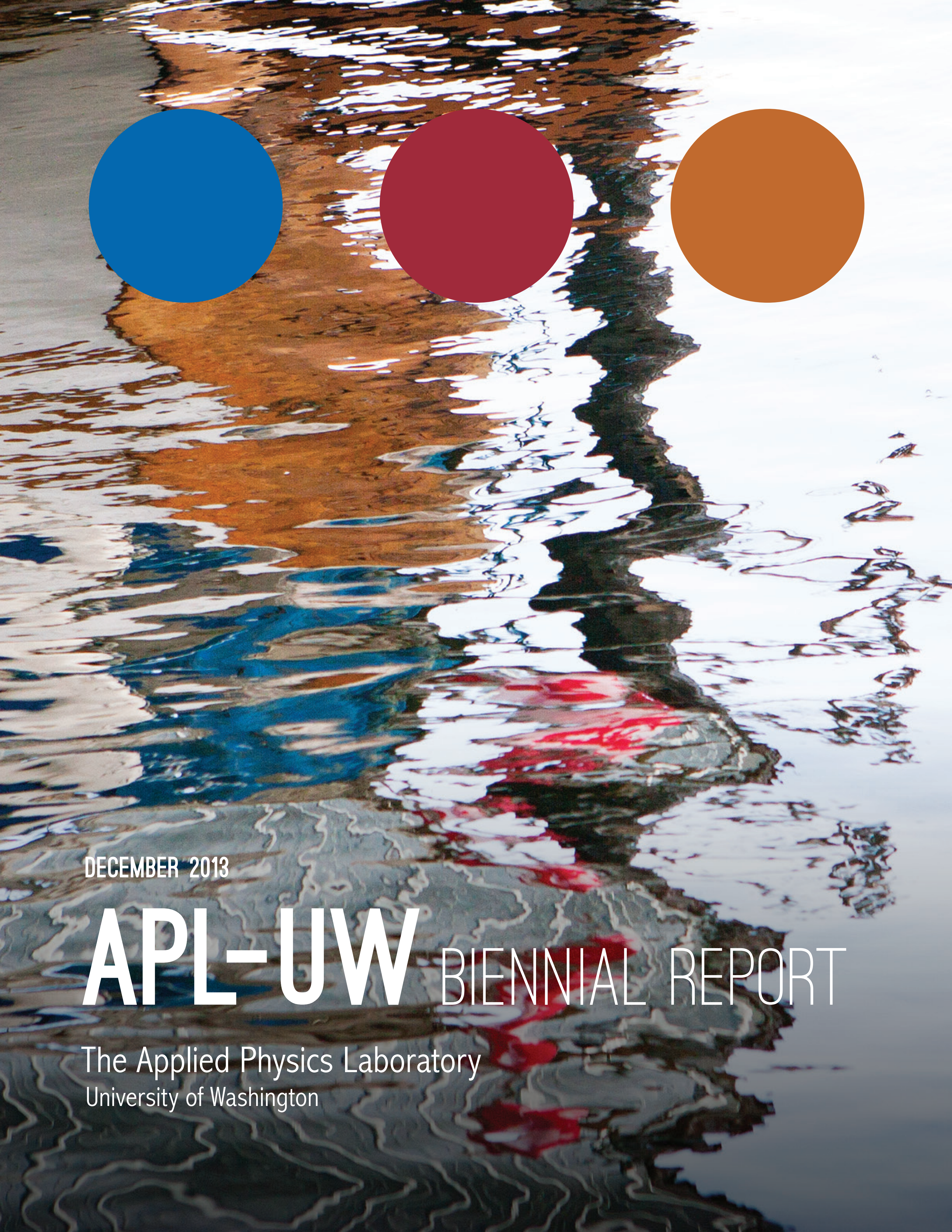

DECEMBER 2013

APL-UW BIENNIAL REPORT

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welcome

Recent years have been productive ones for APL-UW, despite added challenges of annual uncertainties in federal budgets, delays in research funding, and increasing sponsor-mandated burdens on our researchers. We continue to advance the leading edge of discovery and invention related to the dynamics of ocean environments, acoustic and electromagnetic sensing, environmental and information systems, and electronic and photonic systems. These advances have contributed to the prosperity of our region, the defense of our nation, and the understanding of our global environment. Research programs and field experiments conducted worldwide by Laboratory staff this past biennium surpassed previous campaign numbers and show a growing international component. A small sampling of the Laboratory's exciting work in science and technology is presented in this biennial report.

Grant and contract awards received by APL-UW this past biennium remained robust, with total biennial funding approaching the level of the previous (record-breaking) biennium. Research funding for fiscal year 2012 reached an all-time annual high, and the Laboratory continues to maintain a diverse portfolio of research sponsors. Our recent research has been well recognized, through numerous media stories and peer-reviewed scientific publications, including several in the prestigious journals *Science* and *Nature*.

In addition to conducting scholarly research, one of APL-UW's strategic goals is to more ably bring research into application, through better integration of basic and applied research and more effective collaboration with industry. Accelerating the transfer of science and technology enables us to more readily address urgent challenges we face today. Technology transfer was exceptional over the last biennium, and in fiscal year 2012, for example, we had 27 invention disclosures, 24 patent applications, 5 patents issued, and 14 commercialization licenses and agreements. APL-UW continues to create spin-off companies, maintaining a pace of one spin-off (on average) per year since 2000.

Within the past decade and prior to this past biennium, much of the focus of APL-UW's leadership has been on establishing new and significant research programs and on improving the Laboratory's infrastructure, and we had great success. In the latest biennium we took advantage of these gains and focused on our most important asset, our people. In this vein, we recently completed a management review and reorganization to improve efficiency, communication, and balance within the Laboratory. We also began the implementation of our new ten-year strategic plan, with an initial emphasis on recruitment of new talent to replenish our personnel pipeline, and on improving communication and optimizing administrative operations within the Laboratory.

APL-UW continues to pursue its vision, *to be a world-renowned center of excellence in cutting-edge research and development that integrates across the spectrum of basic research to applied science, serves as a trusted leader informing decision makers, and adapts to effectively address time-critical and long-term needs of our country, our university, and our world.* Our truly extraordinary staff, the solid support of the University of Washington, and the continued commitments of the U.S. Navy and our other federal sponsors have enabled the execution of this vision and our prolonged success.

Jeff Simmen

jeffrey simmen, apl-uw executive director

honors + awards

LAWRENCE CRUM received the Acoustical Society of America's prestigious Gold Medal in 2013—the ASA's highest award for distinguished leadership in the field of acoustics and service to the society.

IAN JOUGHIN received the 2012 Louis Agassiz Medal. The award was established by the Division on Cryospheric Sciences of the European Geophysical Union in recognition of Agassiz's scientific achievements. It was presented to Joughin for his outstanding contributions to understanding the dynamics and mass balance of polar ice sheets (see **clocking greenland's glaciers**, page 19) using differential synthetic aperture radar interferometry and other techniques he has helped to pioneer.

ROBERT SPINDEL was selected for the 2012 IEEE Ocean Engineering Society Distinguished Service Award. He was lauded for his sustained efforts to champion the society as an essential part of the oceanography community, serving as an associate editor of the *IEEE Journal of Oceanic Engineering* for 32 years, and chairing three OCEANS conferences.

TODD HEFNER has been awarded the 2013 A.B. Wood Medal by the Institute of Acoustics, a prize presented to a young acoustician for distinguished contributions to the application of acoustics. It is presented in alternate years to persons residing in the United Kingdom and United States of America or Canada.

center (l to r): jeffrey simmen; frank herr, head, office of naval research ocean battlespace sensing department; chief of naval research rear admiral matthew l. klunder

MATTHEW ALKIRE was awarded a 2012–2013 Fulbright U.S. scholar grant. He traveled to Longyearbyen, Norway, to collect ice cores in Kongsfyorden during January–March 2013. He is working to determine if glacial meltwater can be detected in sea ice, which is a complicated question because of the release of brine from sea ice during freezing.

PETER DAHL was elected Acoustical Society of America Vice President and VERA KHOKHLOVA was elected to the society's executive council; both began terms in May 2012.

JAN NEWTON has been named Co-Director of the Washington Ocean Acidification Center. Created by the governor and state legislature, and the first of its kind in the nation, the center will coordinate ocean acidification research and monitoring efforts in state waters. The mission is to improve forecasts of where and when corrosive waters may occur and to create mitigation strategies.

APL-UW received visits by administrators and program managers from the Office of Naval Research, Defense Advanced Research Projects Agency, Defense Threat Reduction Agency, National Oceanic + Atmospheric Administration, National Science Foundation, Naval Sea Systems Command, Office of Naval Intelligence, and Space + Naval Warfare Systems Command. In September 2013 the National Science Board, a 25-member group appointed by the President, held a public meeting at the University of Washington. While on campus, APL-UW engineers gave board members a hands-on experience with the technologies under development for the regional cabled observatory of NSF's Ocean Observatories Initiative (see **vision takes form**, page 12).

Distinguished visitors during 2012–2013 included Chief of Naval Research REAR ADMIRAL MATTHEW L. KLUNDER and Assistant Secretary DAVID W. MILLS, U.S. Department of Commerce Bureau of Industry and Security. University of Washington President MICHAEL K. YOUNG and Provost ANA MARI CAUCE visited and were briefed on the Laboratory's core research areas, ambitious field experiments around the globe, and significant contributions to the University of Washington's education mission.

what we do...

advance scientific discovery + invention
enhance national security
educate future generations of scientists + engineers

APL-UW serves society by contributing new knowledge and technology to the national defense enterprise, industry, public policy makers, and academia. A unique research organization established in 1943 at the request of the U.S. Navy, we have provided continuous access to the highest levels of academic expertise in scientific research and engineering to address Navy-specific problems.

The Laboratory's broad and deep experience in undersea science and technology is a significant reason why APL-UW is one of only five Department of Defense-designated University Affiliated Research Centers (UARCs) having long-term, large-scale, formal connections to the U.S. Navy. Expertise spans acoustic and remote sensing, ocean physics and engineering, medical and industrial ultrasound, polar science and logistics, environmental and information systems, and electronic and photonic systems.

highlights

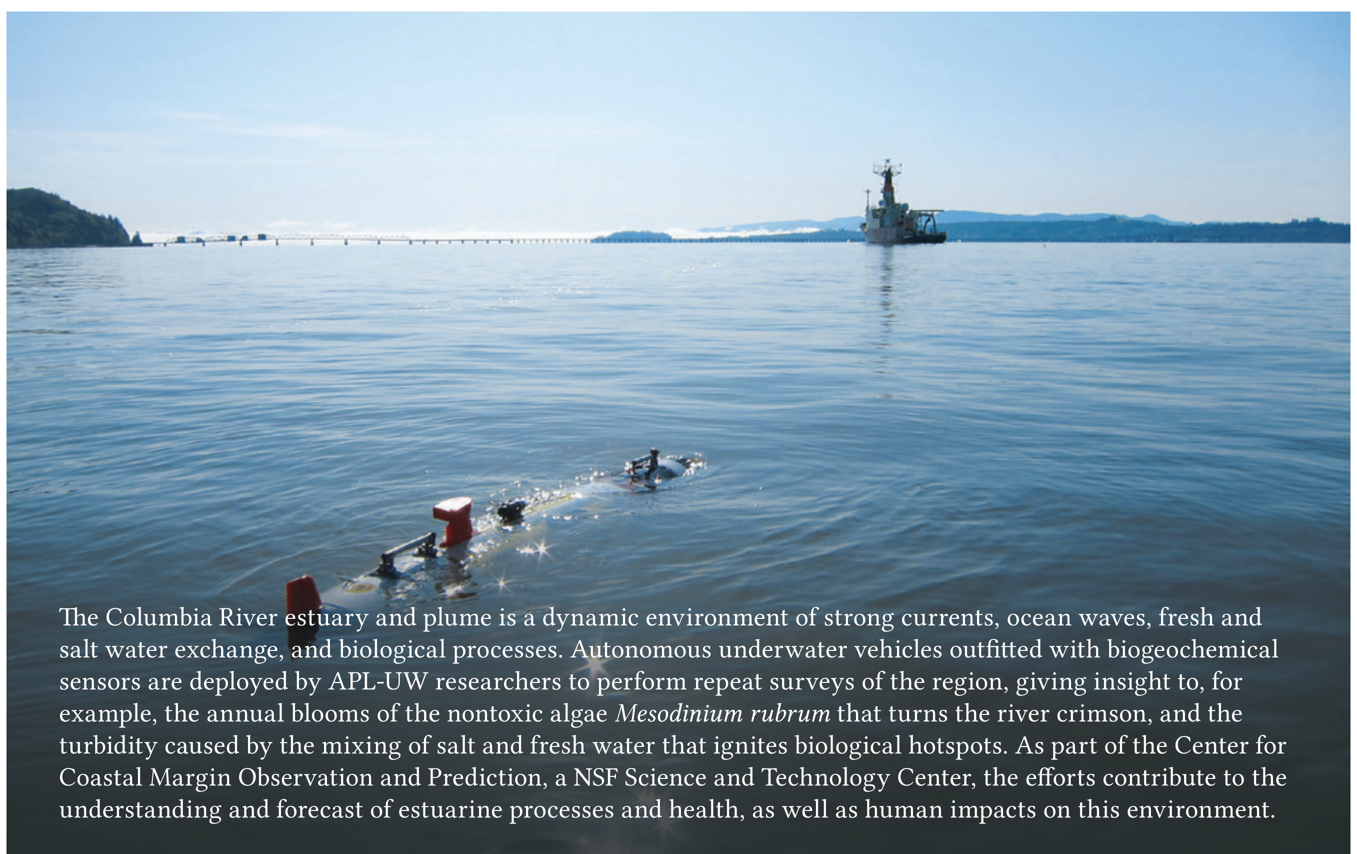
The satellite *Aquarius* circles pole-to-pole 400 miles above the Earth, measuring salinity in the top 2 cm of the ocean's surface. Rainfall on the ocean creates a lens of less dense fresh water overlying the saltier ocean, potentially introducing measurement errors. To correct and calibrate the satellite measurements and understand how surface readings relate to salinity at depth, APL-UW researchers have instrumented the R/V *Thompson* for through-the-hull salinity measurements on its worldwide expeditions and are deploying a Laboratory-designed and developed towed sea surface salinity profiler from other research vessels of opportunity.

For decades the prevailing understanding of the annual phytoplankton bloom in the North Atlantic was that strengthening sunshine in spring warms the surface, creating stratification, which in turn holds the phytoplankton near the sunlit surface where they grow. Intensive field observations and modeling efforts, however, reveal that eddies create stratification up to several weeks before sunlight has warmed the surface layer. Reported in the AAAS journal *Science*, eddies can trigger colder, denser waters to the north to slip under the warmer, lighter waters to the south. This creates stratification, initiating the North Atlantic bloom and explaining much of its non-uniformity.

A two-year and counting continuous record of wind and wave observations at Ocean Weather Station P in the North Pacific is now available thanks to a waverider buoy deployed by APL-UW researchers. Data analysis shows that wind-driven waves rapidly and continually adjust through wave breaking to maintain an energy balance with the winds. This equilibrium persists most of the time; it is only the small difference between the wind energy into the ocean and the energy dissipated through breaking that creates the evolving wave field over the North Pacific Ocean.

Sitting on the ocean bottom over one mile deep, COVIS (Cabled Observatory Vent Imaging Sonar) has watched with acoustic eyes a hydrothermal vent complex on the Juan de Fuca Ridge continuously since September 2011. Connected to the power and communications backbone of the NEPTUNE Canada observatory,

listening to narwhals + spying beluga whales off west greenland



The Columbia River estuary and plume is a dynamic environment of strong currents, ocean waves, fresh and salt water exchange, and biological processes. Autonomous underwater vehicles outfitted with biogeochemical sensors are deployed by APL-UW researchers to perform repeat surveys of the region, giving insight to, for example, the annual blooms of the nontoxic algae *Mesodinium rubrum* that turns the river crimson, and the turbidity caused by the mixing of salt and fresh water that ignites biological hotspots. As part of the Center for Coastal Margin Observation and Prediction, a NSF Science and Technology Center, the efforts contribute to the understanding and forecast of estuarine processes and health, as well as human impacts on this environment.

COVIS is measuring the geometry and discharge rates of hydrothermal plumes. Over its years of operation, there has been no detectable degradation in sonar performance. COVIS data are showing scientists that the plumes rising from the vents respond to tidal oscillations and ambient ocean currents. The energy from surface winds during storms, which can propagate to the deep ocean by internal waves, also influences the heat flux, and chemical and biological dispersals from the plumes.

An extremely powerful and extensive storm in August 2012 over the Arctic Ocean has been implicated in causing the record-breaking lowest sea ice extent observed that September. This new record was 18% below the previous set in September 2007. Polar Science Center researchers report that the cyclone's intense winds caused rapid ice movement, which stirred a relatively warm near-surface layer of water up under the ice, where it quadrupled the rate of bottom melt. Though the cyclone had dramatic immediate impacts, scientists conclude that the 2007 sea ice extent minimum record would have been broken in September 2012 even if the storm had not occurred.

Because of the efforts of APL-UW polar scientists, sea ice volume is becoming an accepted metric to describe the declining ice cover in the Arctic Ocean. PIOMAS, the Pan-Arctic Ice Ocean Modeling and Assimilation System, uses limited observations to compute ice volume from 1980 to 2012. The often controversial estimate that the Arctic had lost about 80% of its summer sea ice volume over this period has now been confirmed by the latest ice thickness measurements returned by the CryoSat-2 satellite. In fact, the PIOMAS estimates may have been too conservative.

Rapidly changing sea ice conditions in the Arctic require observation platforms suited to the seasonal ice cover. 'UpTempO' buoys, designed at APL-UW, focus on ocean temperature in the euphotic (light-influenced) surface layer. These relatively inexpensive ocean buoys can be deployed in open water or ice-covered conditions and survive an annual melt and freeze-up cycle. Each buoy's 60-m-long string of thermistors measures the magnitude of warming and telemeters data via an Iridium link.

Visual grading of burn wounds by experienced surgeons is 65–70% accurate. Recent research at APL-UW has applied terahertz spectroscopy methods to the problem. Terahertz waves are sensitive to post burn edema—overall water concentration in the skin—as well as density of skin structures—microvascular capillaries, hair follicles, and sweat glands. Combined analysis of these two factors shows promise to improve the differentiation of partial-thickness burns that will heal naturally from those that require surgical intervention.

A Center for Industrial and Medical Ultrasound team is working to develop a dedicated ultrasound system for non-invasive, real-time, image-guided repositioning of kidney stones. Ultrasonic detection and propulsion of stones has caught the attention of the urologist community. The research team presented findings at the American Urological Association annual meeting in 2012, and in 2013 was invited back to give a 'state-of-the-art' lecture and demonstrations that garnered overwhelming, positive responses. In fall 2013 the team and their urologist colleagues received Food + Drug Administration approval to begin human clinical studies.

APL-UW researchers developed and, working with the UW Center for Commercialization, have recently licensed a Raman spectroscopic immersion probe that determines molecular information from solids, liquids, and gases. It uses a spherical sapphire lens as the optical focusing element and the sampling interface, greatly increasing precision over traditional spectroscopic immersion optics. Compact and durable, the probe is used in the pharmaceutical, oil and gas, petrochemical, food, environmental, and polymers industries.

The Center for Oceanographic Visualization and Command (COVAC) is a new capability for APL-UW. With over one dozen contiguous, wall-mounted displays, desktop workstations, and nine independent servers, the center can put a wide range of information and visuals into a single view to aid researchers and decision makers. Tasks that require simultaneous visualization of environmental and engineering data streams from numerous instruments and sensors, such as the Northwest Association of Networked Ocean Observing Systems (NANOOS) and the Ocean Observatories Initiative Regional Scale Nodes (RSN), are primary COVAC users.

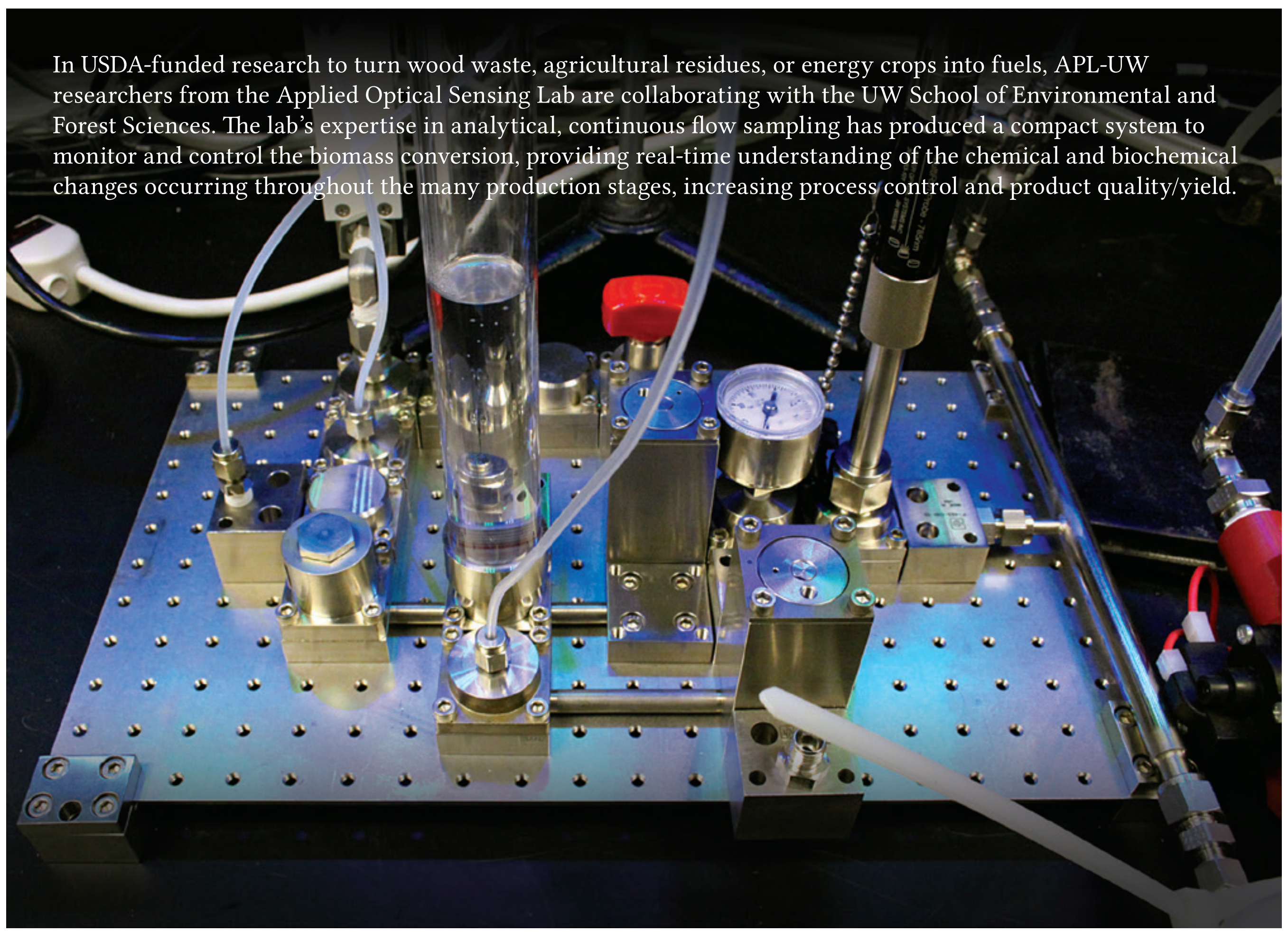
APL-UW engineers have recently completed a redesign, production, and delivery to the U.S. Navy submarine fleet of enhanced data recording systems. Modern submarines host a wide range of sensors, especially acoustic sensors. Data collected by them are used for tactical and analytical purposes during and after a mission. The re-engineering by APL-UW of data recording systems for every submarine in the U.S. fleet resulted in greater bandwidth and data throughput, as well as enhanced signal processing tools, reliability, and redundancy.

Research into the rapid development and deployment of medical countermeasures against national security threats marks a new collaboration for APL-UW scientists with the UW Institute for Protein Design. The vision is to respond to a declared emergency with a synthesized protein therapeutic within six months of threat identification. The UW initiative is planning how to achieve such a rapid response using integrated design, manufacturing, and distribution tools within the confines of existing regulations.

X-ray spectroscopy expertise at APL-UW is being applied to the problem of nuclear waste disposal. With Swiss and French sponsorship, a prototype spectrometer has been developed that is small enough to fit through boreholes and achieves 10 parts per million detection limits for non-radioactive nuclear waste products. During a 10-year-long experiment it will measure the migration of the most mobile of these products, iodine, through indurated clay rock in real time and at high spatial resolution to verify reactive transport models.

Expertise in developing and transitioning autonomous underwater vehicles at APL-UW stretches back to the late 1950s. Now engineers are working on an Office of Naval Research program to develop algorithms and software to enable vehicles to avoid obstacles on the surface and underwater. These capabilities will soon be tested on an autonomous vehicle platform in a realistic underwater environment. The project is central to APL-UW's continuing focus in autonomous systems, which are fast finding their way into everyday life.

This past August, APL-UW hosted the 8th consecutive annual Office of Naval Research Joint Active–Passive Sonar Signal Processing Peer Review. Participants from about 40 organizations and government agencies attend each year. The three-day review features presentations by ONR program managers and U.S. Navy representatives, as well as presentations by researchers supported by the ONR Undersea Signal Processing Program. The information exchange and candid technical discussions are of great value to this area of U.S. Navy-relevant research and development.


In USDA-funded research to turn wood waste, agricultural residues, or energy crops into fuels, APL-UW researchers from the Applied Optical Sensing Lab are collaborating with the UW School of Environmental and Forest Sciences. The lab's expertise in analytical, continuous flow sampling has produced a compact system to monitor and control the biomass conversion, providing real-time understanding of the chemical and biochemical changes occurring throughout the many production stages, increasing process control and product quality/yield.


Scientists from APL-UW set out for the North Pacific Ocean in fall 2012 in search of rough weather — intense winds and large waves. During two weeks on fully developed seas they measured waves, wind, and turbulence generated by wave breaking to understand the energy cascade that may ultimately improve open ocean wave forecasts.

vision takes form

regional cabled observatory infrastructure installation a success

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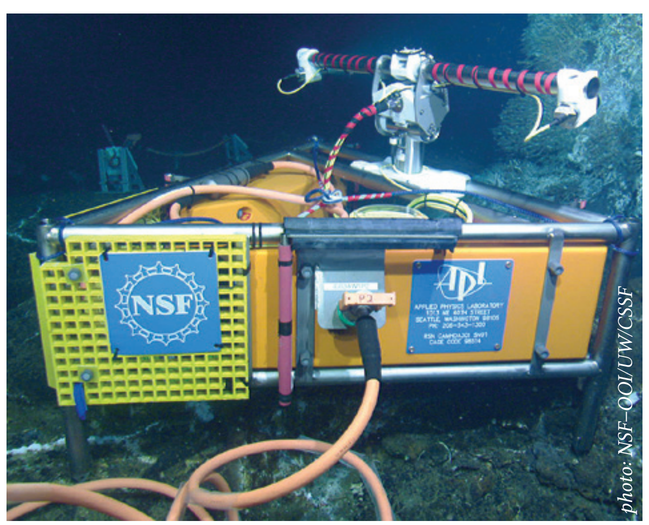


high-definition video camera system

Teams of scientists and engineers at the University of Washington have been pursuing a grand vision to propel oceanographic sciences into the future through the installation of the world's largest undersea observatory: the Regional Scale Nodes component of the National Science Foundation Ocean Observatories Initiative. A power and communications network stretching hundreds of miles offshore the Pacific Northwest will host remote-controlled instruments and high-definition video cameras, shifting fundamentally how humans interact with and study the ocean.

APL-UW engineering expertise is a big part of making this vision of "plugging into" the deep ocean a reality. "This concept of a real-time observatory will change what we do as ocean engineers, what we will learn to do, and what ocean scientists can do with these systems now and in the future," explains Gary Harkins, Chief Engineer on the project. The successful VISIONS'13 cruise on the R/V *Thomas G. Thompson* last summer made large strides in infrastructure installation needed to bring the observatory on line.

Laboratory engineers have been designing and constructing network components over the past four years. In 2011 and 2012, 540 miles of 'backbone' fiber-optic/power cables were laid on the seafloor and connected to the shore station at Pacific City, Oregon, and seven primary nodes that serve as terminals and jumping off points for the distributed network were set in environmentally benign locations.

Laboratory teams worked in high gear to ready 19 miles of secondary power and communications cable and secondary nodes (junction boxes) for the VISIONS'13 cruise. These components are the extension cords and sockets that join the backbone infrastructure to all of the instruments at places of scientific interest. There are five major study sites at Axial Seamount, an active undersea volcano 300 miles off Astoria, Oregon, and Hydrate Ridge, the site of massive subseafloor deposits of methane gas-rich ice about 60 miles off Newport, Oregon.

a secondary node ready for deployment by *ROPOS*, operated by the canadian scientific submersible facility

"

To turn it on, have the systems work flawlessly, and to get data immediately was exhilarating.

"

Each carefully mapped run of cable to link primary and secondary nodes and instruments had to be sectioned, terminated with connectors that could be coupled in seawater under crushing pressure, and spooled on specially designed drums so that it could be laid out by *ROPOS*, the remotely operated vehicle that proved to be the workhorse of the installation expedition.

Systems Engineer Dana Manalang recalls, "There was so much planning in place before the cable left the ship, and even before it was loaded on the ship. When it was spooled, it was marked at intervals so that we would know exactly how much cable had been laid out as we viewed it through the *ROPOS* camera working one mile below the *Thompson*."

Electronics for the secondary nodes were designed to interface with the variety of instruments envisioned to operate on the observatory over its lifetime. Tests of the integrated node and instrument(s) system completed in the lab were repeated aboard the *Thompson* before components were flown to the bottom by *ROPOS*. "Once they were deployed we powered them up through *ROPOS* and ran the systems status checks to make sure everything was working as expected," recalls Electrical Engineer James Tilley.

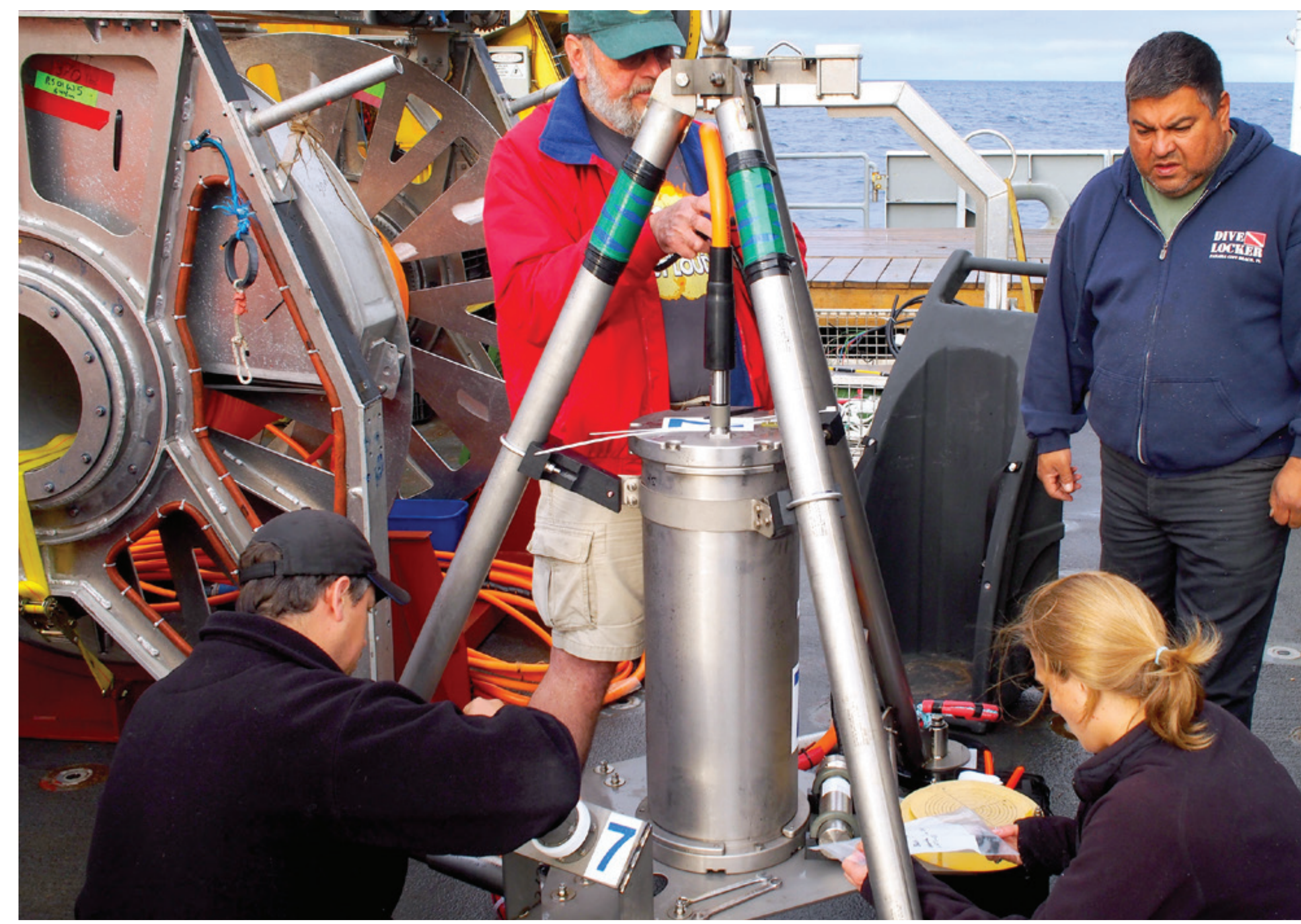
One of the high points of VISIONS'13 came after the deployment of a junction box connected to two seismometers and a bottom pressure tilt instrument. Within a half hour of powering up the instruments an earthquake was recorded. Manalang describes, "That was the most integrated of the networks put down so far, with long cable runs from a primary to a secondary node and to the instruments. To turn it on, have the systems work flawlessly, and to get data immediately was exhilarating."

The engineering and science teams also celebrated the successful installation of the APL-UW designed high-definition video camera system in the caldera of Axial Seamount. The system's camera, lights, pan/tilt and attitude sensors, and integrated junction box will provide uncompressed 1080 video resolution of an active high-temperature hydrothermal vent called Mushroom.

Lead engineer on the camera project, Russ Light, remarks, "This was the first time a high-definition camera has been placed on the ocean floor that is capable of delivering the video signal in an uncompressed format. To go from the standard video output of the camera into a format that can be transported over the Internet-style 10 GB/second fiber optic network was a major challenge. That kind of hardware didn't exist until now."

Installation began with *ROPOS* spooling out 2.5 miles of cable directly across the volcano's caldera, and on a subsequent trip, the camera system was flown from the *Thompson* to the seafloor. To test the camera, a wet-mate connection and 30 feet of power and communications cable was run by *ROPOS* between the camera and itself. Powered by *ROPOS* and its tether to the *Thompson*, lights, pan/tilt, focus, and zoom features were tested. Images streamed through *ROPOS*, up its cable to the ship, and then beamed to a satellite and back to the UW for transmission over the Internet. Mission accomplished!

Successes celebrated, the science and engineering teams are preparing for VISIONS'14. The balance of the infrastructure that will link the secondary nodes with 100 sensors of 33 different types will be installed and tested next summer. The entire observatory will be commissioned in early 2015, providing a continuous 24/7/365 Internet connection to the deep ocean for at least 25 years.



depth seen from height

airborne remote sensing for littoral applications

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Gordon Farquharson
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Seth Zippel

sponsor

Office of Naval Research

deploying a SWIFT

DARLA is the Data Assimilation and Remote Sensing for Littoral Applications project, which is a 5-year collaboration among APL-UW, Oregon State University, and the Woods Hole Oceanographic Institution. DARLA is funded by a Department of Defense Multidisciplinary University Research Initiative administered by the Office of Naval Research.

The ocean surface, a surf zone, and a ribbon of sandy beach may be the most prominent features visible when flying over the coast, but looking more closely, it may be possible to make out waves shoaling on a sandbar, surface boils caused by currents and turbulence, or plumes of differing water colors. Can these views from on high also discern the speed and direction of currents or probe below the surface, measuring processes within the water column, and even the depth and shape of the bottom? In a collaborative research program known as DARLA sponsored by the Office of Naval Research, APL-UW scientists and engineers are developing the technologies to help infer this information from measurements of the water's surface.

Bathymetry is the key variable to guide navigation as well as to make predictions of currents and waves in the nearshore region. A lightweight and inexpensive airborne interferometric synthetic aperture radar (SAR) and thermal infrared cameras developed at APL-UW are providing measures of surface velocity and temperature in coastal regions. When used to initialize and constrain numerical model simulations of nearshore processes and physical parameters—the dynamic wave field, currents, turbulence, mixing, and bathymetry—a complete picture of this complex environment can be formed from these aerial snapshots.

Over the past several decades, research has focused on understanding littoral processes, for example, the effects of waves on coastal currents. Now researchers are considering an additional complicating physical process often encountered at the coast—flows from tidally-driven inlets or discharges from rivers.

new river inlet, north carolina

When U.S. Navy forces must navigate near the coast or up a river's mouth, especially where there are no recent measurements, they need to be aware of hazards, and simply whether it is deep enough to operate a vessel. A small plane or unmanned aerial vehicle flown over a large area in a short time carrying a remote sensing system that can return these measurements is a capability with great potential.

The APL-UW SAR and infrared systems have been flown in experiments over the New River Inlet, North Carolina, and the mouth of the Columbia River, Washington and Oregon. The SAR has two receiving antennas, configured with one trailing the other. At some time, the leading antenna measures the distance to a point on the surface. A short time later, the aircraft advances so that the trailing antenna is located where the leading antenna was, measuring the distance to the same point on the surface. The difference in the distance between the measurements is the change in position of the surface. Dividing this value by the time between the measurements estimates the surface position's rate of change—its velocity.

At the New River site, an inlet with flows driven by the tide, the aerial measurements of velocity and temperature discerned two navigable channels, one older and shallower, and the second deeper and maintained by dredging. The mouth of the Columbia River is a much more complex environment with very strong river currents meeting Pacific Ocean swell and wind driven waves. Especially at ebb tide the river flow meets opposing waves propagating toward the mouth; the waves steepen and break at the interface, setting up the infamous navigation hazards of the Columbia bar.

SWIFT drifters, an autonomous platform that measures waves, winds, and turbulence from wave breaking at the air–sea interface, also developed at APL-UW, are providing in situ measurements in these collaborative experiments. They are used to calibrate and validate the measurements inferred by the remote sensing platforms and to add input to the model simulations.

The observations made by the airborne and drifting platforms are unique because the hazardous conditions at the bar hinder ship-based measurements. Drifters are launched on ebb tides from the estuary in timed sequence so that as the airborne sensors take snapshots from above, the buoys are spread out in many locations on the ocean surface below. The drifters cover a large area over several hours and the airborne sensors survey a large area over several minutes, compositing a rich picture of structures and processes.

The dramatic processes at the Columbia bar are fleeting in time and space. When the tide is at maximum ebb, the breaking waves can appear as a shoal or beach surf zone, even though the water is up to 20 meters deep. Because the river current exits the mouth as a narrow jet, the zone of river current–ocean wave interaction is confined to a sharply defined area.

The overall goal is to improve predictions of nearshore processes using data assimilative modeling, in which observations from multiple sources are incorporated into a numerical model of a geophysical system. This type of modeling is done routinely for weather prediction, where in situ measurements of the atmosphere are combined with remote sensing (radar) measurements to drive forecasts. In the case of an estuarine river, the accuracy of the model predictions of surface velocity and temperature fronts depends largely on the accuracy of the bathymetry, which is often the unknown quantity of interest. DARLA will help determine the extent to which data assimilation modeling—initialized and constrained with accurate remote sensing and in situ measurements—can infer bathymetry that can be used for navigation.

clocking greenland's glaciers

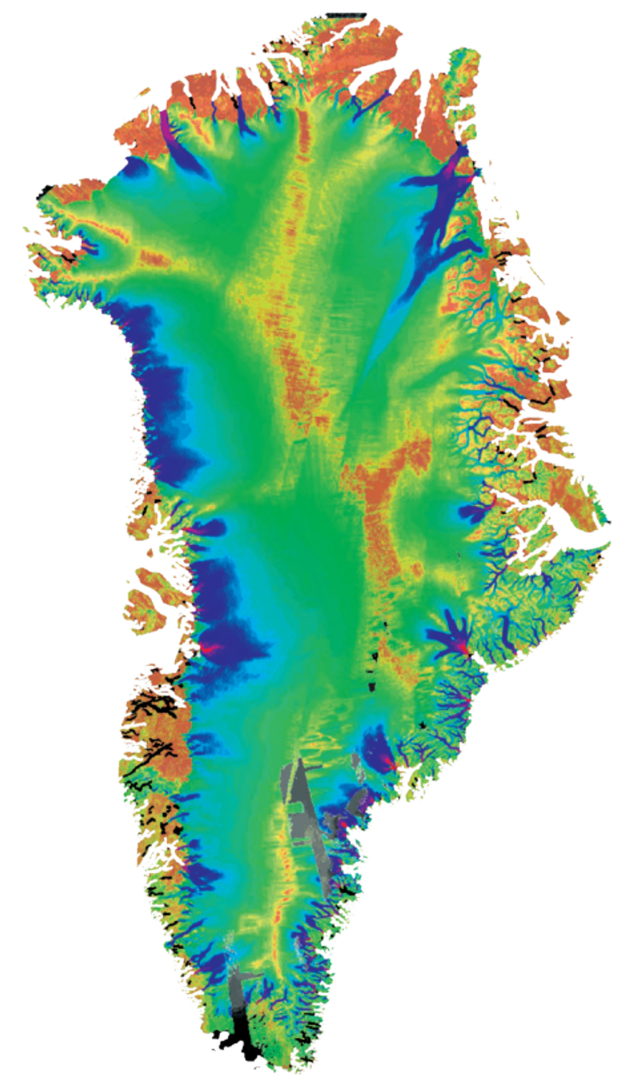
ice-sheet-wide velocity mapping

researchers

Ian Joughin
Twila Moon
Benjamin Smith

sponsors

National Aeronautics + Space Administration
National Science Foundation



Many of Greenland's largest glaciers were slipping twice as fast through fjords. Videos of enormous ice shelves falling into the sea spread quickly over the Internet. NASA reported in July 2012 that nearly the entire surface of the massive ice sheet was melting. While making dramatic headlines, these events are only part of the story. APL-UW researchers have painstakingly collected and analyzed over a decade of satellite observations to clock the changing velocities of 200 individual Greenland glaciers. Though they are moving about 30% faster than at the turn of the century, this acceleration is mostly for the fast-moving marine-terminating glaciers; others remained steady or even slowed.

"Glaciology has traditionally been a data-limited science. The speed up of the largest glaciers was not even discovered until a decade ago," notes Ian Joughin of the APL-UW Polar Science Center. Ice sheet observations made by sensors on satellites have filled the gap. Joughin pioneered and perfected satellite radar interferometry methods to map glacier velocities. Interferometry involves comparing two images from a radar carrried on a satellite to generate maps of surface deformation, with centimeter precision, over days to months. Even though the ice sheet may seem a huge, white, featureless expanse, the radar signal can differentiate surface patterns, and with some computer processing detailed velocity maps are drawn.

> Glaciology has traditionally been a data-limited science.

The APL-UW research team stitches together many images from several satellites to map nearly the entire Greenland ice sheet, and makes all of these data available to the glaciology community through the National Snow and Ice Data Center. “Now we have over one decade of velocity measurements, which is a tremendous amount of data considering we had nothing before,” Joughin says. Over broad areas of the west and southeast there has been about a 30% increase in velocity during the first decade of the 21st century, but most notable from the observations is the range of behaviors on individual glaciers. Even glaciers of similar type, size, and locale have differing velocities from year to year and from each other.

Physicist Benjamin Smith explains that, “Glaciers have periods of activity and inactivity. Some sped up dramatically in 2004–2005 and then slowed down and gained some mass back, and have sped up again to a lesser extent since then.” Velocity is influenced by fjord length and width, the bed topography, glacier terminus position, and lubricating seasonal injections of surface melt water to the bed, among others. “So to really say what the ice sheet is doing, you have to watch glaciers continuously. You have to see what it’s doing year by year and month by month to get the picture for each glacier,” Smith concludes.

This variability in glacier dynamics makes it difficult to address how they may respond under future warming climate scenarios. Previous predictions of the melting ice sheet’s impact on global sea level rise have been wide-ranging and controversial. The last report from the Intergovernmental Panel on Climate Change, in 2007, predicted only modest contributions from the ice sheets to sea level. Before it had even been published, however, observed outlet glacier velocity changes were rapid and large—a doubling within one year.

With the advantage of a longer and more complete data record, APL-UW scientists are constructing models for particular glacier basins. And if the computer simulations can reproduce observed behaviors at this scale, then they have confidence that the physics driving the model is correct. This allows them to test a range of glacier responses to various forcing mechanisms: if the atmosphere or ocean warms by a certain amount in a particular place, is the ice sheet sensitive to that input?

> . . . to really say what the ice sheet is doing, you have to watch glaciers continuously.

Coupling this understanding of glacial dynamics to global climate models, which operate at resolutions larger than many of the largest and fastest marine-terminating glaciers but are nonetheless used to predict the global impact of the melting ice sheet, remains a challenge. On predictive power, Joughin cautions, “We’re getting a long enough record now that we have a little more confidence. But extrapolations will always be hard because if you base them on observed behavior over the past 10 years, that accounts for climate forcing on that time span, but we’re looking at climate forcing far in excess of the past decade over the next century.”

seeking order in cluttered spaces

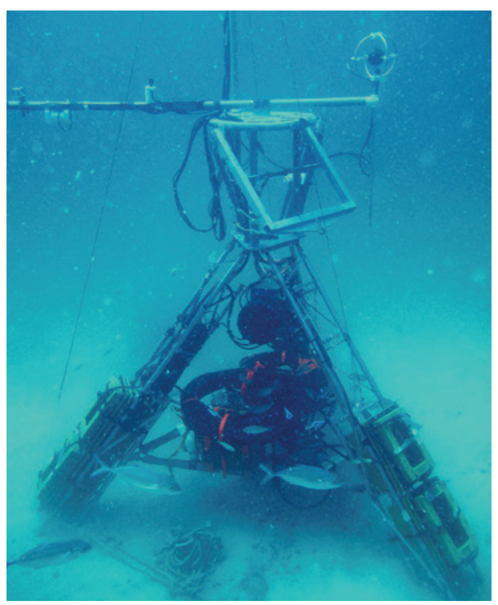
trex13: the target and reverberation experiment 2013

researchers

Peter Dahl
Aubrey España
Todd Hefner
Steven Kargl
Dajun Tang
Eric Thorsos
Kevin Williams
Jie Yang

sponsors

Office of Naval Research
Strategic Environmental Research + Development Program



The Target and Reverberation Experiment (TREX13) was a six-week, international field program in early summer 2013 conducted in the coastal waters off Panama City, Florida. Experiments measured mid-frequency reverberation in a shallow water environment and probed the ability to detect and classify hazardous objects on the seafloor with synthetic aperture sonar.

Sonar is used to detect and identify objects in the water column and resting on the seafloor. A dangerous problem for U.S. Navy operations is detecting and identifying the relatively inexpensive and easily laid anti-ship mines in shallow water. Nearshore regions also pose unique problems for sonar operations related to submarine detection—reverberation caused by the bottom and surface boundaries, and other environmental factors. Here, the many echoes that are NOT from hazardous objects can overwhelm the sonar system.

For APL-UW researchers and their collaborators, a fundamental science question translates to operational applications: What are the causes of the reverberation and is it possible to control or remove environmental false alarms to improve the detection and identification of real targets? The two foci for TREX13 are understanding how bathymetric features, surface waves, biologics, and oceanic processes in the water column impact mid-frequency (here, 1–10 kHz) acoustic propagation and reverberation in a nearshore environment, as well as how the echoes from targets themselves are affected by these environmental conditions.

The sources of environmental reverberation that compete with the target scattering are many—bottom and sub-bottom characteristics, the temperature profile of the water column, the surface wave field, bubbles injected at the surface by whitecaps, and fish schools. These were quantified along a 5-km range, where an omnidirectional acoustic source at one end and receiving arrays and recorders along the range measured acoustic propagation along the path and backscattering toward the source.

A target field of over two-dozen objects was laid and manipulated by research divers in various orientations. Important mine-like targets—proud, buried, or partially buried by the sediment—were interrogated at every angle and several ranges.

“

Our goal is to construct models of acoustic scattering from targets, simulating the experimental measurements as closely as possible.

”

The seafloor off Panama City has been well characterized in past experiments, and was chosen because it is considered as flat, featureless, and homogenous as possible. But researchers found that it is not a simple environment at all—mud patches, sand shoals, and shell deposits all contribute significantly to the measured reverberation. Another surprise sprung by the nearshore environment was the background noise created by fish and other organisms. Each day at sunset the noise increased, made a crescendo just before dawn, then went quiet suddenly at first light. Fish schools interfered with the target experiments too, sometimes blocking the acoustic interrogation of the target field completely.

In past work, APL-UW acousticians studied the characteristic acoustic scattering from mine-like targets at short range in the controlled environment of the Naval Surface Warfare Center test pond. For TREX13 the same experimental sonar system was installed on the seafloor to test whether their understanding of the targets' physics holds up when the targets are placed on a sediment–water interface that is driven by ocean waves and currents.

TREX13 results from the target field are very close to those obtained in the pristine, controlled conditions of the test pond. Most importantly, certain acoustic features that characterize each target are present. Mid-frequency sound creates resonances in the target, that is, the sound does not simply bounce off the target's surface, it excites the target volume to ring. The resonances that are robust at various grazing angles and ranges are especially important.

Even with exhaustive manipulations of the target field, it is not possible to consider every geometry experimentally. Physicist Aubrey España explains: “Our goal is to construct models of acoustic scattering from targets, simulating the experimental measurements as closely as possible. We have a good data set from the pond and we've expanded on that with more ranges, burial depths, and environmental clutter. We see these robust features—characteristic resonances that survive at different ranges and grazing angles—from the targets and use physical acoustics models to understand the key target physics driving these robust features.”

Capturing the essential physics allows the researchers to model the targets' acoustic response in nearly infinite scenarios, which can be used by algorithm developers to improve classification tasks during sonar operations.

intense mixing in the abyss

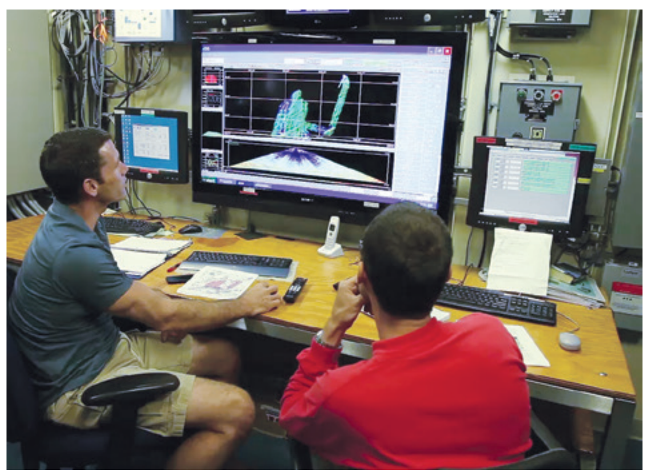
expeditions to the samoan passage

researchers

Matthew Alford
Eric Boget
Andrew Cookson
James Girton
Keith Magness
John Mickett
Zoë Parsons
Andy Pickering
Gunnar Voet

sponsor

National Science Foundation



Inspired by a data set collected near Samoa two decades ago and their search for 'mixing hotspots' in the world's oceans, APL-UW oceanographers are now amid a three-part expedition to map the rough channels of the Samoan Passage and measure the turbulent flows through it. The passage is a critical choke point nearly 5 km deep for the cold and dense Antarctic Bottom Water that flows slowly northward in the Pacific basin. Such encounters of abyssal flows with bottom topography occur in other locations around the world, but here in the Samoan Passage the local effects are especially dramatic and the global effects of significant consequence. The intense mixing during transit transforms the water, which goes on to fill much of the deep Pacific Ocean basin.

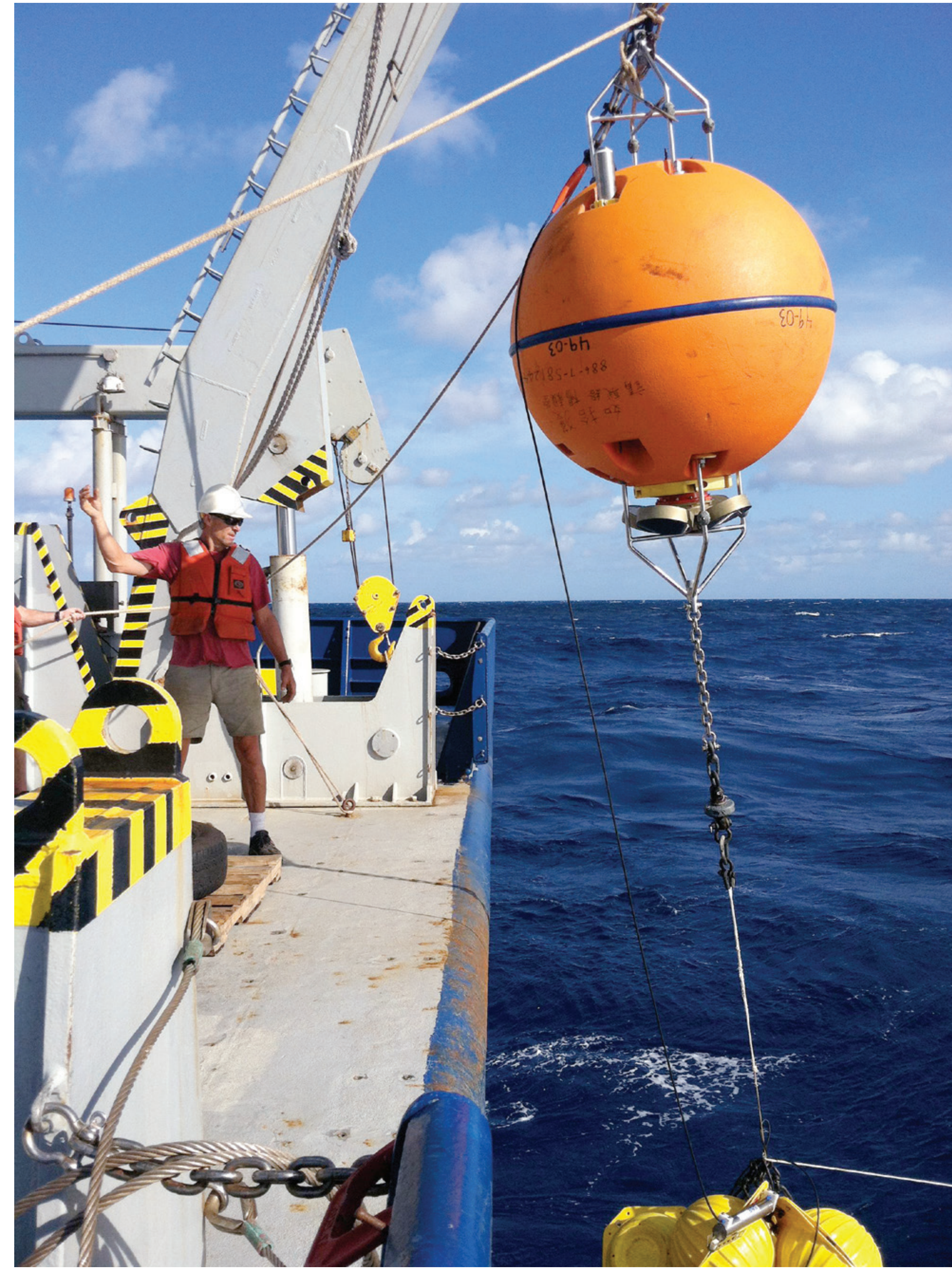
The challenge to measure the massive flow of water coursing northward through the Samoan Passage—6,000 cubic meters per second through a 40-km notch on the seafloor—began with a high-resolution bathymetric mapping cruise in fall 2011. Channels and sills were measured and the team was surprised to find many relatively small, 100-meter-high hills along the bottom. The team returned in summer 2012 for 39 days, deploying moorings, conducting 114 CTD/ADCP stations, 70 microstructure profiles, as well as several towed CTD/ADCP (tow-yo) sections along and across the channels.

Antarctic Bottom Water is cooled at the surface of the Southern Ocean, sinks to depth, and is steered northward in the South Pacific by the base of the continental slope east of New Zealand. Most of the coldest water entering the Samoan Passage from the south takes a deep eastern channel, where it descends to greater depth, accelerates, and encounters a sill. Continuing on, the flow encounters a second sill and accelerates to more than 0.5 meters per second, 10–20 times faster than typical abyssal flows. The flow remains this fast for over 20 km downstream.

Microstructure profiles and tow-yos were used to zoom in on the turbulence and hydraulic processes near the sills, where turbulent mixing is 1,000–10,000 times greater than the open ocean. The bulk of the turbulence is generated by the instability and breaking of lee waves, several hundred meters high, triggered by the accelerated flow over the sills and other topography. The Samoan Passage is indeed a mixing hotspot and it is transformative: the water spilling into the deep Pacific Basin is lighter and warmer than the Antarctic Bottom Water that enters the passage.

During the along- and across-channel sections the team also discovered that locations only a few kilometers apart have different hydraulic responses and turbulence levels. This suggests that abyssal mixing is very sensitive to the bathymetric details measured on the first mapping cruise, and complicates the oceanographers' attempts to describe the flow through the region in broad terms.

Some moorings deployed in summer 2012 were left to monitor Samoan Passage transport for 18 months. One is at the entrance, near the location that recorded the important motivating data set two decades ago. After recovery in January 2014, the team hopes to address seasonal variations and whether there has been a decadal change in Antarctic Bottom Water transport.



count + characterize quickly

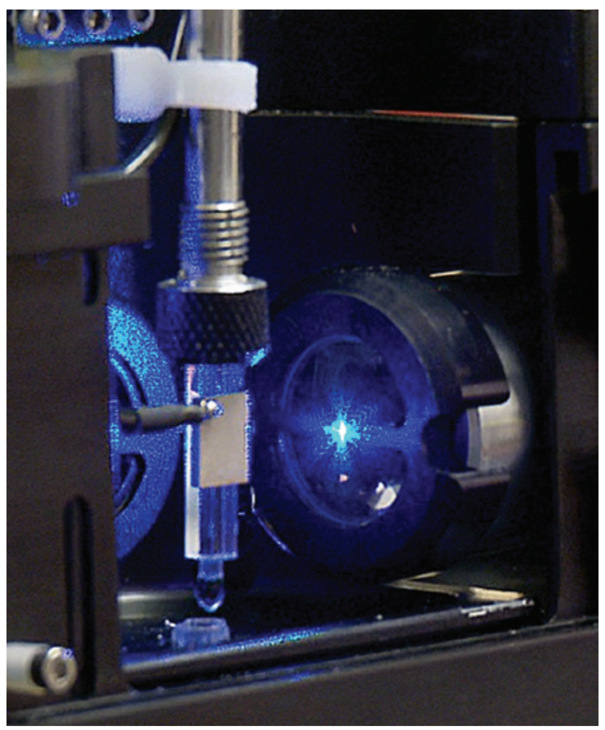
flow cytometry techniques advance microbubble science

researchers

Andrew Brayman
Brian MacConaghy
Thomas Matula
Camilo Perez
Justin Reed

sponsor

Washington Life Sciences Discovery Fund

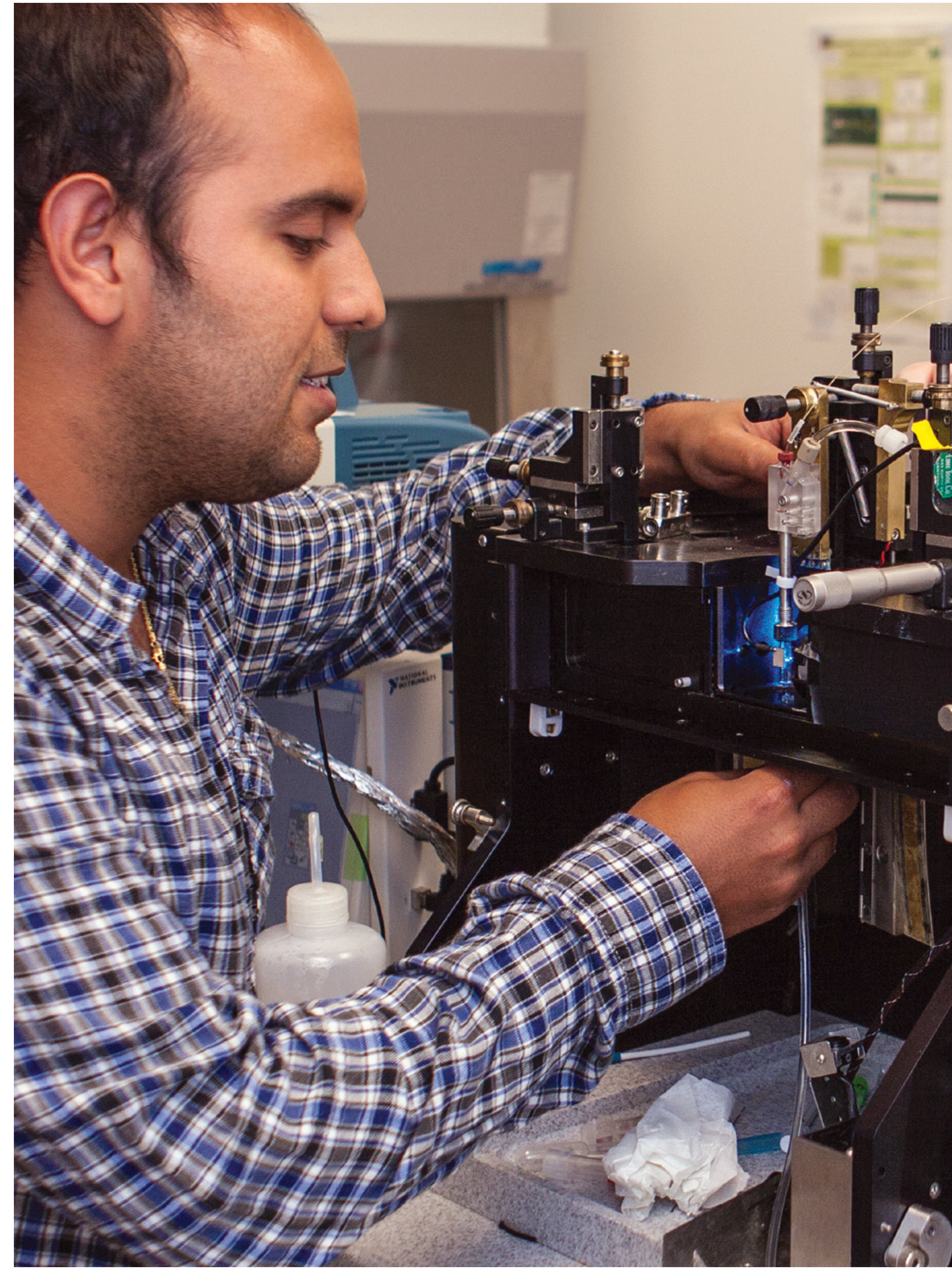


Ask Tom Matula at the Center for Industrial and Medical Ultrasound about the frontiers in medicine, and he'll talk to you about tiny bubbles. He's speaking of ultrasound contrast agents. These extremely small gas bubbles increase the efficiency of ultrasound imaging because the microbubbles become ringing echo chambers and show up as bright images on sonograms when ensonified by an acoustic signal. The diagnostic and therapeutic possibilities of these tiny bubbles are vast: they act as probes and beacons within the body, can perform mechanical work on tissues, and can carry and deploy chemotherapeutic payloads.

Available commercially or manufactured in the lab, ultrasound contrast agents are made by mixing lipids, proteins, sugars, or polymers in a buffered solution saturated with a gas. After mixing, a thin protective shell forms around the gas bubble. At one to eight microns in diameter, billions occupy a small vial.

Matula and colleagues are at the forefront of measuring the physical properties of ultrasound contrast agents with the recent development of a hybrid instrument that combines an off-the-shelf flow cytometer with an acoustic transducer. Flow cytometry is a standard technique of counting and characterizing cells suspended in a flowing fluid. One by one they pass through a laser's focus and light is scattered in characteristic patterns. The signal gives information about the bubble size and calculates a size distribution for the sample. When ultrasound is applied, the light signals also reveal how the bubble responds to the acoustic field, from which viscosity and elasticity properties of the microbubble shell can be inferred.

Matula recounts his early work using light-scattering techniques to characterize microbubbles that, though successful, were time intensive. "An entire Ph.D. thesis could be devoted to getting information about a few bubbles." With the hybrid device, "We're hitting the bubble with megahertz frequencies so we can get enough information in about five to ten microseconds to characterize that bubble. With the flow rates of a cytometer on the same magnitude, we can extract information from thousands of bubbles and build statistics of the ensemble in just a few minutes."



Bioengineering doctoral student CAMILO PEREZ has pursued research in flow cytometry instrumentation and data analysis since joining Tom Matula's lab in 2010. His motivations are personal.

"During my early training in a hospital in Columbia, my home country, I had the opportunity to shadow a cardiologist who was using commercially available contrast agents in his practice. A stroke patient exhibited symptoms that were difficult to diagnose. Was there a problem in the heart muscle or were the problems only in the brain? Contrast agents reflect the ultrasound so efficiently that they are like little beacons in the circulation. After injection of the contrast agents the cardiologist and I could see the bubbles leaking out of the heart, pinpointing the problem. Seeing this motivated me to pursue the methods to characterize these very important tiny bubbles before they are used in a clinical setting."

The microbubble shell is important; it's the bubble's backbone. Is the bubble stable enough to circulate throughout the vasculature? How does it respond to various acoustic pressures? What beacon or drug molecules can be attached to its surface? These questions and others about the bubble's properties are answered by the new device.

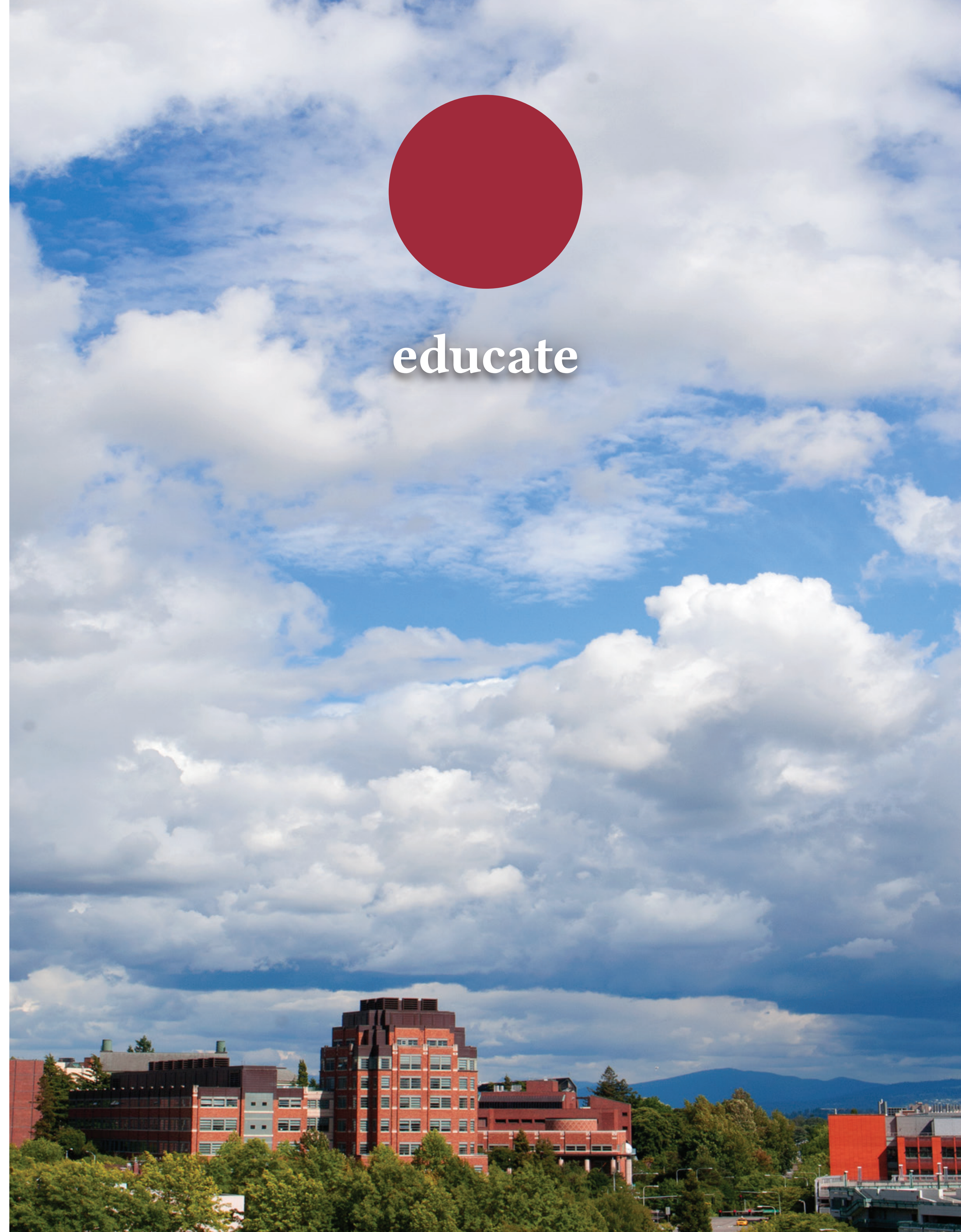
Coupled with biochemistry techniques, ultrasound contrast agents can advance imaging in the patient's body to the molecular level. Bubbles can be conjugated with ligands specific to a disease protein's receptor and injected into the general circulation. Once they find and dock at the receptor, these comparatively large microbubbles can be imaged with standard diagnostic ultrasound techniques, thus the very molecules that comprise a disease protein are pinpointed on sonograms.

Cancers, inflammatory diseases, and cardiovascular plaques, for example, all have protein receptors that can be targeted by microbubbles coated with a complementary ligand. Early diagnosis and treatment for these and other diseases could have profound benefits for patients.

The horizon for microbubble therapeutics is in sight. Imagine a microbubble loaded with a chemotherapeutic drug and coated with a ligand that attaches to the cancer protein receptor. After injection to the general circulation it finds its target and acts as a beacon for imaging the cancer cells. Then with a change in acoustic intensity, the microbubble could be exploded to release its payload, delivering drug therapy to a tumor that is as yet undetectable by other diagnostic methods. This is image-guided, site-specific chemotherapy at the molecular level.

commercialization

A U.S. patent for the technology, *Dynamic Characterization of Particles with Flow Cytometry*, has been granted. Matula reflects that, "We immediately thought about commercialization and brought the UW Center for Commercialization into our meetings. We talked with other scientists in the community and received funding from the Washington Life Sciences Discovery Fund to pursue the invention. During that period, a global health care company became interested in our flow cytometry techniques because their researchers use ultrasound contrast agents in commercial applications and want to characterize them for targeted imaging and therapy. The company has also funded our continuing work with the invention to a level that their researchers and labs will be able to use it on a full-time basis to characterize their bubbles."



teach

From its beginnings, the Applied Physics Laboratory has been integrated into the education mission of the University of Washington. In 2013 APL-UW efforts to train the next generation of scientists and engineers are as robust as ever. Laboratory scientists and engineers with academic appointments in UW departments work collaboratively with the faculty and teach, advise, sponsor, and mentor graduate and undergraduate students.

APL-UW researchers hold 62 faculty appointments across 15 UW departments; the greatest number of these ties are with the College of Engineering and the College of the Environment. Sixteen hold 'without tenure' appointments that integrate them even more closely into the academic faculty. FRANCO CURRA is the most recent to join these ranks as Assistant Professor of Bioengineering. Over the past biennium APL-UW faculty directed the advanced degree programs of 25 students (see pages 40–41) and entrained scores of graduate and undergraduate students in sponsored projects, offering valuable research experience.

The topics of university courses taught by APL-UW faculty mirror their interests and expertise and focus on imparting essential skills to developing researchers.

MICHAEL BAILEY and PETER DAHL each lead courses on applied acoustics in the Department of Mechanical Engineering to confer knowledge of the discipline and its subfields—nonlinear, medical, and underwater acoustics. PIERRE MOURAD tailors a course in diagnostic and therapeutic ultrasound to bioengineering students. GORDON FARQUHARSON'S *Probability and Random Processes* and JIM THOMSON'S *Fluid Mechanics* are essential foundations for respective electrical and mechanical engineering majors, where they are introduced to mathematical representations of uncertainty in engineering systems and fluid motions for engineering applications. In his senior capstone course for electrical engineers, PAYMAN ARABSHAHI challenges students to design, build, and test an end-to-end wireless communication system on software defined radio platforms.

Polar scientists KRISTIN LAIDRE, BONNIE LIGHT, and REBECCA WOODGATE offer respective courses on arctic marine vertebrate ecology in the School of Aquatic and Fishery Sciences, the physical, thermodynamic, and mechanical properties of sea ice in the Earth + Space Sciences Department, and the interaction of physical, chemical, and biological components of the changing arctic system in the School of Oceanography.

KATHRYN KELLY teaches *Oceanographic Data Analysis* for student oceanographers who may have taken MATTHEW ALFORD'S and CRAIG LEE'S *Methods and Measurements in Physical Oceanography*, where they learn the instruments and techniques used by physical oceanographers and also hone skills writing research proposals.

In the Statistics Department CAREN MARZBAN offers a course on probability and statistics in engineering and science; DON PERCIVAL teaches *Applied Regression and Analysis of Variance* and *Spectral Analysis of Time Series.* The techniques taught in these are imperative for contemporary scientists and engineers who must analyze large and complex data sets.

Two experts in autonomous underwater vehicles, TRINA LITCHENDORF and SARAH WEBSTER, led a month-long UW study abroad course in Brisbane, Australia. Undergraduate science and engineering students worked in small teams to propose a research idea, program an AUV to run a mission, conduct field experiments, analyze data, and write a final report in the form of a peer-reviewed scientific or engineering paper. Designing the curriculum for such a fast-paced course and teaching students with widely varying skill sets was challenging, but Litchendorf and Webster look forward to teaching similar courses in the future.

On the construction site at a Washington State Ferries terminal, doctoral student researcher DARA FARRELL is part of a student team from the UW Department of Mechanical Engineering studying the effects of impact and vibratory pile driving on the undersea soundscape. Hydrophones are deployed close to the noise source to determine mitigation strategies, as well as hundreds of meters away to investigate the rate of sound decay and the 'zone of influence' that may affect marine organisms.

share science + mentor

Scientists, students, and other volunteers from APL-UW present dozens of hands-on activities and live shows to demonstrate how polar research is conducted, why it matters, and how cool it is during the annual POLAR SCIENCE WEEKEND. 2013 marked the eighth consecutive year of the partnership between the Laboratory and Pacific Science Center, Washington State's most well-attended museum.

Science communication is an increasingly important skill for practicing scientists, and the weekend's face-to-face interaction with thousands of visitors provides a real world experience to sharpen the skill. In 2013 about 1000 students from 26 Seattle-area schools visited. Two high school groups attended with free admission provided by the generous NASA grant that has funded POLAR SCIENCE WEEKEND for the past four years.

The science center debuted its Portal to Current Research in 2012—an exhibit showcasing the research of local scientists. During POLAR SCIENCE WEEKEND and continuing through the summer for the past two years, an interactive exhibit, *Investigating Arctic Ice Melt*, has featured the work of APL-UW polar scientists.

washington state educators participating in ocean science aboard the r/v *thompson*

In 2013 the 35 APL-UW participants joined 59 from other UW academic units and organizations. The long-term success of POLAR SCIENCE WEEKEND has generated more collaborative efforts between the University of Washington, the greater Seattle science and technology community, and Pacific Science Center. The inaugural SCIENCE EXPO in June 2012 drew over 10,000 visitors. PAWS-ON SCIENCE, now in its fourth consecutive year, involves over 40 UW units and organizations that provide interactive learning opportunities at the center over a weekend. Each year the event is kicked off by a rousing visit from the UW Husky Marching Band. At these events APL-UW teams have given hands-on demonstrations about ocean wave measurements, ocean salinity, hurricanes, and ocean physics.

On Earth Day (April 22) 2013, the UW-operated R/V *Thompson* began a week-long expedition for research and education off the Washington coast. APL-UW scientists and UW oceanography graduate students deployed moorings for the Northwest Enhanced Moored Observatory and then turned attention to using shipboard and towed instruments to detect and track nonlinear internal waves propagating across the continental shelf break. These waves had been observed by moored instruments during the preceding year and may explain why the continental shelf is so productive. Also aboard were middle and high school teachers who gained knowledge on current ocean science research and how to bring real time ocean data to their classrooms.

JIM THOMSON posted to the *New York Times* 'Scientist at Work' blog from the North Pacific in late 2012 and the Chacao Channel, Chile, in early 2013. In these contemporary field journals Thomson gave *Times* readers a glimpse into the day-to-day operations of oceanographic research cruises, including the logistical perils that accompany transport of equipment by the literal ton. He also painted a clear view of why his scientific explorations are worth pursuing: a more accurate wave forecast for shippers on the open ocean and improving the design of turbines for a seafloor installation that will generate electricity from the tides.

understanding seaglider buoyancy at polar science weekend 2013

Several undergraduate students mentored by APL-UW faculty prepare and present posters at the annual UW Undergraduate Research Symposium, now in its sixteenth year. **KRYSTAL SLATTERY**'s research is on *Colwellia psychrerythraea*, a bacterium that lives in polar ice. Interests in astrobiology drew her to advisor **KAREN JUNGE** and the topic. She mapped the bacterium's metabolic pathways that are active down to −10°C showing that significant protein synthesis occurs at these temperatures. She reported that bacteria reduce their energy consumption at these temperatures, but also synthesize more proteins that are thought to be important cryoprotectants.

Local action taken by **LAURENCE TOMSIC** at his children's school is effecting change in "STEM readiness" for hundreds of students. Since 2010 he has chaired the school's annual science fair. His goals are clear: to bring scientists to the classroom and have them judge the exhibits, to excite participation from teachers and school leaders, and to gain community recognition. Several weeks before the fair, APL-UW scientists and engineers visit the classrooms to introduce the concepts of the scientific method and experimentation. Teachers are enthusiastic to have scientists visit their classes and mentor individual students. The community, home to many high-tech industries, has taken notice too. The local mayor presents the fair's prizes each year, and teachers from other schools in the community are looking to the event as a model they wish to emulate.

science fair judge + winner

student achievements

ANDY PICKERING was awarded a National Defense Industry Association fellowship in fall 2012. Pickering, a doctoral student advised by **MATTHEW ALFORD**, is studying internal waves generated by tidal flow over undersea topography. Specifically, he is analyzing data collected during an Office of Naval Research experiment conducted in Luzon Strait, where two steep undersea ridges run north–south between Taiwan and the Philippines. Strong barotropic tides flow across the ridges, generating extremely large internal waves and turbulent mixing. These internal waves also interact with eddies and strong currents in the region, impacting the propagation and dissipation of tidal energy as well as underwater acoustics.

Doctoral student researchers **WEI LU** and **JULIANNA SIMON**, both advised by **MICHAEL BAILEY** and **LAWRENCE CRUM**, were co-winners of the 2012 "UW Invents" Award. Provided by the UW Center for Commercialization, the award is presented to students who have made the greatest contribution to commercialization of their research products. Julianna was recognized for developing a technology to support a therapy with potential to treat breast and kidney cancer or remove non-cancerous tissue in the uterus or prostate, and proving the safety of ultrasonic propulsion of kidney stones. Wei was recognized for increasing understanding of the 'twinkling artifact' to improve visualization of kidney stones and for developing new algorithms and techniques to better detect stones with ultrasound.

The 2013 UW Graduate School Medal was awarded to **CHRISTOPHER BASSETT**, a doctoral mechanical engineering student advised by **JIM THOMSON** and **BRIAN POLAGYE**. Bassett works on problems related to marine renewable energy, measuring and modeling the ambient noise of the highly energetic coastal waters that are suitable for tidal in-stream energy conversion. His published studies of marine vessel noise and its environmental effects in Puget Sound drew academic praise and were covered widely by the local media. The prestigious award is given to one doctoral candidate whose academic expertise and social awareness are integrated in a way that demonstrates active civic engagement to promote political, cultural, and social change.

oceanography graduate student andy pickering in the field

JULIANNA SIMON is also the recipient of a First Award Fellowship from the National Space Biomedical Research Institute. During the two-year program she will join the institute's smart medical systems and technology team and conduct research that aims to protect astronaut health during long-duration spaceflights as well as improve life on Earth.

bioengineering graduate student julianna simon in the lab

The Hardisty Undergraduate Scholarship, established in 1997, provides funds for 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, Under-represented 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 scholars 2011 + 2012

BEN BRAND	*Electrical Engineering*	Light
AMEEN TABATABAI	*Bioengineering*	Bailey

boeing scholars 2011 + 2012

ABBI McCLINTIC	*Environmental Health*	Mourad
STEPHANIE CHU	*Bioengineering*	Mourad

BEN BRAND completed a B.S. in electrical engineering in 2012 after support from the Hardisty Undergraduate Scholarship and working for two summers in the APL-UW Ocean Engineering Department. He is now an Electrical Engineer in the department, applying the technical expertise he developed during his degree program to many projects—underwater acoustics ranging in the Gulf of Mexico and Arctic, and underwater imaging with a high-definition camera. The camera, deployed on the Regional Cabled Observatory (see **vision takes form**, page 12) near a hydrothermal vent 5000 feet below the ocean surface, will be used to monitor the vent in real time with unprecedented bandwidth. A versatile and enthusiastic engineer, Ben is known as "the Labrador of ocean engineering," by many of his mentors who are now colleagues.

AMEEN TABATABAI has a team of mentors at the Center for Industrial and Medical Ultrasound, where he is pursuing research to evaluate the fitness of donor livers for transplant patients. Studies show that high fat content in livers correlates with poor graft function and lower patient survival. Ameen's research is focused on an acoustic caliper device that uses ultrasound measurements to quickly, accurately, and noninvasively evaluate the fat in transplant donor livers.

Boeing Scholar ABBI McCLINTIC completed her B.S. degree in 2012 and has joined the APL-UW science and engineering staff. One of the projects she pursued as an undergraduate was on stimulation of neuropathic tissue with intense focused ultrasound. She demonstrated in an animal model that a pain response could be elicited in injured nerves with ultrasound stimulation, while the same evocative test failed to elicit a response in adjacent normal tissue. Results have been published and data from the project were used to obtain funding to begin a human subjects study to develop a noninvasive diagnostic test to localize and assess deep peripheral sources of neuropathic pain.

Bioengineering student STEPHANIE CHU is working to optimize a method of detecting traumatic brain injury by ultrasound tissue pulsatility. This means measuring the oscillating patterns of brain tissue expansion and contraction as a result of the natural respiration and cardiac cycles. Though it's possible to imagine important applications of the research for brain injury patients, Stephanie also appreciates the pursuit of pure research, "… where the outcome is unknown."

Both McCLINTIC and CHU are mentored by PIERRE MOURAD. In 2013 he was nominated by his students and chosen to receive a UW Undergraduate Research Mentor Award, presented at the opening of the annual Undergraduate Research Symposium.

engineers ben brand + andrew stewart in the regional scale nodes electronics laboratory

graduate degrees earned

student	degree/topic	advisor(s)
Hassan Arbab	Electrical Engineering + Nanotechnology, Ph.D., 2012 *Terahertz imaging and spectroscopy*	Chen + Lin
Hong Chen	Bioengineering, Ph.D., 2011 *Ultra-high-speed optical imaging of ultrasound-activated microbubbles*	Matula
Brian Chinn	Applied Mathematics + Oceanography, M.S., 2012 *Internal waves in the Philippine Sea*	Alford + Girton
Charles Elliott	Electrical Engineering, M.S., 2012 *Photothermal detection of trace chemicals in the air*	Chen + Lin
Cecilia Peralta Ferriz	Oceanography, Ph.D., 2012 *Arctic Ocean circulation patterns revealed by ocean bottom pressure anomalies*	Morison
Christopher Fisk	Electrical Engineering, M.S., 2012 *Miniaturized interferometric synthetic aperture radar techniques for nearshore ocean characterization*	Farquharson + Ritcey
Joseph Graber	Mechanical Engineering, M.S., 2011 *Land-based infrared imagery for marine mammal detection*	Thomson + Polagye
Evan Hanusa	Electrical Engineering, Ph.D., 2012 *Incorporation of features in multistatic active sonar tracking*	Krout

student	degree/topic	advisor(s)
Simon Henriksen	Civil and Environmental Engineering, M.S., 2011 *Effective turbulence metrics for wind power*	Thomson
Byron Kilbourne	Oceanography, M.S., 2011 *Wind forcing of near-inertial waves in the Southern Ocean*	Alford + Girton
Nathan Lauffenburger	Oceanography, M.S., 2011 *Remote sensing of salinity intrusions in a marine estuary*	Sanford
Wei Lu	Bioengineering, Ph.D., 2012 *Ultrasonic detection and expulsion of kidney stones*	Bailey + Crum
Rosalinda Mrvaljevic	Oceanography, M.S., 2011 *The wake of Typhoon Fanapi*	D'Asaro
Michael Palodichuk	Mechanical Engineering, M.S., 2012 *Observations of near-inertial internal waves during the Internal Waves Across the Pacific Experiment*	Alford
Nathan Parrish	Electrical Engineering, Ph.D., 2012 *Supervised dimensionality reduction for different learning architectures*	Arabshahi *(committee member)*
Eric Rehm	Oceanography, Ph.D., 2012 *Estimation of inherent optical properties and phytoplankton community structure from hyperspectral in-water radiometry*	D'Asaro
Michael Schwendeman	Civil and Environmental Engineering, M.S., 2012 *Wave breaking in fetch-limited seas*	Thomson
Andrew Shao	Oceanography, M.S., 2012 *Mixed layer saturation of CFC-11, CFC-12, and SF_6 in a global isopycnal model*	Mecking + Thompson
Mark Stockham	Mechanical Engineering, M.S., 2011 *Spectral analysis of pile driving noise*	Dahl + Reinhall
Kevin Taylor	Oceanography, M.S., 2012 *Observations of the typhoon-induced Kuroshio intrusion northeast of Taiwan*	Sanford
Samantha Terker	Oceanography, Ph.D., 2012 *Measurements and analysis of internal tides in the Monterey Bay region*	Sanford
Cynthia Travers	Oceanography, M.S., 2012 *Quantifying sea ice volume flux using moored instrumentation in the Bering Strait*	Woodgate
Ranran Wang	Statistics, M.S. and Ph.D., 2011 *The post-processing and verification of numerical weather prediction model output and Bayesian inference of exponential-family random graph models for social networks*	Marzban
Jinting Zhang	Oceanography, M.S., 2012 *The role of heating, winds, and topography on interannual sea level changes in the North Atlantic Ocean*	Kelly + Thompson
Shuang Zhang	Oceanography, M.S., 2012 *A numerical study of sub-inertial internal waves in a fjord using ROMS*	Alford

publications

APL-UW scientists share their discoveries by publishing results of their research in books and journal articles as well as by participating in conferences and workshops. Since 2000, over one thousand papers authored by Laboratory researchers have appeared in the peer-reviewed literature.

2012 articles in journals, reports, books, + book chapters

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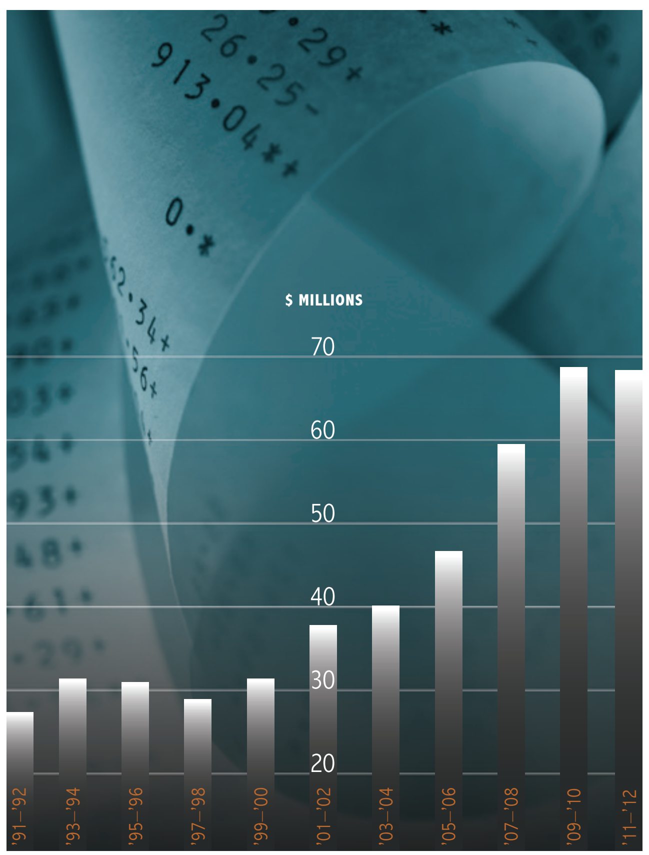
finances

The Applied Physics Laboratory has never been in a stronger financial position. For federal fiscal years 2011–2012 APL-UW grant and contract awards remained at historic highs. During this period the Laboratory's total awards were $136.4M — an all-time one-year record of $76.6M in FFY 2012 broke the previous all-time record from FFY 2010. Record-breaking revenues for the period FFYs 2010–2012 averaged $70.9M/year compared to the FFYs 2007–2009 average of $59.9M/year.



biennium averages of annual revenues over two decades

The Laboratory's primary partner remains the U.S. Navy, which provided about 43% of total funding. Annual grants from the National Science Foundation during the past biennium averaged $21M/year, placing the Laboratory in the upper echelon of University of Washington units receiving NSF funds. Other key federal agency sponsors include (non-Navy) DoD, NASA, NOAA, and NIH. Much of the increase in FFYs 2011 and 2012 is attributed to the National Science Foundation, though most other research funding remains at historically high levels.

The Laboratory's revenue base continues to diversify, with 43 different sponsors in FFY 2012 and a bias toward basic research programs. About 20 years ago, the U.S. Navy provided over 90% of the Laboratory's funding, and the ratio between applied research and basic (fundamental) research was approximately 65% to 35%. The current percentage balance between applied and basic research has shifted in the opposite direction to reflect growth in fundamental research areas.

APL-UW obtained a new U.S. Navy (NAVSEA) 'omnibus' contract in 2010 that was larger and longer than any contract in APL-UW history, moving from the prior seven-year $78M contract to a ten-year $256M contract. Some funds from this NAVSEA and other U.S. Navy contracts have been used to fund an APL-UW Institute for Advanced Research and Training Endowment; earnings will be used to help hire and train the next generation of scientists and engineers that are vital to our success.

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.

naval surface warfare center
$2,560,002 | $8,358,300 | 8%

national oceanic + atmospheric administration
$4,815,472 | $2,973,535 | 6%

other u.s. navy
$1,128,424 | $1,105,014 | 1.5%

office of naval research
$18,023,376 | $22,329,652 | 30%

other federal
$1,617,608 | $615,138 | 1.5%

national science foundation
$18,837,291 | $23,143,616 | 31%

national institutes of health
$1,882,974 | $1,831,625 | 3%

non-federal
$1,945,402 | $2,356,590 | 3%

naval sea systems command
$1,839,715 | $2,285,490 | 3%

other department of defense
$3,270,077 | $7,071,889 | 7%

national aeronautics + space administration
$3,876,974 | $4,503,655 | 6%

grant + contract funding by research sponsor
FFY 2011 | FFY 2012 | biennium percentage

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> "It is with sadness that I note the passing of Robert Hillyer in 2013. He contributed great insight and wisdom to the board since 1989. His wit and intelligence made him a joy to know."
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