

THE APPLIED PHYSICS LABORATORY
College of Ocean and Fishery Sciences
University of Washington

Biennial Report
2007

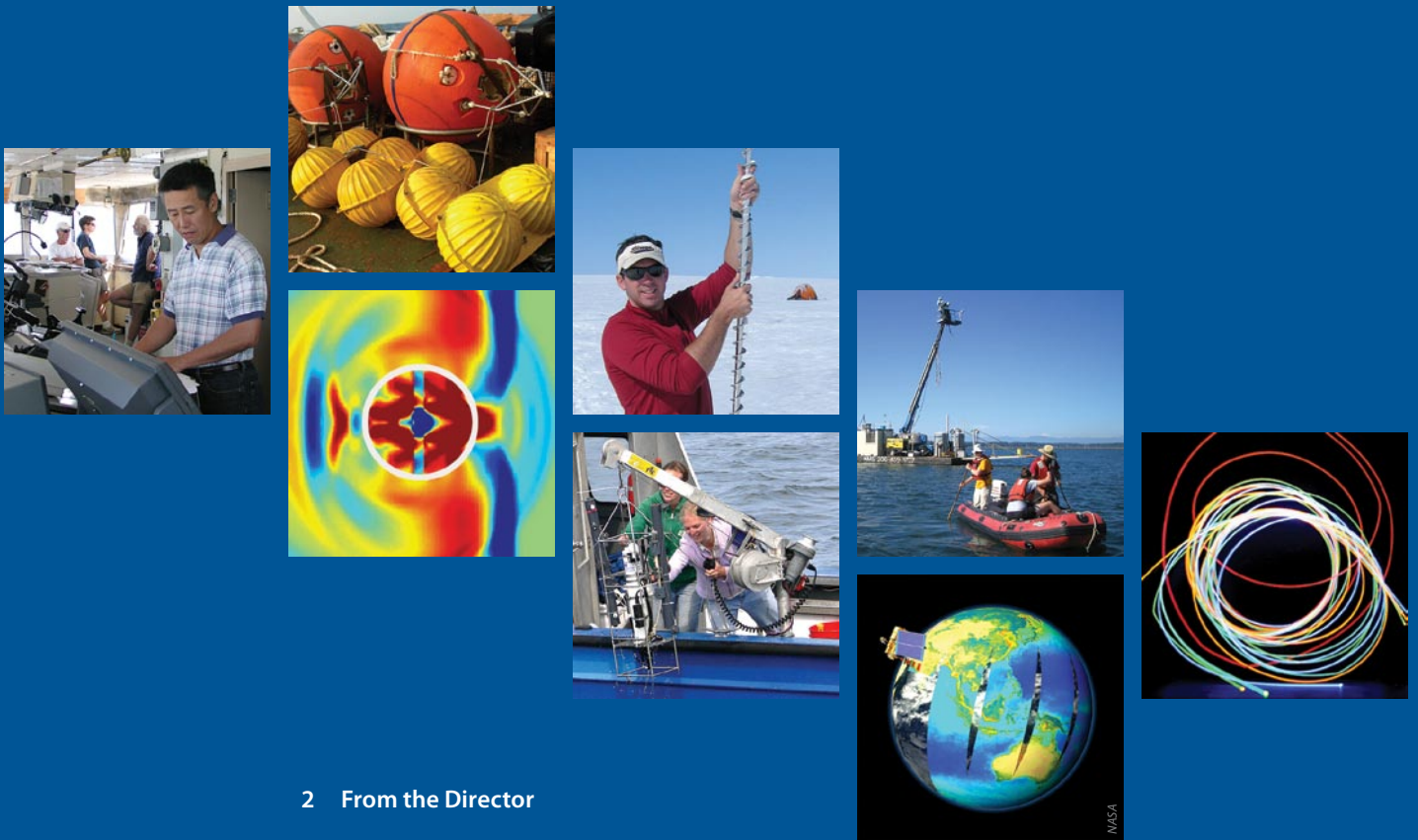
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From the Director





The Applied Physics Laboratory of the University of Washington is a premier center for research, development, and advanced education in its core research areas: marine acoustic and remote sensing, ocean physics and engineering, polar science, medical and industrial ultrasound, and environmental information and electronic systems. This biennial overview of our discovery and invention includes eight profiles of our science and technology efforts, as well as a summary of our education and outreach activities.

In the past two years we have taken on significant roles in major science and engineering projects that involve multiple APL-UW departments. Mobile and autonomous undersea surveillance, ocean observing systems, maritime security, photonics applications, and counter-terrorism efforts are some of the emerging areas of intense focus. We have encouraged collaboration, locally and regionally, in several of our research efforts, resulting in increased cooperation

with other departments of the University of Washington, with university partners in Oregon, and with Washington State agencies, industries, and tribes.

APL-UW investigators have again executed world-class field programs covering the globe, from the Arctic to the Antarctic, from the Pacific to the Atlantic oceans, and from the Mediterranean to the Philippine seas. This past spring we successfully supported the U.S. Navy's submarine under-ice exercises in the Arctic, and now we are shifting emphasis towards scientific discovery for the International Polar Year. Our entrepreneurial activity is strong, and the latest spin-offs from the Laboratory bring us to a total of five companies in about as many years.

Federal research funding for the Laboratory continues to grow. In response to this increased activity we have recruited some impressive new people to the APL-UW team and have made an investment to build up the Laboratory's infrastructure. So far we have developed new laboratories for experimentation and renovated common spaces and meeting rooms; additionally, a new research vessel is under construction and will be delivered to us soon, and we are in the final stages of expanding office and laboratory space. This past year we also welcomed several valuable new members to our Advisory Board.

By any measure the last two years have been excellent ones. Our notable discovery and invention would not have happened without the strong support of the U.S. Navy, especially the Office of Naval Research, and other key federal funding agencies, in particular, the National Science Foundation. I look forward to continuing these partnerships as we work together to meet our nation's greatest challenges.

Jeff Simmen

The Laboratory



The Laboratory's underwater rail and trolley structure that moves along the seafloor in precise motions while interrogating the sediments with acoustic signals was modified to support interactive operation with a parametric sonar at Naval Surface Warfare Center-Panama City. For one month in their large, open air, artificial pond, the system was used to perform backscattering and bistatic scattering experiments on a variety of simple and mine-like target shapes. Installation and support of the system required hundreds of dives in the pond and resulted in ~1 terabyte of very high quality acoustic data used to examine basic sediment acoustics and the problem of buried mine detection and classification.

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Fundamental Research—Applied Science

Founded by the U.S. Navy as one of four university laboratories to focus intellectual and technical resources on problems encountered during World War II, the Applied Physics Laboratory of the University of Washington has built a world-class reputation through service to the Navy and other federal agencies.

The early acoustic and oceanographic studies devoted to understanding the effects of the ocean environment on U.S. Navy systems provided the foundation for Laboratory research and development. Today the Laboratory leads the way with discovery and invention in polar science, ocean physics and engineering, acoustical and remote sensing, medical and industrial ultrasound, and environmental information and electronic systems. This report highlights examples of how the Laboratory fulfills its mission to conduct a program of fundamental and applied research, development, engineering, and education for science, industry, and national defense.

Noteworthy Research & Development

■ The Laboratory's strength in polar research programs makes our scientists important participants in the International Polar Year (IPY), which began in spring 2007. In total the effort involves scientists from 60 countries and is funded for \$350 million. The Laboratory's arctic IPY projects contribute to the marine component of the Arctic Observing Network, which seeks to build on and enhance existing U.S. and international efforts. These pan-arctic observations to detect fundamental variations in the arctic system will be a quantum leap in understanding the nature and causes of change in the Arctic Ocean, and the impact of these changes on the World Ocean.

■ Oceanographers set out on two cruises totaling 50 days on the R/V *Roger Revelle* during summer 2006 to track the "internal tide" that radiates from the Hawaiian Ridge and travels at least 1000–2000 km northward. Six instrumented moorings were deployed along a transect that followed the "beam" of maximum tidal energy flux to understand how the large undersea transport of wave energy affects North Pacific Ocean climate.

■ The National Science Foundation established a Science and Technology Center for Coastal Margin Observation and Prediction in 2006. The Laboratory is taking on infrastructure challenges for a proposed observatory—providing power and communications among all the sensors and instruments to be deployed in the lower reaches of the Columbia River and the coastal regions of Oregon and Washington.

■ Collaborating with over one dozen research and development institutions, APL-UW has been active in many facets of the Office of Naval Research's Persistent

Littoral Undersea Surveillance – Networked (PLUSNet) program to develop the next generation of underwater surveillance concepts that involve fixed and mobile sensing nodes connected by acoustic, radio frequency, and satellite networks. An electric field sensor has been developed to operate as a bottom-fixed node and is also being fit into the XRay glider, co-developed with the Scripps Institution of Oceanography Marine Physical Laboratory.

■ Seagliders enhanced with an acoustic modem were deployed in PLUSNet missions in the Philippine Sea, near Hawaii, and in Monterey Bay. With a modem working in concert with the Iridium satellite communications system, the gliders serve as gateways between pilots on shore and other ocean instruments and mobile platforms (see *A Smart Sensor Web for Ocean Observation*, p. 29). A hydrophone also detects low-frequency source signals, marine mammals (blue and humpback whales), and ambient ocean noise, enriching the data collected by Seaglider’s oceanographic sensors.

■ The Laboratory joins the University of Washington to begin the five-year design/build and initial five-year operations/maintenance periods of an undersea observatory off the Pacific Northwest coast. Spanning the Juan de Fuca tectonic plate, the observatory will be connected by more than 850 miles of cable for power and communications— data, video, still imagery, and instructions will be sent to and from shore via the Internet. This revolution in ocean science will rely on creative and precise engineering; while many of the components are well tested, they have never been implemented in a long-term autonomous system at a depth of 10,000 feet.



■ On neighboring Lake Washington, Laboratory scientists made simultaneous in situ and remote sensing measurements of breaking wave distribution and associated energy dissipation to improve understanding of how wind and waves drive mixing in the upper ocean. Their centimeter-scale measurements in various wind/wave regimes will be included in predictive numerical models, which had neglected such a fine scale quantification until now.

■ Many research programs at the Center for Industrial and Medical Ultrasound focus on improving the human health condition; one used ultrasound technology to build the ultimate toothbrush. A collaboration between APL-UW and the UW School of Dentistry synergized the action of powered bristles, which generate bubbles, with an ultrasound waveguide, whose emitted ultrasound activates the bubbles. The bubbles oscillate, expand and contract, or burst—all creating shear forces that clean teeth surfaces even where bristles do not touch. The Ultreo toothbrush was first marketed through dentists' offices, and will soon be available directly to consumers.

Awards, Honors & Celebrations

■ Oceanographer Jim Thomson won a Young Investigator Program prize from the Office of Naval Research. The Acoustical Society of America presented its Medwin Prize in Acoustical Oceanography to Senior Oceanographer Brian Dushaw, and its Mentoring Award to Principal Physicist Lawrence Crum; Engineer Michael Bailey and Senior Oceanographer Dajun Tang were named fellows of the society. Crum also



received the Distinguished Service Award and Medal from the Civilian Research and Development Foundation.

■ Principal Oceanographer Kathryn Kelly was elected fellow of the American Meteorological Society and Professor Mike Gregg was presented with the society's Strommel Research Award. Gregg also became a fellow of the American Association for the Advancement of Science.

■ With Naval Undersea Warfare Center Division, Keyport, the Laboratory shared in the celebration of the 50th anniversary of the first underwater tracking range. In Dabob Bay, Washington, on May 22, 1957, APL-UW and Keyport personnel first tracked a torpedo with the newly installed acoustic array. This seminal experiment provided critical ground truth tracking data; similar systems continue in use today.

Distinguished Visitors

Over the past biennium honored guests included several U.S. Navy commanders and personnel who received tours and briefings on research and development efforts of special relevance to naval operations. They were: **Rear Admiral William D. French**, Commander Navy Region Northwest; **Mr. Pat Tamburrino**, Executive Director, Naval Sea Systems Command; **Rear Admiral Frank M. Drennan**, Commander, Submarine Group 9 and 10; and the **Honorable BJ Penn**, Assistant Secretary of the Navy, Installations



The Applied Physics Laboratory Ice Stations (APLIS) have provided all logistics support for U.S. Navy submarine ice exercises since 1974. Fred Karig, pictured here during the exercises on the Beaufort Sea in spring 2007, has led efforts for most of the stations.

and Environment. The many visitors from the Office of Naval Research included: **Dr. Patricia Gruber**, Director of Research; and **Mr. William Melton**, Associate Director for Science and Technology, ONR Global–Latin America, who visited the Laboratory with colleagues from the Argentinean Navy, **Drs. Marta Milou** and **Silvia Blanc**. **Dr. Marshall Orr**, Program Manager for Submarine Security and Technology also visited, as did program managers from the Office of Naval Intelligence and other Navy sponsors.

Congressional visitors included **Mr. Bill Natter**, Committee Staff, House Armed Services Committee; **Mr. Andy DeMott**, military legislative aide to Congressman Norm Dicks; and **Lieutenant Commander Nicole Shue**, Congressional Liaison, Navy Science and Technology. APL-UW and the University of Washington are engaged in the important fundamental research to counter improvised explosive devices; **Colonel Barry L. Shoop**, Ph.D., Science Advisor to the Director and Chief Scientist, Joint IED Defeat Organization, traveled to the Laboratory to be briefed on current efforts.

The Laboratory was pleased to welcome the University of Washington's new Provost, **Dr. Phyllis Wise**, for mutual introductions and an extensive tour. Over the past two years APL-UW has hosted many science and technology meetings and workshops, including the Office of Naval Research Northwest Regional Progress Review, led by **Dr. Frank Herr**. This three-day conference drew two dozen program managers to the Laboratory to receive formal presentations on funded research from scientists in the Pacific Northwest.



A photograph showing three people on the deck of a research vessel. One person in a white shirt and dark shorts is standing on a red ladder, reaching up to adjust a horizontal metal beam. Another person in a dark t-shirt and a green hard hat is standing on a metal platform below, also reaching up. A third person in a white shirt and blue shorts, wearing a white hard hat, is standing on the deck looking towards the equipment. The equipment consists of a large metal frame with a crane arm extending over the side of the boat. A large wooden pulley is hanging from the crane. The background is a vast blue ocean under a clear sky. On the deck, there are several red buoys and a yellow inflatable boat.

Research Highlights



Conquering Uncertainties in Shallow Water Acoustics

The Laboratory established its early reputation on understanding and quantifying how the ocean environment affects U.S. Navy systems by combining oceanographic parameters measured on the appropriate scales with the relevant physics of underwater acoustics. In littoral regions (shallow water typically less than 200 m deep) the performance of many sonar systems is strongly influenced by acoustic interactions with the bottom, surface, and water column. The bottom can be rocky, rippled sand, or silt over bedrock; depending on the winds, the surface is flat or dominated by waves; temperature, stratification, thermocline intrusions, and internal waves all affect how acoustic signals propagate through the water column. The combined variability of these elements significantly affects U.S. Navy sonar tasks of target detection, localization, and classification.

Collecting direct path forward and backscatter acoustic data from the boundaries and through the water column required a complex observation strategy. During the LEAR field studies a surface wave buoy logged sea surface roughness and wind speed while APL-UW's IMP (In situ Measurement of Porosity) gathered bottom roughness data at a horizontal resolution of 1 cm. Experiments began in a small local area to study single interactions of sound with the bottom, surface, and water column over space and time. The Moored Receiving Array (MORAY), recently modified to include a horizontal line array of acoustic receivers in addition to its two vertical line arrays, made short-range bottom/surface interaction measurements at 50–1000 m from multiple directions from an acoustic source deployed on the R/V *Knorr* in a frequency range of 1–20 kHz. Similar measurements were made by researchers from the Scripps Institution of Oceanography and the University of Victoria, but at slightly lower frequencies (0.5–4 kHz) and longer range (10 km).

Senior Oceanographer Dajun Tang and his colleague from the Woods Hole Oceanographic Institution, James Lynch, served as co-chief scientists for the Littoral Environmental Acoustics Research (LEAR) study at a site off the New Jersey coast, where intensive oceanographic and environmental data have been gathered previously. The Office of Naval Research-funded study was coordinated with the Nonlinear Internal Wave Initiative (NLIWI) and the Autonomous Wide Aperture Cluster for Surveillance (AWACS) project to form the joint experiment Shallow Water 2006. Five APL-UW Principal Investigators were involved: Tang and Principal Engineer Peter Dahl (LEAR), and Principal Physicist Frank Henyey, Principal Research Scientist William Plant, and Assistant Director Ellen Lettvin (NLIWI).

Long-range (10–20 km) acoustic propagation in littoral regions is dominated by multiple forward scattering and reverberation issues. Waves propagating at larger grazing angles suffer greater scattering by interfaces, and are then lost into the bottom. At propagation distances greater than 4 km LEAR researchers observed mode stripping: sound propagation at these distances became increasingly coherent, a finding that is promising for undersea acoustic communications.

APL-UW engineers designed and deployed the Sediment Acoustics Measurement System (SAMS) to gather in-sediment sound speed data with a spatial resolution of 10 cm in both horizontal and vertical dimensions. SAMS uses a vibro-core fitted with a hydrophone at its tip to penetrate into the bottom in controlled depth-steps while 10 acoustic sources located above the bottom transmit sound in the 2–35-kHz band. The source/receiver arrangement crisscrosses the sediment volume, so sediment sound speed as a function of depth is measured directly. SAMS data show that sound speed is nearly constant in the sediments up to a depth of 1.7 m. These data also provide the ground truth measurements to determine the acoustic direct-path bottom loss without ambiguity.

The U.S. Navy is intensely interested in the effect of nonlinear internal wave trains on mid-frequency acoustic propagation (see *Giant Waves Beneath the Sea*, p. 14). With the goal of making a deterministic assessment of the impact, snapshots of internal waves were taken along an acoustic path. This was done by making transmissions between a source deployed from the stationed R/V *Knorr* and the MORAY 1000 m away while a conductivity-temperature-depth (CTD) chain with 50 elements was towed by the R/V *Endeavor* in the depth range where nonlinear internal waves were strongest.

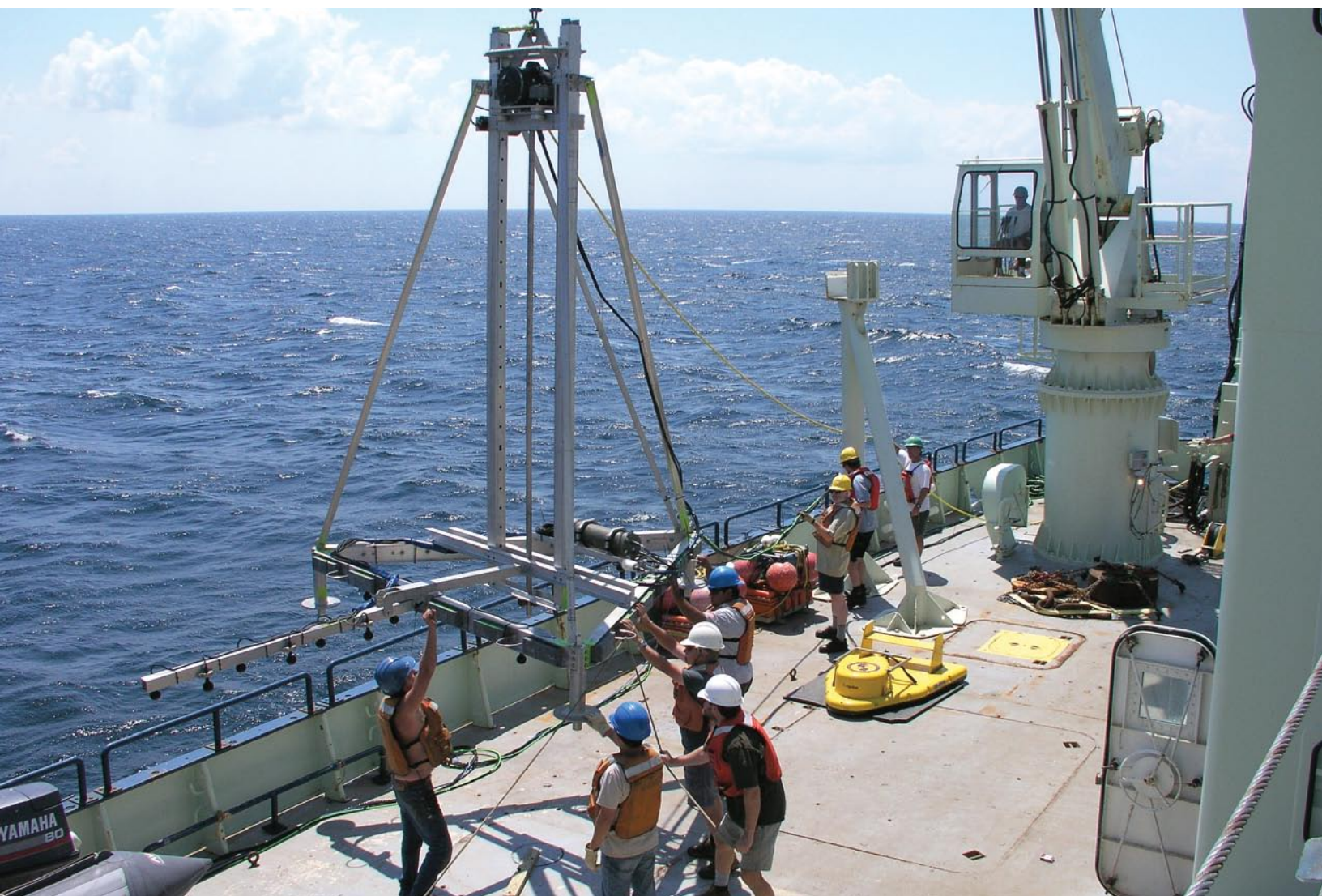


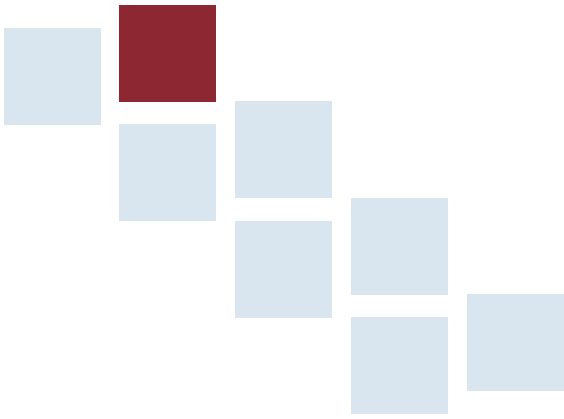
Steaming at 6 kt (fives times faster than the propagating waves) in the vicinity of the source and receiver, the *Endeavor* circled and crossed the wave train multiple times. Here the waves were mapped over time simultaneous with the interrogation of the isopycnal displacement by acoustic signals sent between sources and receivers at fixed locations and depths. Both acoustic propagation and CTD chain measurements were made when internal waves were either present or absent as a control on quantitative evaluation.

Also deployed on the *Endeavor* over the duration of her operations at the study site was the APL-UW-developed RiverRad pulsed Doppler radar. The radar detects the surface signatures of the nonlinear internal waves. Also deployed was an airborne Doppler radar mounted on a Cessna Skymaster, which flew patterns over the ships on 15 occasions on 11 different days. These remote sensing data will be compared with the extensive oceanographic measurements with the ultimate goal of determining how the microwave signatures reveal the physical properties of the wind, surface waves, and nonlinear internal waves.

Measurements of fully three-dimensional coastal oceanography and acoustics are not common, and the shallow water experiments on the New Jersey coast provided the largest, highest quality data set to date.

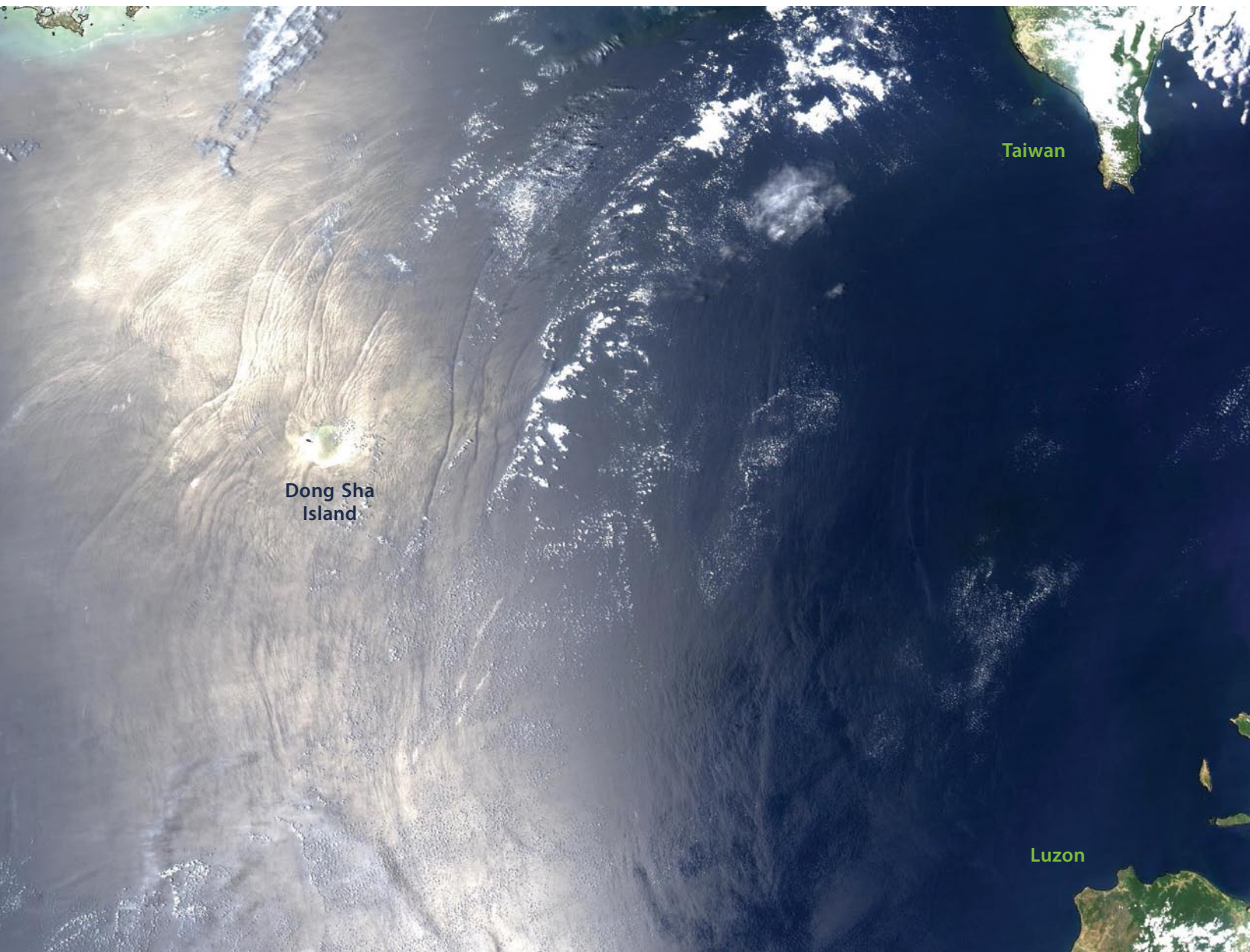
Team members: Paul Aguilar, Jee Woong Choi, Peter Dahl, Evan Gander, Frank Henyey, Ellen Lettvin, Russell Light, Vernon Miller, William Plant, Daniel Rouseff, Peter Sabin, Dajun Tang, and Kevin Williams





Giant Waves Beneath the Sea

During conditions of glassy calm in the South China Sea, APL-UW researchers and their international colleagues watched as the sea surface on the eastern horizon riffled and advanced toward their ship. Soon after the band of breaking surface waves

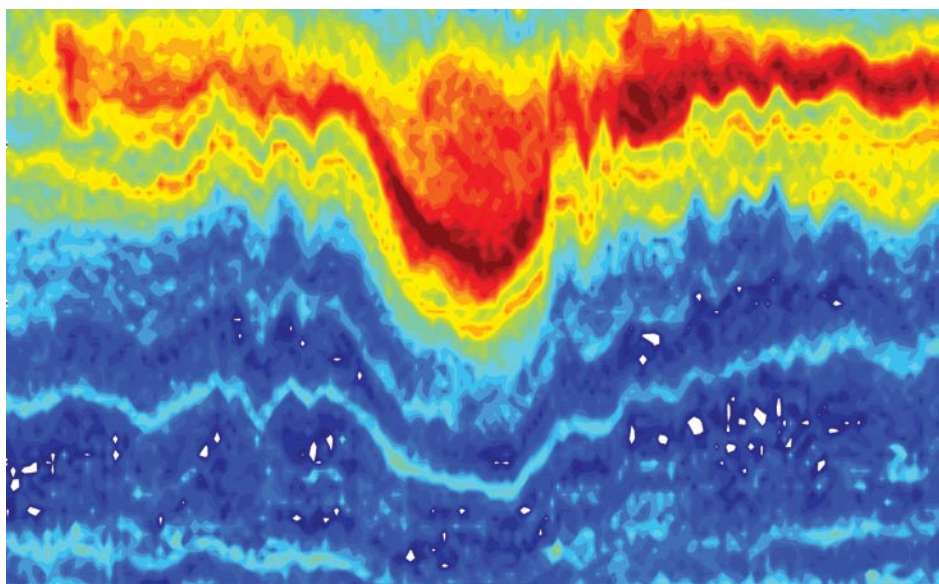


passed, water from depth boiled to the surface. This deckside observation confirmed that a predicted event had just occurred—a nonlinear internal wave had just passed beneath.

Internal waves are found throughout the world's oceans, but the strongest occur in the South China Sea due to its unique bottom topography and strong tidal forcing. While barely displacing the sea surface, the waves are visible to Earth-imaging satellites. They are roughly a few kilometers wide, travel at speeds of 1–3 m/s, may have subsurface displacements greater than 200 m, and horizontal currents of 2 m/s in the center of the wave. The strong downwelling at the wave front creates breaking surface waves, and upwelling trailing the wave creates the surface boils.

APL-UW is one of several institutions participating in the Office of Naval Research initiative to understand nonlinear internal waves. They are of profound interest to the U.S. Navy because these waves affect submarine operations and the acoustic properties of the water column. With isopycnal displacements of up to 200 m in only 600 m of water, submarine buoyancy and ballasting, as well as sonar signal propagation, are critical challenges during nonlinear internal wave events.

Strong internal tides, and perhaps nonlinear internal waves, are generated in Luzon Strait and propagate westward across the South China Sea basin. During propagation the internal tide may develop into nonlinear internal waves. Two to three days and 400 km later, the waves approach DongSha Island, where they are amplified by the shoaling topography that rises from 2000 to 500 m depth in about one degree of longitude. It is here that the internal waves become compressed and strongly nonlinear.



Previous research has correlated the timing of the tide at Luzon Strait to the arrival of the nonlinear internal waves at DongSha Island. The correlation of tide height to nonlinear internal wave amplitude, however, is subject to several complex influences during the transit across the South China Sea basin—water temperature, salinity, and stratification, as well as the strong Kuroshio current. In ONR-funded experiments spanning several years, APL-UW researchers are measuring the energy of nonlinear internal waves in the South China Sea, relating this energy to the incoming internal tides and astronomical tides at Luzon Strait, and then relating the energy flux of nonlinear internal waves to internal tidal flux energy.

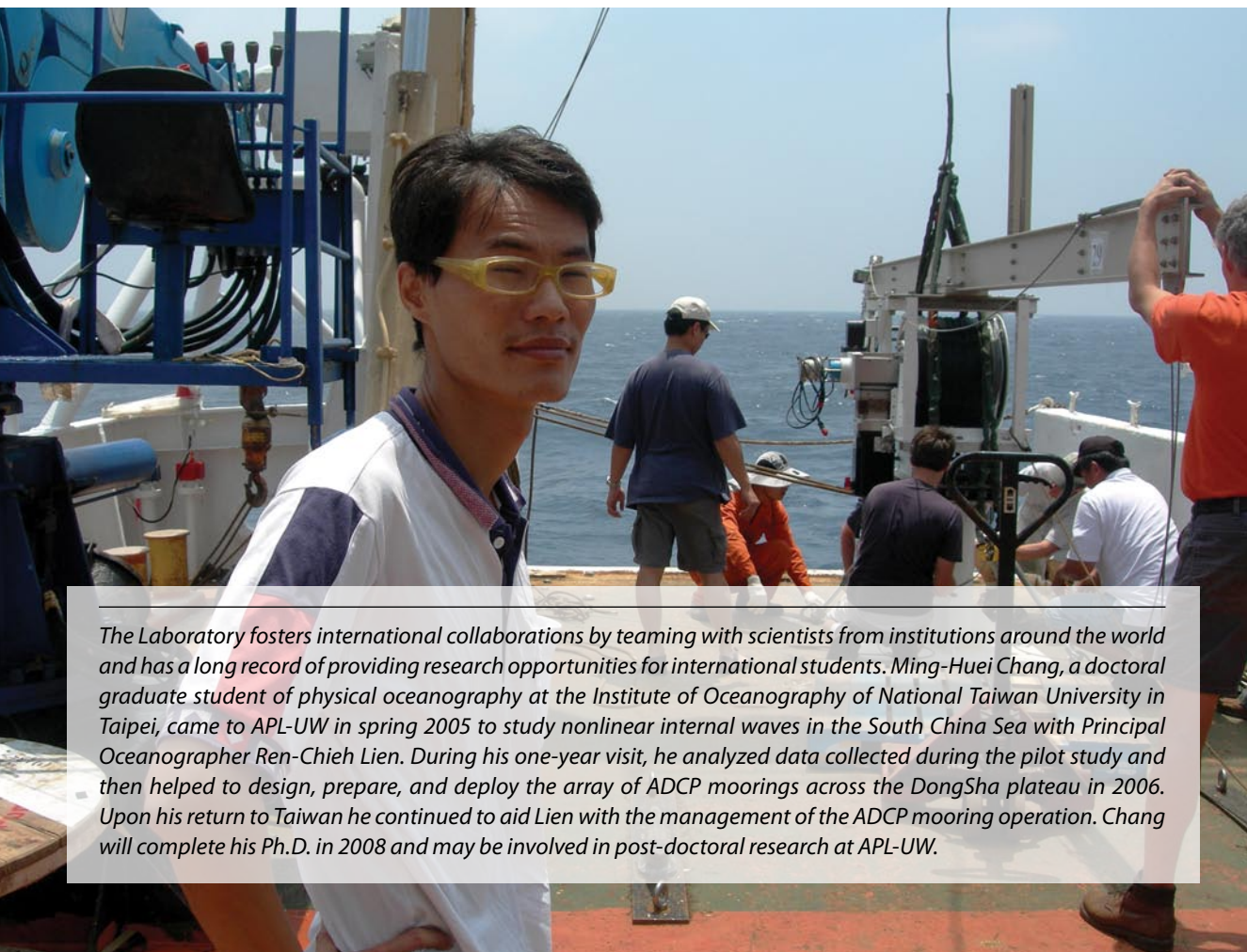
A pilot field study near DongSha Island was conducted in spring 2005 to quantify the background current, stratification, and tidal energy. In June 2006 researchers returned to the South China Sea to deploy three moorings with upward looking acoustic Doppler current profilers (ADCPs). Arranged in a line on the DongSha plateau, they recorded the geographic and seasonal variation of nonlinear internal wave events for one year. This past June they were recovered during a 15-day cruise on the Taiwanese R/V *Ocean Researcher 1*. The cruise began with deployment of two moored McLane profilers, one at the middle of the continental slope in 1500 m of water, and one about 150 km to the west where the plateau rises and the water is only 300 m deep. Gathering data over the entire water column, observations from these two sites provide beginning and ending boundary conditions for the internal tides and nonlinear internal waves crossing the plateau.

The June 2007 cruise survey strategy involved the ship holding station at the eastern boundary of the experiment site to measure a passing nonlinear internal wave event with a shipboard ADCP and intensive conductivity-temperature-depth (CTD) casts using the Scripps Institution's fast CTD profiler. After measuring the ocean behind the waves, the vessel steamed westward, overtaking the waves just observed, then took station and waited for the waves to pass again, when another round of measurements was gathered. Data comparisons will show how the wave energy evolves during propagation across the plateau.

Nonlinear internal waves create disturbed sea surface conditions that are detected by shipboard radar. The surface scattering could be equivalent to wind-generated surface waves about 1.5 m high (winds ~6 m/s). The APL-UW-developed RiverRad coherent radar was installed on the *Ocean Researcher 1* at the beginning of the cruise; operating automatically, it ran around the clock during the intensive survey. The radar looked about 2 km ahead of the ship and detected the surface signatures of the nonlinear internal waves as bright streaks in the radar return from the sea surface, both in the intensities of the returns and the Doppler shifts.

An unexpected highlight during the experiments in 2006 and 2007 was the observation of small pods of short-finned pilot whales (*Globicephala macrorhynchus*), sometimes traveling in chorus-line formation following the nonlinear internal waves. The strong vertical currents could be enough to entrain deep-swimming fishes and squid to the surface. It is possible that the whales use the waves to aggregate prey; this is the first reported observation of cetaceans associated with internal waves.

Team members: Matthew Alford, Eric Boget, Ming-Huei Chang, Gene Chatham, Andrew Cookson, Eric D'Asaro, Kenneth Hayes, Sean Huang, Ren-Chieh Lien, Michael Ohmart, and William Plant

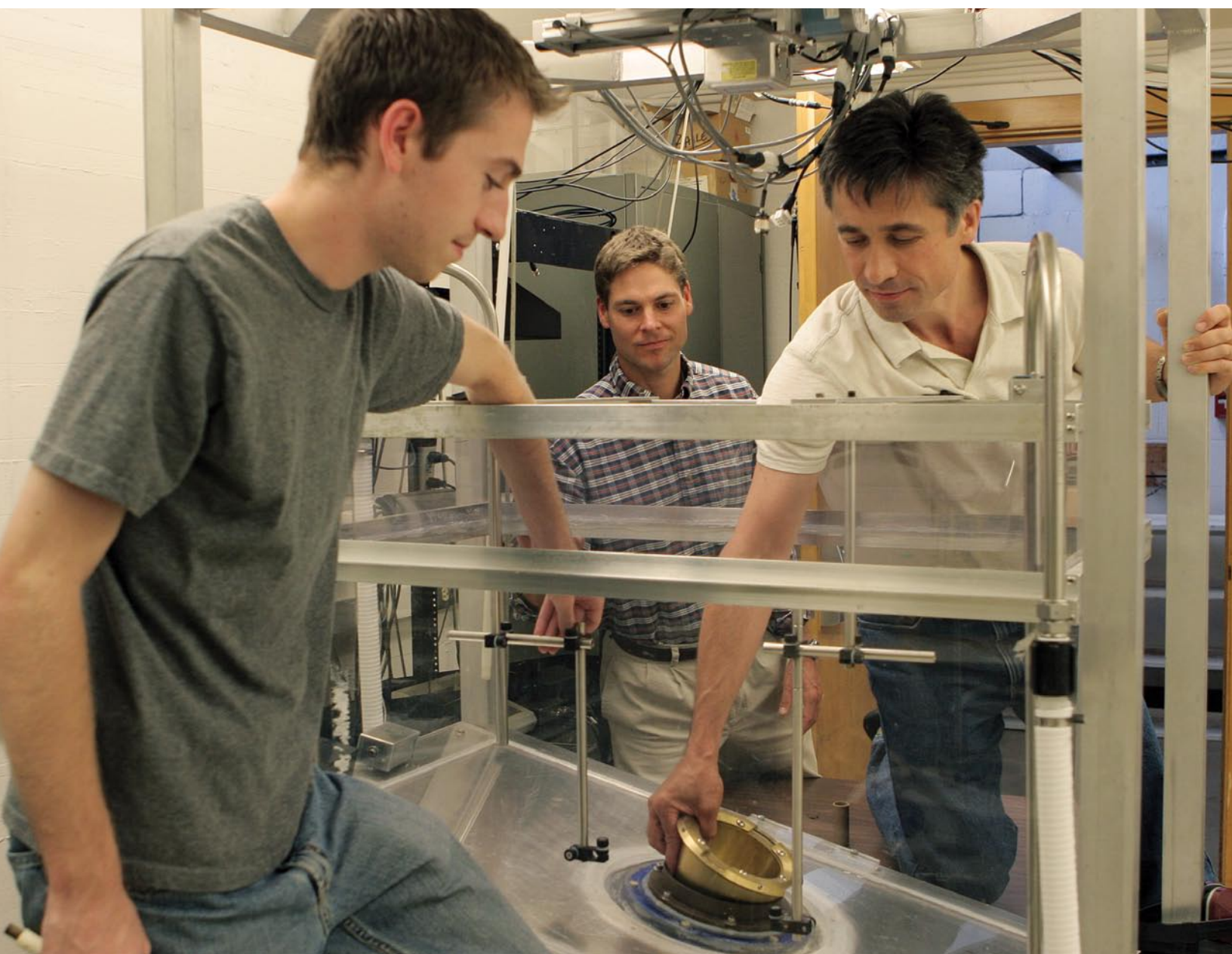


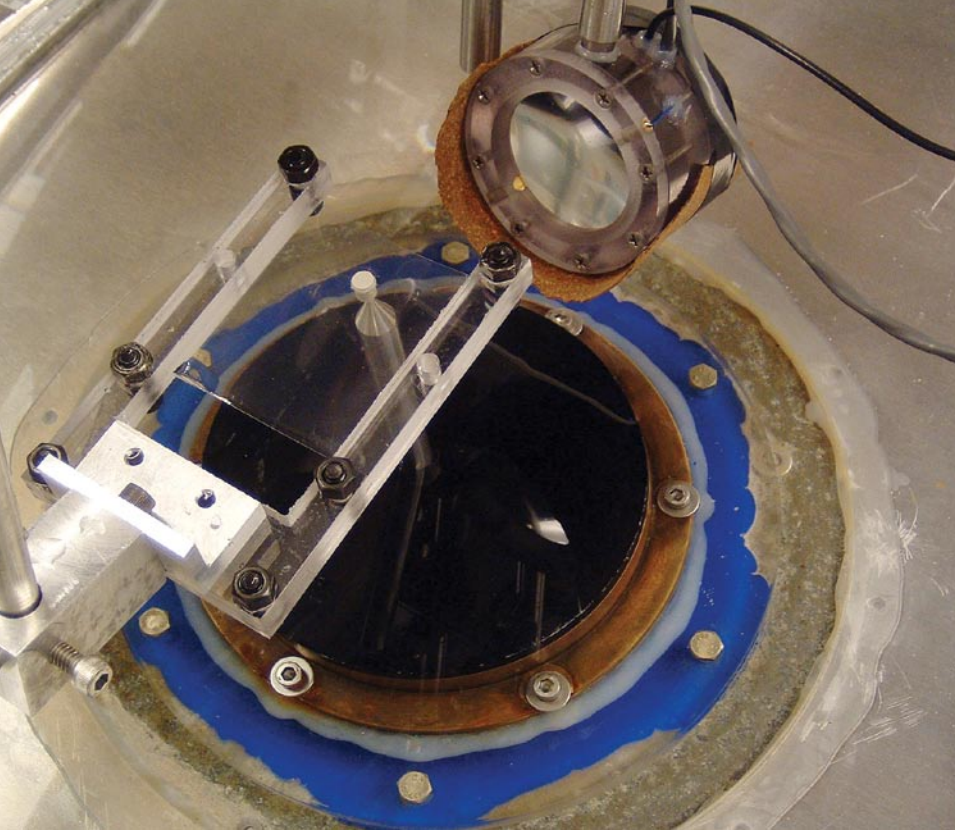
The Laboratory fosters international collaborations by teaming with scientists from institutions around the world and has a long record of providing research opportunities for international students. Ming-Huei Chang, a doctoral graduate student of physical oceanography at the Institute of Oceanography of National Taiwan University in Taipei, came to APL-UW in spring 2005 to study nonlinear internal waves in the South China Sea with Principal Oceanographer Ren-Chieh Lien. During his one-year visit, he analyzed data collected during the pilot study and then helped to design, prepare, and deploy the array of ADCP moorings across the DongSha plateau in 2006. Upon his return to Taiwan he continued to aid Lien with the management of the ADCP mooring operation. Chang will complete his Ph.D. in 2008 and may be involved in post-doctoral research at APL-UW.

Basic Research Improves Patient Outcomes

As the most common treatment for kidney stones worldwide, nearly a half-million lithotripsy procedures are performed each year in the U.S. alone. This noninvasive technique to break stones with acoustic shock waves has been an alternative to surgical treatment since the mid-1980s.

The shock waves that break stones effectively also damage kidney tissue. A patient usually receives the maximum allowable dose of 2000–4000 shock waves. Because stones can break in only hundreds of shock waves, patients are exposed to many





more than needed, and research shows that damage to renal tissue is nonlinear: scars from 2000 pulses are 10 times larger than those after 1000. Can the number of shock waves administered be reduced and still achieve the same treatment endpoint of stone comminution?

Recent research conducted at APL-UW's Center for Industrial and Medical Ultrasound (CIMU) has led to a method to track a kidney stone during treatment so that shock waves are fired only when the stone is in range, and another to monitor the treatment endpoint when the stone is pulverized into fragments small enough to pass through the urinary tract. CIMU researchers have also made intriguing discoveries into the mechanisms of stone fracture that could lead to treatment methods that will subject the target stone to maximum stress with each shock wave.

Lithotripsy numerical and laboratory experiments with barrel-shaped kidney stone models typically result in a stone fractured in two pieces at about one-third of the length from the distal end. But what mechanism is responsible for stone fracture — spallation, squeezing, or cavitation? Through controlled tests and numerical calculations, it is now shown that the stress due to spallation is low, but adds to the primary fracture mechanism, which is dynamic squeezing. As the longitudinal wave passes through the stone it reflects off the distal surface. The shear wave created is reinforced by the slower moving pressure wave that is traveling through the water along the stone's surface and focuses in the distal end of the stone to create the maximum tension. Cavitation appears to contribute little to stress within the stone, but cracks formed by cavitation bubbles at the surface grow inward toward the maximum stress region. Surface erosion by cavitation becomes particularly important in grinding stone fragments to a small enough size to pass.



These experiments demonstrate that a shock wave beamwidth broader than the stone is critical to maximize stress and suggest that in a clinical setting real-time imaging and simulation could be used to change the beamwidth or shock waveform to increase treatment efficacy.

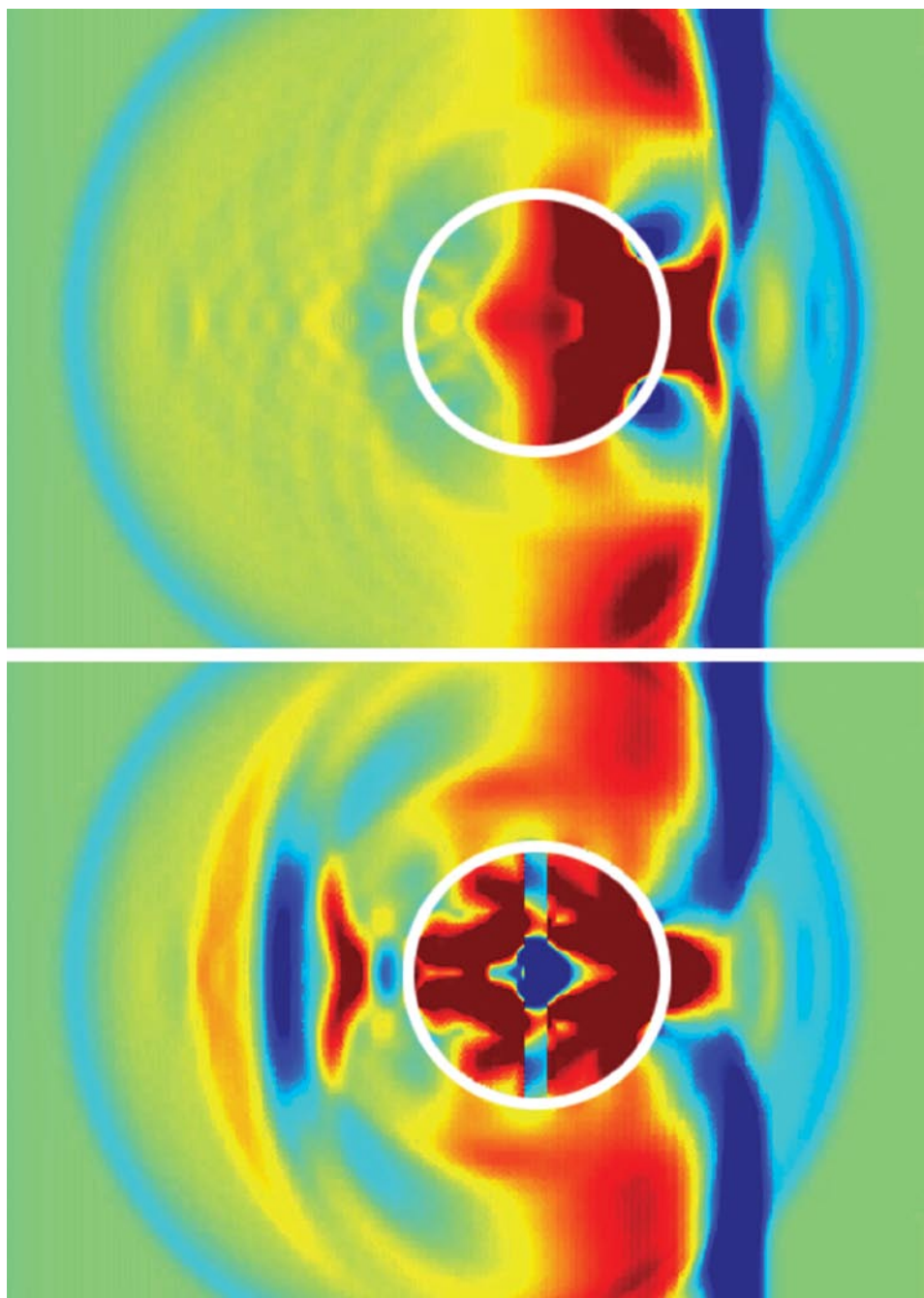
APL-UW was among the founding institutions in 1993 of the Consortium for Shock Waves in Medicine. The original idea was to assemble acousticians, engineers, biologists, anatomists, and clinicians to better understand lithotripsy treatment and assess its risks. This worldwide multidisciplinary team funded by the National Institutes of Health has generated methods to improve treatment outcomes and proposed numerous safety guidelines. APL-UW and another founding institution, Moscow State University, developed a special relationship. Drs. Sapozhnikov and Khokhlova, professors at MSU and Senior Engineers at APL-UW, have maintained a continuous research collaboration for over 10 years.

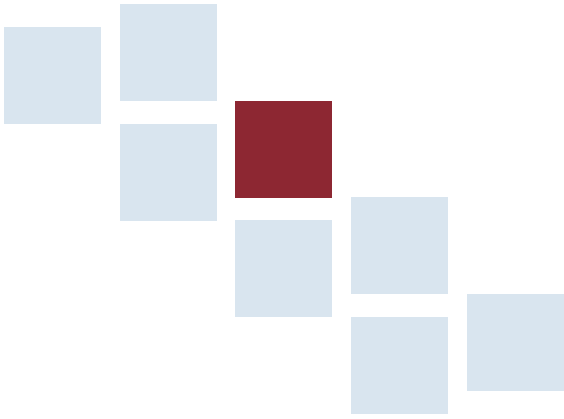
To provide much needed feedback to a clinician during shock wave lithotripsy, a CIMU team has developed a system that fires shock waves only when the stone is on target and detects when breakage is complete. An acoustic wave, similar to diagnostic ultrasound, is localized to the lithotripter focus; scattering of the wave from the stone has a higher amplitude than from tissue because the stone's acoustic impedance is higher. This feedback determines when the stone is in focus, and the lithotripter shock wave is triggered automatically. In laboratory experiments where respiratory movements are simulated, shock waves at 1 Hz directed at a model stone in water produced only 9% comminution in 100 pulses, but when the targeting and triggering system was added, a 22% rate was achieved.

In laboratory simulations and studies, resonant scattering of the lithotripter shock wave was used to differentiate intact and fractured stone models. These experiments have led to a passive acoustic detection system to determine treatment endpoint. The shock wave reverberates within the stone causing vibrations that are detected by a device similar to a simple stethoscope. As the stone cracks, acoustic reflections off the crack increase the frequency of reverberation. And just as the size of a bell can determine its pitch, broken stone fragments reverberate at higher frequencies than larger, intact stones.

CIMU's long history of close collaboration with clinical and industrial partners has put the target, trigger, and endpoint monitoring system on track for clinical application. The University of Washington Office of Technology Transfer filed a U.S. patent for the system and granted seed funds to begin development. Inexpensive and easily retrofitted to current lithotripters, the system is an example of fundamental science and creative engineering working to reduce the number of shock waves administered to effect comminution, which will represent a revolution in lithotripsy treatment and improve patient outcomes directly.

Team members: Michael Bailey, Kirk Beach, Michael Canney, Stephen Carter, Hong Chen, Lawrence Crum, Francesco Curra, Lori Ferro, Bion Johnson, Tatiana Khokhlova, Vera Khokhlova, Wayne Kreider, Brian MacConaghy, Thomas Matula, Adam Maxwell, Fran Olson, Neil Owen, Marla Paun, Oleg Sapozhnikov, Jarred Swalwell, Rebecca Taylor, and Wendell Thompson





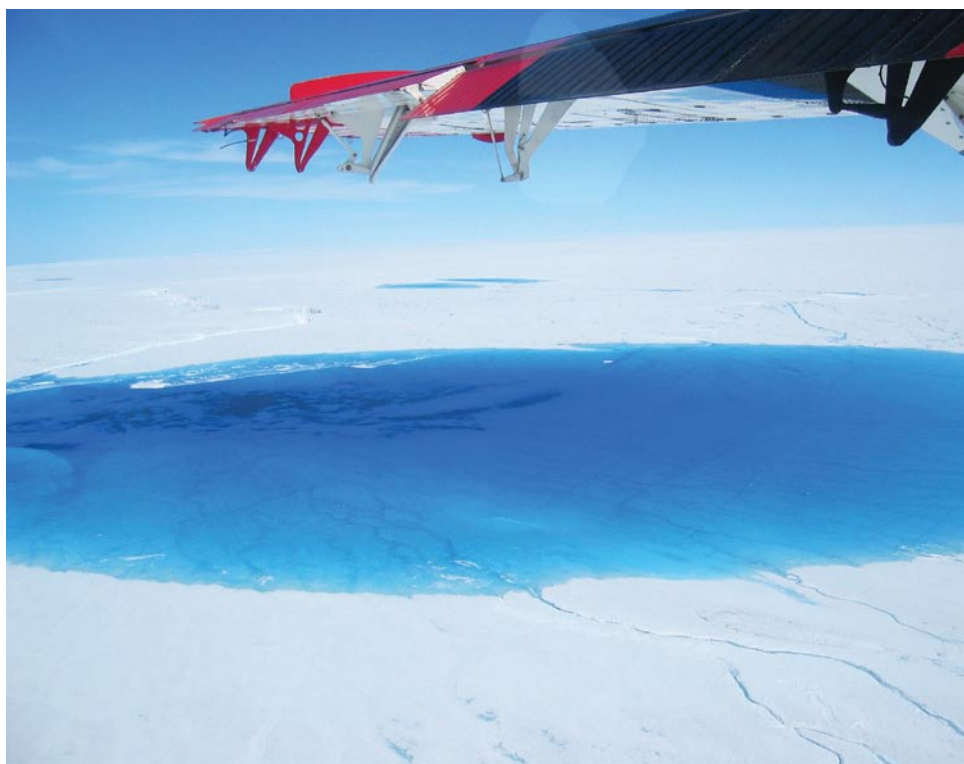
A Rapidly Changing Greenland



Contrary to long-held views about the stability of the massive Greenland Ice Sheet, scientists are now observing that a modest, short-term rise in air temperatures over the island produces a nearly immediate response. Glaciers thin, retreat, and slide faster to the sea. It is not known whether the past decade of warming is natural or anthropogenic, but an increase in mean summer temperature of only 1°C has caused significant changes to the glaciers.


The Intergovernmental Panel on Climate Change issued its anticipated summary report in February 2007, commenting that Greenland's glaciers are melting and moving faster on average, but the changes do not follow a linear trend. Factors such as meltwater runoff and calving of the glaciers' fronts to the sea are used to calculate the ice sheet's contribution to sea level rise. Caveats were noted: while it is understood that surface meltwater injection to the bottom of the ice sheet could lubricate and speed its flow, data are limited on this effect and it is not included in the predictions of melting under various warming scenarios.

At APL-UW's Polar Science Center, Senior Engineer Ian Joughin, postdoctoral researchers Ben Smith and Ian Howat, and graduate student Twila Moon are using a combination of satellite data and field observations to understand the processes that affect ice sheet flow and its contribution to sea level. Using data from RADARSAT and other satellites, they are constructing annual ice velocity maps for the entire Greenland Ice Sheet to determine the variability in flow speed. At its interior, where the sheet is up to 3000 m thick, the ice moves quite slowly. In the large outlet glaciers, however, the ice flows toward the sea at several kilometers per year. Joughin reports that Jakobshavn Isbrae, Greenland's largest and fastest outlet glacier, more than doubled its speed between 1992 and 2003, from 5.7 to 12.6 km/year, following the collapse and retreat of the glacier's floating tongue. Once this impediment to flow was removed the glacier began disgorging to the ocean an additional 30 cubic kilometers of ice each year.



Meltwater on the surface can drain through the ice—sometimes over 1 km thick—to the bed by way of large holes or “moulins.” There is widespread belief that as temperatures rise increased meltwater production could destabilize the ice sheet by lubricating its base, causing it to flow faster. There are relatively few observations, so Joughin and Sarah Das from the Woods Hole Oceanographic Institution are conducting a field study south of Jakobshavn Isbrae to determine the seasonal variability in ice flow around two of the several hundred meltwater lakes that form on the surface of the ice sheet each summer.

In 2006 the APL-UW team occupied sites adjacent to two lakes, each 1–2 km in width. They were about 35 km from the ice sheet's edge where ice flows at about 100 m per year. Using a steam drill, they placed a steel pipe 4.5 m into the ice to support instruments—GPS to measure seasonal flow-speed variability, seismometers to detect hydrologically-driven fracturing as moulins open to drain the lakes, and weather



Twila Moon was awarded a National Science Foundation Graduate Student Research Fellowship to study changes on the Greenland Ice Sheet—specifically, the ice front positions for all of the sheet's outlet glaciers larger than 2 km wide. Using the satellite data record from 1992 to the present, she is mapping the temporal patterns of the glaciers' fronts. She hopes to use these survey findings to identify possible mechanisms for retreat and stabilization cycles.

She has also won funding from the Comer Foundation to acquire satellite data going back to the 1960s so that she can extend her survey of front positions to a time when Greenland was slightly colder than it is now. Twila is working toward a Ph.D. in the UW's Department of Earth and Space Sciences, where her advisor, Ian Joughin, is an Affiliate Associate Professor.

stations for energy balance calculations to determine the amount of melt. The group also had a small raft, which they used to place pressure transducers in the lake to monitor lake level. As they performed a bathymetric survey they hovered only briefly over the ominously dark and deep section of the lake where it appeared the moulin was located. A 10-m deep, 3-km wide lake can drain in less than two hours.

The research camp was located on the ice sheet's bare ice zone, where the snow from the previous winter completely melts each summer along with much of the underlying ice. In July daily high temperatures were 30–50°F, so the tents insulated the area beneath them. After a few days of rapid melting, they sat on “pedestals” several inches above the melting surface.

The instruments were deployed in summer 2006. Data were recovered and instrument maintenance was performed in 2007, and the instruments will be recovered during the 2008 season. Analysis of these data will determine the degree of seasonal variability associated with drainage of the lakes and the degree to which the meltwater makes its way to the base of the ice sheet.

Team members: Ian Joughin, Ian Howat, Twila Moon, and Benjamin Smith
Research is funded by the NSF Office of Polar Programs and NASA.

What Drives Critically Low Oxygen Levels in Hood Canal?

Jan Newton

Fish gasping on the surface and washing up on beaches are the most dramatic indications of a marine ecosystem in trouble. In Hood Canal low dissolved oxygen concentrations (hypoxia) are getting worse. Over the past decade the presence, persistence, and distribution of hypoxia has increased. Hood Canal has a long history of low oxygen conditions, even anoxia and fish kills, as shown in data collected by Eugene Collias at the University of Washington in the 1950s and 1960s. What is tipping the balance now and will it persist?

Hood Canal is a deep fjord-like sub-basin of Puget Sound. Both Puget Sound and Hood Canal are much different from other estuaries in the nation, such as Chesapeake and San Francisco bays; for example, Hood Canal is twenty times deeper on average.



While it does not have the urban density of the main Puget Sound basin, Hood Canal has slow circulation and there are changes in the watershed, such as the dominance of particular tree species and homeowners' septic tanks. These factors, as well as inputs of ocean and fresh water that affect the flushing rate and stratification of Hood Canal, may all be important to the chronic hypoxia.

Led by Principal Oceanographer Jan Newton, the Hood Canal Dissolved Oxygen Program—Integrated Assessment and Modeling (HCDOP–IAM) science study is funded primarily with federal appropriations secured by Norm Dicks, U.S. Representative of Washington's sixth congressional district. The three-year study is using marine, freshwater, and biota observations to quantify the various natural and human influences on the concentrations of dissolved oxygen in Hood Canal. Computer models informed with the observational data are testing corrective actions with the ultimate goal of relaying useful information to policy makers and others considering potential actions to try to alleviate the condition.

The field observation and data collection component of the study is co-managed by Newton and Dan Hannafious of the Hood Canal Salmon Enhancement Group. Over 25 groups in total are involved with the study, including scientists from tribes, county, state, and federal agencies, non-profit groups, and other universities. Volunteer citizen monitors, trained by UW scientists and coordinated by the Salmon Enhancement Group, are critical to the observation strategy, collecting data and even providing diver observations that are recorded on the study's website. The Skokomish Tribe participates in the citizen monitoring effort and conducts watershed sampling.

Understanding Hood Canal's dynamics requires even higher resolution observations than humans can provide. With the UW School of Oceanography, APL-UW has established five autonomous profiling buoys in Hood Canal, with live data relays to campus and the capability to measure currents, oxygen, and nutrients several times a day. There are also storm water collection devices in the watershed and over 23 streams are gauged and recorded remotely.



Modeling of the marine waters and watershed is a collaborative effort with the scientists and resources of the university's Puget South Regional Synthesis Model (PRISM) group. The watershed model accounts for land use and tracks water and nutrients. The marine models are coupled physical circulation and biogeochemical cycling models. Both receive input from an atmospheric model for forcing and are calibrated with observational data. This approach is necessary to understand what is driving the change, because so many factors are involved. The model is used to track an increase or decrease of various factors (sunlight, watershed nutrient loads, or ocean density) one by one in order to quantify the effect on oxygen.

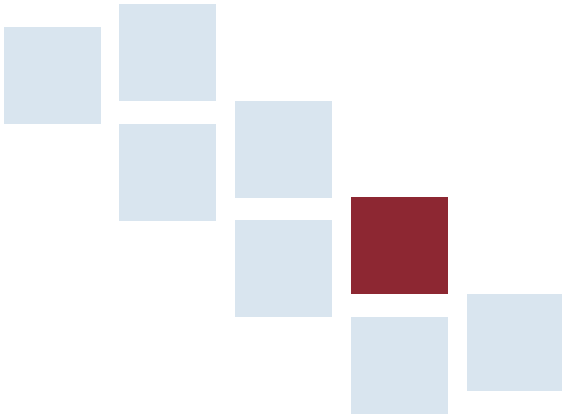
With the university's School of Aquatics and Fishery Sciences, studies have begun on the various Hood Canal biota and their food web energetics, including assessment of the benthic and pelagic communities—bacteria, phytoplankton, fish, eelgrass, mollusks, and crab. Computer models of the entire food web are being constructed. The HCDOP-IAM study also includes an event response capability that posts observations of algal blooms on the study website and explains whether any are harmful to the public.

A September 2006 fish kill event was tracked by the mature HCDOP observing system. The severity of the 2006 event was caused by several synchronized factors. Offshore coastal ocean upwelling had contributed high-density seawater to Hood Canal during the late summer. This intrusion displaced the deep water of the canal higher in the water column, pushing low oxygen water to relatively shallow depths. Washington State Department of Fish and Wildlife divers had noted more fish higher in the water column than usual prior to the event. Because the oxygen minimum zone was so close to the surface in late summer 2006, the system was particularly poised for wind-induced upwelling to bring low-oxygen water all the way to the surface. During the period of southerly wind bursts after a long period of northerlies, fish essentially lost their shallow refuge as the entire upper water column became very low in oxygen. Model runs verified that wind forcing could produce this result.

This is an example of how an integrated observation and modeling approach can yield powerful results. The data collected by autonomous instruments, as well as the scientists and citizen volunteers in the field, identified the necessary conditions for such an event and explain why this did not occur in other years with similarly low oxygen. As the frequency of low-oxygen occurrence and persistence in Hood Canal increases, so too the risk for such events. Their causes are the subject of our ongoing research in Hood Canal.



Team members: Matthew Alford, Corinne Bassin, John Mickett, and Jan Newton



Remote Sensing of Coherent Structures Reveals Riverine Flow

Trina Litchendorf



COHSTREX (COHerent STructures in Rivers and Estuaries EXperiment) is a five-year project funded through the DoD Multidisciplinary University Research Initiative (MURI) program and administered by the Office of Naval Research. The project, led by Principal Oceanographer Andy Jessup, brings together researchers from the UW Department of Civil and Environmental Engineering and School of Oceanography, and Stanford University, Woods Hole Oceanographic Institution, and the Naval Research Laboratory. Research results will have an immediate impact on Department of Defense capabilities, demonstrating that model outputs based on data gathered by autonomous remote sensing instruments can characterize the physical flow parameters of rivers and estuaries before the commitment of other assets and/or personnel. The Snohomish River experiment was conducted in year two of the project with a second major field experiment planned for year four.

For three weeks during summer 2006, APL-UW researchers lived and worked aboard a barge near the mouth of the Snohomish River in Everett, Washington. Here, where the Snohomish outflows to Puget Sound, they studied coherent structures on the river surface to determine the extent to which the remotely sensed infrared and microwave signatures can be used to guide numerical models that predict the river's flow. Coherent structures are generated by the interaction of the flow with bathymetric and coastline features; the interaction creates eddies and boils on the surface. These surface signatures can be detected with remote sensing instruments—infrared cameras, radiometers, and microwave radars. Mean velocity, bottom roughness, shear, turbulence, surface stratification, and temperature gradients may be inferred from the remotely sensed signatures of coherent structures.

To provide a stable platform for the remote sensing instruments and researchers on the river, two 20' x 40' spud barges were anchored in place with long pilings (spuds) driven down into the riverbed, allowing the barges to remain on station while riding up and down with the tide, which ranged up to 5 m at the study site. An infrared camera, two radiometers, a video camera, and a RiverScat microwave radar were mounted on the platform of an aerial lift crane secured to the barge deck. Fully extended, the crane elevated the sensor package 28 m above the water surface.

Aerial measurements were also taken from a Twin Otter aircraft outfitted with an infrared camera, radiometers, and a video camera. Oceanographer Trina Litchendorf was able to monitor the development of cold boil fields as a saltwater wedge moved up the mouth of the river. During the flood tide colder, denser water from Puget Sound moves up the river mouth along the bottom while the less dense river water flows over it to form a saltwater wedge. As the salt wedge passes over the sill, the turbulence brings the cold water up from below where it penetrates the warmer surface water; it was visible in the infrared imagery as cool boils.

Oceanographer Kate Edwards is analyzing the infrared temperature data collected during these flights, which were timed to resolve the tidal cycle over the course of the experiment. The raw data are calibrated to give temperature, geo-referenced, then composited into a single view of the river. The resulting composites are analyzed for the signature of coherent structures and are compared to in-water measurements.

Another APL-UW team led by Principal Research Scientist William Plant mounted their pulsed Doppler radar RiverRad on the opposite shore of the Snohomish across from the spud barge position, and also flew their CORAR Doppler radar on a seaplane over the site. These radar observations, both long term and over a large spatial area, capture velocity data to provide a good measure of the river's variable current over ebb and flood.

The defining bathymetric feature of the study site is a rocky sill; as the tide rises and falls, flow over the sill and through the gap between the sill and the shore generates turbulent features. The convergence of the Snohomish River and Puget Sound waters through the gap is visible as a line separating sediment-laden fresh water from the clearer salt water in the video image (left), but is much more sharply defined in the infrared image (right) because the river water is significantly warmer. The infrared imagery provides a dramatic visualization of the vortices that occur along this shear line, as well as other mixing features downstream of the sill.



Concurrent with the measurements from remote sensing instruments, postdoc Chris Chickadel and Senior Engineer Tim Wen deployed conductivity-temperature-depth sensors on a mooring with cable connections back to the barge. The data provided stratification information in real time to correlate changes in the boil temperature with the location of the saltwater wedge. The time series of temperature, salinity, and pressure show the typical behavior associated with the passage of the saltwater wedge on both ebb and flood tides. High-resolution acoustic Doppler current profilers (ADCPs) and acoustic Doppler velocimeters were also deployed to characterize the river hydrodynamics. A mooring with three Biosonics echosounders and an ADCP anchored downstream of the sill captured the subsurface signatures of the coherent structures. To resolve spatial and temporal variability in the river during a complete tidal cycle, profiles of turbulence were taken in the river during two 30-hour surveys. A REMUS autonomous underwater vehicle also mapped the riverbed.

All of these in situ and remote sensing data gathered during the COHSTREX field experiment are being used by researchers at Stanford University to develop numerical models to predict, interpret, and characterize coherent structures. The experiment demonstrates that remotely sensed signatures of coherent structures captured by mature imaging technologies can be used with in-hand numerical modeling schemes to provide a rapid and straightforward diagnostic tool to determine the navigability of rivers and estuaries.

Team members: Eric Boget, Chris Chickadel, Chris Craig, Kathleen Edwards, Andrew Jessup, Fred Karig, William Keller, Trina Litchendorf, William Plant, Peter Rusello, and Timothy Wen



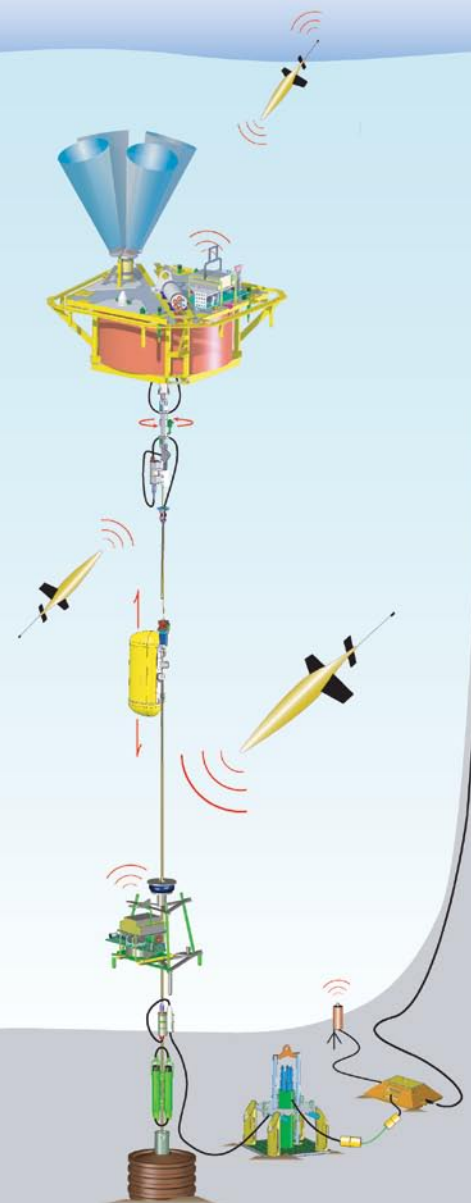
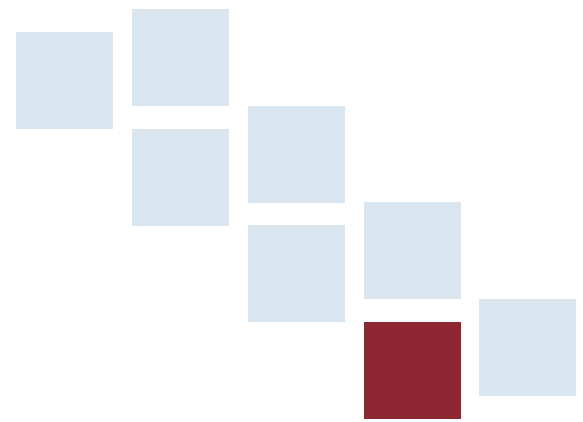
A Smart Sensor Web for Ocean Observation

Ship surveys, autonomous floats, instrumented moorings, cabled sensor systems powered from shore, land-based radar, and orbiting satellites are some of the many assets deployed to observe and understand the ocean environment. NASA's goal is to establish an ocean observing system that uses satellites in an integrated web of sensors distributed from space to the Earth's subsurface. Knit together by a communications fabric, the sensor web is made 'smart' by combining autonomy with adaptive control and dynamic configurability.

Senior Engineers Payman Arabshahi and Warren Fox, Principal Oceanographer Bruce Howe, and colleagues at the UW Department of Electrical Engineering and the Jet Propulsion Laboratory are designing and deploying a first-of-its-kind sensor web with support from NASA's Earth Science and Technology Office—Advanced Information Systems Technology program. The system incorporates dynamic reconfiguration of sensor assets, adaptive sampling, and high-bandwidth, high-power observations. The Laboratory's horizontal and vertical integration of science and technology expertise is uniquely suited to the task. Satellite data analysis, signal processing, acoustical oceanography, and mechanical, software, and electrical engineering are all components of the sensor web.

One component of the network, a moored sensor system, is designed for use with a range of ocean observatories. It is connected to shore by an electro-optical cable for power and Ethernet communications. The mooring's three main parts work synergistically to sample the ocean with high temporal and vertical resolution: a subsurface float at a depth of 165 m is outfitted with sensors; an instrumented, motorized vertical profiler collects oceanographic data as it crawls up and down the mooring line between the float and the bottom; and a secondary fixed node on the seafloor is replete with sensors. During summer 2007 the cabled node system providing seafloor power and Ethernet communications and a short version of the subsurface mooring were installed in Puget Sound. Another test version will be deployed in 900 m of water in Monterey Bay in spring 2008.

Seagliders, autonomous undersea vehicles developed by the UW School of Oceanography and APL-UW, are robust and operate on modest power; they are capable of profiling in a local area or surveying across ocean basins. Seaglider's standard oceanographic sensors complement those on the mooring and the bottom fixed nodes, extending the web's horizontal range. While on the surface Seagliders obtain GPS fixes and use the Iridium satellite system to pass data to the pilots on shore and to receive mission commands. The vehicle's sensor payload now includes a passive hydrophone to record ambient noise and an acoustic modem developed by the Woods Hole Oceanographic Institution. With these sensors Seagliders can, for example, record nearby marine mammal vocalizations and transfer commands to an acoustic bottom array, as well as relay remote sensor status information and data to the shore via the cable system.



If Seagliders are to be used effectively in concert with other subsurface fixed and mobile sensors, a robust underwater acoustic communications network is needed. The difficulties are well known: overall bandwidth is limited due to acoustic absorption that increases with frequency, and typical shallow water regions where communications are desired have high degrees of spatial and temporal variability.

The Sonar Simulation Toolset (SST), developed by Senior Physicist Robert Goddard, allows assessment of a wide range of proposed undersea acoustic communication scenarios for the sensor web. Users specify an ocean environment in SST with a wide variety of parameters relevant to acoustic signal propagation and reception: sound speed profile, bathymetry, surface and bottom characteristics, ambient noise levels, and others. The user also specifies locations and trajectories of acoustic sources and receivers within that environment, and signals to be transmitted by the sources. SST then uses acoustic propagation models and time series simulation techniques to produce properly calibrated digital time series of the signals that would be 'heard' by the receivers. These received time series are used to test acoustic modem processing algorithms, or to estimate the communications capabilities between two modems as a function of the transmitter and receiver locations in a variety of environmental conditions.

In the envisioned sensor web system, satellites would be used to relay data gathered by sensors to scientist workstations, to download mission commands from shore or ship to the Seaglider, and to collect their own mission data to be assimilated with those from all other sensors into a regional ocean modeling system (ROMS). With a real-time view of the ocean state, the mobile sensor platforms can be redirected to adaptively sample ocean sub-volumes that have greater degrees of uncertainty, are rapidly changing, or



have features of specific interest. In this way, satellite remote sensing data are validated and regularly calibrated against the in situ data to increase accuracy and value.

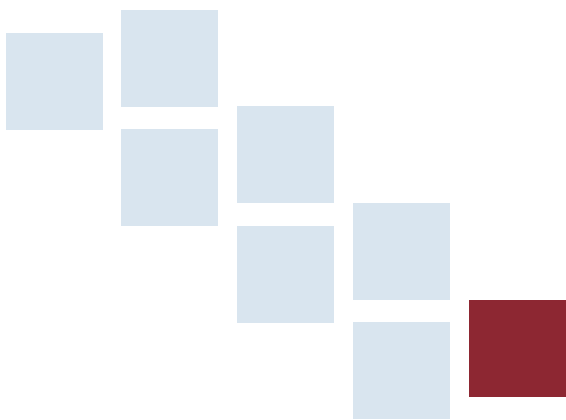
When deployed in Monterey Bay, the mooring system will be near whale feeding grounds in an area of periodic intense upwelling of nutrient-rich water. Here Seaglidors might be directed in real time to specific locations to better track the whales, using their hydrophones to triangulate on vocalizations. The oceanographic and biological data collected by the mooring system and the Seaglidors will expand understanding of the ocean conditions that give rise to this patch of intense ocean life.

The undersea sensor web system will also be able to conduct acoustic tomography experiments using the Seaglidors as moving receivers of low-frequency signals. These acoustic travel time data will be assimilated in the ROMS model; in concert with other sensor data, such as shore-based high-frequency radar surface current measurements, the ROMS output may lead to better forecasts of all oceanographic variables. The bottom line is that a smart sensor web will maximize the science return on investment as sensors and their platforms are able to adjust their data collection parameters to optimize their own performance and return measurements requested by science users.

Team members: Payman Arabshahi, Warren Fox, Bruce Howe, and Timothy McGinnis

Research and development of the smart sensor web components is funded by the National Science Foundation Ocean Technology and Interdisciplinary Coordination Program, the Office of Naval Research, and the NASA Earth Science Technology Office–Advanced Information Systems Technology.





A New Light on Sensor Technologies: Photonics and Terahertz Research

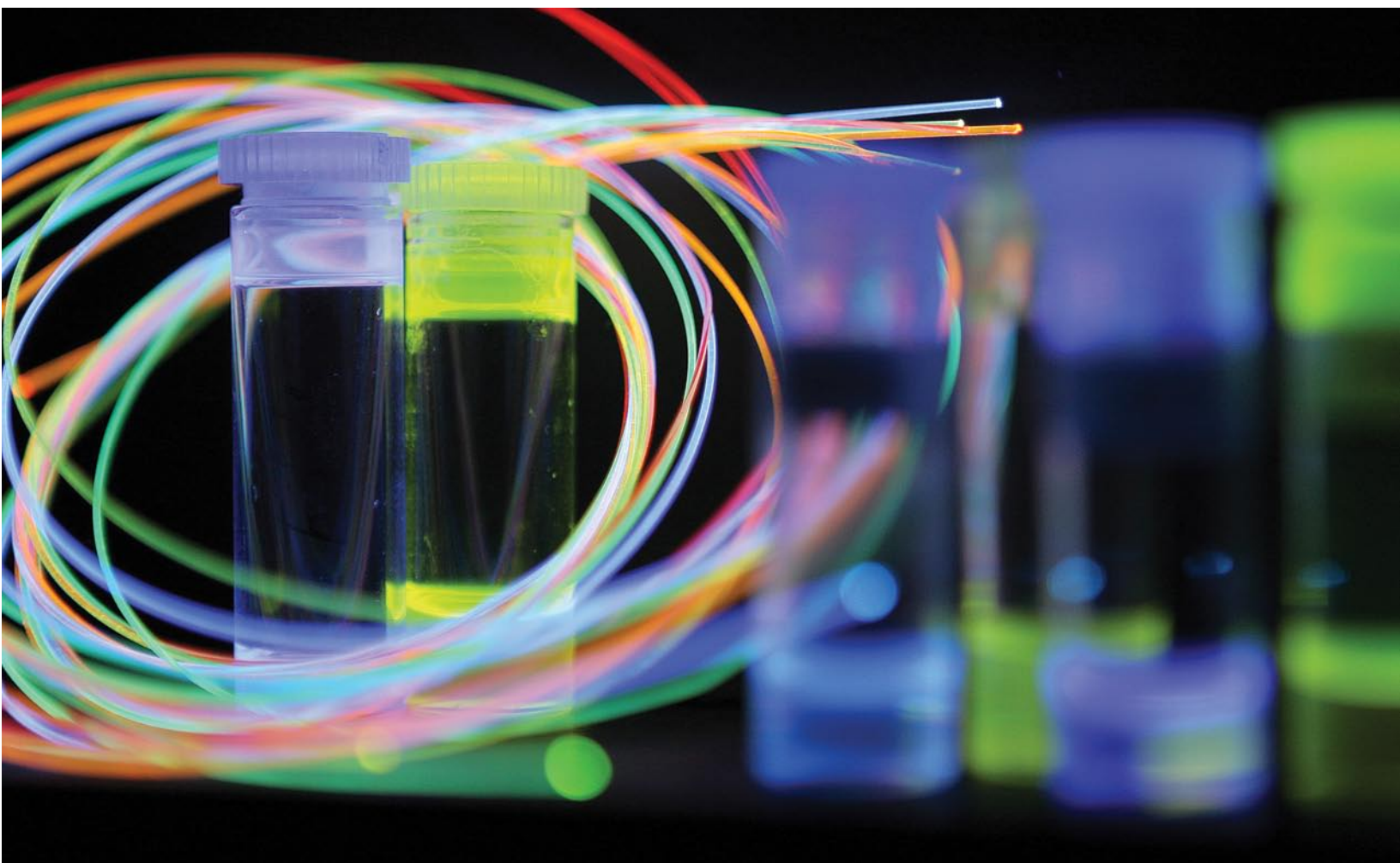
Photonics is the use of light to acquire, transfer, and store data of all types. And like electronics a half-century ago, photonics technology is rapidly entering our daily lives. Fiber optic networks provide the backbone of the Internet, and CD and DVD drives and TV remote controls use semiconductor diode lasers. With the advancement of broadband Internet there is an ever-increasing demand on the bandwidth of fiber optic systems.

■ APL-UW is engaged in multidisciplinary research on advanced fiber optic materials and devices to address the bandwidth needs of the future. Collaborating closely with research groups in the University of Washington Chemistry and Materials Science departments, we are developing fiber optic modulators and switches based on novel organic electro-optic polymer materials. These new materials are being applied to innovative photonic device concepts that have micro- and nano-meter scale. Fabrication technologies including electron beam lithography and two-photon polymerization are used to create these micro- and nano-scale structures.

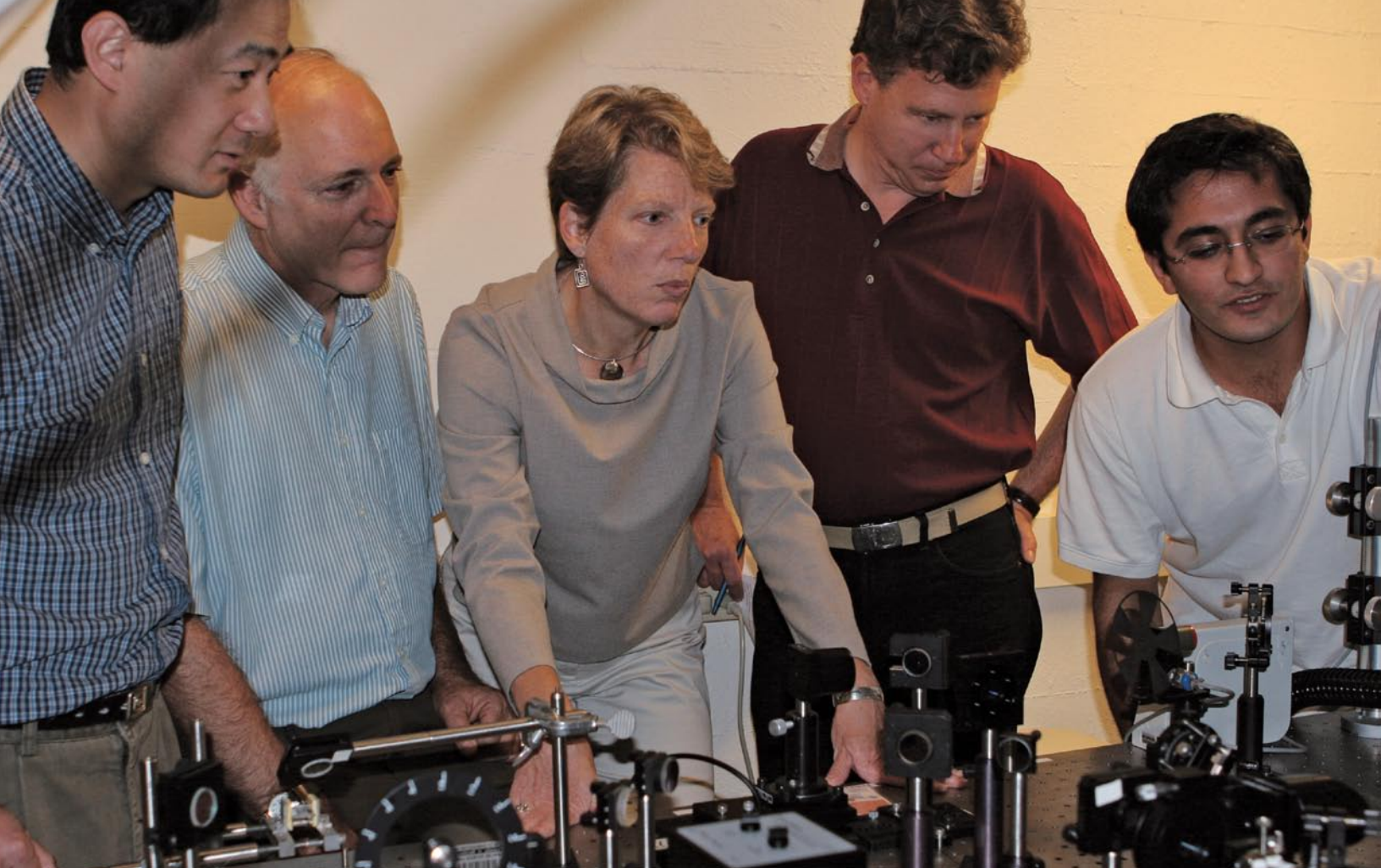
■ Another type of polymer material is being used to develop fiber optic sensors that can detect trace amounts of hazardous chemicals, including explosives. Fiber optic technology makes possible a distributed sensor that can provide the concentration profile of a targeted chemical along the length (hundreds to thousands of meters long) of the fiber, pinpointing the source of the chemical. The research is focused on two types of sensors based on polymer sensing materials. One operates on a chemo-optic polymer that changes its index of refraction upon bonding with target molecules. Another is based on fluorescent polymers whose fluorescence is strongly affected by the concentration of trace amounts of chemicals in their local environment. Tested with an explosive simulant, these sensors have achieved part-per-billion sensitivity.

A major challenge in chemical sensor technology is specificity. The sensor should respond only to the targeted chemicals and not to other chemicals that might be present. The sensing materials developed by us have shown good specificity against many common chemicals. And using multiple sensing materials and detection mechanisms in concert will further enhance sensor specificity.

A National Science Foundation research center in photonics is based at the University of Washington. It was established five years ago and a renewal grant in 2007 brings total funding to more than \$35 million. So far center scientists have generated new organic photonic materials that are 10 times faster and require 100 times less power than inorganic materials. To further the center's work, the university has established the Institute for Advanced Materials and Technology and is forming a nanophotonics steering committee to explore commercialization opportunities based on the center's research.



Chemo-optic polymer sensing materials, in solution and extruded as fiber optic strands



■ Hydrophones—underwater listening devices—using fiber optic technology are being developed that, compared to their piezoelectric cousins, have lower noise, higher sensitivity, and the ability to multiplex a large number of channels using wavelength division techniques. Fiber optical hydrophones do not require an electrical connection, and therefore are immune to electro-magnetic interference. Existing fiber optical hydrophones employ optical fiber wound on a bulky mandrel to achieve the required sensitivity. They can only be deployed from large vessels. With support from our industry partners, we are conducting research to develop fiber optical acoustic sensors that are compact and can be operated on small autonomous underwater vehicles, such as the Seaglider. Grating reflectors are inscribed in an optical fiber with a pulsed ultraviolet excimer laser (routinely used in eye surgery). The sharp resonance of the grating leads to high sensitivity in only a very short piece of fiber, thus significantly reducing the hydrophone size.

■ The Laboratory has begun work to solve a wide variety of problems using electromagnetic waves with frequencies higher than the highest 'radio waves' (roughly 100 gigahertz, or billions of cycles per second), yet lower than the frequencies of infrared light. Light that falls in this range has frequencies of trillions of cycles per second, and is hence known as terahertz radiation.

The prospective applications of terahertz waves are exciting because the waves penetrate packaging, clothing, and bandages, thus seeing what lies inside or beneath. Yet unlike X-rays, terahertz radiation is non-ionizing and safe for use around people. Moreover, many materials of interest—drugs and pharmaceuticals, explosives, and

Chen, Thorsos, Zurk, and Winebrenner review the setup of the terahertz time-domain spectrometer with graduate student Hassan Arbab in the APL-UW photonics laboratory.



many other crystalline solids—absorb wavelengths (i.e., ‘colors’) of terahertz radiation in characteristic ways that can identify those materials in personnel or package screening settings.

We are working on spectroscopic identification of materials and on ways of making images of obscured or concealed objects using terahertz radiation. With funding from the Office of Naval Research, we have acquired a new terahertz short-pulse spectrometer system, which is useful for both applications simultaneously. In collaboration with Professor Lisa Zurk of Portland State University, we are studying how spectroscopic information can be acquired in operationally robust ways, using, for example, backscattered rather than transmitted terahertz waves. Some of our work has shown that microstructure of a highly variable explosive mixture can influence terahertz detection signatures.

Another important issue under consideration is the excessively long acquisition time, from 10 minutes to a few hours, for two-dimensional terahertz images. One approach to solving this problem is to extract image information using sparse sampling. A technique under investigation is based on curvelets, which apply to two-dimensional data (analogous to wavelets, which apply to one-dimensional data). We believe there is potential for this approach to yield rapid, near-real-time terahertz imaging.

Team members: Antao Chen, James Luby, Robert Miyamoto, Eric Thorsos, and Dale Winebrenner

In UV-filtered lighting conditions, graduate student Nathaniel Burt prepares fiber for grating inscription

Finances



Sponsor	FFY05 (x \$1,000)	FFY06 (x \$1,000)
Office of Naval Research	14,767	18,107
National Science Foundation	9,816	10,961
Naval Surface Warfare Center	6,268	2,656
National Aeronautics and Space Administration	1,547	3,905
Naval Sea Systems Command	1,578	1,863
National Institutes of Health	1,108	2,076
Defense Advanced Research Projects Agency	–	2,579
National Oceanic and Atmospheric Administration	405	1,950
Space and Naval Warfare Systems Command	757	1,439
Naval Research Laboratory	983	600
Office of Naval Intelligence	838	628
Other Non-Navy	2,108	2,871
Other Navy	1,893	1,471
TOTAL	42,068	51,106

William Bakamis

Research and development at the Applied Physics Laboratory is funded nearly entirely by grants and contracts. The Laboratory's ability to win competitive funding set an all-time record for federal fiscal year (FFY) 2006, when revenues totaled over \$51 million, a 21% increase over FFY 2005. In the five years since FFY01, APL-UW funding has grown about 60%.

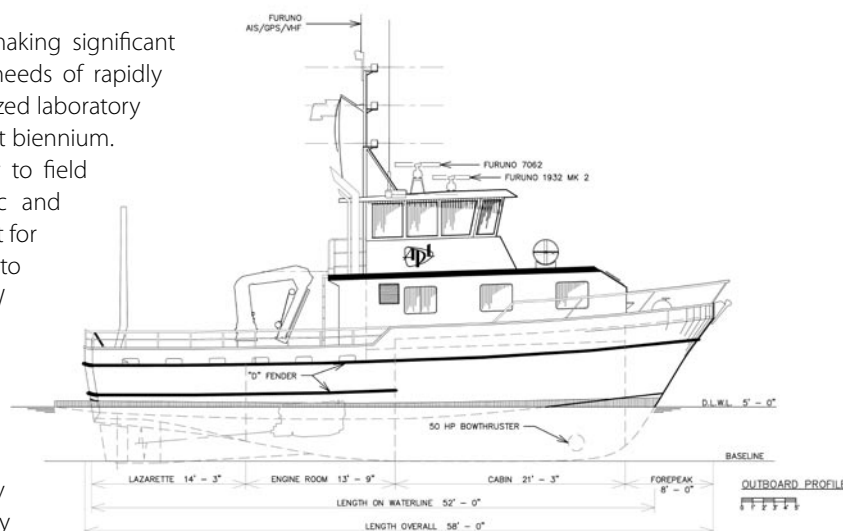
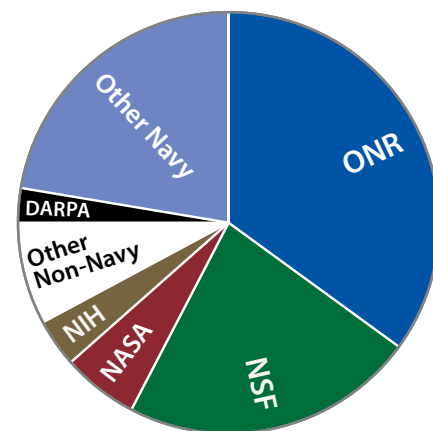
The Laboratory's primary partner remains the U.S. Navy, providing over 50% of total funding. Other federal agencies sponsoring APL-UW research include the National Science Foundation, National Aeronautics and Space Administration, National Oceanic and Atmospheric Association, and National Institutes of Health.

The Laboratory's revenue base continues to diversify, with about 50 different sponsors, and features basic research programs. Twenty years ago the U.S. Navy provided over 90% of the Laboratory's funding, and the ratio between applied science and basic research was about 2:1. The current percentage balance between applied and basic research has shifted in the opposite direction to reflect faster growth in basic research areas.

Buoyed by robust fiscal growth overall, APL-UW is making significant investments in research infrastructure. To meet the needs of rapidly growing research and development programs, specialized laboratory and office space will increase by almost 40% in the next biennium. Additionally, to further Laboratory researchers' ability to field ambitious observational programs at sea, a historic and continuing strength, a new research vessel is being built for APL-UW. The vessel, the first in over 50 years, is designed to provide a versatile platform to test and deploy APL-UW ocean instrumentation.

APL-UW-billed contract fees, which provide the Laboratory's discretionary resources, represent about 1.5% of total income. They will continue to support strategic initiatives and business expenses not covered by grants and contracts. These and other vital discretionary funds provide the means to create unique and advanced research and development capabilities, and give support for new areas of inquiry and discovery. Recent examples of the funds' use include the development of specialized laboratories for cryoscience, laser and photonics research, and operational glider development.

APL-UW remains committed to ensuring that the long-term investments in the Laboratory by the Navy and federal government are applied to national strategic and technical needs, and to preserving our ability to respond effectively and efficiently to present and future Navy and national defense needs. The Laboratory's strengths in advanced research and technical areas are important to the nation and will ensure its sound financial health.



Education



Robert Odom & Ellen Lettvin

The Applied Physics Laboratory's education efforts are aimed at allying the Laboratory with the educational mission of the University of Washington. APL-UW conducts tours, demonstrations, and school visits, sponsors scholarships for undergraduates, start-up and bridge support for graduate students working with APL-UW scientists, and both undergraduate and graduate fellowships for APL-UW employees. This is in addition to the 48 graduate students and 51 undergraduate students over the past biennium who have worked with APL-UW faculty scientists and been supported by externally funded APL-UW research grants.

The Hardisty and Boeing Company Scholar Programs are endowed fellowships awarded to one undergraduate student per year to participate in a Laboratory research project under the supervision of an APL-UW faculty scientist. The Hardisty Scholar for 2005 and 2006 was Evan Gander, an electrical engineering student who worked with Principal Engineer Russ Light and Senior Engineer Tim McGinnis. The respective Boeing Company Scholars for 2005 and 2006 were physics and computer science student Julia Schwarz, who worked with Senior Engineer and Affiliate Associate Professor Antao Chen, and electrical engineering major Jodi Shi, whose APL-UW advisor was Senior Engineer and Affiliate Associate Professor Warren Fox.

Principal Engineer and Research Associate Professor Peter Dahl led a very popular one-month UW Discovery Seminar for incoming freshmen prior to the beginning of their first fall quarter titled "What is Sound?" A highlight of the course is a demonstration illustrating the inability of sound to propagate in a vacuum. Dahl places a ringing cell phone into a bell jar that is slowly evacuated. As the air is removed, the ringing becomes fainter and fainter until the air density becomes so low that sound will not propagate.

To simulate undersea pressures, students squeeze a Seaglider's oil-filled bladder that controls its buoyancy.





APL-UW is pursuing educational outreach partnerships where the Laboratory provides expertise on the scientific content and a museum institution provides the content delivery mechanism. A great success with this model is the Polar Science Weekend—a four-day event conducted in 2006, 2007, and scheduled again for March 2008. In 2007 over 10,000 visitors came to Seattle's Pacific Science Center to learn about the polar regions. The event brings the audience face to face with active polar researchers who present current research as well as basic concepts in science and technology. Event content emphasizes inquiry-based learning and is linked to national and state science standards, such as the Washington State Essential Academic Learning Requirements.

As an investment in our own future, the Laboratory awards an APL-UW Undergraduate Fellowship in the form of tuition payment for a staff member to pursue an undergraduate degree at the University of Washington. Fellowship recipient Trina Litchendorf completed a degree in oceanography and Sheila Ocoma is pursuing a degree in the social sciences. The APL-UW Graduate Fellowship supports Marilee Andrew, Andrew Ganse, and Megan Hazen studying for doctorates in bioengineering, electrical engineering, and earth and space sciences, respectively.

APL-UW is developing, implementing, and evaluating a distance learning professional development course for high school science teachers to improve awareness of the Earth as a system, and how it can be studied with satellite observations. Course development is a collaborative effort with the Cooperative Institute for Meteorological Satellite Studies at the University of Wisconsin and is supported by the National Science Foundation.



Graduate Student Profiles

Wayne Kreider's research has contributed important new understanding to the fundamental science of bubbles subjected to high-amplitude acoustic fields. Shock waves—sometimes greater than 1000 atmospheres of pressure—are used in lithotripsy, the most common treatment for kidney stones, and to treat a range of orthopedic injuries. High intensity focused ultrasound (HIFU) is used to treat uterine fibroids and holds promise for a range of conditions. Therapies rely on the mechanical disruption of tissue by the production and excitation of gas bubbles and heating of the tissue by absorption of the acoustic wave. Wayne was one of the first researchers to recognize that these two effects must be understood in concert, not separately.

Wayne notes, "When I began this work, the paradigm in the HIFU research community was to consider bubbles containing only non-condensable gases rather than bubbles with both non-condensable gases and vapor. During HIFU treatment tissue is heated and eventually water in the tissue reaches boiling temperatures at which point the bubbles would be predominantly vaporous. My idea was to write a numerical model to better understand how a bubble is affected by both large acoustic pressures as well as elevated temperatures."

The most basic effect of vapor trapping is that when a bubble collapses violently, the vapor cushions the collapse so that more energy is conserved and thus available as the bubble rebounds. Wayne's model of gas-vapor bubbles accounts for liquid compressibility, heat transfer, vapor transport, vapor trapping by non-condensable gases, diffusion of non-condensable gases, and heating of the liquid at the bubble wall. Beyond writing the code to simulate the physical processes, he knew that he would have to set up an experiment to quantify the phenomena.

Wayne Kreider defended his dissertation in fall 2007 to earn a Ph.D. in bioengineering. His advisors in APL-UW's Center for Industrial and Medical Ultrasound are Lawrence Crum and Michael Bailey.



Wayne envisioned experiments run with a lithotripter, water tank, high-speed camera, and cavitation detector—all pieces of equipment available in his advisors' laboratories. It would be critical, however, to control the percentage of dissolved gas in the water tank. Putting mechanical engineering and plumbing skills to use, he designed and built a water filter system that could de-gas regular tap water to precise values, plus heat the water to various temperatures (human body temperature and beyond). The water was also kept in circulation between the experimental tank and the filtration system to maintain dissolved gas and temperature constants during the trials.

His efforts were doubly successful. "The observed trends in the bubble rebounds were supported by the model predictions, and using my experimental data in conjunction with the physical understanding supplied by the model, we can now use a more physically realistic model to investigate cavitation behavior in the acoustic and thermal fields characteristic of therapeutic ultrasound," says Wayne.

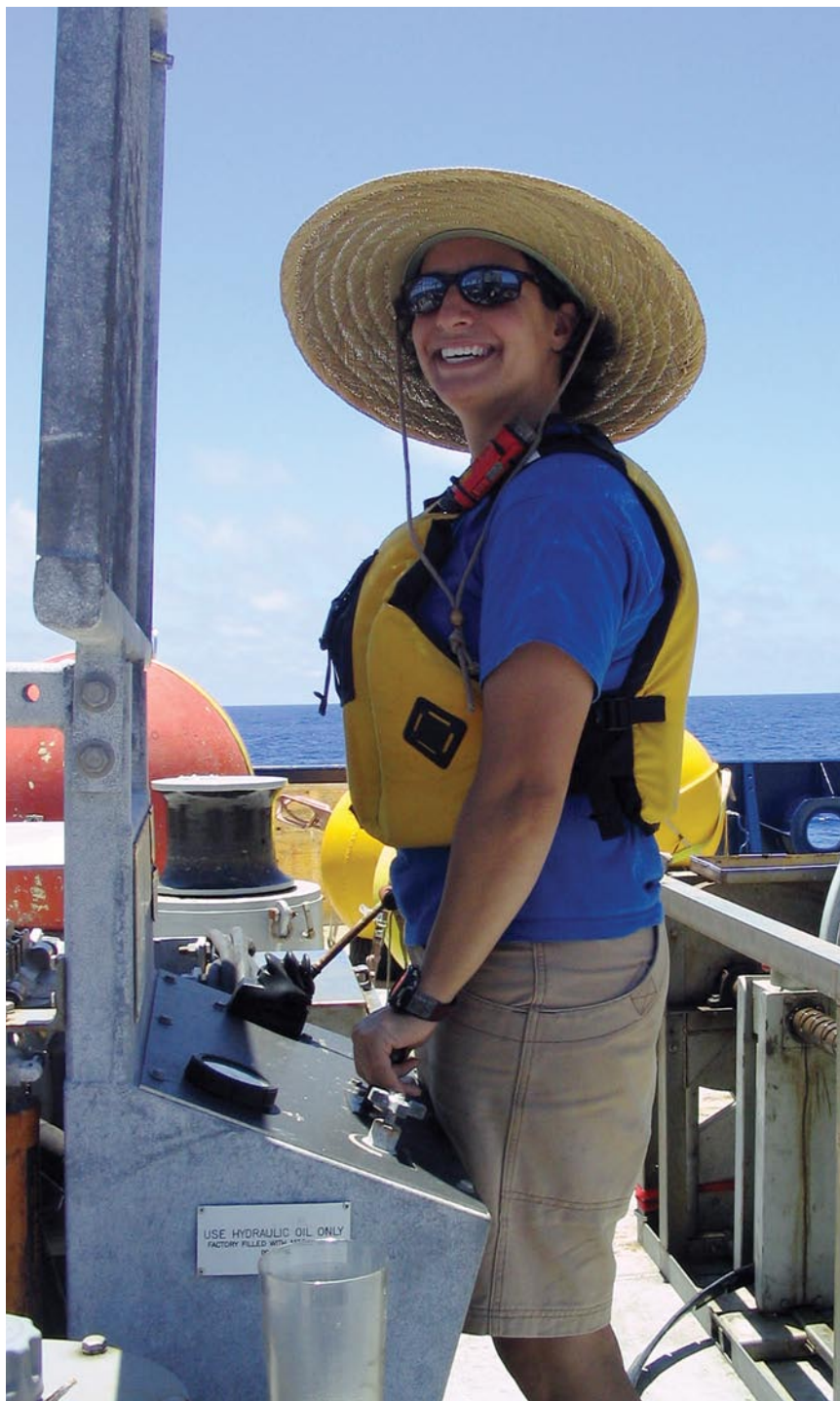
The fundamental physics of Wayne's theoretical and experimental work shows the dominant effect of vapor trapping in bubbles excited acoustically. His co-workers at APL-UW are now using the appearance of boiling in tissue, which is easy to detect, as an exact measure of the acoustic exposure and heating in the body, both of which are hard to measure but important to know. Wayne's discovery has led to collaborative work on cavitation clouds (his model shows that faster shock wave rates in lithotripsy are less effective because too many bubbles are created, reducing pressures exerted on the kidney stone), and to hypotheses concerning sonar effects on deep-diving whales, whose blood and tissues become supersaturated with dissolved gases.

Kim Martini's academic career took a turn when she realized she preferred travel and field research to experiments at the laboratory bench. After having earned undergraduate degrees in fine arts and physics, and then a master's degree in physics at the State University of New York at Albany, Kim came to the University of Washington to begin the Ph.D. program in oceanography. "Physical oceanography was the logical choice for me, as I already had a love of the ocean having grown up in a sailing family." Over the past four years she has participated in research cruises all over the world with her advisor, Oceanographer Matthew Alford.

One field experiment centered on Mamala Bay, Oahu, Hawaii, where the research team observed standing internal waves and enhanced mixing. Internal waves, similar to waves on the surface, occur at the interface between fluids of differing densities, but because the density differences in stratified seawater are much smaller than those between water and air, internal waves can have much larger amplitudes, achieving wave heights up to several hundred meters. Like their surface counterparts, internal waves can also shoal onshore, break, and even form standing waves.

Standing internal waves are caused by the superposition of two free internal waves traveling in opposite directions along the same axis. Kim describes the dynamics observed in Mamala Bay: "An eastbound wave from Kaena Ridge and a westbound wave that originates from Makapuu Point combine to create a standing wave. When averaged over a wave period, standing waves have kinetic and potential energy peaks. These kinetic and potential energy peaks occur at the headlands and the center, respectively, of Mamala Bay. The potential energy peak in the bay center creates vertical displacements over 100 m in water only 500 m deep, which may promote the enhanced mixing measured there." Kim's analysis of the standing internal waves in Mamala Bay was the subject of her master's thesis in oceanography and has also been published as a paper in *Geophysical Research Letters*.

During a 45-day cruise off the Oregon coast, further questions of internal wave propagation and turbulent mixing were explored. Moorings were placed on the Oregon continental slope to measure whether the semidiurnal internal wave signal detected there is due to the local baroclinic tide, or the onshore shoaling of internal waves generated elsewhere in the Pacific. Alford made Kim an important part of the mooring deployment team, giving her the responsibility of programming, preparing, and recovering the 20+ instruments on each mooring. All were equipped with a profiler that obtains full-depth profiles of velocity, conductivity, temperature, and pressure every three hours using a small motorized wheel to crawl up and down the mooring wire. With the velocities and calculated vertical displacements, the semidiurnal baroclinic internal wave signal was extracted and used to determine the direction and modal content of the internal wave field across the continental slope. "Early analysis suggests that the semidiurnal baroclinic internal waves interact with 'rough' bathymetry on the slope creating near-bottom patches of strong turbulence or 'hotspots', instead of weakly dissipating over a broader area," notes Kim.



Kim brings creativity, a fun spirit and hardworking attitude to my research group, as well as a different perspective and tool kit owing to her artistic background. Her masters-level research and thesis were super and I have every confidence that she will pass the milestone of her general exam successfully in late 2007 and be one step closer to her Ph.D. in oceanography.

– Matthew Alford

Student Achievements

Degrees Awarded

Student	Department	Advisor
Ajay Anand	Electrical Engineering, Ph.D., 2005	Crum & Kaczkowski
Abdullah Bamasoud	Oceanography, M.S., 2005	Lee
Nishant Bhatambrekar	Chemistry, Ph.D., 2005	Chen
Glenn Carter	Oceanography, Ph.D., 2005	Gregg
Bryan Cunitz	Electrical Engineering, M.S., 2005	Crum & Kaczkowski
Asanka Savani Dewaraja	Bioengineering, M.S., 2006	Beach
Wendy Ermold	Physics, M.S., 2005	Steele
Lingyun Huang	Bioengineering, Ph.D., 2006	Beach
Joo Ha Hwang	Bioengineering, Ph.D., 2005	Crum
Teiichiro Ikeda	Mechanical Engineering, Ph.D., 2006	Bailey
David Krout	Electrical Engineering, Ph.D., 2006	El-Sharkawi & Fox
Brian MacConaghy	Applied Mathematics, M.S., 2006	Bailey & LeVeque
Kim Martini	Oceanography, M.S., 2006	Alford
Patrick Ngatchou	Electrical Engineering, Ph.D., 2006	El-Sharkawi & Fox
Justin Reed	Physics, M.S., 2006	Bailey & Crum
Travis Sherwood	Materials Science and Engineering, M.S., 2005	Chen
Juan Tu	Bioengineering, Ph.D., 2006	Crum & Matula
Maya Whitmont	Oceanography, M.S., 2006	Alford

Graduate Students

Student	Topic	Advisor
Ajay Anand	Noninvasive temperature estimation technique for HIFU therapy monitoring using backscattered ultrasound	Crum & Kaczkowski
Mohammad Hassan Arbab	Terahertz spectroscopy and imaging	Chen
Oleg Babko	Temporal evolution of ice-draft data	Rothrock
Abdullah Bamasoud	Dynamics of Arabian Sea coastal filaments	Lee
Nishant Bhatambrekar	Realizing a fractional volt half-wave voltage in Mach-Zehnder modulators using a DC biased push-pull method and synthesis and characterization of indole based NLO chromophores for improving electro-optic activity	Chen
Samantha Brody	Refurbishment of the EM-POGO	Sanford
Nathaniel Burt	Fiberoptic acoustic sensors	Chen
Glenn Carter	Turbulent mixing near rough topography	Gregg
Hong Chen	Affect of blood vessel wall constraints on ultrasound contrast agent oscillations	Matula
Bryan Cunitz	Vector-Doppler ultrasound system for the detection of internal bleeding	Crum & Kaczkowski
Beth Curry	Arctic-North Atlantic exchange through the Canadian Arctic Archipelago/Davis Strait	Lee

Graduate Students, continued

Student	Topic	Advisor
David Dall'Osto	Ambient noise	Dahl
Asanka Savani Dewaraja	Monitoring tissue perfusion using video pulse oximetry	Beach
Wendy Ermold	Sea surface salinity trends on the Siberian shelves	Steele
Andrew Ganse	Nonlinear inverse problems for ocean acoustics	Odom
Amanda Gray	Carbon flux and the North Atlantic spring bloom	Lee
Lingyun Huang	Ultrasound plethysmography: Signal processing and application	Beach
Sean Huang	Internal waves in the South China Sea and the Kuroshio	Lien
Joo Ha Hwang	Ultrasound-mediated vascular bioeffects: Applications for hemostasis and sclerotherapy	Crum
Teiichiro Ikeda	High-speed imaging of lithotripsy bubbles	Bailey
Chuan Li Jiang	An improved upper ocean heat budget in the tropical Pacific Ocean using scatterometer winds	Kelly
Michael Kalnoke	Long-range acoustic propagation	Mercer
Michael Keim	Wavelet-based analysis of arctic sea ice types	Percival
Wayne Kreider	Gas-vapor bubble dynamics in high-amplitude acoustic fields	Bailey & Crum
David Krout	Intelligent ping sequencing for multiple target tracking in distributed sensor fields	El-Sharkawi & Fox
Lucas Lezamiz	Ambient noise data processing	Dahl & Williams
Brian MacConaghy	Modeling and measurement of elastic waves generated by lithotripters	Bailey & LeVeque
Joseph MacGregor	Radar sounding of ice sheets	Winebrenner
Kim Martini	Diagnosing a standing internal wave in Mamala Bay, Oahu	Alford
John Mickett	Mixing in Puget Sound	Gregg
Debashis Mondal	Wavelet variance analysis of time series and random fields	Percival
Twila Moon	Glacier retreat on the Greenland Ice Sheet	Joughin
Andrew Morabito	Ricean parameter estimation using phase information in low SNR environments	Percival
Patrick Ngatchou	Intelligent techniques for optimization and estimation	El-Sharkawi & Fox
Neil Owen	Ultrasound-guided HIFU therapy systems	Bailey & Crum
Ana Cecilia Peralta Ferriz	Bottom pressure variations in the Arctic Ocean from in-situ sensors and the GRACE gravity satellite system	Morison
Scott Philips	Perceptually-driven signal analysis for acoustic event classification	Pitton
Anna Pyayt	Electro-optics and nano-photonics	Chen
Justin Reed	Separating cavitation and nonlinear acoustic effects in high intensity focused ultrasound	Bailey & Crum
Eric Rehm	Biophysical interactions, ocean productivity and ocean optics	D'Asaro
Travis Sherwood	Polymer ring resonator made by two-photon polymerization and vertically coupled to a side-polished optical fiber	Chen
Haishan Sun	Chemical and RF sensors	Chen
Zolton Szuts	Electric currents generated by the Gulf Stream	Sanford
Juan Tu	Fundamental aspects of ultrasound contrast agent dynamic behaviors and inertial cavitation quantification	Crum & Matula
James Westphal	Electric-optic polymers	Chen
Andrew White	Acoustic scattering	Mercer
Maya Whitmont	Seasonal and spatial variability of near-inertial kinetic energy from historical moored velocity records	Alford
Kai-Chieh Yang	Kuroshio variability and intrusion through the Luzon Strait	Lee

Undergraduate Students

Student	Topic	Advisor
James Anderl	Environmental visualization	Carr
Daniel Blizzard	Use of ultrasound to predict intracranial pressure	Crum & Mourad
Sean Burgess	Investigation of image-guided HIFU for treating hemorrhage from the posterior liver parenchyma	Vaezy
Nathan Chin	Increasing the efficiency of chemotherapy for brain tumors	Mourad
Evan Gander	NEPTUNE power supply; ALOHA/MARS mooring sensor network; Dual Passive Acoustic Listener; fuel gauge for acoustic recorder system–Seaglider	Light & McGinnis
Freddy Gella	Use of ultrasound to move bubbles in microgravity aboard the NASA Parabolic Research Aircraft	Matula
Francisco Gomez-Gamino	Use of ultrasound to move bubbles in microgravity aboard the NASA Parabolic Research Aircraft	Matula
Elie Goral	Video/animation production titled “The Life of Sea Ice”	Krembs, Olsonbaker, & Steele
Seth Gordon	Use of ultrasound to move bubbles in microgravity aboard the NASA Parabolic Research Aircraft	Matula
Amanda Gray	Seaglider software	Lee
Erik Henne	Computer simulation to determine optimum cooling set-up for a thin-plate transducer	Vaezy
James Jenson	Use of ultrasound to move bubbles in microgravity aboard the NASA Parabolic Research Aircraft	Matula
Bion Johnson	Lithotripsy tissue injury	Bailey
H. Ryan Jones	Evidence of internal waves in the Mediterranean Sea from visible and SAR images	Dickinson & Kelly
Julian Kelly	Acoustic holography for medical device characterization	Bailey
Nathan Kohagen	River surface current sensors	Hayes & Plant
Marta Krynytzky	Analysis of IPCC models with regard to arctic climate and its influence on indigenous people	Bitz
Min Kyeong Lee	Use of ultrasound to move bubbles in microgravity aboard the NASA Parabolic Research Aircraft	Matula
Emily Lemagie	Observations of the internal tide from current meter moorings off Pt. Sur, CA	Girton
Trina Litchendorf	CBLAST hurricane spray measurements	Asher
JoAnn Lin	Medical diagnostic optics	Chen
Kelvin Ma	Development of graphics for wavelet software in the R language for analysis of multi-scale geophysical data	Percival
Paul Mandeville	Video/animation production titled “The Life of Sea Ice”	Krembs, Olsonbaker, & Steele
Violet Manning	Use of ultrasound to move bubbles in microgravity aboard the NASA Parabolic Research Aircraft	Matula
Zach Martin	Video/animation production titled “The Life of Sea Ice”	Krembs, Olsonbaker, & Steele
Adam Maxwell	A new hydrophone for medical ultrasound	Bailey
Caitlin McHugh	Vanishing shear modulus as a singular perturbation problem; Wavelet filter for the Geophysical Acoustic Bottom Interaction Model (GABIM)	Anderson, Odom, & Moravan
Aaron Midkiff	Engineer an MRI-compatible HIFU system to confirm that appearance of bubbles is due to boiling	Bailey
Robert Mott	Growth of conductive ZnO nano-wires and their application to electro-optic devices	Chen
Mary-Margaret Murphy	Eddies in the Denmark Straits seen by satellite SST imagery	Alford & Girton
Lisa Nguyen	Observation of HIFU “pre-lesions” in the brain using diagnostic ultrasound	Mourad
Kristin Pederson	Transcutaneous acoustic palpation for improving the anatomic specificity of pain diagnosis	Mourad
Panita Pichawong	Use of ultrasound to move bubbles in microgravity aboard the NASA Parabolic Research Aircraft	Matula

Undergraduate Students, continued

Student	Topic	Advisor
Nathan Powel	Collocating ship-based, buoy-based, and satellite-based observations of nonlinear internal waves in the South China Sea	Lettvin
Adam Przybilla	Use of ultrasound to move bubbles in microgravity aboard the NASA Parabolic Research Aircraft	Matula
Blake Riebe	Use of focused ultrasound to raise the temperature of the hypothalamus (for core body temperature regulation)	Curra
Julia Schwarz	Impact of an explosion on the concentration of negative ions in the air	Chen
Jodi Shi	Optimization algorithm parameter study	Fox
Alison Snyder	Nonlinear internal waves in the South China Sea	Lettvin
Rachel Sparks	Opening the blood–brain barrier with ultrasound to enhance drug delivery to the brain	Mourad
Gauri Sudame	Longitudinal analysis of data related to the menopausal transition	Percival
Faezeh Talebi	Growth of conductive ZnO nano-wires and their application to electro-optic devices	Chen
Zuotian Tatum	Development of tissue phantom gels for HIFU research	Crum & Mitchell
Rebecca Taylor	Use of two-frequency focused ultrasound to erode kidney stones	Bailey
Wendell Thompson	A new kidney stone holder for investigation of why faster rates are less effective in lithotripsy and how to monitor ineffective rates	Bailey
Rowen Tych	Transcutaneous Acoustic Palpation for improving the anatomic specificity of pain diagnosis	Mourad
Pavan Vaswani	Non-invasive means of predicting intracranial pressure	Mourad
Alice Ward	Use of ultrasound to transiently and therapeutically disrupt the blood–brain barrier	Mourad
David Wright	Use of ultrasound to predict intracranial pressure	Mourad
Kang Ya	Use of ultrasound to predict intracranial pressure	Mourad
Clement Yang	Assessing ice type distribution using wavelets	Percival & Yu

Development & Community Outreach



To augment its education mission, APL-UW is developing a broad-reaching and innovative community presence through complementary outreach efforts to corporations, foundations, public and private institutions, educators, and students. Because APL-UW receives no 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 allows us to expand our education outreach programs, to mentor undergraduate students throughout the UW, and to seed new research projects.

Ellen Lettvin

Over the past biennium APL-UW launched a development website providing staff, retirees, alumni, or other friends of the Laboratory with the opportunity to make gifts to specific research projects, establish endowments, and participate in or organize efforts intended to produce support for students, research, or community outreach programs at APL-UW. We have engaged prospective corporate partners and sponsors in discussions about opportunities for partnering with APL-UW, and hope to grow this aspect of Laboratory support in coming years. We have also successfully engaged a subset of the APL-UW Advisory Board to help increase our profile in this important area, and assume a more active role with individuals and companies who have an interest in supporting Laboratory activities.

During the 2005/2006 academic year, the Laboratory launched a new seminar series on technology commercialization devoted to emerging technologies of regional, national, and international relevance where APL-UW is a recognized leader—medical device and environmental monitoring technologies. The motivation for the series was to elevate the Laboratory's profile among prospective corporate partners, and encourage APL-UW researchers to consider a variety of mechanisms for transitioning their research to commercial applications.

Building on the success of the seminar series and working to extend the impact to the entire UW research community, APL-UW teamed with the Center for Innovation and Entrepreneurship of the UW Business School to introduce *From Invention to Start-up* during the 2006/2007 academic year. This series focused on issues unique to the high-tech start-up process to raise entrepreneurial awareness on campus and improve the odds of commercial success of resulting ventures. Over the fall and winter quarters, 18 seminars were given and were attended by 575 faculty, staff, post-docs, and graduate students, representing 37 different departments on campus. To make the seminar series available more broadly, and to alleviate scheduling conflicts with other seminars or departmental meetings, the seminars were videotaped and posted on the Web; over 2,900 video downloads of the seminars have been made.

APL-UW's emphasis on research collaborations with private entrepreneurs and technology commercialization is an important aspect of community outreach, as it transfers federally funded research to the business community and results in the creation of jobs and the generation of local revenue. Companies that have been founded recently by APL-UW researchers include BlueView Technologies, SoundMetrics, Mirabilis Medica, UST (Ultrasound Technologies), Allez Physionix, and Ultreo.

We have launched *Reverberations*, a newsletter for APL-UW alumni and retirees, to keep them informed of news and activities at the Laboratory. This component of the APL-UW community is now better apprised of opportunities to participate in or attend seminars and events.

Washington Weekend is held campus-wide each spring to promote the university's connections with the public of Washington State. APL-UW and the entire College of Ocean and Fishery Sciences participate by hosting an open house where Laboratory departments assemble hands-on exhibits based on current research programs. Over 160 adults and 75 children visited the Laboratory's display in 2007 to learn, for example, how buoyancy changes propel the autonomous undersea vehicle Seaglider, what equipment is needed to conduct research at the North Pole, and how an infrared camera can detect temperature differences on the surface of water.

Personnel

Directorate

Jeffrey A. Simmen – Director

William T. Bakamis – Associate Director, Business & Finance

Ellen E. Lettvin – Assistant Director, Education & Development

David L. Martin – Associate Director, Science & Technology Integration; Principal Oceanographer

Robert T. Miyamoto – Associate Director, Science & Technology Transition; Affiliate Associate Professor, Electrical Engineering

Robert I. Odom, Jr. – Assistant Director, Education & Development; Principal Physicist; Research Associate Professor, Earth and Space Sciences

Dian L. Gay – Administrator, Program Operations

Assigned outside Washington State

Kenneth W. Lackie, Manager

Air–Sea Interaction & Remote Sensing

Andrew T. Jessup – Chair; Principal Oceanographer; Affiliate Associate Professor, Civil Engineering & Mechanical Engineering

William E. Asher – Principal Oceanographer

Gene H. Chatham – Engineer I

C. Christopher Chickadel – Research Associate

Suzanne Dickinson – Oceanographer III

Brian D. Dushaw – Senior Oceanographer; Affiliate Assistant Professor, Oceanography

Kathleen A. Edwards – Oceanographer IV

Ralph C. Foster – Physicist IV

Chuan Li Jiang – Predoctoral Research Associate

William C. Keller – Senior Physicist

Kathryn A. Kelly – Principal Oceanographer; Affiliate Professor, Oceanography

Hanzhuang Liang – Research Associate

Trina Litchendorf – Oceanographer II

Sabine Mecking – Oceanographer IV

Jeffrey A. Nystuen – Principal Oceanographer; Affiliate Associate Professor, Oceanography

William J. Plant – Principal Research Scientist; Affiliate Associate Professor, Atmospheric Sciences

Andrew W. Spott – Student Helper

James M. Thomson – Oceanographer IV

Robert N. Vosper – Fiscal Specialist II

Keith A. Walls – Administrator

Members of the Air–Sea Interaction and Remote Sensing (AIRS) Department use remote sensing techniques to study the interaction of the atmosphere and ocean, which plays a key role in local weather and global climate. AIRS researchers use satellite measurements to study processes on ocean basin scales; aircraft, ships, and moorings are employed for field studies, and laboratory-based experiments study the small-scale physics of air–sea exchange. Remote sensing instruments used include electro-optical sensors (microwave, infrared, and laser) and acoustic sensors (sonars and hydrophones).

Several of our scientists who use satellite measurements are members of the NASA Ocean Vector Wind Science Team. They are studying large-scale phenomena such as the effect of the ocean on the intensity of mid-latitude storms and the occurrence of atmospheric roll vortices in a hurricane boundary layer. Satellite measurements are also being used to study the seasonal heat budget across the California Current and the role of large-scale eddy circulation in harmful algal blooms in the coastal waters of the Pacific Northwest.

AIRS was privileged to have representation on the Executive Committee of the National Academy of Science's Decadal Survey for the Earth Sciences. The recently released survey makes strong recommendations for a sustained satellite observing system over the ocean. This study will be used by Congress, government agencies, and the community to determine the future direction and support for ocean satellite remote sensing.

Acoustic remote sensing applications include the use of hydrophones to record ambient sound, to measure oceanic rainfall, and to monitor marine mammals. A recently completed campaign in the Ionian Sea demonstrated that rainfall over large areas of the ocean can be monitored by placing hydrophones on moorings as deep as 2 km. The effectiveness of passive acoustic mammal monitoring was demonstrated in 2006 when killer whales were detected a total of 56 times over the winter months off the Washington coast, compared to an average of only one wintertime sighting per year over the past 25 years.

A new area of research is the use of nonlinear laser spectroscopy to detect trace levels of high explosives remotely. A new laser laboratory has been established for this project, which is part of the Office of Naval Research program to counter improvised explosive devices. Another new application of remote sensing techniques developed in the department is the study of coherent structures in rivers and estuaries (see *Remote Sensing of Coherent Structures Reveals Riverine Flow*, p. 26), where surface signatures are used to infer physical phenomena in river flows.

Center for Industrial & Medical Ultrasound

**Thomas J. Matula – Acting Director; Senior Physicist;
Affiliate Assistant Professor, Electrical Engineering**

Marilee A. Andrew – Senior Engineer

Katherine R. Apfel – Student Helper

Michael R. Bailey – Senior Engineer

Bradley M. Bell – Principal Mathematician

Andrew A. Brayman – Senior Physicist

Michael S. Canney – Predoctoral Research Associate

Hong Chen – Predoctoral Research Associate

Lawrence A. Crum – Principal Physicist; Research Professor,
Electrical Engineering and Bioengineering

Bryan W. Cunitz – Engineer III

Francesco P. Curra – Engineer IV

Asanka S. Dewaraja – Predoctoral Research Associate

Barbrina Dunmire – Engineer IV

Lori J. Ferro – Administrative Specialist

Yingying Gu – Predoctoral Research Associate

P. Ray Illian – Mathematician II

Bion H. Johnson – Student Helper

Travis C. Johnson – Student Helper

Peter J. Kaczkowski – Senior Engineer

Steven G. Kargl – Senior Physicist

Riley M. Kent – Student Helper

Vera A. Khokhlova – Senior Engineer

John C. Kucewicz – Engineer IV

Daniel F. Leotta – Engineer IV

Adam D. Maxwell – Student Helper

Lisa Day Mercer – Administrative Specialist

Stuart B. Mitchell – Engineer IV

Pierre D. Mourad – Principal Physicist; Research Associate
Professor, Neurological Surgery; Adjunct Research
Associate Professor, Pediatric Dentistry

Terrence W. Myntti – Field Engineer

Ryan Ollos – Physicist II

Neil R. Owen – Predoctoral Research Associate

Marla Paun – Engineer IV

Andrew H. Proctor – Senior Field Engineer

Oleg A. Sapozhnikov – Senior Engineer

Gavriel A. Speyer – Predoctoral Research Associate

Frank L. Starr – Research Manager

Susan M. Strachila – Student Helper

Rowen E. Tych – Student Helper

Yak-Nam Wang – Research Associate

Kang Yu – Student Helper

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.

Stuart Mitchell leads a collaboration with the UW Department of Medicine to advance high intensity focused ultrasound (HIFU) technology for clinical applications. Now completed is a pre-clinical evaluation of a HIFU device manufactured by the Yuande Bio-Medical Engineering Company (Beijing, China) for the palliative treatment of pancreatic cancer. An investigational device exemption application is being prepared for the FDA. If granted, the UW will be the first clinical site in the U.S. to evaluate HIFU technology for cancer treatment.

Tom Matula, with other CIMU researchers, is developing imaging techniques to understand and optimize cavitation used to clean semiconductor parts at MHz frequencies. As the feature size of polysilicon structures decreases, it is more difficult to remove nanometer-sized particulates, and damage to those structures is increasing.

CIMU and Moscow State University collaborate with colleagues in the Consortium for Shock Waves in Medicine to engineer safer and more effective lithotripters (see *Basic Research Improves Patient Outcomes*, p. 17). CIMU is focusing on new ultrasound monitoring to give useful feedback to the urologist, and working to optimize the acoustic and cavitation fields to aid lithotripter manufacturers. The knowledge gained from years of research on these devices that break kidney stones is being used by our scientists to proactively define safe protocols and devices for the treatment of musculoskeletal conditions.

Pierre Mourad invented a novel toothbrush that combines standard power toothbrush capabilities with ultrasound such that the ultrasound stimulates the bubbles in the mouth to become localized cleaning agents. With APL-UW scientists and engineers, and colleagues within the UW schools of Medicine, Public Health, and Dentistry, he worked to demonstrate its practicality. Mourad also cofounded a company (Ultreo) based on the invention, and only four years after initiating the research project, the toothbrushes are now for sale.

Electronic & Photonic Systems

Gary L. Harkins – Director

J. Craig Bathgate – Engineer IV

A. John Black – Software Engineer II

John A. Blattenbauer – Senior Engineer

Clark A. Bodyfelt – Senior Engineer

Neil M. Bogue – Senior Engineer

Matthew R. Carpenter – Engineer IV

Antao Chen – Senior Engineer; Affiliate Associate Professor, Electrical Engineering

April J. Greenwell – Fiscal Specialist II

Matthew D. Grund – Engineer IV

Michael J. Harrington – Senior Engineer

Benjamin M. Henwood – Senior Engineer

Robert E. Johnson – Principal Engineer

William A. Jump – Senior Engineer

Jill M. Lane – Student Helper

Carl J. Larson, Jr. – Field Engineer

Shan Lu – Student Helper

James C. Luby – Principal Engineer; Affiliate Assistant Professor, Electrical Engineering

Robert J. Mott – Student Helper

Larry D. Nielson – Field Engineer

J. Aaron Nix-Gomez – Engineer IV

Bradley A. Parham – Student Helper

Nancy L. Penrose – Research Coordinator

Steven E. Purcell – Engineer III

Carlos J. Rufin – Student Helper

Justin J. Schultz – Field Engineer

Marcelino B. Soriano – Manager

Eric W. Strengé – Field Engineer

Marvin L. Strengé – Principal Engineer

Laurence C. Tomsic – Field Engineer

Angela S. Wood – Oceanographer II

Xuang Qi Zhang – Field Engineer

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 — systems designed at APL-UW play a special role in the latter.

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, 20-foot wing span undersea flying wing glider for surveillance applications. This work is leveraging off the Laboratory's very successful Seaglider development program. 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.

The University of Washington has been selected by Joint Oceanographic Institutions, Inc., to lead the regional component of the National Science Foundation Ocean Observatories Initiative: The Regional Scale Nodes. This underwater cabled observatory will be installed off the Washington and Oregon coasts to span the Juan de Fuca Plate. For the first time, continuous real-time scientific measurements of ocean processes will be taken over a long term and on a regional scale. APL-UW leads the engineering of this high-bandwidth (tens of gigabits/second) and high-power (tens of kilowatts) distribution system, and will also deliver the scientific instrument packages that connect to the system, including a 3-km-long vertical mooring with over 50 sensors.

Environmental & Information Systems

David W. Jones – Department Head; Senior Oceanographer

Gregory M. Anderson – Senior Engineer

Payman Arabshahi – Senior Engineer; Affiliate Associate Professor, Electrical Engineering

Corinne J. Bassin – Oceanographer

Michael L. Boyd – Principal Physicist

Peter M. Brodsky – Engineer IV

Robert J. Carr – Engineer III

Luca G. Cazzanti – Engineer III

Keith L. Davidson – Senior Engineer

Christian J. Eggen – Principal Physicist

Judith D. Ellingwood – Senior Engineer

William J. Felton – Senior Field Engineer

Warren L.J. Fox – Senior Engineer; Affiliate Associate Professor, Electrical Engineering

Andrew A. Ganse – Engineer III

Gail M. Gilliland – Administrator

Robert P. Goddard – Senior Physicist

Megan U. Hazen – Engineer III

Sachiko Honda – Engineer III

Julia B. Hsieh – Engineer III

Michael J. Keim – Predoctoral Research Associate

Elizabeth V. Kirby – Engineer IV

William C. Kooiman – Engineer IV

Nicholas C. Lederer – Scientist III

Hilary Lyons – Predoctoral Research Associate

Michael Macaulay – Senior Oceanographer

Stuart D. Maclean – Engineer IV

Brian J. Marquardt – Engineer IV

Caren Marzban – Senior Physicist

John J. McLaughlin – Senior Engineer

Robert T. Miyamoto – Associate Director; Affiliate Associate Professor, Electrical Engineering

Kou-Ying Moravan – Senior Physicist

David W. Morison – Scientist III

Jan A. Newton – Principal Oceanographer; Affiliate Assistant Professor, Oceanography

Janet I. Olsonbaker – Engineer IV

Lane M.D. Owsley – Engineer IV

Donald B. Percival – Principal Mathematician; Affiliate Associate Professor, Statistics

James W. Pitton – Principal Engineer; Affiliate Assistant Professor, Electrical Engineering

John M. Pyle – Engineer III

Eric A. Rust – Research Assistant

Scott A. Sandgathe – Principal Oceanographer

Marc S. Stewart – Senior Physicist

Shelby F. Sullivan – Senior Engineer

Troy T. Tanner – Senior Computer Specialist

Robert H. Tyler – Oceanographer IV; Affiliate Assistant Professor, Earth & Space Sciences

Keith B. Wiley – Engineer IV

Lan Yu – Fiscal Specialist II

We are a diverse group with a wide array of skills and expertise. Our overarching focus is the flow of information, from the sensor in the environment to a decision maker, and includes new methods to process, analyze, and visualize information. Our knowledge is applied to the needs of the Department of Defense and other federal agencies. Future directions for our group are signaled by new research staff with expertise in chemical sensors engineering, biological oceanography, and applied nonlinear statistics.

Because of our proven record applying autonomous undersea vehicle technology to U.S. Navy problems, the department has been tasked under the Office of Naval Research's Technology Transition Initiative for buoyancy driven gliders to develop a new human-computer control interface. Currently called the Glider Monitoring, Piloting, and Communication (GLMPC) system, it will allow glider pilots to control many gliders representing a range of platforms simultaneously from one command interface.

Members in the department have secured funding from the National Geospatial Intelligence Agency to address the gravitational inverse problem. Given the observed value of a gravitational field some distance away from a source, can we infer the density of the source that produced the field? The project aims to develop a statistical methodology, with an inclination towards machine learning techniques. The methodology may be applied to detecting physical features underground, including tunnels, bunkers, or oil pockets, with gravimeters and/or gradiometers.

We are taking a leading role in the ONR Broadband Mine Countermeasures program, initiated two years ago to develop automatic classification technology for mine countermeasures sonar systems using broadband signals. The project's goal is to deploy by 2011 a real-time implementation of an automatic classifier onboard a U.S. Navy autonomous undersea vehicle (AUV).

Department software engineers have been involved in the XRay flying wing AUV since the program's inception. They are developing flight control software and other new capabilities including a dual-pump buoyancy engine, onboard acoustic array data processing, and real-time navigation using bottom-mounted transponders. APL-UW is also working on a sophisticated command and control language for vehicle mission planning, and integrating a micro-modem designed by the Woods Hole Oceanographic Institution that will give XRay underwater acoustic communication capability in the Persistent Littoral Undersea Surveillance-Networked system.

Ocean Acoustics

**Robert I. Odom – Department Chair; Principal Physicist;
Research Associate Professor, Earth & Space Sciences**

Rex K. Andrew – Senior Engineer

Robert M. Bolstad – Research Manager

Linda J. Buck – Systems Analyst/Programmer III

Ting Chan – Predoctoral Research Associate

Jee Woong Choi – Research Associate

Peter H. Dahl – Principal Engineer; Research Associate Professor,
Mechanical Engineering

David R. Dall'Osto – Research Assistant

Wm. Timothy Elam – Senior Physicist

Brian T. Hefner – Physicist IV

Bruce M. Howe – Principal Oceanographer; Research Associate
Professor, Oceanography; Adjunct Research Associate
Professor, Electrical Engineering

Anatoliy N. Ivakin – Senior Physicist

Darrell R. Jackson – Principal Engineer Emeritus

Christopher D. Jones – Senior Engineer

James A. Mercer – Principal Physicist; Research Professor,
Earth & Space Sciences

Daniel Rouseff – Senior Engineer

Kathleen M. Stafford – Oceanographer IV

Dajun Tang – Senior Oceanographer

Eric I. Thorsos – Principal Physicist; Affiliate Associate Professor,
Electrical Engineering

Kevin L. Williams – Principal Physicist; Associate Professor,
Oceanography

Michael A. Wolfson – Mathematician IV

Jie Yang – Research Associate

The scientists, engineers, and students in the Ocean Acoustics Department study the generation, propagation, and scattering of sound in the ocean and its use as a tool to probe the structure, dynamics, and inhabitants of the ocean. We are interested in frequencies from a few hertz to several tens of kilohertz. Propagation ranges of interest are a few millimeters to several mega-meters, and water depths from a few tens of meters to the full water column depth of the deep ocean.

A recent effort covering many of the areas of interest and expertise was the Office of Naval Research-funded Shallow Water '06 experiment (see *Conquering Uncertainties in Shallow Water Acoustics*, p. 10), where quantitative measures of how sound interacts with the environmental uncertainties in littoral regions were taken at sufficient spatial and temporal resolutions, extending to millimeter scales for these mid-frequency acoustics experiments.

The forward problem of ocean acoustic propagation is, "Given the ocean environment, what is the received signal?" The inverse problem is, "Given recorded acoustic data, what is the ocean environment?" The inverse problem may be nonlinear, non-unique, and sensitive to uncertainty in environmental properties and the details of the acoustic data. Departmental researchers are actively developing new techniques and algorithms to quantify the nonlinearities, non-uniqueness and uncertainty. Future applications include improved ocean environmental characterization, and higher fidelity tracking algorithms.

Marine mammal scientists employ passive listening techniques to monitor large whales in the North Pacific. Long-term hydrophone arrays record seasonal blue whale call patterns throughout the North Pacific Ocean, which are then 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 area of multi-megameter acoustic propagation, the Long-Range Ocean Acoustic Propagation Experiment studied the evolution, with distance, of the acoustic arrival pattern and in particular the range and frequency dependence of the spatial and temporal coherence. Data analysis over the past biennium has produced the first ever moving acoustic source thermographic image of a major ocean basin.

Principal Engineer Peter Dahl co-chaired the first ever Pacific Rim Underwater Acoustics Conference in October 2007. Drawing participants from the U.S., Canada, Russia, Korea, China, Japan, and Australia, the conference was devoted to the characterization, applications, and impacts of underwater ambient noise. Among the many topics were noise generation and propagation modeling, measurement of noise, inversion of noise for environmental properties, and noise impacts related to sonar signal processing.

Ocean Engineering

Russell D. Light – Department Head; Principal Engineer

Paul A. Aguilar – Senior Field Engineer

Eric S. Boget – Engineer IV

Chris L. Craig – Maintenance Mechanic II

John B. Elliott – Senior Engineer

Evan P. Gander – Student Helper

Lyle F. Gullings – Senior Field Engineer

Frederick W. Karig – Principal Engineer

Michael F. Kenney – Oceanographer IV

Harold A. Kolve – Principal Engineer; Affiliate Assistant Professor, Electrical Engineering

Keith E. Magness – Field Engineer

Timothy M. McGinnis – Senior Engineer

Vernon W. Miller – Senior Engineer

Michael A. Ohmart – Senior Field Engineer

Francis G. Olson – Senior Field Engineer

Colin H. Saari – Coordinator–Research

Peter L. Sabin – Senior Field Engineer

Colin J. Sandwith – Principal Engineer; Research Associate Professor, Mechanical Engineering

Christopher J. Siani – Engineer III

Daniel A. Stearns – Field Engineer

Troy G. Swanson – Field Engineer

Keith L. Van Thiel – Engineer III

Michael L. Welch – Senior Engineer

Timothy Wen – Senior Engineer

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

Department engineers developed several unique instruments to study ocean acoustics in sediments and the effect of internal waves on acoustic propagation in ONR-funded research off the New Jersey coast (see *Conquering Uncertainties in Shallow Water Acoustics*, p. 10). The Sediment Acoustic Measurement System provides a method to drive an acoustic receiver into the ocean sediment in precise steps while a source array transmits sound to the receiver through the sediment surface. This is the first device that can measure in situ sediment sound speed to this depth. Combined with vertical line array receivers in several configurations and shipboard source systems, the suite of instruments provided APL-UW with a self-sufficient capability to conduct shallow water experiments in the mid-frequency (1–10 kHz) range.

The autonomous underwater vehicle Seaglider was enhanced with a new acoustic sensor—an extremely low power and small recorder to make ocean ambient noise measurements and to receive very low frequency signals from ATOC (acoustic thermometry of ocean climate) sources. It was deployed successfully in a major Navy exercise and a scientific experiment near Hawaii. Efforts are underway to design and fabricate a second-generation glider that will travel faster and deeper, and carry a larger payload.

Department staff successfully planned, fabricated, and operated an arctic ice camp for the U.S. Navy that supported over 50 personnel on the ice pack in the Beaufort Sea for six weeks in spring 2007. Engineers also deployed and operated an acoustic tracking range used in under-ice submarine operations. The camp was extended by several weeks for NSF-funded scientists.

We delivered the Low Voltage Power System (LVPS) for the MARS Observatory in Monterey Bay, which provides up to 9 kW at either 400V or 48V to eight connections at the seafloor science node. We are designing and fabricating the ALOHA-MARS mooring that will be one of the first sensor networks to plug into the observatory. The complete mooring system consists of several secondary nodes—on the seafloor, on a subsurface float, and on a motorized profiling node that moves up and down the cable. Each has a suite of sensors that can be monitored remotely in real time.

Ocean Physics

Ren-Chieh Lien – Chair; Principal Oceanographer

Matthew H. Alford – Oceanographer IV; Affiliate Assistant Professor, Oceanography

Stephen J. Bayer – Senior Engineer

Samantha R. Brody – Research Assistant

James A. Carlson – Senior Engineer

Andrew C. Cookson – Senior Field Engineer

Eric A. D'Asaro – Principal Oceanographer; Professor, Oceanography

John H. Dunlap – Senior Engineer

Terry E. Ewart – Principal Physicist Emeritus

James B. Girton – Oceanographer IV

Jason I. Gobat – Senior Oceanographer

Amanda M. Gray – Research Assistant

Michael C. Gregg – Professor, Oceanography

Ramsey R. Harcourt – Oceanographer IV

Frank S. Henyey – Principal Physicist

Shieh-Hsun Huang – Predoctoral Research Associate

Adam A. Huxtable – Student Helper

Ryuichiro Inoue – Research Associate

Eric L. Kunze – Principal Oceanographer

Craig M. Lee – Principal Oceanographer; Affiliate Associate Professor, Oceanography

Joseph P. Martin – Oceanographer IV

Kim I. Martini – Predoctoral Research Associate

Jack B. Miller – Principal Engineer

Sheila S. Ocoma – Fiscal Specialist II

Eric C. Rehm – Predoctoral Research Associate

Thomas B. Sanford – Principal Oceanographer; Professor, Oceanography

Andrey Y. Shcherbina – Research Associate

Nancy J. Sherman – Administrator

Geoffrey B. Shilling – Engineer IV

Daryl L. Swensen – Senior Field Engineer

Zoltan B. Szuts – Predoctoral Research Associate

David P. Winkel – Oceanographer IV

Kai-Chieh Yang – Predoctoral Research Associate

Zhongxiang Zhao – Research Associate

Our scientists, engineers, and graduate students design and fabricate instruments, collect and analyze data, develop and test theory, and apply numerical modeling to further our understanding of heat fluxes, ocean currents, waves, turbulence, mixing, and acoustic propagation and scattering.

In partnership with private industry, the EM-APEX autonomous profiling float was deployed successfully in hurricanes, obtaining measurements of air–sea heat and momentum transfer, which may improve storm intensity predictions. The floats will be used in a Southern Ocean tracer release experiment and to make exploratory measurements in the Philippine Archipelago. Another project, funded by the National Science Foundation, will develop a microT-APEX float to measure temperature microstructure and estimate diapycnal diffusivities.

The long-endurance autonomous Seaglider has been modified by department engineers to operate in ice-covered waters. A new experiment combining robotic Lagrangian floats and Seagliders equipped with biogeochemical sensors will study the springtime bloom in the North Atlantic. Lagrangian floats are also being used to study mixing associated with El Niño in the equatorial Pacific, and to study air–sea gas exchange in both high and low winds regimes.

Unique mooring technology is being used to measure the evolution and energy flux of large nonlinear internal waves in the South China Sea (See *Giant Waves Beneath the Sea*, p. 14) as well as to measure internal tidal beams propagating away from the Hawaiian Ridge. A towed CTD chain was used in an experiment off the New Jersey coast (see *Conquering Uncertainties in Shallow Water Acoustics*, p. 10) to take multiple snapshots of nonlinear internal waves at the resolution necessary to understand their effects on acoustic propagation.

Several department researchers are participating in a large U.S. Navy study to assess model parameterizations for various small-scale (<10 km) ocean processes. These projects evaluate whether the parameterizations capture appropriate physics. Another group participated in CLIMODE fieldwork during winter in the North Atlantic to identify the sources and mechanisms producing large lenses of relatively homogenous water south and east of the Gulf Stream. This work is part of the international CLIVAR (Climate Variability) program seeking to improve predictability of climate variations over intervals from years to decades.

As part of International Polar Year efforts, department scientists will conduct research in Davis Strait (a critical gateway between the Arctic and North Atlantic), in the region north of the Canadian Arctic Archipelago, and, in collaboration with Norwegian scientists, in the boundary flows off the Norwegian coast.

Polar Science Center

Richard E. Moritz- Chair; Principal Oceanographer

Knut Aagaard – Principal Oceanographer; Professor, Oceanography

Roger H. Andersen – Mathematician IV

Wendy S. Ermold – Physicist II

Andreas Heiberg – Principal Engineer

Ian M. Howat – Research Associate

Suzan V. Huney – Administrator

James M. Johnson – Senior Field Engineer

Ian R. Joughin – Senior Engineer; Affiliate Associate Professor, Earth & Space Sciences

Karen Junge – Oceanographer IV

Christopher Krembs – Oceanographer IV

Kristin L. Laidre – Oceanographer IV

Bonnie Light – Physicist IV

Ronald W. Lindsay – Senior Physicist

Mari S. Litzenberger – Fiscal Specialist II

Twila A. Moon – Predoctoral Research Associate

James H. Morison – Principal Oceanographer; Affiliate Professor, Oceanography

Mark L. Ortmeier – Oceanographer II

Ana Cecilia Peralta Ferriz – Research Assistant

Ignatius G. Rigor – Mathematician IV

David A. Rothrock – Principal Research Scientist

Kay A. Runciman – Mathematician III

Axel J. Schweiger – Oceanographer IV

Benjamin E. Smith – Research Associate

Michael Steele – Senior Oceanographer

Harry Stern – Mathematician IV

Dean J. Stewart – Field Engineer

Mark R. Wensnahan – Physicist IV

Dale P. Winebrenner – Principal Physicist; Research Professor, Earth & Space Sciences; Adjunct Research Professor, Electrical Engineering

Rebecca A. Woodgate – Senior Oceanographer; Affiliate Assistant Professor, Oceanography

Yanling Yu – Oceanographer IV

Jinlun Zhang – Senior Oceanographer

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 among air, sea, ice, and biota. Leading large-scale observation and process study programs, we have made major contributions to understanding how the Arctic has changed since the middle of the twentieth century.

2007 marks the beginning of the “International Polar Year” (IPY), a large scientific program focused on the polar regions. We are a major participant with five NSF-funded projects, two NASA projects, and many others proposed. Along the Amundsen Coast of Antarctica, Ian Joughin aims to document the mass budget of glaciers from radar altimeters, interferometric synthetic aperture radar, and ice core data. Combined observations may diagnose the changes in glacier mass, the flow velocity, and the past variations of snow accumulation to explain the mass-balance deficit in this part of Antarctica.

Jamie Morison and Mike Steele lead two IPY projects that conduct annual surveys of ocean temperature, salinity and chemistry, plus sea-ice properties in three interior regions of the Arctic Ocean: the polar cap north of 85°N, the “switchyard” region off the north coasts of Greenland and Ellesmere Island, and the southern Beaufort Gyre north of Alaska. Rebecca Woodgate and Craig Lee spearhead two projects focused on the “gateways” (Bering and Davis straits) where water, ice, chemicals, and energy are exchanged with the oceans of lower latitude. The Davis Strait oceanographic sensor array employs Seagliders modified to operate beneath the pack ice.

In a new analysis of sea-ice draft data collected by naval submarines from 1975 to 2000, Drew Rothrock, Mark Wensnahan, and Don Percival report that ice draft declined from a peak of 3.4 m in 1980 to a minimum of 2.3 m in 2000, decreasing fastest in the early 1990s. The annual cycle has a peak-to-peak amplitude of 1.1 m and a maximum on May 1st. The time mean ice draft varies spatially from a minimum of 2.2 m near Alaska to a maximum of over 4 m at the edge of the data release area 200 miles north of Ellesmere Island.

Recent staff recruitment has expanded our areas of study to include cryobacteriology—the study of interactions between bacteria and surfaces (especially ice) at low temperature. Fundamental research into microbial communities may elucidate important and interesting feedbacks involving climate and sea-ice biology, and provide insights into life in extreme environments with application to astrobiology.

ADMINISTRATIVE & TECHNICAL SERVICES

Business & Administration

William T. Bakamis – Associate Director, Business and Finance

Financial Information Systems

Larry C. West – Senior Computer Specialist

Financial Management

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

Grant and Contract Administration

William E. Preiss – Administrator
 Angela D. Van Valkenburg – Administrator

Human Resources/Personnel

Robert M. Bratager – Manager
 Linda M. Marsh – Program Operations Specialist

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
 Michael G. McCurdy – Student Helper
 Nicholas A.L. Plemel – Fiscal Technician III
 Tina M. Stremick – Fiscal Specialist I
 Susan L. Womack – Fiscal Specialist I

Resources

Gordon K. Glass – Department Head

Building & Safety Services

Jim Fahey – Manager
 Oliver R. Hartman – Maintenance Supervisor II
 Stephen L. Hayes – Warehouse Worker II
 Dale K. Johnson – Maintenance Mechanic II
 Stuart R. Woolfield – Maintenance Mechanic II

Distributed Computing Services

David D. Fetrow – Senior Computer Specialist
 Samuel H. Friedman – Student Helper
 Adam L. Morehead – Senior Computer Specialist
 Jarrid A. Robinson – Student Helper
 Ryan S. Tibayan – Student Helper

Library

Jane M. Doggett – Manager
 Leslie A. Harding – Library Specialist

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

(Machine Shop, cont'd.)

Robert L. Prong – Manager
 Bobby J. Scott – Instrument Maker III
 Richard W. Syverson – Maintenance Mechanic II

Marine Department

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

Publications

Brian S. Rasmussen – Manager
 Kim E. Reading – Graphic Designer

Security & Central Services

Charlotte A. Boynton – Manager
 Nancy A. Harding – Fiscal Specialist I
 Jason Matsune – Program Assistant
 James W. Poland, Jr. – Senior Computer Specialist
 Joseph S. Wigton – Engineer IV

Shipping & Receiving

Michael G. Miller – Program Support Supervisor I

—personnel as of June 1, 2007

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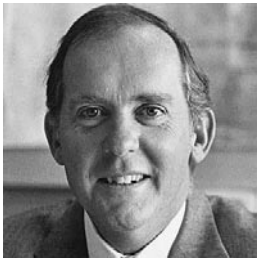
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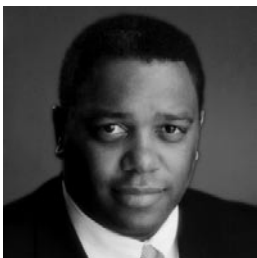


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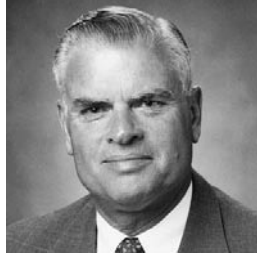
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