Biennial Report
THE APPLIED PHYSICS LABORATORY
University of Washington

2009

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FROM THE DIRECTOR

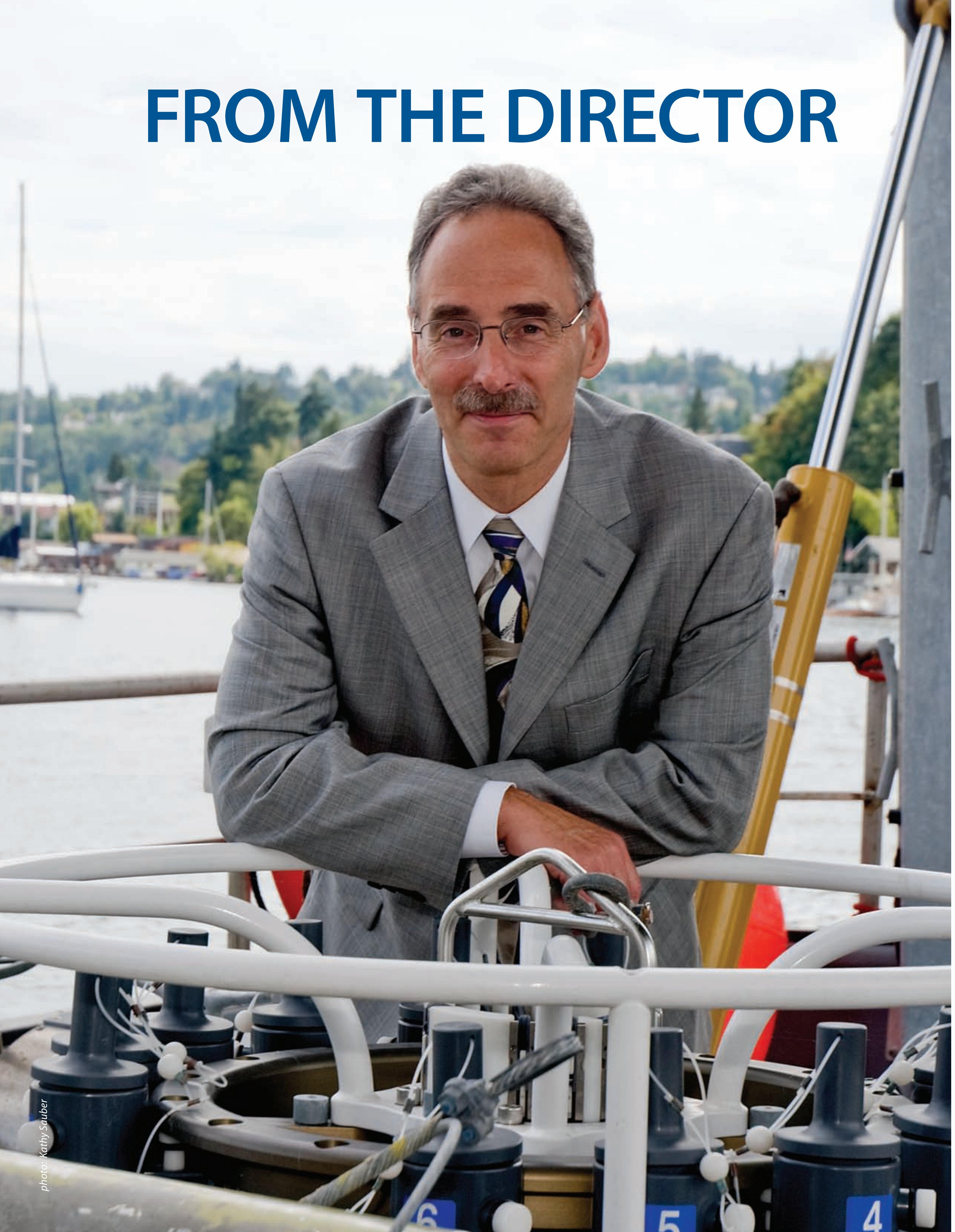


photo: Kathy Sauber

Since my message in the 2007 Biennial Report the Laboratory has been very busy. We have much to report. Many of our strategic initiatives to enhance and advance APL-UW—new research and development programs, improved research integration, and upgraded infrastructure—have been realized.

We are in the early stages of executing major new programs. A multi-investigator team is developing the next generation of long-endurance, semi-autonomous, mobile undersea vehicles and another is designing and building an interactive, regional, cabled-to-shore ocean observatory having real-time control and data return. Several scientists have been awarded new grants to assess the mechanisms responsible for the thinning of the Arctic ice cap, and our broad collection of single-investigator projects in marine sciences, underwater and medical acoustics, and other areas of applied physics continues to be active and productive. At-sea experimentation remains in high demand, and invention is thriving: APL-UW has spun off eight companies in nearly as many years and a record number of licenses and agreements involving APL-UW intellectual property have been made.

Research funding for the FFY2007–2008 biennium was unprecedented. Annual Laboratory research awards have nearly doubled in a six-year period, from $32M in FFY2001 to $60M in FFY2007. In the latest fiscal year (2009) funding exceeded $60M, setting another record for annual research awards.

On 1 July 2009 the Applied Physics Laboratory's organization within the UW changed: the Laboratory now reports to the Provost. Reporting to the highest levels of the University of Washington will stimulate interdisciplinary activities and integration between the Laboratory and campus. This move comes as we strive to build further academic connections by increasing the number of APL-UW researchers with faculty appointments that include funding to support research collaboration and teaching. Several new appointments have been made in the departments of Statistics, Mechanical Engineering, Electrical Engineering, Civil and Environmental Engineering, Neurological Surgery, Pediatric Dentistry, and Urology. These new connections will help us to address emerging cross-disciplinary research priorities.

Our plans to expand office and laboratory space have concluded successfully. We now occupy space in the new, state-of-the-art Benjamin Hall Interdisciplinary Research Building on campus. This space addition, which allows for Laboratory decompression and growth, is vital to our continuing success. The APL-UW fleet has been enhanced with a new and more capable research vessel, the R/V *Robertson*, which is already finding good use in instrument testing and regional marine studies. And we recently completed the renovation of other facilities, including scientific laboratories, meeting and common spaces, and other research vessels.

The past few years have been important and outstanding ones for APL-UW. Significant recent accomplishments flow from the talent and energy of Laboratory staff and the strong support from our sponsors, especially the U.S. Navy and the Office of Naval Research, the National Science Foundation, and other key federal funding agencies. I look forward to the next biennium and the Laboratory's continued success.

THE LABORATORY

Science, Engineering & Education

Founded by the U.S. Navy in 1943 as one of four university laboratories to focus intellectual and technical resources on the war effort, the Applied Physics Laboratory of the University of Washington has built a world-class reputation through service to the Navy and other federal agencies. This report highlights examples of how APL-UW fulfills its mission to conduct a program of fundamental and applied research, development, engineering, and education for science, industry, and the national defense.

Noteworthy Research & Development

- Autonomous Lagrangian floats, designed and developed at the Laboratory, are now enhanced with dissolved gas sensors. When air-deployed in the path of hurricanes such as Hurricane Gustav in 2008, they follow particles of water in the ocean mixed layer and measure the injection and ventilation of gases at the air–sea interface during these extreme high-wind events.

- The Sonar Simulation Toolset turned 20 years old. This computer program produces simulated sonar signals in an artificial ocean that sounds like a real ocean. Continuing improvements have made it valuable for designing new sonar systems, predicting performance, developing tactics, planning experiments, and training the fleet's sonar operators.

- Strong currents in Puget Sound are being measured with an eye toward tapping renewable tidal energy. The U.S. Department of Energy has funded scientists and engineers to study the site-specific potential of the energy resource and environmental effects. Researchers have found surprisingly strong currents with very brief slack water periods between cycles and are working with a local energy company that is planning a pilot project.

- Significant strides have been made in command and control software for autonomous undersea gliding vehicles. APL-UW is the technical lead of the Glider Consortium and has developed a web-based piloting and communications system. It integrates the display of incoming glider data with pilot commands for missions that include many gliders from several manufacturers in one operational area.

- The dynamics of the Philippine Archipelago straits are the focus for several Laboratory oceanographers. A two-year observational effort deployed profiling floats and moorings, ship-towed instruments, and autonomous gliders to measure dense overflows between basins, wind-driven eddies, and nonlinear internal waves.

In a study of the equatorial cold tongue in the eastern Pacific, where the sea surface temperature anomaly indicates an El Niño or La Niña, a research team deployed a buoy outfitted with 34 sensors and encountered a large amplitude, westward propagating tropical instability wave and astounding new features of equatorial turbulence mixing. The new observations will improve predictions of the phase and strength of the climate cycles.

Polar scientists who have been monitoring the Greenland ice sheet for several years with satellites and sensors placed on the glacial surface report compelling new observations. The meltwater lakes that form on the surface each summer can drain to the ice sheet's base with a flow intensity greater than Niagara Falls. With so much water injected below so quickly, the 3-km thick ice sheet actually rises several feet. The water's lubrication causes the glacier to slip faster toward the sea, but only temporarily.

The U.S. Navy civilian laboratory system is facing a growing problem of replacing science, technology, engineering, and math (STEM) professionals. Under the Office of Naval Research the Laboratory has completed an initial effort to address the deficit of STEM professionals. Adopting the Navy's practice of long-term planning for difficult problems, a strategic plan has been developed that leverages existing programs and incorporates new thinking and tactics.

Honors, Awards, & Celebrations

Thomas Sanford was named a Secretary of the Navy/Chief of Naval Operations Chair of Oceanographic Sciences in 2008. The award recognizes his reputation as an international leader in physical oceanography, the broad support of his research programs across many sponsoring agencies, and his collaborations to develop instruments and collect field observations. Sanford was also presented the IEEE/Oceanic Engineering Society's 2008 Distinguished Technical Achievement Award. The society cited his novel measurements and interpretation of physical signals in the ocean, and lauded his work as bearing "… the signature of a creative, imaginative mind and independent thinker."

Fred Karig received a Commander-in-Chief Fleet's Commendation from the British Royal Navy recognizing his exceptional dedication and skill while aiding injured British sailors after a submarine accident at the spring 2007 APL-UW Ice Station. "Mr. Karig's experience in this harsh Arctic environment, and more particularly his strong leadership and lack of regard for his own safety, were instrumental in saving the life of a badly injured man and in assisting the submarine to recover from a most serious incident."

Peter Dahl was elected to the Acoustical Society of America (ASA) Executive Council in 2008. At its October 2009 meeting the ASA presented **Director Emeritus Robert Spindel** the Silver Medal in Acoustical Oceanography, recognizing his implementation of ocean acoustic tomography and basin scale acoustic thermometry.

■ **Benjamin Smith** received a Presidential Early Career Award for Scientists and Engineers—the highest honor bestowed by the U.S. government on young professionals in the early stages of their independent research careers. The award will support his research programs of designing new satellite instrumentation to measure snow and ice in the Arctic, and making computer models to explain glacier growth, melt, and speed.

■ Many APL-UW scientists have been honored recently as invited participants in the National Academy of Sciences panels on Climate, Energy and National Security; the NAS workshop ***Oceanography in 2025***; and the National Research Council Committee on Earth Sciences and Applications from Space. The Seattle Aquarium Society Board of Directors Research Award for 2009 was presented to **Jan Newton**. Her contributions to the increased understanding of Puget Sound have guided conservation policy and helped to shape the aquarium's programs.

■ The **R/V *Jack Robertson*** was launched in September 2008, the first significant addition to the APL-UW research fleet in 50 years. The *Robertson* is a capable vessel, named after a capable leader from the Laboratory's early days. This new vessel is critical for testing advanced instrumentation in local waters prior to at-sea deployment in other parts of the world, and is supporting APL-UW's rapidly growing involvement in studies focused on Puget Sound.

The Laboratory

Distinguished Visitors

Over the past biennium several U.S. Navy commanders and personnel received tours and briefings on research and development efforts of special relevance to naval operations. They were: **Rear Admiral James A. Symonds**, Commander Navy Region Northwest; **Rear Admiral Jerry Ellis**, Special Assistant for Undersea Strategy; **Captain Chip Fowler**, Commanding Officer, Office of Naval Research Global; **Captain Dave Norris**, Deputy Special Assistant for Undersea Strategy; **Captain David Harrison**, Deputy Director, Deep Submergence; **Rear Admiral Cecil D. Haney**, Director, Submarine Warfare; **Rear Admiral David W. Titley**, Oceanographer of the Navy; **Commander Tim Gallaudet**, Navy Task Force on Climate Change; **Ed Gough**, Technical/Deputy Director, Naval Meteorology and Oceanography Command; **Eui Lee**, CNO Strategic Studies Group; and **Rear Admiral Nevin P. Carr, Jr.**, Chief of Naval Research.

APL-UW received visits from many administrators and program managers from the Office of Naval Research, Defense Advanced Research Projects Agency, Department of Homeland Security, National Oceanic and Atmospheric Administration, National Science Foundation, Naval Sea Systems Command, Office of Naval Intelligence, and Space and Naval Warfare Systems Command. The **APL-UW Advisory Board**, which has several new members; **Andy DeMott** and **Pete Modaff**, Defense and Interior Appropriations Specialists, respectively, to Congressman Norm Dicks; and **Mark Emmert**, President, University of Washington, also received tours and updates during the past biennium. Many representatives of U.S. industries were received and APL-UW was pleased to host international researchers from Asia, Australia, and Europe including Russia.

RESEARCH HIGHLIGHTS

Ocean Observing Systems
A Nexus for Technology & Discovery

Rising sea levels, coastal erosion and flooding, undersea earthquakes, and toxic algae blooms are just a few of the concerns of our coastal regions. What sensors and observing systems could mitigate impacts on society? How will data be collected and shared to further knowledge of oceanic processes that are critical to a habitable planet? APL-UW is now on the forward edge of 21st century ocean observing technologies, developing the infrastructure required to make sustained, long-term, and adaptive observations in the ocean, on the seafloor, and at the air–sea interface.

These efforts are motivated by the broad goals of the U.S. Integrated Ocean Observing System: to improve predictions of climate change and weather, improve maritime operations and national security, mitigate natural hazards and public health risks, and sustain ocean and coastal resources. By congressional act in 2009 a federation of 11 regional associations representing all areas of the nation was established to contribute to the U.S. IOOS vision.

Operational Observations by Regional Association

The Pacific Northwest regional component of the federation — the Northwest Association for Networked Ocean Observing Systems — had its genesis at APL-UW in 2005. NANOOS is comprised of more than 30 organizations including tribes, state and local governments, industry, academic institutions, and non-profit groups. Members identified priority areas for data product development — climate, maritime operations, fisheries, coastal hazards, and ecosystem impacts.

NANOOS integrates more than 50 kinds of ocean data from its regional stakeholders and makes them available through a single access point — the NANOOS web portal. Portal users can browse data products such as a coastal radar current mapping system or seasonally-repeated hydrographic cruise surveys. They can also search by region of interest, data type (observation, model, or forecast), and parameter (e.g., winds, temperature, salinity, dissolved nutrients).

Data available at the portal have immediate, operational applications. Oregon tuna fishermen, for example, use output from an ocean circulation model that forecasts ocean temperature to optimize the timing of putting vessels to sea, thus reducing fuel costs. The Quinault Nation's coastline in Washington State has been the site of hypoxia events that leave thousands of dead fish on the beach. NANOOS stakeholders are running glider surveys in the region and posting data to the portal that trace when and where low-oxygen water infiltrates the coast.

The sensors, instrument platforms, and cyber-infrastructure that allow real-time, sustained monitoring of the coastal ocean are the very assets required by scientists to conduct fundamental research. Scientists at APL-UW and associated academic institutions are using NANOOS portal data to probe the biophysical processes of Pacific Northwest waters.

Recent funding will add a moored, profiling buoy and autonomous ocean glider to the NANOOS assets off the Washington coast. While providing near real-time monitoring of algae blooms and low-oxygen waters, over the long term scientists will use the observations to determine the lineages between bloom formations and the physical and chemical oceanographic environment, and whether hypoxia in coastal waters is due to increased upwelling frequency or intensity associated with a climate shift. The coordinated efforts under NANOOS are showing that research-focused and operationally-oriented ocean observatory efforts are synergistic and supportive.

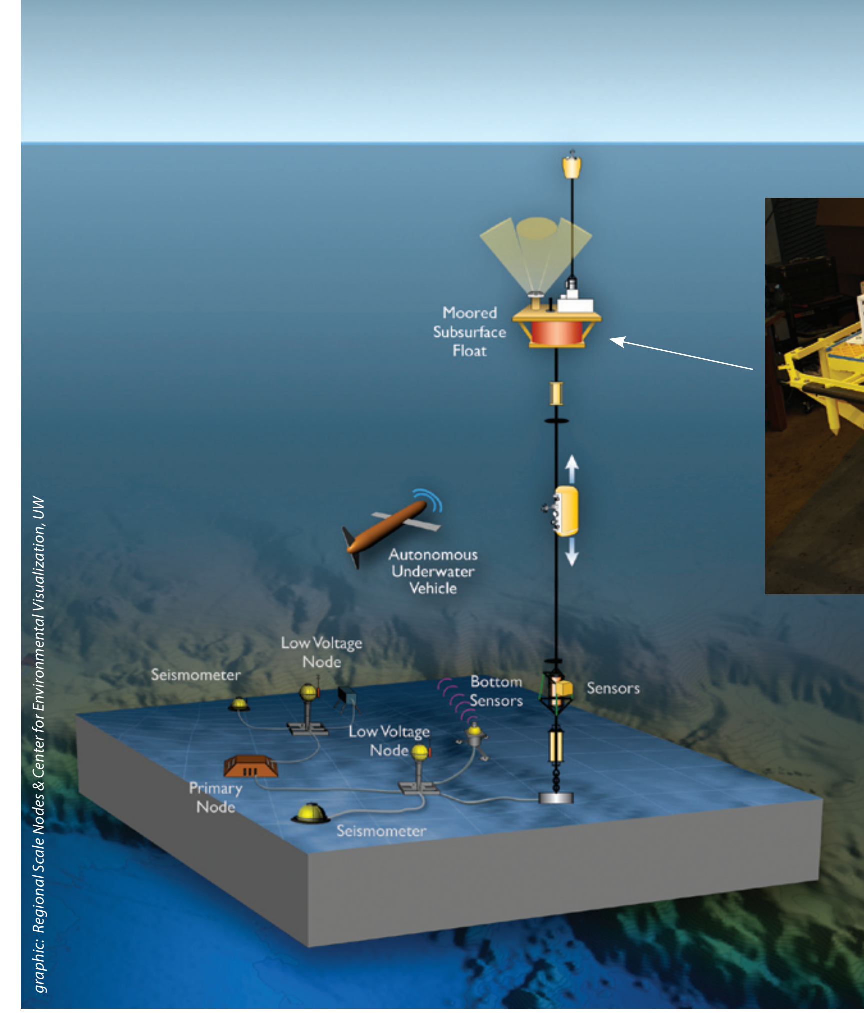
Eye on the Sound: A Networked Grid of Buoys

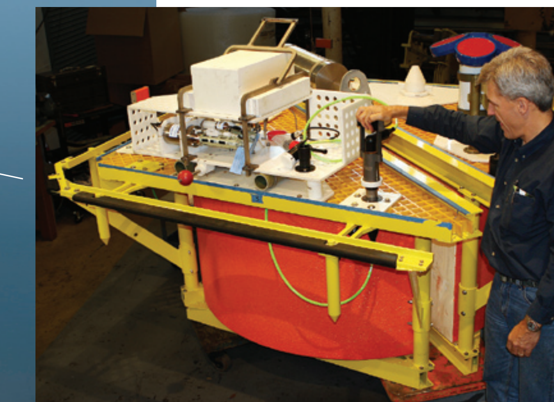
The first buoy (page 10) of a networked system has been deployed in Puget Sound. Powered exclusively by solar and wind systems, it raises and lowers an instrument package between the surface and 200 m with an electromechanical cable winch. These profile data as well as atmospheric and near surface measurements are beamed to terrestrial data centers and the Internet by radio-frequency transceivers.

Moored offshore from a sewage treatment facility, the prototype buoy will provide immediate feedback of harmful discharges to Puget Sound. Several dozen will be distributed at other critical monitoring points throughout the basin. Data collected over many years will be used to drive numerical oceanic and atmospheric models that predict the future state of the vital and fragile ecosystem.

A Permanent Telepresence in the Ocean

APL-UW and the University of Washington School of Oceanography are leading the design, development, and construction of an ambitious ocean observatory in the Northeast Pacific Ocean — the Regional Scale Nodes. Funded by the NSF Ocean Observatories Initiative — the science-driven arm of U.S. IOOS — the observatory's construction will begin in 2010 when nearly 500 miles of electro-optical power and communications cable are laid across the Juan de Fuca tectonic plate, running from a shore station in Pacific City, Oregon. Nodes densely populated with instruments and full water column moorings will be installed at several study sites. Once operational, high-bandwidth data and video imagery will be transmitted via the Internet and available to users around the world, dramatically changing the way scientists, educators, students, decision-makers, and the public access the oceans.





APL-UW is designing and developing the RSN secondary infrastructure, which includes low-power nodes, junction boxes, vertical moorings, instrument platforms, and sensors. After the program's five-year development phase, the APL-UW engineering team will assume responsibility for the health and safety of the entire observatory. A control center will operate 24/7 to diagnose problems, recommend corrective action, and monitor operations. For the expected 25-year life of the RSN, APL-UW will provide engineering support and technical assistance to scientists and instrument developers who wish to install sensors on the observatory's infrastructure.

Over one hundred core sensors will be installed first, many of them standard oceanographic sensors with proven reliability and accuracy on other platforms. None, however, were developed to operate on a cabled system for decades. Will the sensors' calibration drift over time? Will they remain reliable at extreme pressures and/or pressure cycling on profiling excursions? For those sensors that will be profiled to the surface from one of the subsurface moored floats, biofouling is a concern. Initially, all sensors will be revisited annually during the summer weather window for testing and calibration.

The network is designed for expansion, and when complemented by the NEPTUNE Canada assets would encompass an entire tectonic plate and observe all the natural phenomena that occur there.

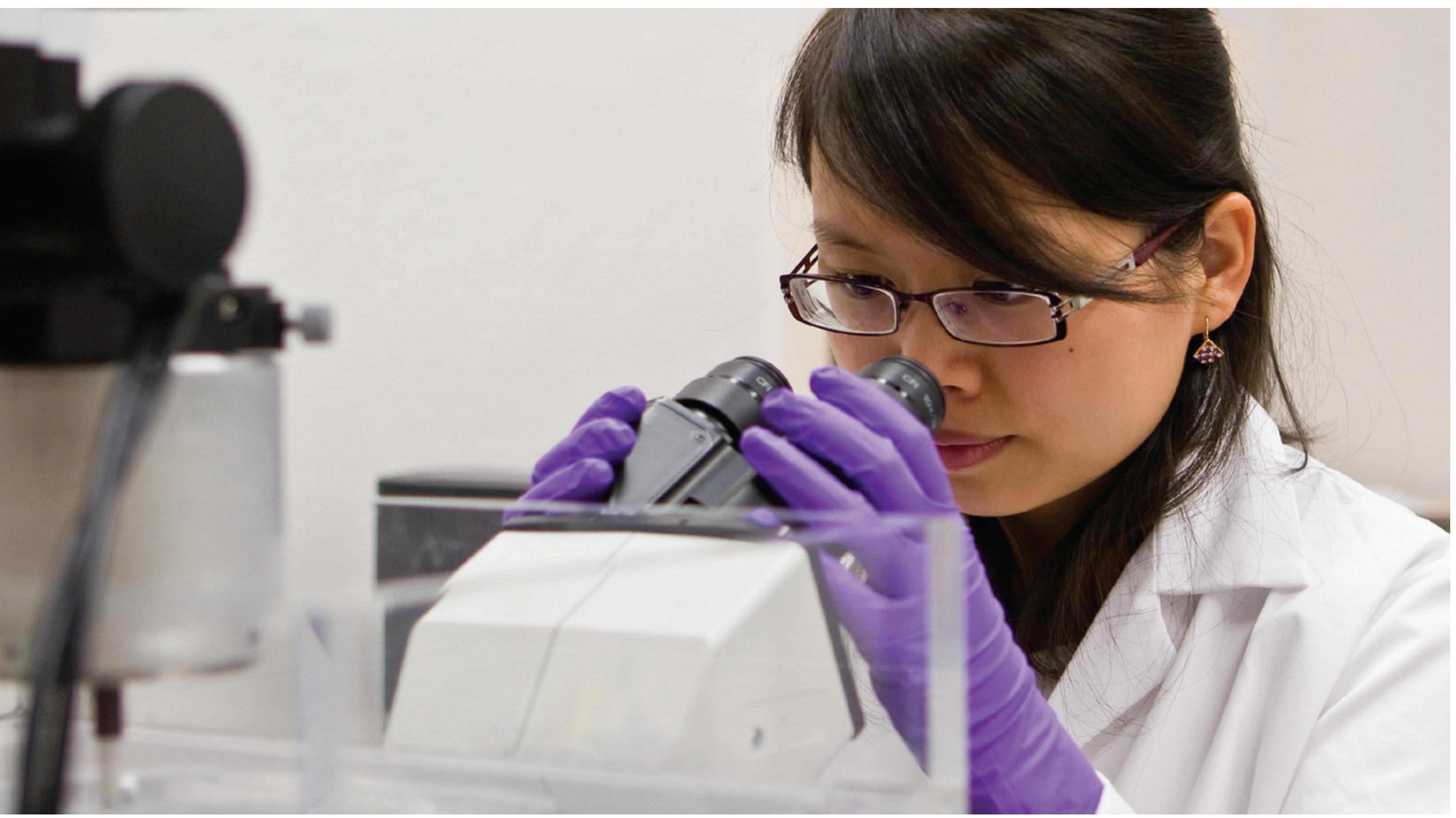
NANOOS team members: *Matthew Alford, Corinne Bassin, David Jones, Nicholas Lederer, Russell Light, Stuart Maclean, David Martin, Emilio Mayorga, Jan Newton, Janet Olsonbaker, Eric Shulenberger, Amy Sprenger, Troy Tanner, Michael Welch, and Timothy Wen;* Regional Scale Nodes team members: *Clark Bodyfelt, Gerald Denny, Jesse Dosher, Gary Harkins, Michael Harrington, Timothy McGinnis, Nancy Penrose, Eric Strenge, Marvin Strenge, and James Tilley*

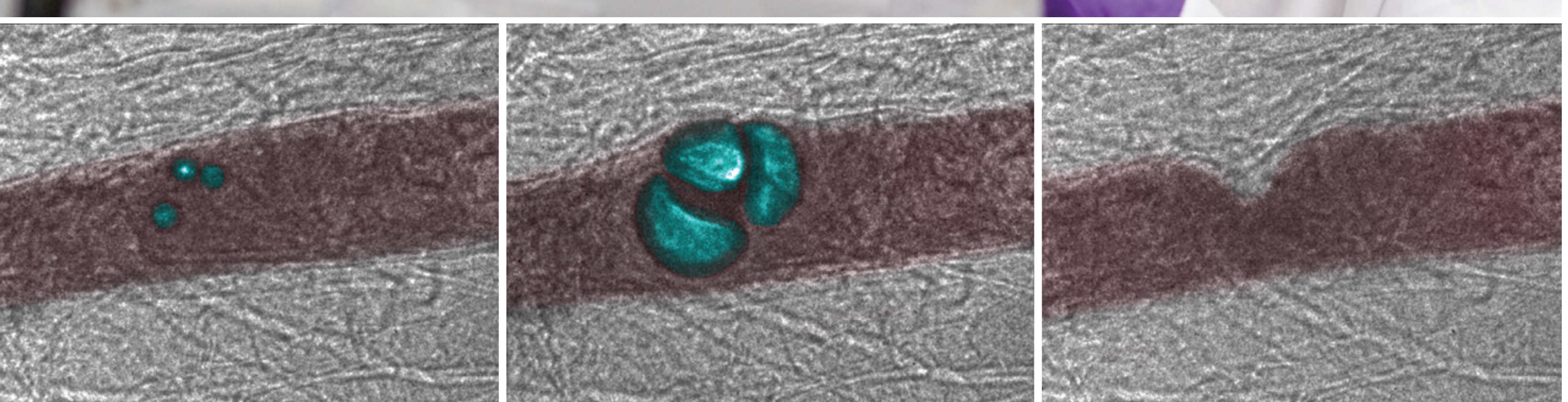
Sponsors: *NOAA, NSF, M.J. Murdock Charitable Trust*

Huge Discovery in Tiny Bubbles

Ultrasound contrast agents are extremely small gas bubbles. They increase the efficiency of diagnostic ultrasound imaging, such as echocardiography, because the microbubbles act as echo chambers when ensonified by an acoustic signal.

Advances in ultrasound imaging have reached a level where even a single microbubble —about one micron in size—can be imaged. Research is now exploring the possibility of targeting ultrasound contrast agents to site-specific regions of the body and using them to carry therapeutic agents. Acoustically activated microbubbles alter the shape of cell membranes and can increase vascular permeability, which may enhance local delivery of drugs or genes. But high acoustic pressures can damage vessels. The interaction between the microbubble and the vessel wall is very important, yet not well understood, so a research team at the Center for Industrial and Medical Ultrasound devised experiments to capture high-speed microphotographs of single microbubbles ensonified in tiny vessels.





Research Highlights

Ultra Small, Ultra Fast

Microbubbles are made in the lab by mixing several different lipids together in a buffered electrolyte solution saturated with a perfluorocarbon gas. After mixing, the lipids form a thin (a few nanometers) protective shell around the gas to form the microbubble and prevent the gas from escaping. Ultrasound contrast agent microbubbles have a diameter of about 2–3 microns, with about 99% of the bubbles in the range of 1–10 microns. In a single milliliter vial there might be one hundred million microbubbles.

To stage a microbubble/microvessel experiment, a microscope is coupled with an extremely fast-exposure camera capable of 50-nanosecond acquisition times. A high-intensity flash lamp coupled to a fiber optic light path is required to generate enough photons to create a photographic image. The tissue samples must be transparent so that microbubbles in the blood vessel can be observed. Finally, the synchronization of optical and acoustic systems has to be precise so that the acoustic phase is known exactly at the time point where each high-speed image is acquired.

Expand, Contract, Collapse

To understand the interaction between a bubble and the surrounding tissue, consider a sinusoidal pressure wave. As the acoustic pressure goes negative, the microbubble expands under the tensile pressure and it continues to expand until the pressure turns positive, forcing the microbubble to contract. When the bubble contacts the vessel wall, the wall may dilate, but it also hinders the bubble from expanding much further.

Our high-speed microphotographs confirm that blood vessels do indeed dilate as the microbubbles push against them. But even more amazing is that when a microbubble collapses, the vessel wall is pulled inward, probably due to fluid rushing into the bubble void. This invagination effect is more dramatic than dilation and may be the dominant mechanism for increasing vascular permeability and/or tissue damage.

Technology Commercialization

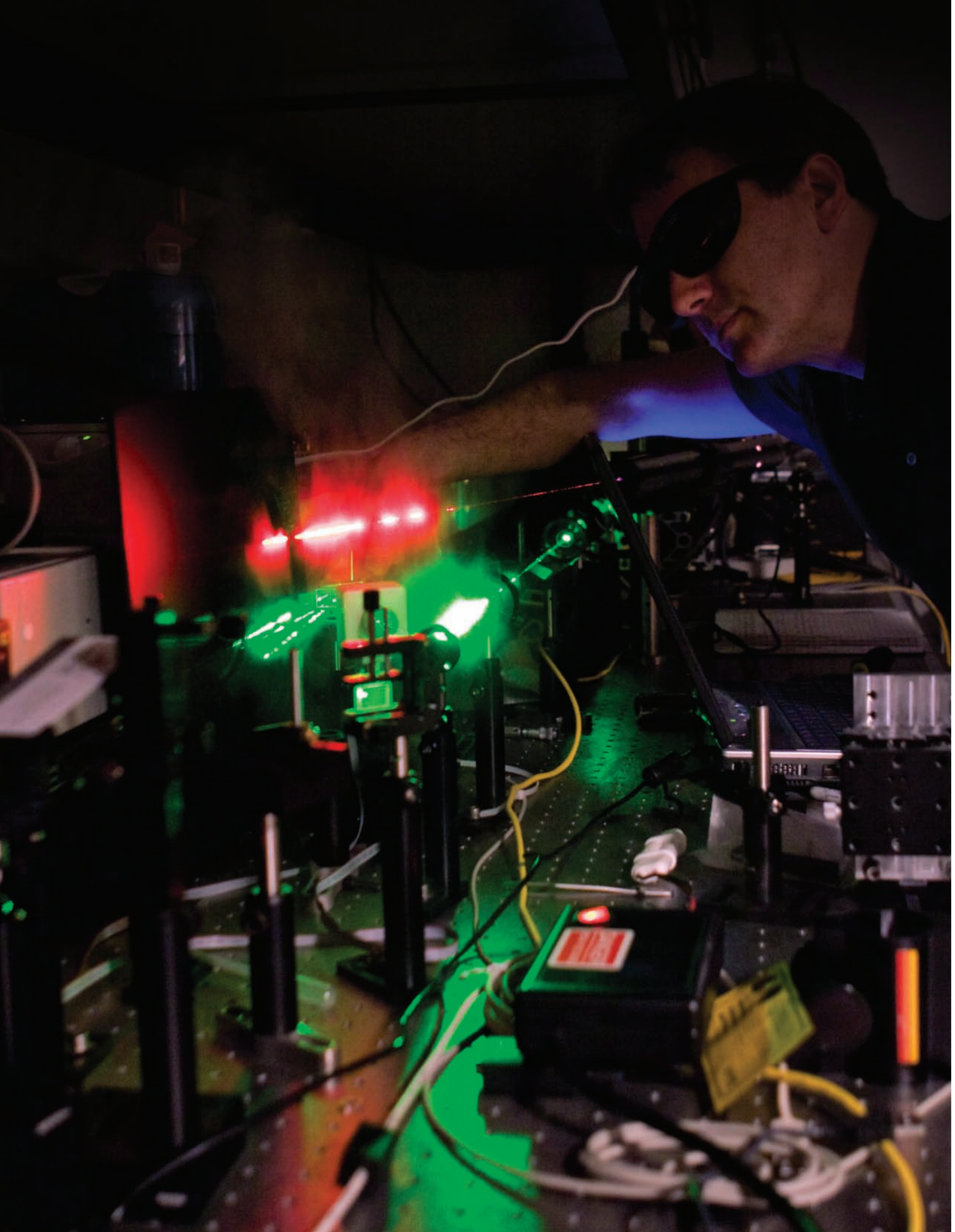
The contributions of these discoveries to the ultrasound research and therapy communities are great, but one component of these novel experiments has commercial potential as well. Ultrasound contrast agents are being developed to target specific diseases. It is thus important to understand their protective shell's properties because the shell stabilizes the bubble and is the surface on which specific targeting ligands must adhere. The CIMU team has developed a light-scattering technique to indirectly characterize the shell by monitoring the bubble's oscillation when subjected to ultrasound. The observed dynamics are compared to a model where the shell viscosity and shear modulus are the fitting parameters. A patent application has been filed for this technology with the objective of developing an integrated system to characterize the microbubble size distribution and the shell properties together.

Top-Flight Student Research

Bioengineering doctoral student Hong Chen's thesis is based on these novel experiments. Research advisor Thomas Matula is very pleased with her work. "She has excelled in conducting these extremely difficult experiments—imaging micron-sized bubbles on nanosecond timescales to show the mechanical interaction of a microbubble in a constraining blood vessel with surrounding tissues." Her work won the student poster competition when presented in Beijing at the 2008 IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society meeting.

Team members: *Michael Bailey, Andrew Brayman, Hong Chen, Joo Ha Hwang, Wayne Kreider, and Thomas Matula*

Sponsor: *NIH*



Fundamental Science Enlisted to Counter Threat

The Office of Naval Research has undertaken a long-term basic research initiative to support scientific studies that may lead to significant discoveries in countering improvised explosive devices. The five Navy university-affiliated laboratories were tasked with the program in 2005; since then several research thrusts at APL-UW have shown promise. The program employs basic scientific research to increase the predictive capabilities of counter-IED efforts and to detect IEDs at distance and speed before they can cause harm.

Sum-Frequency Spectroscopy

One project seeks to detect trace levels of explosive materials adsorbed on surfaces. The method employs the second-order nonlinear optical technique of sum-frequency vibrational spectroscopy. Sum-frequency spectroscopy works by shining two laser beams of different optical frequencies (i.e., different colors) onto the surface of a material. Photons with frequencies equal to the sum of the two incoming frequencies can be detected, and the intensity (or number) of those photons can be related to the concentration of contaminants on the surface. Because under many conditions the sum-frequency response of a surface depends on contaminants adsorbed on the surface but not the bulk material itself, sum-frequency spectroscopy has a long history of use as a surface probe in biochemical and chemical systems. This effort seeks to demonstrate its effectiveness in detecting explosives adsorbed on surfaces that might be found in a typical urban environment.

Results have shown that some explosives have extremely large nonlinear optical cross sections, meaning they generate many sum-frequency photons when the incoming laser beams are tuned to a certain intensity. This means detection levels are low enough to sense the presence of these explosives at concentrations as low as a few hundred nanograms per square centimeter. Researchers have detected explosive residues on surfaces likely to be encountered in real-world environments and are now investigating detection techniques in the presence of chemical interferences from environmental pollutants and compounds produced by the degradation of explosives.

Chromophores and Nanowires

Chromophores are parts of molecules that absorb, transmit, or reflect certain wavelengths of visible light to give color. Polymers engineered with chromophores are sensitive to the physical and chemical environment to which they are exposed. Experiments in the APL-UW photonics lab show that some of these polymers have a strong interaction with molecules that comprise high-explosive compounds.

The polymer films are manufactured to one micrometer thick and their color change, from dark blue to light purple in the presence of trace explosive vapors, is visible to the unaided eye. Accompanying this change in the absorption spectrum is a change in the refractive index — the speed of light waves passing through the medium — which can be measured much more accurately. The sensing films are further enhanced with micro-ring resonating structures and Bragg gratings tuned to certain wavelengths, which amplify the effect of the sensor material on the optical wave. Tests show that such sensors have part-per-billion sensitivity to simulated explosive vapors in air.

Another discovery was reported recently by APL-UW scientists and students: thin films of random nanowires of certain metal oxides change their electric resistance significantly and rapidly upon exposure to explosive vapors. Nanowires are structures with a diameter on the order of nanometers and length-to-width ratios greater than 1000. Their extremely large surface-to-volume ratio renders them nearly one-dimensional materials, yielding interesting quantum mechanical properties. A test sensor of titanium oxide film has gone through millions of cycles between explosive vapor and fresh air without noticeable degradation. It is possible that a low-power microsensor could be integrated on silicon chips to enable unattended perpetual surveillance against explosive devices.

Terahertz Spectroscopy

Terahertz (THz) radiation—electromagnetic waves at frequencies of trillions of cycles per second (between radio waves and infrared light)—penetrates common obscuring materials such as cloth, wood, or paper, and "sees" targets hidden behind them. Explosives have characteristic spectral features (fingerprints) at THz frequencies. Well-controlled laboratory experiments using carefully prepared test samples have shown that THz spectroscopy can identify concealed explosives, but significant challenges exist for real-world applications. Most THz spectroscopic measurements have been conducted in transmission mode. Unfortunately, measurements of transmission spectra are unlikely in practice because they require a non-opaque target (i.e., small sample thickness) and placement of the sample between the THz source and detector. These requirements compromise the feasibility of standoff detection.

APL-UW researchers, in a joint effort with Dr. Lisa Zurk of Portland State University, are seeking to develop and validate a model for backscattering of THz waves from targets. With the THz source and detector co-located and "looking" at the target from a distance, a reflection geometry of the THz response can be processed to produce spectral signatures. Most target surfaces, however, are rough at THz frequencies, so simple reflections from targets cannot be expected. Instead, the THz waves returning after interacting with a target spread over a wide range of angles.

Researchers are exploring the idea that the rough surface scattering of THz waves can be exploited to produce a more robust method of spectroscopic detection. When rough surface scattering from a target applies, no special target orientation would be required to see the returning THz waves, that is, we need not hope to catch a "glint" from the target, but instead attempt to detect the diffuse scattering return. The goal of the ongoing research is to understand if the spectral signatures of explosive chemicals can be detected reliably in the diffuse backscattered THz waves from rough targets.

A Superresolution Algorithm

Another project is directed toward enhancing the capabilities of radar systems to detect and locate IEDs. Because explosive devices are often located in very complex environments, radar sweeps encounter a great deal of clutter, which often gives a stronger radar signal than the target itself. Some of the clutter is used to conceal the devices, such as boxes, cars, vegetation, or soil. This means that longer-wavelength radar must be used to penetrate the concealment, but the longer wavelengths limit the resolution, and poorer resolution makes it harder to distinguish an explosive device from the clutter.

APL-UW researchers are developing a fast data-fitting algorithm, originally used in sonar applications, to improve the resolution of any radar system. It uses a simple, computationally efficient model to fit the data, beginning with the strongest signal first, rather than fitting the entire scene. These brightest signals are subtracted from the data and successively weaker ones are fit through iteration, thus increasing the ability to discern a signature of interest. More capable radar systems will improve the detection and location of targets from a moving vehicle before approaching to within a dangerous range of the explosives.

Machine Learning

The Navy's program includes predicting and preventing the emplacement in the first place. The key to successful prediction is the ability to learn complex patterns from heterogeneous data sources, such as surveillance reports, cell phone traffic, and the social network structure of the local population. These types of data are naturally described by pairwise relationships between entities, and pose challenges to traditional machine learning techniques.

Troops in the field can often discern these complex patterns and make good predictions based on some cognitive measure of similarity between a potential threat and past IED events. Can computers be taught to learn effectively from similarities? APL-UW is advancing the state-of-the-art in machine learning by developing algorithms that natively learn based on the pairwise similarity of heterogeneous data. The end goal is to assist the deployed troops with tools that increase their decision throughput and accuracy.

This effort is an example of how the Navy has tapped the complete resource available at a university-affiliated research center. The APL-UW machine learning research is a close collaboration with the Information Design Laboratory in the University of Washington's Department of Electrical Engineering. The collaboration has advanced the field of machine learning in the scientific literature and has provided funding to train students in Navy-relevant problems. Luca Cazzanti, who now heads the APL-UW side of the collaboration, completed his Ph.D. under the project and now helps guide the research of current graduate students.

Team members: *M. Hassan Arbab, William Asher, Luca Cazzanti, Antao Chen, Wm. Timothy Elam, Frank Henyey, Jeffrey Simmen, Eric Thorsos, Danling Wang, and Dale Winebrenner*

Sponsor: *ONR*

Research Highlights

The Future Arctic Ocean
Waves Lapping or Ice Crunching?

One sign of summer at APL-UW is the increased media attention turned to polar scientists and their thoughts on the pace of the season's sea ice melt in the Arctic Ocean. This topic has generated great public interest since the dramatic retreat in September 2007 when 40% of the Arctic Ocean was ice-free compared to a more typical 10%. An ice-diminished Arctic Ocean will have wide-ranging effects on, for example, indigenous peoples, polar bears and other wildlife, international shipping, geopolitics, and resource development.

APL-UW researchers in the Polar Science Center know that warming trends, changes in atmospheric circulation, advection of oceanic heat to the Arctic from lower latitudes, and enhanced solar heating of the ocean surface are components of a causal web. As physicists, mathematicians, oceanographers, and atmospheric scientists who field ambitious observational programs and construct numerical simulations of climate change, they are uniquely positioned to describe what is happening now to the Arctic Ocean's ice.

What's Happened?

The total sea ice extent in the Arctic measured each September has declined at a rate of over 11% per decade since 1979, when satellite observations began. Arctic sea ice ranges in age from first-year ice, which forms over open water during one winter freeze, to ice that has survived the summer melt seasons for over a decade. The area of sea ice over two years old has declined from 35% of the Arctic Ocean in 1980 to 10% today. Ice thickness, as measured by submarines and satellites, at the end of the melt season has decreased by about one meter, or one third, in most of the deep portions of the Arctic Ocean over the past half century.

A Causal Web

Greenhouse gases are warming the entire Earth, but the effect is amplified in the Arctic. This warming slows the growth of ice in winter and accelerates the melt in summer through earlier onset of melt. Cloudiness in the Arctic may be changing, or the increased heat from the south may create warmer clouds, which increases downwelling infrared radiation from them and slows the growth of ice in winter. The average strength and direction of the winds shift occasionally. This increases the amount of old, thick ice blown out of the Arctic Ocean and into the North Atlantic through Fram Strait. Oceanic heat advects north through Bering Strait, though the total impact of this changing Pacific Ocean heat on the Arctic is uncertain. And as the ice cover is reduced more solar radiation is absorbed by the dark ocean, which then melts more ice — the ice-albedo feedback.

The Emerging Picture

Summer 2007 began with the sea ice in a highly vulnerable state, the culmination of thinning since the late 1980s. During the summer, unusually persistent winds blew ice out of the Beaufort Sea where the open water absorbed solar energy. As open water reflects only 7% of this energy, compared to 65% for bare sea ice, warming from the sun was a primary source for high ocean temperatures and sea ice melt. Summer 2007 was dramatic and the weather events were unusual, but sea ice mass and thickness have followed a rather consistent downward trend over the last two decades. Ice extent, volume, and thickness declines are explained by the cumulative loss over many years of older, thicker ice that is more resistant to summer melt. Another large retreat in ice extent was recorded for summer 2009, the third largest in the satellite record and close to the long-term trend of decreasing late summer ice extent.

What Now?

It is hard to identify a mechanism that would increase the sea ice extent, volume, and thickness in the face of global warming. As the Earth warms the ice will diminish, though there may be temporary increases, sometimes substantial, due to natural variability or a temporary global cooling caused by, for example, a large volcanic eruption.

Polar Science Center researchers contribute to sea ice forecasts, but the limits of prediction are bounded by the spatial and temporal time scales considered. For local short-term predictions, knowledge of the initial ice conditions and the weather are most important, but there is little predictive skill outside about one week. For seasonal to annual predictions, the weather conditions are unknown, but the initial ice thickness distribution (or age distribution) can be used with some skill over a large region such as the entire Arctic Ocean. At climate time scales, decades to centuries, the initial ice conditions are less important, but a global model that accurately incorporates all of the important physical processes and feedbacks has predictive value.

Team members: *Knut Aagaard, Roger Andersen, Wendy Ermold, Bonnie Light, Ronald Lindsay, James Morison, Richard Moritz, Mark Ortmeyer, Ignatius Rigor, Kay Runciman, Axel Schweiger, Michael Steele, Harry Stern, Mark Wensnahan, Rebecca Woodgate, Yanling Yu, and Jinlun Zhang*

Important data sets collected and made available to the research community by the Polar Science Center at APL-UW:

- International Arctic Buoy Program • *ice motion, sea level pressure, and air temperature*
- Polar Science Center Hydrographic Climatology • *ocean temperature and salinity*
- North Pole Environmental Observatory • *ocean temperature, salinity and currents; ice draft; surface weather; ice mass balance*
- Bering Strait • *currents, temperatures, salinity, and sea surface temperature*
- Chukchi Borderlands • *temperature, salinity, and currents*
- TIROS-N Operational Vertical Sounder Polar Pathfinder • *atmospheric temperature, humidity, and cloud profiles*
- Submarine Ice Draft Measurements • *1958–2005*
- Unified Sea Ice Thickness Climate Data Record • *ice thickness data from many platforms*

Ingenious Research Platforms for Ice-Covered Seas

Oceanographers at APL-UW now report success collecting profiles of ocean properties in the ice-covered seas of winter between the Canadian Arctic coast and Greenland. Two research platforms were used in this inhospitable environment. One is a robot: the autonomous undersea vehicle Seaglider, and the other is a marine mammal indigenous to the high Arctic: the narwhal.

In a project that began in 2004 as part of the National Science Foundation–Office of Polar Programs Freshwater Initiative and continues through 2011 in the Arctic Observing Network, freshwater exchange between the Arctic and North Atlantic has been measured as it passes through the Canadian Arctic Archipelago. Some scientists have hypothesized that a freshening Arctic Ocean—the result of increased glacier melt in Greenland and increased precipitation in Siberia—could impact the formation of very cold, dense water in the Labrador Sea, which is a critical driver of global ocean circulation.

APL-UW moorings deployed across the strait between Baffin Island and Greenland have captured the longest continuous measurement of fresh water exiting the Arctic to the Labrador Sea. But moorings are not ideal for detecting freshwater plumes, which reside in a thin layer near the surface. Tethering an instrument atop a mooring so it reaches that uppermost layer puts the instrument at risk of being ruined if an especially thick, low-hanging piece of ice comes along and strikes it.

New Arctic Capabilities for Seaglider

Seagliders sample the ocean's uppermost layer regularly because they surface during each dive cycle to navigate and communicate by satellite with their pilots. In ice-covered waters, however, gliders cannot access the surface and must operate without this satellite link. An acoustic system, with sensors on board the vehicle and five acoustic beacons deployed in the depths of Davis Strait, provides the needed navigation instructions. Several other hardware and software modifications have been made as well.

Although it is risky for Seaglider to brave the ice, the vehicle considers how long it has been under and how urgent it is to try to reach an opening to transmit data and receive mission commands. An onboard ice atlas calculates the odds of encountering open water above, and while rising to the surface, Seaglider measures the water temperature to determine if the surface is covered by ice. If so and there is no urgent need to download data, Seaglider proceeds on another dive cycle rather than chance damaging itself on the underside of the ice. If the vehicle senses an impending mechanical, electrical, or communications failure, it tries to get out from under the ice and into open water where it can relay its position and be recovered. Seaglider #108 collected profiles of ocean properties for 25 weeks during winter 2008–2009, traveling more than 450 miles under the ice in Davis Strait.

The five-year data record from the moorings across the strait shows a total volume and freshwater outflow peak in autumn, and a slight increase in freshwater transport from 2004–2007. APL-UW scientists and colleagues at the Woods Hole Oceanographic

Institution suggest that this increase in freshwater flux led to increased sea ice formation, which modified the patterns of atmospherically driven oceanic heat loss in a way that enhanced deep convection in the Labrador Sea. This is interesting because it is the opposite of what is expected of a freshwater cap—inhibiting convection by laying down a layer of lighter water at the surface. This may still happen, but the outcome may depend on how much fresh water exits the Arctic, the timing of the outflow, and the exact water properties.

The Narwhal: Persistent, High-Resolution, Basin-Wide Ocean Sampler

Oceanographer Kristin Laidre has studied narwhals for nine years, living three to four months of each year with the Inuit of Greenland's west coast. By tagging the whales with transmitters that beam the whales' location to a polar orbiting satellite each time they surface, she has tracked their migrations in the high Arctic and learned much about their behaviors. In 2005 she augmented the sensor package attached to the whales with satellite-linked time-depth-temperature recorders.

Laidre's research shows that narwhals are predictable. In summer they reside near the east coast of Baffin Island and Greenland's Melville Bay. In October and November they undertake a 1000-km southbound migration to their winter feeding sites in central Baffin Bay and Davis Strait. Here, in 95% sea ice cover, narwhals dive to depths over 1,500 m 10–25 times per day to prey on Greenland halibut. These dives last over 25 minutes and are performed nearly perpendicular to the bottom. This behavior is ideal for repetitive depth and temperature casts. These data are particularly valuable because of the scarcity of measurements ever taken during winter in the region.

In spring 2008 a team used a helicopter to fly from the coast to the ice floe near the whales' winter home. Researchers established a line of hydrographic stations and performed conductivity-temperature-depth casts to 500 m to augment and calibrate the satellite-linked recorders from whales in the immediate area.

The data record from 15 tagged whales during 2005–2007 shows a warming of about 1°C in the depths of the West Greenland Current compared with historical data records and hydrographic climatology models. A warming Baffin Bay may affect the water masses that reach the deep convection zone of the Labrador Sea, as well as the seasonality and location of ice floes. And for the narwhals, a warming sea may exert pressure on their sole food source, the Greenland halibut, which lives in sea temperatures less than 2°C. Thanks to the narwhals' service to science, Kristin Laidre and her colleagues have a better view of the environmental changes of Baffin Bay and potential consequences for the ecosystem.

Team members: *Eric Boget, M. Beth Curry, Wendy Ermold, Craig Lee, Jason Gobat, Adam Huxtable, James Johnson, Kristin Laidre, Richard Moritz, Geoff Shilling, Avery Snyder, and Michael Steele*

Sponsors: *NSF, NOAA Office of Ocean Exploration, and NASA*

Research Highlights

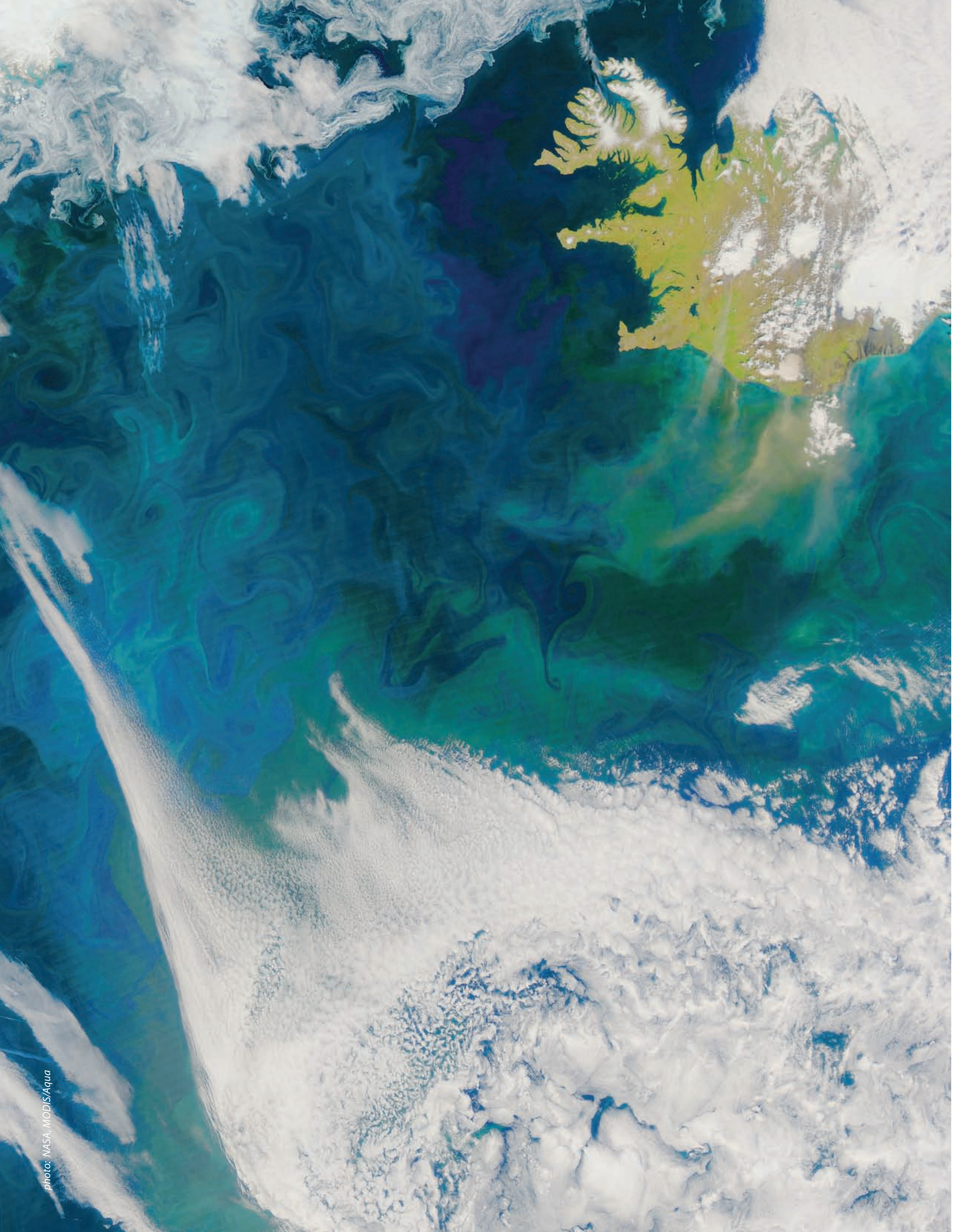


photo: NASA MODIS/*Aqua*

Integrated and Expansive Science: Biophysical Oceanography

A vast renewal event happens each spring as a wave of tiny plant growth covers the North Atlantic Ocean. This mass greening of the ocean's surface is observed dramatically from space by color-sensitive sensors on satellites as it extends from Bermuda to the ice edge in the Arctic during the season. The phytoplankton of the North Atlantic bloom play a major role in pulling CO_2 from the atmosphere and storing it in the ocean. Despite the magnitude and importance of this event, it has rarely been observed from start to end due to the difficulty and expense of maintaining ships in the region for many months.

APL-UW investigators, their students, and colleagues from the University of Maine and Dalhousie University in Nova Scotia led an ambitious collaborative experiment in the North Atlantic near Iceland to coincide with the bloom in 2008. The challenge of the experiment was to characterize the bloom's temporal and spatial evolutions of physics, biology, and chemistry over its entire duration.

Autonomous, Robotic Ocean Sampling

Almost all of modern physical oceanography is conducted by collecting data with electronic sensors. Biological and chemical oceanography may be, in part, following this example, though there are obstacles. New sensor technologies are not yet proven and the data collection efforts are complicated by the vast number of variables—the diversity of life in the ocean—that must be sampled.

For the North Atlantic Bloom program, Seagliders and Lagrangian mixed-layer floats, both developed at the Laboratory, were enhanced with new biochemical sensors. In addition to the standard temperature, conductivity, and pressure measurements, sensors for chlorophyll fluorescence, optical backscattering, beam attenuation, oxygen, nitrate, and light were distributed across the floats and gliders. In all, over 60 data channels were sampled to give a time–space resolved picture of physical, biological, and chemical properties.

Instruments were deployed from the Icelandic vessel R/V *Saemundsson* in early April before the bloom began. The Lagrangian float followed the three-dimensional motion of water parcels within the ocean's mixed layer, thus measuring the actual motion and conditions experienced by a phytoplankton in the bloom. Four Seagliders were piloted (usually from APL-UW) in an array around the float to extend the horizontal and vertical range of the measurements. Their missions continued during a month-long R/V *Knorr* cruise in May, and on through the bloom's end in June when they were recovered.

Calibrate & Complement: Shipboard Sampling

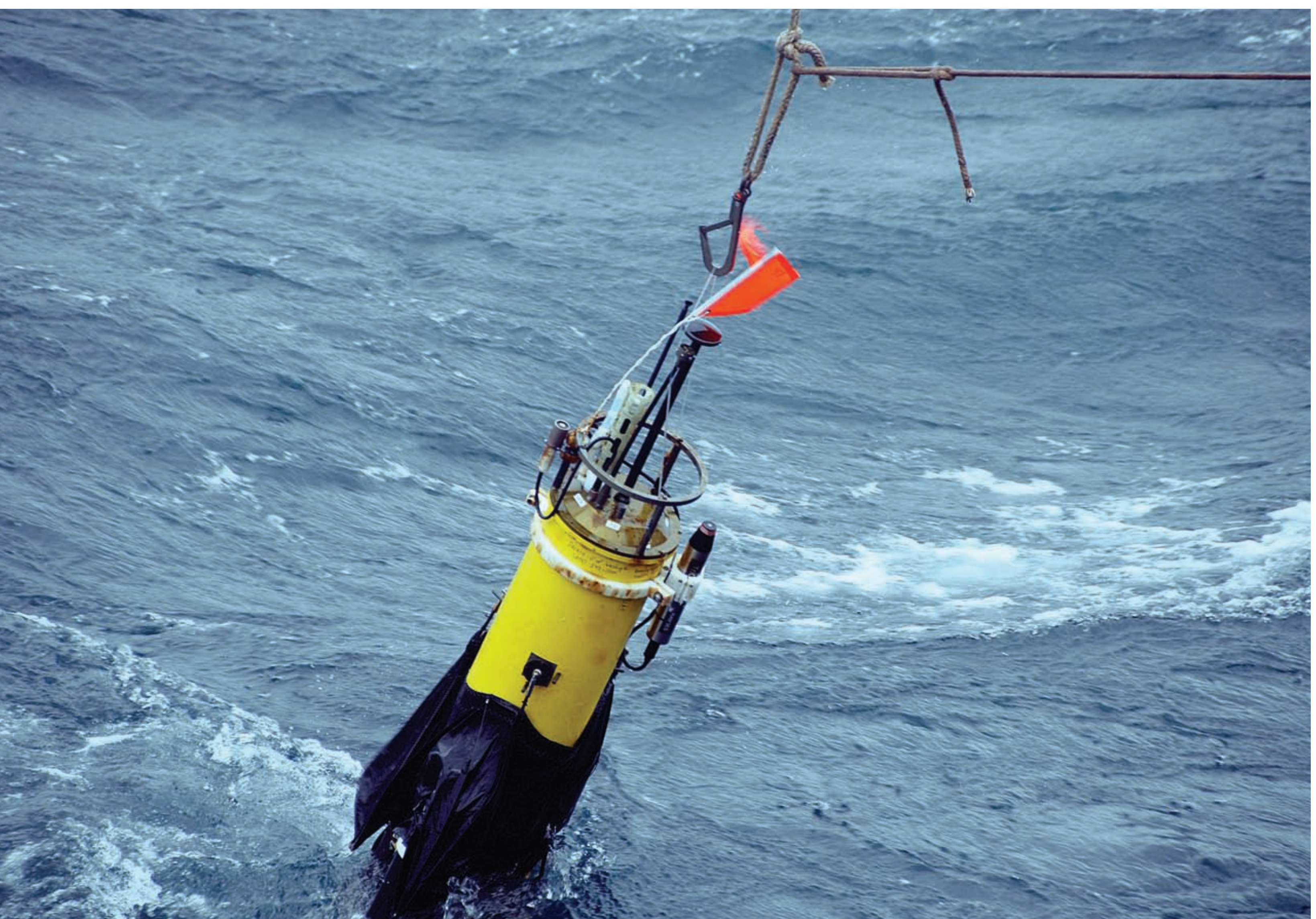
Every glider and float sensor was calibrated using shipboard sensors and/or water bottle samples collected on casts from the *Knorr*. To get the best calibrations, casts were performed within 500 m of the robotic platforms. This involved piloting the glider and float to park on the surface, maneuvering the ship as close as possible, and then making the cast as the autonomous platforms began a dive or profile.

Some float and glider biochemical sensors measure proxy quantities for a variable, so complementary data collected by the ship's measurement systems were used. For example, an optical transmissometer on the float measures beam attenuation — the absorption and scattering of light due to particulate organic matter. To translate the optical float data to an estimate of particulate organic carbon due to phytoplankton growth requires shipboard water sample collection and laboratory analysis.

Observations Through Adaptive Sampling

The bloom began in the Icelandic basin on April 20 when the mixed layer shallowed rapidly to 5–20 m (the wintertime mixed layer is up to 250 m deep). Sensors showed rises in backscatter, beam attenuation, chlorophyll and dissolved oxygen concentration, and a decrease in nitrate — all signatures of a phytoplankton bloom.

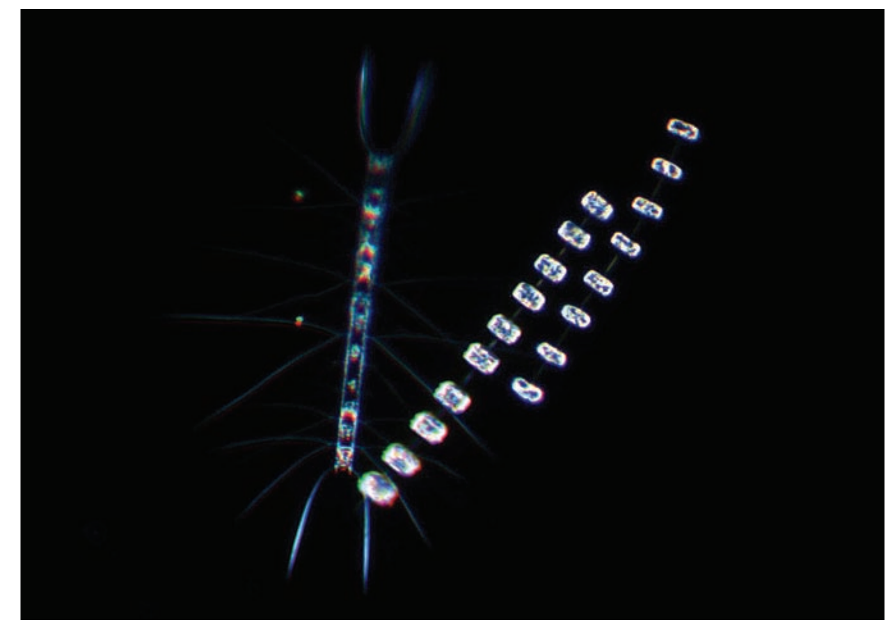
As the diatom bloom peaked in mid-May, vertical profiles of beam attenuation and backscattering performed from the *Knorr* showed large spikes, increasing with depth over time, indicating that large phytoplankton were sinking to depth. Seagliders were instructed to extend optical measurements from 300 m to 600 m. The combined measurements yielded a detailed picture of this large carbon export event — a "diatom dump."



Students Tackling Tough Science

Oceanography graduate students Eric Rehm and Amanda Gray have been involved in nearly every aspect of the experiment. They prepared the instruments for deployment, piloted them during the cruises, and presented and distributed all the results. Both are writing theses based on data analyses from the experiment.

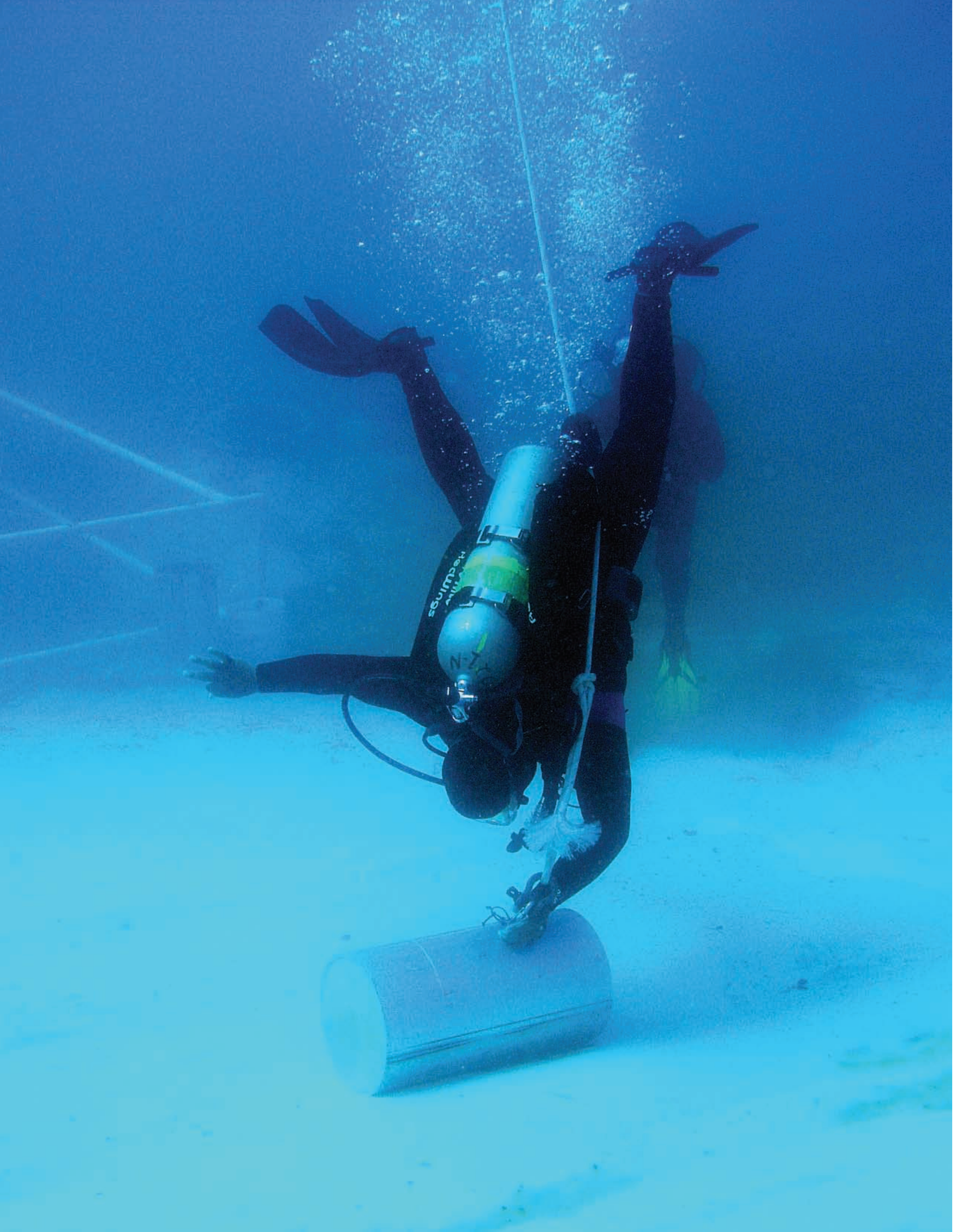
Gray is tying together float and glider observations with satellite and hydrographic data to examine the physical processes surrounding a seemingly stationary phytoplankton patch. At one point the float became caught in an eddy and traveled around its edge. Data from the float and a Seaglider show that one side of the eddy had a patch of high chlorophyll fluorescence, and the other low. Why did the phytoplankton not spread or advect in a filament? Was it renewal of nutrients through heightened vertical mixing on that edge, or were phytoplankton on the downstream edge being subducted out of the euphotic zone? Stitching together the disparate data from autonomous platforms, shipboard sampling, and satellite imagery, she hopes to create a coherent view of the eddy's physical environment.



Rehm, by studying measurements of the fine spectral variations in the color of light in water, can estimate the size and taxonomic structure of the phytoplankton community during the course of the bloom. This is possible because small phytoplankton absorb light differently than large ones. The 50-day record from the float is rich, but he hopes a similar system is deployed over decadal time scales so that the timing of the bloom and temporal evolution in the phytoplankton size structure can be observed for any impacts due to climate change. Such phenological measurements are standard in the terrestrial studies of primary production, but rare in the marine environment.

Team members: *Eric D'Asaro, Jason Gobat, Amanda Gray, Adam Huxtable, Craig Lee, Michael Ohmart, Eric Rehm, and Geoff Shilling*

Sponsor: *NSF*



Sound, Sand, Shapes

Full-Scale Lab Experiments in Mine Countermeasures

Sonar is used to "see" objects underwater and on the seafloor. A particularly difficult and dangerous problem is to detect and identify anti-ship mines or unexploded ordnance resting on the seafloor or partially buried by sediments in coastal environments. APL-UW physicists and engineers have fielded several experiments to study aspects of the problem — measuring and modeling the coastal undersea environment, and understanding high-frequency acoustic scattering, penetration, and propagation in sediments to detect buried objects.

One U.S. Navy goal is to equip an autonomous undersea vehicle with all the computer software needed to collect sonar data and make detection/classification/identification decisions with few false alarms while underway.

APL-UW and Naval Surface Warfare Center, Panama City (NSWC-PC) researchers constructed a full-scale underwater laboratory by outfitting the facility's 110 x 80-m, sand-bottom test pond with two rail-guided acoustic source/receiver systems. Divers deploy the rails in sections, and then place aluminum shapes (targets) in various orientations within view of the rails. Electric motor-driven source/receiver towers traverse the rails at 5 cm/s making transmissions twice per second.

Moving a small transducer along a line and pinging and receiving at many positions builds a virtual line of acoustic transducers. Data are analyzed immediately by physicists, signal processors, and sonar engineers so that the next source/receiver/target geometry can be determined and tested. For example, the sonar images often have one to several triplets of hot acoustic spots within them. The distance between these hotspots and their relative loudness were examined using physical acoustics models that take the geometry into account. The hotspot triplets were attributed to (1) sound bouncing directly off the target back to the receiver, (2) sound bouncing off the sand to the target and then off the target to the receiver, and (3) sound bouncing off the sand to the target then off the target back to the sand and finally going back to the receiver.

Despite all the geometries explored and test pond data collected, there are too few data, considering all the possible geometries, for signal processors and software engineers to write effective detection/classification/identification algorithms. Instead, the experiment results are used to test finite element numerical simulations of target acoustic response. The finite element modeling (FEM) can then be used to realize an unlimited set of geometries.

FEM breaks up the target into thousands of points, each of which has the physical properties of the target at that point. The laws of physics are used to calculate the response of each of these points to acoustic interrogation. All these separate responses are summed to realize the signal heard by the receiver. Here, too, the physical acoustics models are used to guide which physics need to be included in the FEM and whether the FEM is calculating the physics correctly. The FEM results will generate data for a large set of targets and geometries. Based on their anticipated operating environments, the Navy will choose a subset. These results will then be used as if they were "real" data by the algorithm developers.

Team members: *Paul Aguilar, Eric Boget, B. Todd Hefner, Steven Kargl, Michael Kenney, Russell Light, Vernon Miller, Michael Ohmart, Dajun Tang, Eric Thorsos, Keith Van Thiel, and Kevin Williams*

Sponsor: *ONR and the Strategic Environmental Research and Development Program*

Insights from Infrared

Tidal flats are among the most dynamic coastal environments. Skagit Bay, for example, is the site of the largest river entering Puget Sound, having extensive sand flats at the river mouth and a complex combination of tidal and wind wave influences. Willipa Bay (Pacific coast), another example, is dominated by the influence of the Columbia River plume and has continually expanding mud flats.

The Office of Naval Research began a research initiative in early 2007, aligning resources to understand and predict the interactions among tidal and riverine water circulation, sediment strength and transport, and the formation and stability of channels in tidal flats. APL-UW researchers, working in Skagit and Willipa bays, have deployed advanced thermal remote sensing technologies and are integrating their data into calibrated models with strong underlying physics to better observe and predict these coastal environments.

photo: Chris Linder

Heat from Heights

Light from the infrared (IR) region of the electromagnetic spectrum is related to the heat radiated by an object. A thermal IR camera detects the energy and produces an image. APL-UW investigators have mounted thermal cameras on various platforms to measure the tidal flats on multiple time and space scales. One camera is flying in a light plane to collect snapshots that are mosaicked into synoptic thermal maps. Monthly flights in a 'lawn mower' pattern over Skagit Bay capture any one point nearly every 45 minutes over the course of many hours — enough time to span an ebb or flood tide. Another camera is mounted to a tethered helikite (a dynamically stabilized aerostat). The helikite system, developed by Principal Oceanographer Andrew Jessup's lab at APL-UW, can be flown from a platform over water or shore. A third tower-mounted imager is erected on an island. The latter two, while imaging successively smaller areas, can collect thermal images continuously for weeks to years.

Infrared images of the tidal flats show a strong contrast between exposed warm sediments and cooler surrounding water as well as subtle differences among sediments of various composition and among water masses.

photo: Chris Linder

Bathymetry

Using the strong contrast between exposed warm sediments and cooler surrounding water, researchers map the waterlines over a falling or rising tide. This technique effectively produces depth contours that interpolate into a digital bathymetry map. Vital to the technique is accurate image mapping, accomplished with standard photogrammetry techniques using GPS and heading-pitch-roll sensors on board the platforms. Infrared sensing is ideal for this application because waterlines can be determined day and night, and IR images are less prone to errors from pooled water left on the flats at low tides. Theses IR techniques are a lower cost alternative to lidar surveys and a logistically simpler and faster alternative to GPS surveying.

> "When this project began we got boats stuck in the mud and spent a lot of time wading around looking for channels, giving a real appreciation for the project's naval application. Now, thanks to our remote IR sensing, we can navigate the study sites skillfully."
>
> – J. Thomson

Plumes and Fronts

Complex structures of the Skagit River plume and its multiple fronts that shift with the tides are seen in the IR images. During winter, coincident with high river flows, the plume of river water pushes to its greatest extent in the bay and recedes in summer. The plume is the dominant feature in the Skagit tidal flats and bay, exerting hyrodynamic control as well as delivering a significant amount of sediment to the flats.

The velocity of flows can be extracted from the IR images. Particle image velocimetry matches corresponding features from frame to frame in an image time series, and combined with the known mapping of the images in real-world coordinates, it is possible to estimate the distance and direction a feature has moved from the previous time—its exact velocity. This method applied to IR imagery is new, and rigorous tests of its accuracy are under way.

Sediment Strength

Small temperature loggers are moored in the water and driven into the sediments to provide interior temperature validation for water masses and sediment layers within the thermal cameras' fields of view. Sandy sediments have a much stronger response to solar heating, because the water content and porosity are lower, compared with muddy sediments. The temperature at depth in the sediment is related to its heat capacity, which is in turn related to the relative portions of sand and mud. Because sandy areas are firm and easy walking compared with muddy areas, which are soft and difficult to walk across, the remote identification of tidal flat properties allows real-time monitoring and safe operation, e.g., amphibious landings, in these environments.

Expanding Opportunities

Jim Thomson was awarded research funding under ONR's Young Investigator Program in 2007; the funds are supporting the in situ portion of the project, especially the sediment heat flux observations, which are essential for interpreting the remote IR measurements. ONR initiative funding extended the thermal estimates of sediment porosity beyond the tower-based scales with overflight and helikite observations, allowing investigations of feedbacks between porosity and channel dynamics.

> "The tools to make the necessary measurements of heat flux in tidal flat sediments didn't exist, so we built them."
>
> – Undergraduate student Alex de Klerk

> "I've been interested in the coastal environment since undergrad studies, so when I went looking for a Ph.D. project and I learned about the IR sensing of tidal flats, I knew I had found my thesis project."
>
> – Ph.D. student J.Paul Rinehimer

Alex de Klerk, a junior in Materials Science and Engineering, has been working on the instrumentation and deployments, often knee-deep in water or mud. J. Paul Rinehimer, a Ph.D. student in Civil and Environmental Engineering, is processing the IR data to investigate hydrodynamics. Both are advised by Thomson, who holds a joint appointment as Assistant Professor in the UW College of Engineering.

Team members: *Christopher Chickadel, Daniel Clark, Alexander de Klerk, Devin Poland, J. Paul Rinehimer, Joseph Talbert, and James Thomson*

Sponsor: *ONR*

Ice Station 2009

A research station was established in March 2009 on an ice floe of the Beaufort Sea about 200 nautical miles north of Prudhoe Bay, Alaska. The Applied Physics Laboratory Ice Station (APLIS) supported U.S. Navy and civilian personnel during under-ice exercises that involved the USS *Annapolis* (SSN-760) and the USS *Helena* (SSN-725). Sponsored by the Arctic Submarine Laboratory (ASL), this 2009 ice station re-establishes APL-UW as the U.S. Navy's premier arctic logistics provider, and recognizes the Laboratory's expertise in arctic operations and science that stretches back over three decades.

U.S. Navy submarine operations in the Arctic are challenged by the ice cover. The complex environment—an irregular, reflective surface from the underside of the ice and salinity variations caused by river runoff and ice melt—affects sound propagation and the performance of acoustic sensors and systems including navigational sonars.

The APL-UW logistics team and colleagues from ASL arrived in Prudhoe Bay in late February to establish the forward base and to scout for a station location on the ice. Once found, a small village—insulated plywood huts, tents, and two runways—was built to house, feed, and transport the population of up to 72 people. The team encountered the usual challenges of working in the Arctic—extreme cold, winds, and unpredictable ice movement. One night the camp moved more than nine miles and a windchill of –53°F was observed.

> "We couldn't conduct any pioneering flights for the past two days due to whiteout conditions. But the aircraft were aloft by 0915 today looking for a refrozen lead large enough to accommodate a 2000-foot runway and multiyear ice nearby for the camp's fresh water supply."
>
> *– Monday, 2 March 2009*

As the camp was being built, another APL-UW team installed the acoustic tracking range, which was set up with hydrophones installed in a quadrilateral pattern with the camp's command hut at the center. Several thousand yards of cable were laid to connect the hydrophones to the command hut—with enough slack to accommodate the shifting ice floe.

> "USS *Annapolis* arrived a day early so we spent most of the day prepping. She was on site mid-morning and surfaced in a designated lead at about 1530. We cleared the forward hatch and installed the brow for visitor and personnel transfer."
>
> *– Tuesday, 17 March 2009*

The U.S. Navy's under-ice exercises with two submarines at the station were designed to evaluate and improve torpedoes, their detection capabilities, and their ability to discriminate targets in an ice-covered sea. These torpedoes are not armed but instead gather data until they run out of fuel and then float up under the ice cap. After a shot, the approximate resting location relative to camp was determined acoustically using the APL-UW tracking range and converted to GPS coordinates. A search team was then flown by helicopter to those coordinates.

"A very challenging recovery today in every aspect: search, melt, and dive. The torpedo was found far from camp in a rubble field with a lot of rafted ice. It took three attempts to auger a starting hole for the dive and recovery holes. Ice thickness was 8–9 feet. The dive hole was clear but the recovery hole had a large sheet of rafted ice about three feet underneath, so the divers switched. The divers had to do some crawling through rafted ice to get to the hole, but once in, they maneuvered the torpedo to the recovery hole after applying many counterweights to overcome the torpedo's buoyancy."

– Monday, 23 March 2009

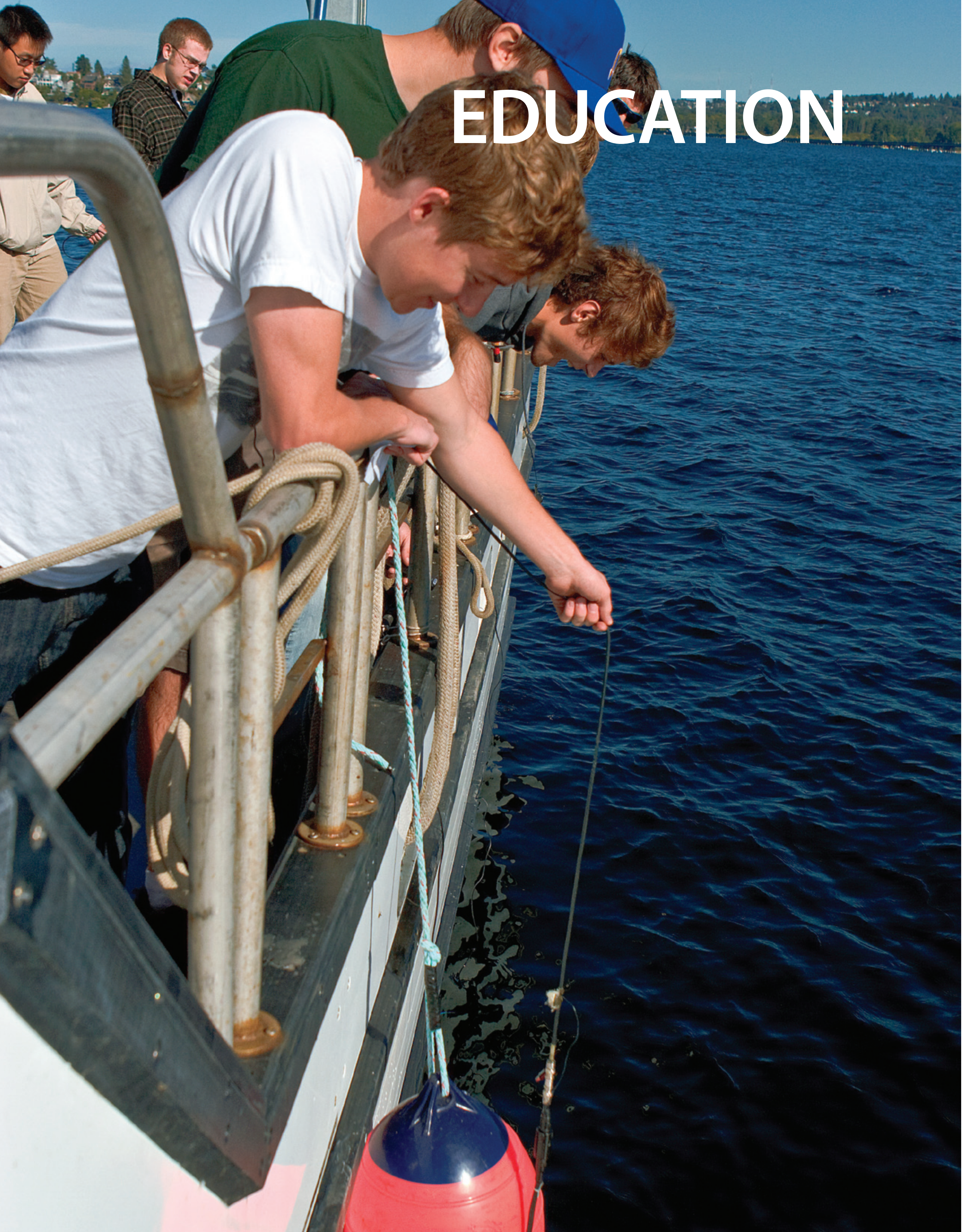
With the torpedo found, a team was sent with a diesel-fired melting system to make two 3-foot diameter holes in the ice, one for divers and one for the torpedo recovery. After the holes were melted, divers entered the water to move the torpedo to the recovery hole and rig it for lifting by helicopter. The APL-UW dive team readied a torpedo for lifting in fifteen minutes or less once they hit the water.

Sixteen torpedo recoveries were performed over ten days. Recovery times varied from two hours to one full day depending on ice conditions. Due to the exemplary performance of the APL-UW team and cooperative weather, the project was completed five days ahead of schedule.

APLIS 2009 was a significant training year for new APL-UW personnel who will be responsible for future stations. New team members were able to cross-train during the complete planning and operation cycle with veteran personnel who have been involved with ice stations for over three decades.

Team members: *Paul Aguilar, Eric Boget, Adam Huxtable, Frederick Karig, Michael Kenney, Sean Lastuka, Trina Litchendorf, Keith Magness, Timothy McGinnis, Nicholas Michel-Hart, Francis Olson, Peter Sabin, Troy Swanson, Keith Van Thiel, and Timothy Wen*

Sponsor: *U.S. Navy and Arctic Submarine Laboratory*



EDUCATION

Campus Connections

Since its inception, the Laboratory has been integrated into the education mission of the University of Washington. In 2009 APL-UW efforts to train the next generation of scientists and engineers are more robust than ever.

APL-UW staff hold over 40 faculty positions in 10 different academic departments on the University of Washington campus. A formal process was established during the past biennium to create new faculty positions without tenure. These positions include funding for teaching and research collaboration and are similar to traditional university faculty appointments in terms of rank and duties, with the exception of tenure. Recent appointments are Don Percival, Professor, Statistics; Peter Dahl, Associate Professor, Mechanical Engineering; Payman Arabshahi, Associate Professor, Electrical Engineering; Pierre Mourad, Associate Professor, Neurological Surgery; James Thomson, Assistant Professor, Civil and Environmental Engineering; and Michael Bailey, Associate Professor, Mechanical Engineering.

APL-UW faculty are teaching high-demand courses in Oceanography, Electrical and Mechanical Engineering, and Statistics. Payman Arabshahi led *Design in Communications*, Caren Marzban *Probability and Statistics in Engineering and Science*, Don Percival *Wavelets: Data Analysis, Algorithms and Theory*, and Colin Sandwith *Corrosion Science*. Peter Dahl teaches the graduate-level *Applied Acoustics* and the freshman seminar *What is Sound?* (page 40). Eric D'Asaro was a faculty leader for the 2008 senior thesis project in Oceanography that culminated in a research voyage to Glacier Bay, Alaska, aboard the R/V *Thomas G. Thompson*.

APL-UW hosts over 40 seminars open to the university community and the general public each year. In the past biennium topics included numerical modeling of the diffusion of brain cancer cells; Project STARDUST, which returned samples from a comet to Earth; robotic surgery over the Internet; and ocean circulation from a global compilation of current. Of particular note was a three-seminar series by Principal Physicist Emeritus Terry Ewart that chronicled the founding of the Laboratory's Ocean Physics Department, the study of ocean acoustic wave propagation in random media, ocean mixing and diffusion, and much more seminal research begun or extended by APL-UW scientists over nearly a half century.

A collaboration with the Center for Innovation and Entrepreneurship (CIE) in the UW's Foster School of Business produces a seminar series, ***From Invention to Start-up***, on transitioning research and technology to the private sector. Seattle-area start-up company experts present strategies to the campus community on how to access the capital, talent, and resources necessary to create a successful high-tech company. The 2008–2009 academic year inaugurated another collaborative APL-UW/CIE program. The **Environmental Innovation Challenge** partners engineering and business students together to develop innovative plans to solve an environmental problem. The 2008–2009 theme was water and the winning team of UW students developed a device that screws onto a single water faucet in the home to detect water leaks in the system through acoustic vibrations and pressure differential signatures of water flow.

2007 & 2008

Hardisty Scholars	Advisors
Evan Gander	Harold Kolve
Shan Lu	Antao Chen
Robert Burns	Peter Dahl
Kang Ya	Pierre Mourad

Boeing Scholars	Advisors
Tamisha Downing	Pierre Mourad
Charles Harris-White	Wm. Timothy Elam
Ngocman Nguyen	Payman Arabshahi
Tiffany Stephens	Kathleen Stafford
Ella Willard-Schmoe	Wm. Timothy Elam

Opportunities for Undergraduates

The Hardisty Undergraduate Scholarship was established in 1997 in honor of the late Patricia Hardisty, an APL-UW scientist who was an ardent supporter of women and minorities in science. The scholarship provides funds for undergraduate students to work with an APL-UW staff mentor on a funded research project in addition to a one-time book award. The Boeing/APL-UW Undergraduate Scholarship for Women, Underrepresented Minorities, and Economically Disadvantaged Students is an exact parallel to the Hardisty program. Since 2004 this scholarship has been funded by generous grants from The Boeing Company.

Hardisty and Boeing scholars are integrated directly into their advisors' research projects, treated as de facto graduate students, serve as co-authors of research articles in peer-reviewed journals, and present research results at national and international scientific conferences.

APL-UW/WRF Fellowship

The Washington Research Foundation inaugurated a joint fellowship with APL-UW in 2008 for graduate students who are developing innovative measurement technologies, particularly those with commercial potential. Three fellows were selected for the 2008–2009 academic year.

Charles Branham is a Ph.D. student in chemistry working with Brian Marquardt to develop novel optical oxygen sensing systems based on vapochromic compounds—phosphorescence transition metal complexes that absorb light and efficiently emit phosphorescence at low energy. The fellowship supports field testing of a low-power optoelectronic oxygen sensor package for long-term deployments in various environments. Samuel Gooch is a graduate student in mechanical engineering who is working with Jim Thomson under a grant from the U.S. Department of Energy to develop systems that will assess the power resources from tidal energy. The fellowship supports his work on software and hardware packages to survey potential tidal energy resources, site turbines, and install equipment. Danling Wang, who conducts research in Antao Chen's laboratory, is working on sensitive sensors to detect trace vapor amounts from explosives. She is working to refine a recent discovery that nanowires composed of semiconducting materials like titanium oxide demonstrate rapid, significant change in their electrical resistance at room temperature when exposed to explosive vapors at part-per-billion concentrations.

Advising and Mentoring

Over the past biennium, 50 graduate students (16 completed degrees), and 46 undergraduates conducted research and development programs at APL-UW as part of their university education. They are listed with their research topics and advisors on pages 49–51. Outside the scholarship and fellowship opportunities, graduate and undergraduate student researchers are supported by the grants of their APL-UW advisors and mentors.

One interesting example of student research produced an educational tool targeted to junior high school students. *The Important Little Life of Dylan Diatom* is a short film animated by Anna Czoski, an undergraduate in digital arts and experimental media, who graduated in 2009. Working with Mike Steele, Janet Olsonbaker, and Troy Tanner on the NSF-funded project, she created a realistic environment and ecosystem to tell the story of phytoplankton growth in the Arctic Ocean and how climate changes may alter such growth. Where animation software fell short of accurately portraying fish movements and sea ice structure, Czoski and Tanner used innovative mathematical and geometric techniques to enliven their characters realistically.

COMMUNITY OUTREACH

To augment its education mission APL-UW scientists and engineers lead varied outreach activities every year, reaching hundreds of students and educators, as well as a public of thousands. Many successful collaborations with public and private institutions have been nurtured to extend the Laboratory's presence in the community.

■ Assistant Director for Education & Outreach Robert Odom shares APL-UW science with community college students who are participating in the NSF-funded *From STEM to Stern* program that connects these students with industry and assists their transition to the university environment.

■ The NANOOS (Northwest Association of Networked Ocean Observing Systems) education and outreach mission has expanded with the development of lesson plans and activities for K-12 teachers and students. Ocean observing methods and technologies, satellite tracking of marine animals, and forecasting conditions at sea are some of the topics students can investigate. One interactive learning experience, *Rhythms of Our Coastal Waters*, teaches how salinity plots are created using data from a Pacific Northwest waterway.

■ APL-UW's Polar Science Center teams with the Pacific Science Center in downtown Seattle to present four days of activities to give the public a look into the world of polar research. There are demonstrations on extreme cold and glacier flow. Two highlights are a salinity taste test, where visitors learn what effective salinometers their tongues are, and a simulated Arctic Ocean research station that provides a hands-on experience with a research hut, equipment, and gear.

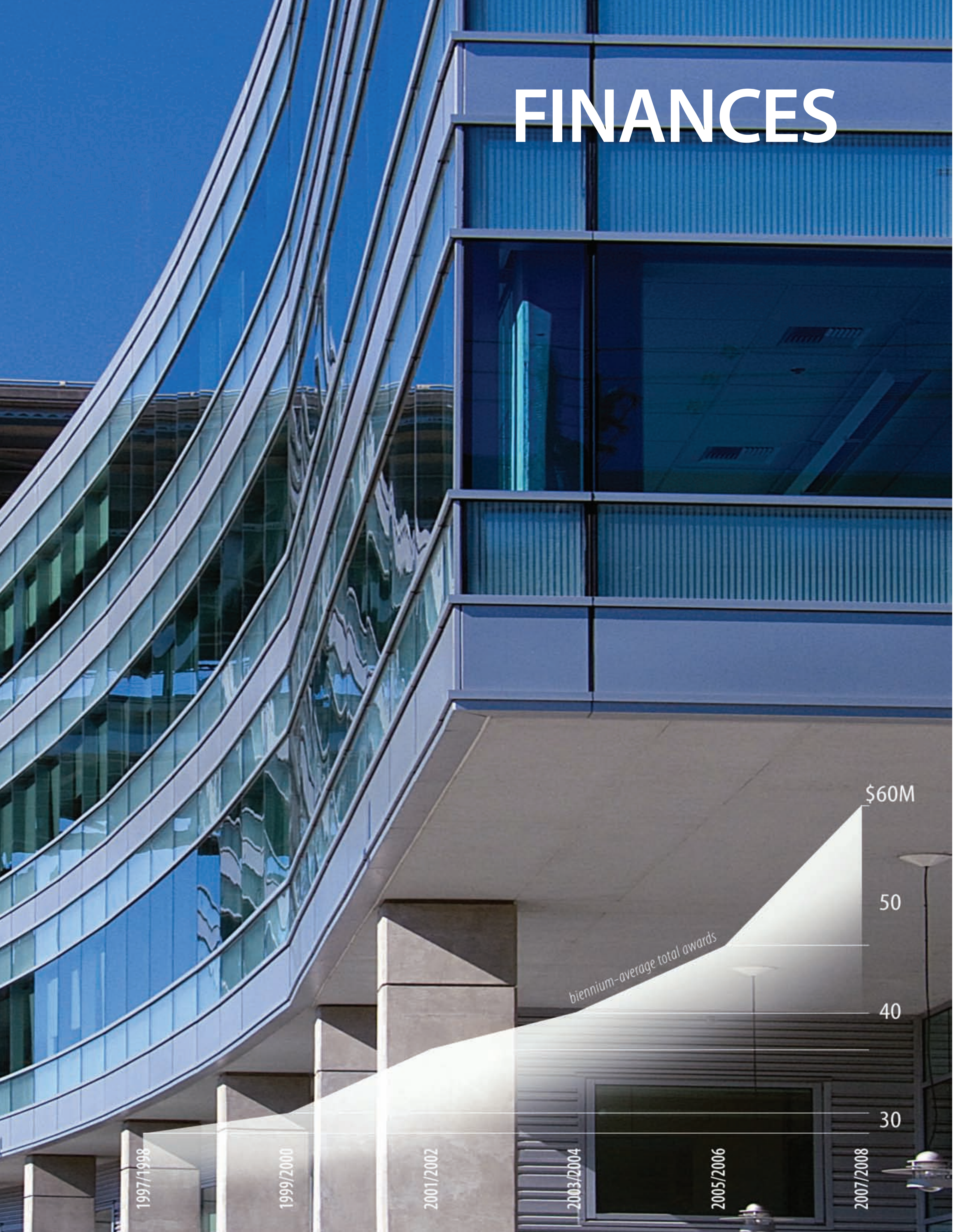
■ Around the Americas is another collaboration between the Laboratory and the Pacific Science Center. Several APL-UW researchers are using the vessel *Ocean Watch* as a platform of opportunity during its historic 25,000-mile circumnavigation of the North and South American continents. The sailboat, equipped with some of the latest technology to support data collection, along with scientists and educators who join during various legs of the voyage, is making 31 stopovers in 13 months to draw attention to the changing condition of the oceans.

photo: David Thoreson

■ APL-UW continued its participation in Washington Weekend — a campus-wide open house over one spring weekend that increases the university's connections to its regional community. Exhibits gave visitors the opportunity to explore freshwater and seawater ice properties, the mechanical effects of ultrasound, thermal portraits made possible by infrared remote sensing, and strategies to observe and conserve the local marine environment.

■ Polar scientists Rebecca Woodgate and Kristin Laidre were featured speakers in the very popular lecture series ***Arctic Adventure! Ocean Tales of Currents and Creatures***, sponsored by the College of Ocean and Fishery Sciences.

FINANCES



Record Revenues

William Bakamis

The Applied Physics Laboratory has never been in a stronger financial position. For FFYs 2007–2008 APL-UW set an all-time record for grant and contract awards received. During this period the Laboratory's total awards were $118.8M — an all-time one-year record of $59.6M in FFY 2007 and an additional $59.2M in FFY 2008. The $118.8M two-year total represents a $25.7M (27.5%) increase in grant and contract awards from the previous biennium and caps a record breaking three-year period (FFY04–FFY07) during which the funding stream grew by more than 50%.

Financial Stability

The Laboratory's primary partner remains the U.S. Navy, which provided about 60% of total funding. Grants from the National Science Foundation grew sharply during the past biennium to $23.6M, moving the Laboratory into the upper echelon of University of Washington units receiving NSF grant funds. Other federal mission agency sponsors include NASA, NOAA, and NIH.

The Laboratory's revenue base continues to diversify, with about 35 different sponsors and a bias toward 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 fundamental research was 65% to 35%. The current percentage balance between applied and basic research has shifted in the opposite direction to reflect faster growth in fundamental research areas.

SPONSOR		FFY2007	FFY2008
Office of Naval Research	U.S. NAVY	*$21,203,925*	*$20,628,389*
Naval Sea Systems Command	U.S. NAVY	*$11,727,183*	*$4,259,000*
Arctic Submarine Laboratory	U.S. NAVY	–	*$3,174,699*
Naval Surface Warfare Center	U.S. NAVY	*$2,708,860*	*$1,928,088*
Office of Naval Intelligence	U.S. NAVY	–	*$1,376,000*
Other Navy	U.S. NAVY	*$322,805*	*$2,367,629*
	Subtotal	*$35,962,773*	*$33,733,805*
National Science Foundation		*$13,113,317*	*$10,454,677*
National Aeronautics and Space Administration		*$4,379,424*	*$4,623,597*
National Oceanic and Atmospheric Administration		*$1,217,750*	*$4,087,311*
National Institutes of Health		*$3,079,892*	*$3,903,797*
Other Federal Agencies		*$750,497*	*$1,264,668*
Other		*$1,145,384*	*$1,107,658*
	Subtotal	*$23,686,264*	*$25,441,708*
	TOTAL	$59,649,037	$59,175,513

Improved Infrastructure

Recent fiscal growth has enabled APL-UW to make significant investments in research space and infrastructure. Specialized laboratory and office space expanded by about one-third as new and some current staff moved into three floors of the Benjamin Hall Interdisciplinary Research Building in fall 2009. To further Laboratory researchers' ability to field ambitious at-sea observational programs, a new research vessel was built for the APL-UW fleet — the R/V *Jack Robertson*. Improvements were also made to the R/V *Henderson* during summer 2009. The Laboratory now has state-of-the-art research vessel capability for the first time since the 1950s.

Billed contract fees provide the Laboratory's discretionary resources and represent about 1.7% of total income. They provide the means to create unique and advanced research and development capabilities, support new areas of inquiry and discovery, and help hire the next generation of APL-UW scientists and engineers.

The Laboratory remains committed to ensuring that the long-term investments in it by the U.S. 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, national defense, and government research and development needs.

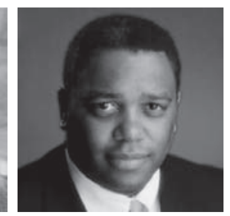
ADVISORY BOARD

Our Advisory Board ensures that the Laboratory's research and development programs are consistent with the highest goals of university research and education, while supporting the missions of the agencies we serve.

VADM Roger F. Bacon
(Ret.) U.S. Navy Assistant Chief of Naval Operations for Undersea Warfare

Robert M. Hillyer
(Ret.) Senior Vice President, Science Applications International Corporation

Thomas J. Cable
Chairman
(Ret.) Cable & Howse Ventures



Ronald S. Howell
CEO, Washington Research Foundation

RADM Jeffrey B. Cassias
(Ret.) U.S. Navy Commander, Submarine Force, U.S. Pacific Fleet

Mary E. Lidstrom
Vice Provost for Research
University of Washington
ex officio

Phil E. DePoy
(Ret.) Chair, Expeditionary Warfare
Naval Postgraduate School

William C. Miller
Academic Dean and Provost
United States Naval Academy

Pamela A. Drew
Vice President, Enterprise Systems
Northrop Grumman Corporation

Arthur R.M. Nowell
Dean, College of Ocean and Fishery Sciences
University of Washington
ex officio

John M. Fluke, Jr.
Chairman, Fluke Capital Management, L.P.

Matthew O'Donnell
Dean, College of Engineering
University of Washington
ex officio

Christine H. Fox
President, Center for Naval Analysis

John B. Slaughter
President & CEO, National Action Council for Minorities in Engineering
President Emeritus, Occidental College

Student Achievements

Graduate Degrees Awarded

Student	Department	Advisor
Samantha Brody	Oceanography, M.S., 2007	Sanford
Nathaniel Burt	Electrical Engineering, M.S., 2007	Chen
Luca Cazzanti	Electrical Engineering, Ph.D., 2007	Gupta
Megan Hazen	Electrical Engineering, Ph.D., 2008	Gupta
ChuanLi Jiang	Oceanography, Ph.D., 2008	Kelly & Thompson
Michael Keim	Quantitative Ecology & Resource Management, Ph.D., 2008	Percival
Wayne Kreider	Bioengineering, Ph.D., 2008	Bailey & Crum
Joseph MacGregor	Earth and Space Sciences, Ph.D., 2008	Winebrenner
John Mickett	Oceanography, Ph.D., 2007	Gregg
Debashis Mondal	Statistics, Ph.D., 2007	Guttorp & Percival
Twila Moon	Earth and Space Sciences, M.S., 2008	Joughin
Andrew Morabito	Statistics, M.S., 2007	Percival
Neil Owen	Electrical Engineering, Ph.D., 2007	Bailey & Crum
Scott Philips	Electrical Engineering, Ph.D., 2007	Atlas & Pitton
Zoltán Szüts	Oceanography, Ph.D., 2008	Sanford
Rob Webster	Applied Mathematics, M.S., 2008	Rouseff

Graduate Students

Student	Topic	Advisor
Marilee Andrew	Quantifying pharmacokinetics in altered physiological states	Bryers & Vicini
M. Hassan Arbab	Terahertz technology for security and medical applications	Chen
Charles Branham	Design, charaterization and optimization of vapochromic sensors for oxygen analysis	Marquardt
Samantha Brody	Internal waves	Sanford
Nathaniel Burt	Fiber Bragg grating acoustic sensor	Chen
Michael Canney	Shock wave induced heating in therapeutic ultrasound	Bailey & Crum
Joshua Carmichael	Seismic studies in Greenland and Antarctica	Joughin
Luca Cazzanti	Generative models for similarity-based learning	Gupta
Hong Chen	Microbubble interactions in the vasculature	Crum & Matula
Brian Chinn	Internal tides in the Philippine Archipelago	Alford & Girton
M. Beth Curry	Volume, heat and freshwater transport across Davis Strait	Lee
David Dall'Osto	Underwater ambient noise directionality	Dahl
Andrew Ganse	Theoretical aspects of nonlinear inversion	Odom
Samuel Gooch	Site characterization for tidal power	Thomson
Amanda Gray	North Atlantic spring bloom experiment 2008	Lee
Megan Hazen	Search strategies in global optimization	Gupta
ChuanLi Jiang	The role of the ocean horizontal advection in SST variablity in the equatorial Pacific: Influence of QuikSCAT winds	Kelly
Michael Keim	Characteristic scale using wavelets	Percival
Byron Kilbourne	Diapycnal and isopycnal mixing in the Southern Ocean	Girton
Jeramy Kimball	Dynamic measurement of condensation	Bailey
Wayne Kreider	Gas–vapor bubble dynamics in therapeutic ultrasound	Bailey & Crum
Wei Lu	Shock wave therapy	Bailey
Joseph MacGregor	Development and applications of a radar-attenuation model for polar ice sheets	Winebrenner

Graduate Students, continued

Student	Topic	Advisor
Kim Martini	Internal tides on the Oregon continental slope	Alford
Brooke Medley	Accumulation in the Amundsen Sea region	Joughin
John Mickett	Turbulent entrainment fluxes within the eastern Pacific warm pool	Gregg
Debashis Mondal	Wavelet variance analysis for time series and random fields	Percival
Twila Moon	Changes in ice front position on Greenland's outlet glaciers, 1992–2007	Joughin
Andrew Morabito	Ricean parameter estimation using phase information in low SNR environments	Percival
William Mortensen	Improving an environmentally adaptive tracker through knowledge of target aspect	Miyamoto
Neil Owen	Targeting of stones and identification of stone fragmentation in shock wave lithotripsy	Bailey & Crum
Nathan Parrish	Underwater communications	Arabshahi
Ana Cecilia Peralta Ferriz	Analysis of Arctic Ocean pressure gauge and GRACE gravity satellite data describing ocean bottom pressure and circulation	Morison
Scott Philips	Perceptually-driven signal analysis for acoustic event classification	Atlas & Pitton
Andrew Pickering	Near-inertial waves observed from the HOT profiler	Alford
Kristin Poinar	Ice sheet modeling	Joughin
Eric Rehm	Ocean productivity and optics	D'Asaro
Jia-Ling Ruan	Medical acoustics	Crum
Gavriel Speyer	Temperature estimation using backscattered ultrasound for noninvasive monitoring of thermal ablative therapy	Crum & Kaczkowski
Haishan Sun	High-speed electro-optic modulators and switches	Chen
Zoltán Szüts	Interpretation of motionally induced electric fields in complex oceans	Sanford
Leonard Tracy	Underwater communications	Arabshahi
Danling Wang	Nanoelectronic chemical sensors	Chen
Ranran Wang	Statistical postprocessing of weather forecasts generated from Numerical Weather Prediction (NWP)	Marzban
Rob Webster	Underwater acoustic propagation modeling	Rouseff
Andrew White	Long-range acoustic propagation	Mercer
Kai-Chieh Yang	Structure and evolution of the Kuroshio Current	Lee
Jinting Zhang	Atlantic meridional overturning circulation	Kelly
Shuang Zhang	Internal tides and mixing in Hood Canal	Alford & Newton
Dejie Zhou	Control of underwater noise from pile driving	Dahl

Undergraduate Students

Student	Topic	Advisor
Sophie Asher	Pain localization	Mourad
Spencer Backus	Underwater float communications system	D'Asaro
Daniel Blizzard	Use of ultrasound to predict intracranial pressure	Crum & Mourad
Robert Burns	Instrument development and testing for measuring underwater noise	Dahl
Anna Czoski	Creating 3D art for an instructional animation on the life of a diatom	Olsonbaker, Steele, & Tanner
Alexander de Klerk	Field instrumentation for measurements of surface waves and tidal flats	Thomson
Trevor Dickey	Using intense focused ultrasound to localize peripheral pain generating tissue	Mourad
Tamisha Downing	Intracranial pressure prediction	Mourad

Undergraduate Students, continued

Student	Topic	Advisor
Evan Gander	NEPTUNE Power Supply, ALOHA/MARS mooring sensor network, dual passive acoustic listener, fuel gauge for acoustic recorder system — Seaglider	Light
Josephine Garcia	Using intense focused ultrasound to localize peripheral pain generating tissue	Mourad
David Giraud	Acoustic shock wave imaging in transparent bone phantoms using photoelastic techniques	Matula
James Gray	Multi-photon polymerization fabrication of 3-D microstructures	Chen
Katrina Hamilton	Narration for *The Important Little Life of Dylan Diatom*	Olsonbaker
Daniel Harmon-Gross	Using ultrasound-induced tissue movement to predict intracranial pressure	Mourad
Charles Harris-White	X-ray spectrometer design	Elam
Aaron Hossack	Building a feedback system for high intensity focused ultrasound (HIFU)	Bailey
Karsten James	Algorithm coding for elastic wave reflection from a gradient layer	Odom
Bion Johnson	Lithotripsy tissue injury	Bailey
Travis Johnson	Intracranial pressure prediction	Mourad
Julian Kelly	Acoustic holography for medical device characterization	Bailey
Emily Lemagie	Satellite, temperature, wind and sea-surface height data in the Gulf Stream	Girton
Sean Livingston	Fabrication of the Hawaii Ocean Time Series profiling mooring	Alford & McGinnis
Shan Lu	Growth of conductive ZnO nanowires and their application to electro-optic devices	Chen
Jonathan Lundt	Develop in-house ultrasound contrast agents	Matula
Adam Maxwell	A new hydrophone for medical ultrasound	Bailey
Abigail McClintic	Using intense focused ultrasound to localize peripheral pain generating tissue	Mourad
Robert Mott	Growth of conductive ZnO nanowires and their application to electro-optic devices	Chen
Mary-Margaret Murphy	Monterey Bay cruise data processing	Girton
Matt Olson	Develop in-house stabilized microbubbles for research and targeted drug delivery	Matula
Kristin Pederson	Transcutaneous acoustic palpation for improving the anatomic specificity of pain diagnosis	Mourad
Christopher Raastad	Processing and analysis of satellite radar ice-front data in Greenland	Joughin & Smith
Cory Robinson	Develop kidney phantoms for lithotripsy research	Bailey
Kira Rombeau	The impact of sea ice changes on the Arctic marine ecosystem through model–data synthesis	Zhang
Carlos Rufin	Chemical sensor	Chen
Caitlin Shannon	Quantitative algorithms for HIFU therapy planning for tumor treatment	Kaczkowski
Andrew Spott	UV LIDAR IR&D project	Asher
Faezeh Talebiliasi	Growth of conductive ZnO nanowires and their application to electro-optic devices	Chen
Zuotian Tatum	Development of tissue phantom gels for HIFU research	Crum & Mitchell
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
Atria Welch	Vacuum system for electron-excited X-ray measurements	Elam
Ella Willard-Schmoe	Calibration and test data for variable resolution radar	Elam
David Wright	Use of ultrasound to predict intracranial pressure	Mourad
Kang Ya	Use of ultrasound to predict intracranial pressure	Mourad
Krysta Yousoufian	Develop automated system to recognize and classify Denmark Strait eddies in satellite sea surface temperature data	Girton

Laboratory Organization & Personnel

DIRECTOR
J. Simmen

ASSOCIATE DIRECTORS
Business & Finance | *W. Bakamis*
Science & Technology Integration | *D. Martin*
Science & Technology Transition | *R. Miyamoto*

ASSISTANT DIRECTOR
Education & Outreach | *R. Odom*

DEPARTMENTS
Air–Sea Interaction & Remote Sensing | *A. Jessup, Chair*
Center for Industrial & Medical Ultrasound | *T. Matula, Director*
Electronic & Photonic Systems | *G. Harkins, Director*
Environmental & Information Systems | *D. Jones, Head*
Ocean Acoustics | *R. Odom, Chair*
Ocean Engineering | *R. Light, Head*
Ocean Physics | *J. Girton, Chair*
Polar Science Center | *A. Schweiger, Chair*

DIRECTORATE

Jeffrey A. Simmen – Director
William T. Bakamis – Associate Director, Business & Finance
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 – Assistant Director, Education & Outreach; Principal Physicist; Research Associate Professor, Earth & Space Sciences

Dian L. Gay – Administrator, Program Operations
Barbara B. Masaki – Fiscal Specialist II

Robert C. Spindel – Director Emeritus; Professor Emeritus, Electrical Engineering

DEPARTMENTS

Air–Sea Interaction & Remote Sensing

Andrew T. Jessup – Chair; Principal Oceanographer; Affiliate Associate Professor, Civil Engineering & Mechanical Engineering
William E. Asher – Principal Oceanographer
Ruth A. Branch – Engineer III
C. Christopher Chickadel – Oceanographer IV
Daniel C. Clark – Engineer III
Alexander H. de Klerk – Student Helper
Suzanne Dickinson – Oceanographer III
Brian D. Dushaw – Senior Oceanographer; Affiliate Associate Professor, Oceanography
Gordon Farquharson – Engineer IV
Ralph C. Foster – Physicist IV
William C. Keller – Senior Physicist
Kathryn A. Kelly – Principal Oceanographer; Affiliate Professor, Oceanography
Craig L. McNeil – Senior Oceanographer
Sabine Mecking – Oceanographer IV
Jeffrey A. Nystuen – Principal Oceanographer; Affiliate Professor, Oceanography
William J. Plant – Principal Research Scientist
Joseph L. Talbert – Field Engineer
James M. Thomson – Oceanographer IV; Assistant Professor, Civil & Environmental Engineering
Keith A. Walls – Administrator
Jinting Zhang – Research Assistant

Center for Industrial & Medical Ultrasound

Thomas J. Matula – Director; Principal Physicist; Affiliate Assistant Professor, Electrical Engineering
Marilee A. Andrew – Senior Engineer
Michael R. Bailey – Senior Engineer
Bradley M. Bell – Principal Mathematician
Andrew A. Brayman – Senior Physicist
Michael S. Canney – Predoctoral Research Associate II
Damon V. Cassisi – Engineer III
Hong Chen – Predoctoral Research Associate II
Lawrence A. Crum – Associate Director; Research Professor, Electrical Engineering and Bioengineering
Bryan W. Cunitz – Engineer III
Francesco P. Curra – Engineer IV
Trevor C. Dickey – Student Helper
Barbrina Dunmire – Engineer IV
Daniel Harmon-Gross – Physicist II
Aaron C. Hossack – Student Helper
P. Ray Illian – Mathematician II
Travis C. Johnson – Student Helper
Peter J. Kaczkowski – Senior Engineer
Steven G. Kargl – Senior Physicist
Tatiana D. Khokhlova – Research Associate
Vera A. Khokhlova – Senior Engineer
Wayne Kreider – Research Associate
John C. Kucewicz – Engineer IV
Daniel F. Leotta – Engineer IV
Brian E. MacConaghy – Physicist III
Abigail M. McClintic – Student Helper
Lisa Day Mercer – Administrative Specialist
Stuart B. Mitchell – Engineer IV
Michelle C. Morelli – Administrative Specialist
Pierre D. Mourad – Principal Physicist; Associate Professor, Neurological Surgery; Adjunct Associate Professor, Pediatric Dentistry and Bioengineering
Terrence W. Myntti – Field Engineer
Neil R. Owen – Research Associate
Marla Paun – Engineer IV
Steve M. Postlewait – Student Helper
Oleg A. Sapozhnikov – Senior Engineer
Caitlin M. Shannon – Student Helper
Gavriel A. Speyer – Predoctoral Research Associate I
Frank L. Starr – Research Manager
Jarred E. Swalwell – Engineer III
Yak-Nam Wang – Engineer IV

Electronic & Photonic Systems

Gary L. Harkins – Director
M. Hassan Arbab – Research Assistant
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
James C. Bowes – Field Engineer
Antao Chen – Senior Engineer; Affiliate Associate Professor, Electrical Engineering
Gerald F. Denny – Senior Engineer
Michael J. Harrington – Senior Engineer
Benjamin M. Henwood – Senior Engineer
Robert E. Johnson – Principal Engineer
William A. Jump – Senior Engineer
Riley M. Kent – Program Assistant
Allison Lamb – Student Helper
James C. Luby – Principal Engineer; Affiliate Assistant Professor, Electrical Engineering
Larry D. Nielson – Field Engineer
J. Aaron Nix-Gomez – Engineer IV
Nancy L. Penrose – Research Coordinator
Justin J. Schultz – Field Engineer
Cameron S. Simmons – Student Helper
Marcelino B. Soriano – Manager
Eric W. Strenge – Field Engineer
Kimberley R. Strenge – Student Helper
Marvin L. Strenge – Principal Engineer
Haishan Sun – Research Associate
Laurence C. Tomsic – Field Engineer
Danling Wang – Research Assistant
Angela S. Wood – Oceanographer II

Environmental & Information Systems

David W. Jones – Department Head; Senior Oceanographer
Gregory M. Anderson – Senior Engineer
Payman Arabshahi – Senior Engineer; Associate Professor, Electrical Engineering
Neil S. Banas – Oceanographer IV
Corinne J. Bassin – Oceanographer III
Michael L. Boyd – Principal Physicist
Peter M. Brodsky – Senior Engineer
Susan B. Brower – Administrator

Robert J. Carr – Engineer III

Luca G. Cazzanti – Engineer IV

Arindam K. Das – Engineer IV

Keith L. Davidson – Senior Engineer

William J. Felton – Senior Field Engineer

Michael Gabbay – Senior Physicist

Gail M. Gilliland – Administrator

Robert P. Goddard – Principal Physicist

Evan Hanusa – Predoctoral Research Associate I

Megan U. Hazen – Engineer IV

Sachko Honda – Engineer III

Julia B. Hsieh – Engineer III

Sarah E. Huffer – Student Helper

Lauren D. Hughs – Helper

Kevin G. Jamieson – Student Helper

Billy D. Jones – Physicist IV

Elizabeth V. Kirby – Engineer IV

William C. Kooiman – Engineer IV

David W. Krout – Engineer IV

Nicholas C. Lederer – Mathematician III

Riley J. Linder – Student Helper

Stuart D. Maclean Engineer IV

Brian J. Marquardt – Senior Engineer; Affiliate Assistant Professor, Electrical Engineering

Caren Marzban – Senior Physicist

Emilio Mayorga – Oceanographer IV

John J. McLaughlin – Senior Engineer

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

David W. Morison – Physicist III

William H. Mortensen – Research Assistant

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; Professor, Statistics

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

John M. Pyle – Engineer III

Steven J. Rutherford – Senior Oceanographer

Scott A. Sandgathe – Principal Oceanographer

Stephanie R. Schutz – Engineer III

Benjamin Schwartz-Gilbert – Engineer III

Amy G. Sprenger – Administrative Specialist

Marc S. Stewart – Senior Physicist

Shelby F. Sullivan – Senior Engineer

Troy T. Tanner – Senior Computer Specialist

Wesley J. Thompson – Research Aide II

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

Keith B. Wiley – Engineer IV

Lan Yu – Fiscal Specialist II

Ocean Acoustics

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

Rex K. Andrew – Senior Engineer

Robert M. Bolstad – Research Manager

Linda J. Buck – Senior Computer Specialist

Robert W. Burns – Student Helper

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

David R. Dall'Osto – Research Assistant

Wm. Timothy Elam – Senior Physicist

Andrew A. Ganse – Engineer III

Brian T. Hefner – Physicist IV

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 – Senior Oceanographer

Dajun Tang – Senior Oceanographer

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

Andrew W. White – Predoctoral Research Associate I

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

Michael A. Wolfson – Mathematician IV

Jie Yang – Research Associate

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

Lyle F. Gullings – Senior Field Engineer

Laurence S. Joireman – Administrative Specialist

Frederick W. Karig – Principal Engineer

Michael F. Kenney – Oceanographer IV

Sean Lastuka – Engineer III

Trina Litchendorf – Oceanographer II

Keith E. Magness – Field Engineer

Timothy M. McGinnis – Senior Engineer

Nicolas Michel-Hart – Engineer III

Vernon W. Miller – Senior Engineer

Michael A. Ohmart – Senior Field Engineer

Francis G. Olson – Senior Field Engineer

Andrew R. Reay-Ellers – Helper

Peter L. Sabin – Senior Field Engineer

Christopher J. Siani – Engineer III

Daniel A. Stearns – Field Engineer

Troy G. Swanson – Field Engineer

Keith L. Van Thiel – Engineer IV

Michael L. Welch – Senior Engineer

Timothy Wen – Senior Engineer

Ocean Physics

James B. Girton – Chair; Oceanographer IV

Matthew H. Alford – Senior Oceanographer; Affiliate Associate Professor, Oceanography

Stephen J. Bayer – Senior Engineer

Samantha R. Brody – Predoctoral Research Associate II

James A. Carlson – Senior Engineer

Ming-Huei Chang – Research Associate

Brian S. Chinn – Research Assistant

Andrew C. Cookson – Senior Field Engineer

Mary Beth Curry – Predoctoral Research Associate I

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

John H. Dunlap – Senior Engineer

Terry E. Ewart – Principal Physicist Emeritus

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

Yu Chin Hung – Student Helper

Adam D. Huxtable – Field Engineer

Ryuichiro Inoue – Research Associate

Byron F. Kilbourne – Research Assistant

Eric L. Kunze – Principal Oceanographer

Nathan E. Lauffenburger – Helper

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

Ren-Chieh Lien – Principal Oceanographer

Joseph P. Martin – Oceanographer IV

Kim I. Martini – Predoctoral Research Associate II

John B. Mickett – Oceanographer III

Jack B. Miller – Principal Engineer

Sheila S. Ocoma – Fiscal Specialist II

Andrew I. Pickering – Research Assistant

Luc Rainville – Oceanographer IV

Eric C. Rehm – Predoctoral Research Associate I

Thomas B. Sanford – Principal Oceanographer; Professor, Oceanography

Nancy J. Sherman – Administrator

Geoffrey B. Shilling – Engineer IV

Avery C. Snyder – Engineering Technician I

David P. Winkel – Oceanographer IV

Kai-Chieh Yang – Predoctoral Research Associate I

Shuang Zhang – Research Assistant

Zhongxiang Zhao – Oceanographer III

Polar Science Center

Axel J. Schweiger – Chair; Oceanographer IV

Knut Aagaard – Principal Oceanographer; Professor, Oceanography

Roger H. Andersen – Senior Mathematician

Joshua D. Carmichael – Predoctoral Research Associate I

Wendy S. Ermold – Physicist III

Andreas Heiberg – Principal Engineer

Lisa A. Isozaki – Administrator

James M. Johnson – Senior Field Engineer

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

Karen Junge – Oceanographer IV

Kristin L. Laidre – Oceanographer IV

Bonnie Light – Physicist IV; Affiliate Assistant Professor, Atmospheric Sciences

Ronald W. Lindsay – Senior Physicist

Mari S. Litzenberger – Program Operations Specialist

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

Richard E. Moritz – Principal Oceanographer

Mark L. Ortmeyer – Oceanographer II

Ana Cecilia Peralta Ferriz – Predoctoral Research Associate I

Ignatius G. Rigor – Senior Mathematician

Kay A. Runciman – Mathematician III

Benjamin E. Smith – Physicist IV

Michael Steele – Senior Oceanographer

Harry Stern – Senior Mathematician

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 Associate Professor, Oceanography

Yanling Yu – Oceanographer IV

Jinlun Zhang – Senior Oceanographer

ADMINISTRATIVE & TECHNICAL SERVICES

Business & Administration

William T. Bakamis – Associate Director, Business & Finance

Financial Information Systems

Larry C. West – Senior Computer Specialist

Financial Management

Rebecca M. Barnett – Program Coordinator
Ashley J. Chambers – Fiscal Specialist I
Anne L. Clark – Administrator
Sandra Y. Duong – Fiscal Specialist I
Becky E. Harrison – Senior Computer Specialist
Anthony J. Nice – Administrator, Program Operations
Donald Obcena – Fiscal Specialist I
Hien D. Tran – Manager
Julia Yeh – Fiscal Specialist II

Grant & Contract Administration

Elroy J. Carlson – Administrator
William E. Preiss – Administrator

Human Resources/Personnel

Linda M. Marsh – Program Operations Specialist

Purchasing & Property Control

Samantha D. Auflick – Fiscal Specialist II
Zale R. Carroll – Fiscal Specialist II
Roberta Hollowell – Fiscal Specialist II
Thomas A. Kerrigan – Fiscal Specialist II
Nicholas A.L. Plemel – Fiscal Specialist II
Tina M. Stremick – Fiscal Specialist II
DeAnn M. Wells – Manager

Resources

Gordon K. Glass – Department Head

Building & Safety Services

Jim Fahey – Manager
Oliver R. Hartman – Maintenance Supervisor II
Dale K. Johnson – Maintenance Mechanic II
Stuart R. Woolfield – Maintenance Mechanic II

Distributed Computing Services

David D. Fetrow – Senior Computer Specialist
Ray A. Glennon – Senior Computer Specialist
David D. Lee – Student Helper
Adam L. Morehead – Senior Computer Specialist
James A. Stroud – 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

(Machine Shop, cont'd.)

Patrick T. McCrory – Instrument Maker Lead
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 July 2009

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