledge of acoustic propagation in shallow water environments, we have begun to study the effects of mid-frequency sound on marine mammal communication, behavior, and health (see *Marine Mammal Soundscapes* on p. 16). This includes sound propagation research in the shallow waters of Puget Sound, where bottom topography and sound speed variations in the water can significantly affect the sound levels incident on marine mammals as they move within their environment. The studies are numerically intensive and use parabolic equation approximations that have been tested and are being improved using in-house exact propagation codes.

To predict the capability of sonar to detect buried mines at shallow grazing angles, we are seeking a mechanistic understanding of scattering from, penetration into, and propagation within the seabed. Studies have shown that diffraction due to sand ripples is the main mechanism of penetration at shallow grazing angles and frequencies above 10 kHz. The SAX04 ocean acoustics experiment carried out in September–November 2004 examined the use of this penetration mechanism as well as other, lower frequency (1–10 kHz) mechanisms to detect buried mines using synthetic aperture sonar.

Ocean Engineering

Russell D. Light - Department Head; Principal Engineer
Paul A. Aguilar - Field Engineer
Eric S. Boget - Engineer IV
John B. Elliot - Engineer IV
Evan P. Gander - Student Helper
Lyle F. Gullings - Senior Field Engineer
Frederick Karig - Principal Engineer
Michael F. Kenney - Oceanographer IV
Harold A. Kolve - Principal Engineer; Affil. Asst. Prof., Electrical Engineering
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
Colin H. Saari - Res. Coordinator
Peter L. Sabin - Senior Field Engineer
Colin J. Sandwith - Principal Engineer; Res. Assoc. Prof., Mechanical Engineering
Christopher Siani - Engineer III
Daniel A. Stearns - Field Engineer
Keith L. Van Thiel - Engineer III
Michael L. Welch - Senior Engineer
Timothy Wen - Senior Engineer

The Department's professional engineers and technicians provide services to the research community at the Laboratory, the UW College of Ocean and Fishery Sciences, and the U.S. Navy. Staff expertise covers ocean, mechanical, electrical, software, and field engineering as well as research diving.

Over several months last year our talents were applied to the Sediment Acoustics Experiment 2004 (SAX04). An eight-member dive team placed undersea measurement systems and acoustic targets on the seafloor. One system is an underwater rail structure and tower that carries a large number of acoustic transducers. The tower could be moved along the seafloor in precise motions while acoustic signals over the frequency range 2–500 kHz were directed at the sediments. This configuration allowed the acoustic echoes to be processed as synthetic aperture sonar, giving unprecedented resolution. The experiment's science return will improve the detection of buried objects, such as mines, in coastal waters.

A new generation of cabled seafloor scientific observatories is being developed and others are being planned. Key to their operation is a power system capable of delivering 10s to 100s of kilowatts of power to arrays of seafloor instruments. In cooperation with other institutions, we are completing the first design of a power system to provide networked power control to and monitoring of numerous science instruments. It will be deployed first at the MARS observatory 60 km offshore in Monterey Bay and may become the standard hardware and software for a variety of future cabled ocean observing networks.

The cabled observatories must include moorings to enable investigations of the water column. We are developing a system that will include a motorized mooring profiler with inductive power and data transfer, and secondary junction boxes at the seafloor and on a subsurface float to allow guest users to plug in their instruments with the aid of a remotely operated vehicle.

Building on a long history of successful autonomous underwater vehicle design, engineers are now partnering with the Scripps Institution's Marine Physical Laboratory on a large ocean glider. A flying wing with a span of 20 feet, it will be capable of carrying large payloads at higher speeds than previous ocean gliders (see *Undersea Glider Science* on p. 14).

Our Arctic Bottom Pressure Recorder is an instrument used to measure the ocean height in very deep arctic basins; it is deployed from the ice canopy and can remain on the seafloor for three years. Research staff can return to the deployment area yearly and telemeter data acoustically from the instrument to the surface.

Ocean Physics

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

Stephen J. Bayer - Senior Engineer

James A. Carlson - Senior Engineer

Glenn S. Carter - Predoctoral Res. Assoc.

Andrew C. Cookson - Senior Field Engineer

Lauren Curry - Student Helper

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

John H. Dunlap - Senior Engineer

Terry E. Ewart - Principal Physicist Emeritus

James B. Girton - Oceanographer IV

Jason I. Gobat - Oceanographer IV

Michael C. Gregg - Prof., Oceanography

Ramsey R. Harcourt - Oceanographer IV

Brian J. Henderson - Student Helper

Frank S. Henyey - Principal Physicist

Philip J. Hosegood - Res. Assoc.

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

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

Ren-Chieh Lien - Senior Oceanographer

Joseph P. Martin - Res. Assoc.

Kim I. Martini - Predoctoral Res. Assoc.

John B. Mickett - Predoctoral Res. Assoc.

Jack B. Miller - Principal Engineer

David W. Morison - Helper

Sheila S. Ocoma - Fiscal Specialist II

Eric C. Rehm - Predoctoral Res. Assoc.

Thomas B. Sanford - Principal Oceanographer; Prof., Oceanography

Nancy J. Sherman - Administrator

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

Maya E. Whitmont - Res. Asst.

David P. Winkel - Oceanographer IV

Zhongxiang Zhao - Res. Assoc.

Our scientists, engineers, and graduate students focus on research in small- to medium-scale physical oceanography. By designing and fabricating instruments, collecting and analyzing data, developing and testing theory, and applying numerical modeling we further our understanding of heat fluxes, ocean currents, waves, turbulence, mixing, and acoustic propagation and scattering.

Instrument development remains a core strength. Unique mooring technology is being used to measure oxygen depletion in Hood Canal, to measure how the continental shelves dissipate internal-tidal energy generated in the deep ocean, and to measure temperature and conductivity in the near-surface region of high-latitude oceans where sea ice decline has been observed. In partnership with private industry, a new autonomous profiling float was developed; several have been deployed successfully in hurricanes to obtain measurements of air–sea momentum transfer (see *Hurricane Ferocity Predictions* on p. 10); these may improve storm intensity predictions. Seagliders are being modified for extended-duration sampling in ice-covered regions, and the latest generation of the Shallow Water Integrated Mapping System was used to investigate the lateral restratification of surface mixed layers in the Pacific Ocean near Hawaii.

Lagrangian floats developed here made the first measurements of ocean turbulence and air–sea gas flux during hurricanes and were deployed at the equator to study mixing and heat flux in the eastern equatorial cold pool. When deployed in the South China Sea, they confirmed what may be the largest internal waves ever measured. Because these waves impact tactical underwater operations, the U.S. Navy is funding additional studies in the South China Sea and near the Hudson Canyon of the Atlantic Ocean.

Department researchers are at the forefront of understanding the extent to which internal waves affect the propagation of sound in the ocean. An important part of the recent LOAPEX (Long-range Ocean Acoustic Propagation EXperiment) fieldwork was the measurement of acoustic energy arriving deeper in the water column than expected. Through modeling we are investigating how internal waves may be responsible.

Many of us are participating in a large U.S. Navy study to assess whether the parameterization of various small-scale (<10 km) ocean processes into models of ocean dynamics are correct and effective. Another researcher has been awarded the first NASA-funded planetary sciences grant at APL-UW; he will apply knowledge of magnetic fields to study the icy oceans on Jupiter's moons. The National Science Foundation has funded an investigation with Lagrangian floats of deep water formation in the Antarctic. Three recently hired post-doctoral researchers are immersed in analyzing rich data sets acquired from the Pacific Ocean near Hawaii, and our program to develop electric field sensors and to collect field measurements with them is expanding rapidly. Our department enjoys a steady influx of new research thrusts to augment the established.

Polar Science Center

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

Kunt Aagaard - Principal Oceanographer; Prof., Oceanography

Roger H. Andersen - Mathematician IV

Oleg Babko - Predoctoral Res. Assoc.

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

Wendy S. Ermold - Physicist II

Andreas Heiberg - Principal Engineer

Paul J. Hezel - Data Control Technician III

Suzan V. Huney - Administrator

James M. Johnson - Senior Field Engineer

Ian R. Joughin - Senior Engineer

Clark H. Kirkman, IV - Res. Asst.

Christopher Krembs - Oceanographer IV

Bonnie Light - Physicist IV

Ronald W. Lindsay - Senior Physicist

Mari S. Litzenberger - Program Coordinator

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

Mark L. Ortmeyer - Oceanographer II

Ignatius G. Rigor - Mathematician IV

David A. Rothrock - Principal Research Scientist; Assoc. Prof., Oceanography; Adjunct Assoc. Prof., Atmospheric Sciences

Kay A. Runciman - Mathematician III

Francis J. Sawatzki - Data Control Tech. III

Axel J. Schweiger - Oceanographer IV

Michael Steele - Senior Oceanographer

Harry Stern - Mathematician IV

Dean J. Stewart - Field Engineer

Mark R. Wensnahan - Physicist IV

Dale P. Winebrenner - Principal Physicist; Res. Prof., Earth and Space Sciences

Rebecca A. Woodgate - Senior Oceanographer; Affil. Asst. Prof., Oceanography

Yanling Yu - Oceanographer IV

Jinlun Zhang - Oceanographer IV

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, ice, and biota. The center has made major contributions to the understanding of how the arctic system has undergone important changes during the past four decades.

Recent staff recruitment has expanded our areas of study to include the huge Greenland and Antarctic ice sheets and the tiny organisms that inhabit sea ice. Satellite imagery and ground-based ice motion data are used to estimate ice sheet mass balance and its contribution to sea level. These data, in conjunction with ice sheet models, provide insight into the processes that control fast ice stream and outlet glacier flow, particularly in response to a changing climate. Research on the large pool of organic, carbon-rich microbial slime found in arctic sea ice brings new understanding of ice as habitat (see *Life of Sea Ice* on p. 8). This fundamental research into microbial communities may elucidate interesting feedbacks between climate change and sea ice biology, and provide insights into life in extreme environments that may be applied to astrobiology.

Our scientists lead large-scale observation and process study programs including the North Pole Environmental Observatory, which has been deployed each April for the past five years and is scheduled to continue through at least 2008. Aerial hydrographic surveys across the Arctic Basin, buoys deployed on the drifting ice, and a 2.5-mile long oceanographic mooring at the pole have documented a partial relaxation of mid-depth temperature and salinity values toward historical averages, and interannual changes in mean ice thickness of 50 cm.

We develop, test, and apply physical–numerical models of the Arctic Ocean and its sea ice cover, making use of *in situ* and satellite remote observations. This research shows how polar regions function within the global climate system, and enhances our confidence in climate predictions. A recent modeling study shows that over 50 years (1948–1999) variable winds produced no substantial trend in arctic sea ice volume, but variable temperatures produced a significant downward trend of –3% per decade.

Another modeling study shows that the water and heat flow from the Atlantic to Arctic oceans at the Iceland–Scotland Ridge increased during 1953–2003 and contributed to substantial thinning of arctic sea ice since 1966. Analysis of ice motions measured by drifting buoys indicates that the area of the Arctic Ocean covered by ice older than ten years decreased dramatically in the late 1980s. This decrease helps to explain the recent downward trend in sea ice extent.

Administrative & Technical Services

Business & Administration

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

Financial Information Systems

Larry C. West - Senior Computer Specialist

Financial Management

Anne L. Clark - Administrator, Program Operations
Anthony J. Nice - Manager
Hien D. Tran - Accounting Supervisor
Kannie Cheung - Fiscal Tech. III
Cheuk Chhann - Fiscal Specialist I
Becky E. Harrison - Fiscal Specialist II
Julia Yeh - Fiscal Tech. III

Grant and Contract Administration

Moira G. McCrory - Administrator
Peggy L. Hartman - Administrator

Human Resources/Personnel

Robert M. Bratager - Manager
Linda M. Marsh - Coordinator, Program Operations

Resources

Gordon K. Glass - Department Head, Resources

Building Services

Ponciano Austria - Maintenance Custodian I
Jim Fahey - Manager
Oliver R. Hartman - Maintenance Supervisor II
Dale K. Johnson - Maintenance Mechanic II
Stuart R. Woolfield - Maintenance Mechanic II

Distributed Computer Services

Stefani P. Banerian - Senior Computer Specialist
David D. Fetrow - Senior Computer Specialist
Adam L. Morehead - Senior Computer Specialist
Heather M. Turchin - Student Helper
Joshua B. Webb - Student Helper

Library

Jane M. Doggett - Library Specialist II Supervisor
Leslie A. Harding - Library Specialist II
Reagan N. Runyon - Student Helper

Machine Shop

Patrick G. DePasquale - Instrument Maker III
John P. Gutensohn - Instrument Maker III
Timothy W. Jansen - Instrument Maker III
Douglas S. Jordan - Instrument Maker III
Patrick T. McCrory - Instrument Maker Lead
Robert L. Prong - Manager
Richard W. Syverson - Maintenance Mechanic II

Marine Department

Eric S. Boget - Engineer IV
Chris L. Craig - Maintenance Mechanic II

Publications

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

Purchasing & Property Control

Samantha D. Auflick - Fiscal Specialist I
Peggy K. Buschmann - Manager
Thomas F. Guthrie, Jr. - Truck Driver I
Thomas A. Kerrigan - Fiscal Specialist I
Christian Skoorsmith - Fiscal Tech. III
Tina M. Stremick - Fiscal Specialist I
Susan L. Womack - Fiscal Specialist I

Security, Safety & Central Services

Charlotte Boynton - Program Support Supervisor I
Mariann DomBek - Fiscal Specialist I
Kelley P. Knickerbocker - Manager
Nicholas A. Plemel - Program Asst.

Shipping & Receiving

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

— personnel as of June 2005

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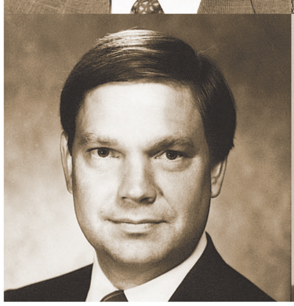

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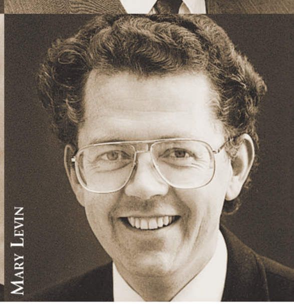

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