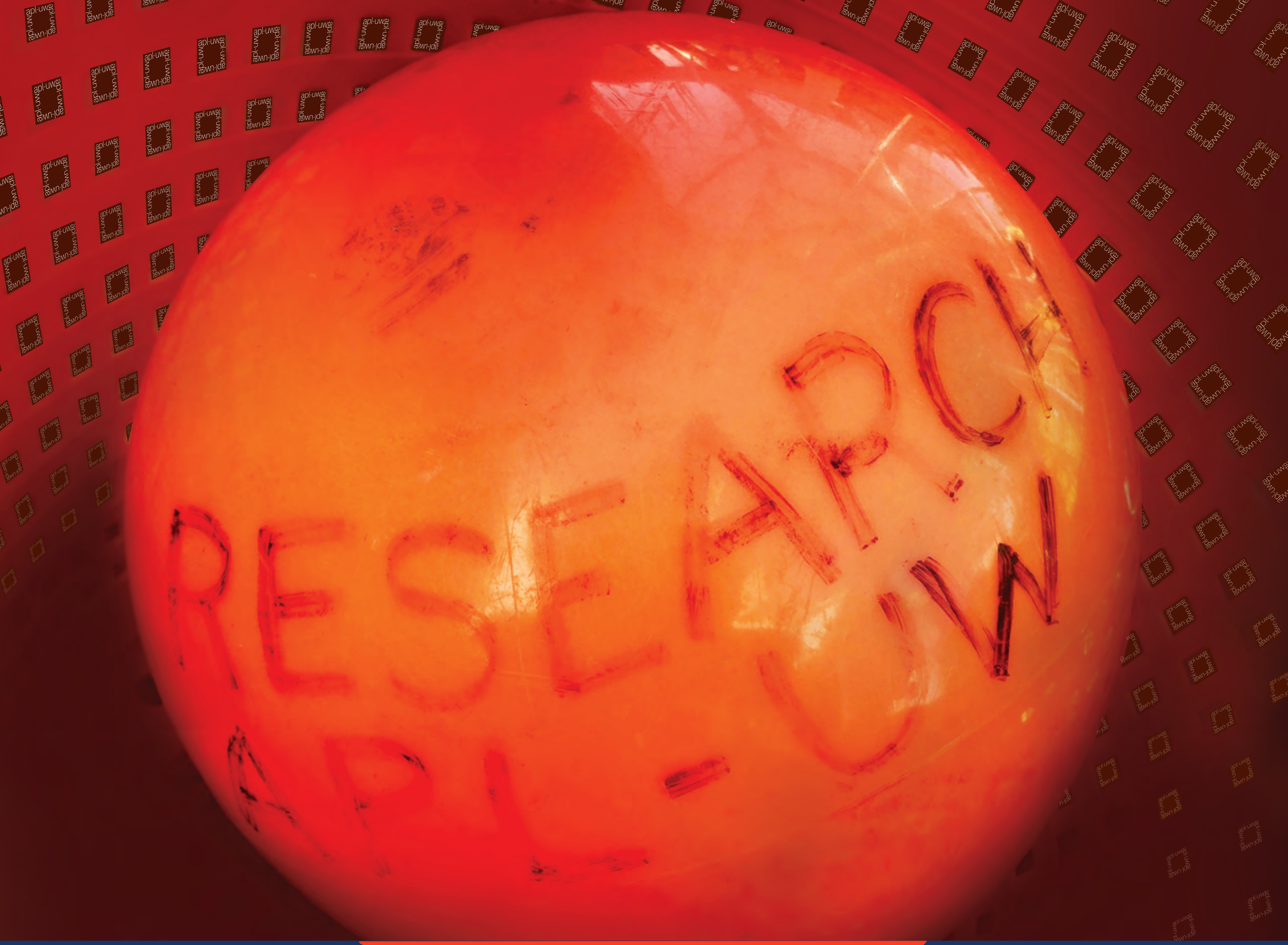

Applied Physics Laboratory

UNIVERSITY OF WASHINGTON

Annual Report

apl-uw

The Applied Physics Laboratory is a research unit of the University of Washington. We serve as a trusted research and development agent by anticipating broad scientific and engineering challenges and responding quickly to rising national research priorities. Core expertise is in ocean physics and engineering, ocean and medical acoustics, polar science, environmental remote sensing, and signal processing.

Designation by the U.S. Navy as a University Affiliated Research Center requires that APL-UW operate in the public interest. From our integral position within the University of Washington scholarship, research, and innovation enterprise, we apply rigorous scientific inquiry and engineering excellence in pursuit of solutions for the good of our region, nation, and world.

scholarship

discovery

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welcome

Kevin Williams, Executive Director

The Applied Physics Laboratory completed its 80th year of operations in 2023. It's my 35th year as an employee, though my association with the Laboratory started in 1979 when I first interviewed for a position at APL-UW. By the end of that interview, I had decided that someday I would work at this Laboratory, but first I needed the knowledge and experience that comes with a Ph.D. The road back to APL-UW turned out to be more convoluted than I had anticipated, but what attracted me toward the Laboratory then is the same that has kept me here — the people and the research projects.

people

The Laboratory is truly defined by the dedication of the staff and their commitment to its purpose and values. Together, we perform amazing feats of science and engineering, even though they're hard, frustrating, and time intensive. These achievements would be impossible without an interdisciplinary team of scientists, engineers, and administrators, as well as the strategic investments in the infrastructure needed to enable and support our research and development enterprise.

In the end, all the hard work is fun when you have the right community of coworkers sharing the challenges. This Laboratory has always been that community for me. So many examples of commitment to community shine though in the pages of this report, and you'll see that we continue to invite new members with diverse backgrounds and capabilities into this *thing we do.*

projects

So, what is this *thing we do?* Essentially, we identify hard problems and we solve them. In taking on hard problems the devil is, indeed, in the details. Those details include everything from advancing the underlying science to the design, construction, and deployment of technology to test and apply that science. To make all of this work, the evolution of solutions often spans disciplines and requires that basic research and its applications are advanced in parallel.

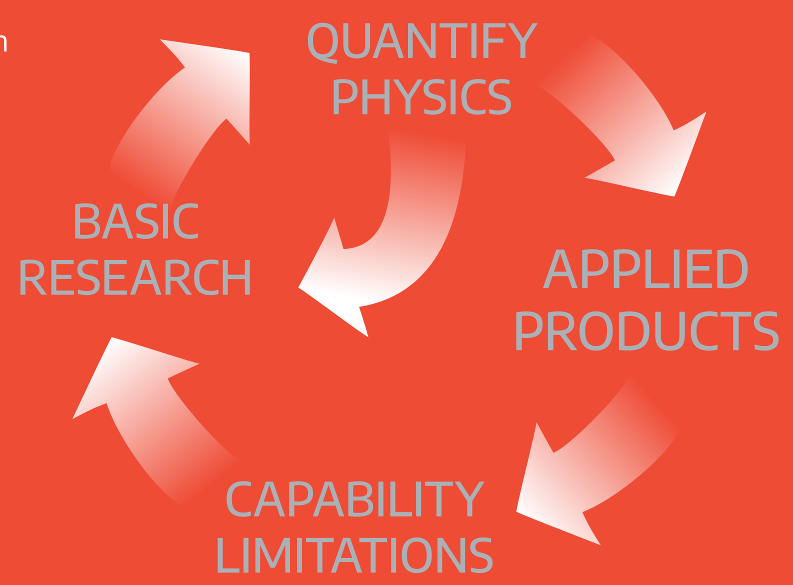
people, again

Our people are key to the Laboratory's success — pursuing scholarship, innovation, and applied solutions in a university setting on behalf of the U.S. Navy and all our research sponsors. Attracting and integrating the talents of scientists, engineers, and administrators under one roof is a great strength and a challenge. It requires individuals and research groups to value our unique mix of basic and applied research through compromise and by finding collaborative opportunities. Eighty years of achievement speaks to the quality and commitment of everyone at the Applied Physics Laboratory.

basic research + applied science

The Applied Physics Laboratory serves as a U.S. Navy University-Affiliated Research Center. Our identity among UARCs is unique in that APL-UW has throughout its history combined basic and applied research under one roof.

Our integration of scientific discovery and innovation, applied research, and technology development is sometimes linear but often cyclical. This approach has allowed us to draw upon a broad portfolio of sponsored projects to solve fundamental physics problems and to create a deep reservoir of scientific and technical expertise. When applied solutions confront operational limitations, our researchers can trace these back to a need to better understand underlying physics and then pursue these questions anew through ongoing research programs. Now for 80 years, APL-UW has remained agile and responsive to our sponsors' changing needs and priorities.



Shared in this **Annual Report** are examples of how we succeed: pursuing discovery and innovation in tandem with applied solutions, developing and deploying novel technologies in challenging environments, and investing in our people, state-of-the-art facilities, and research support infrastructure.

A community science and coastal imaging project brings together Laboratory investigators, citizen scientists, and the Washington Department of Ecology to tackle beach erosion concerns. Coastal hydrodynamics and wave physics research, informed with a low-cost photographic beach monitoring effort by the community, will help state agencies make equitable decisions about future climate change adaptation projects.

PREDICTABLE, RELIABLE POWER FROM TIDES

Tests of greater endurance are underway for the Laboratory's turbine-lander marine energy conversion system — a cross-flow turbine mounted atop a bottom lander structure that supports all the power electronics. Now in Sequim Bay, WA, offshore the Pacific Northwest National Laboratory Marine and Coastal Research Lab, where energetic tidal currents rip through a narrow channel, the turbine-lander is converting the tides to electricity and gathering volumes of valuable data for up to six months.

Turbine-lander research and development has been supported by the Naval Facilities Engineering Systems Command. Throughout the process, field tests have exposed unanswered questions related to marine energy converter design and operations that have driven researchers back to laboratory-scale experiments and numerical modeling studies. Deployed in October to the bottom of the bay's inlet, the turbine-lander is recording operational information including generator position, rotation rate, torque, speed, and power, along with inflow conditions. These real-world data will drive models to better understand and predict performance, improve the system's autonomous control algorithms, and inform mechanical design modifications to extend survivability in extreme marine environments.

An Adaptable Monitoring Package — sensors mounted to the lander structure to measure current velocity and to watch for interactions with marine life — is operating throughout the deployment. Senior Engineer **Chris Bassett** explains, "The most important environmental issue is collision risk, so we are combining optical and acoustic sensing to observe interactions and their outcomes, that is, avoidance strategies or collision. We're also hoping to achieve species identification of marine life near the turbine."

The tests are critical for future work by the APL-UW team in the marine renewable energy conversion space. "Generating power is one part of a much larger objective," says Bassett. "We want to figure out how we can provide the power for use in other scientific or applied research projects, such as distributed sensor networks or recharging autonomous undersea vehicles."

IMAGE: Abigale Snortland

RELENTLESS AND RIGOROUS TRIALS TRAIN RESILIENCE

IMAGES: University of Washington

"Key to our success has been the relentless pace of field testing supported by APL-UW engineers."

— GREG OKOPAL, PRINCIPAL ENGINEER

This is not an off-road rally for utility terrain vehicle enthusiasts. It is RACER, the Robotic Autonomy in Complex Environments with Resiliency program funded by the Defense Advanced Research Projects Agency (DARPA). Laboratory researchers with their University of Washington collaborators are developing autonomy technologies that allow these powerful, off-road vehicles to maneuver across unstructured terrain at or beyond the speeds and efficiencies achieved by vehicles driven by humans. DARPA provided a fleet of Polaris UTVs outfitted with state-of-the-art sensing capabilities to the UW and two other research teams. Each is writing software to improve the vehicle's perception of the environment, then plan and execute navigable routes without a driver.

Unlike robots moving through a warehouse or even your car's self-driving ability to cruise down the highway, the RACER vehicles do not use maps or any prior information about the terrain. "Everything is done using only the vehicle's onboard sensors and computer," explains Principal Engineer **Greg Okopal**. "Also, in the on-road world, anything that occupies space is considered an obstacle. Off-road, these vehicles can easily push through tall grass and bushes, so our system categorizes terrain around the vehicle based on its traversability."

The APL-UW engineers were brought aboard this program by UW lead investigators from the Paul G. Allen School of Computer Science and Engineering because of their extensive expertise testing autonomous systems in rugged field conditions. The key to the team's success so far is that they are putting the vehicles through their paces at a facility in eastern Washington once or twice every week. Summer conditions are hot, dry, windy, and dusty. In winter it's snowy and in spring mud is everywhere.

Because the technology is still at a research stage, a safety operator is usually in the driver's seat to correct mistakes. In early 2023, though, the team began conducting trials with fully unoccupied vehicles.

All RACER teams have demonstrated their work head-to-head on testing grounds in California over the past two years. "It's fun when everything goes right and the vehicle navigates challenging obstacles," says Okopal, "... especially when being evaluated by the government." So far, the UW team's vehicles are proving they can traverse rugged terrain quickly and smoothly, traveling further and faster than any others.

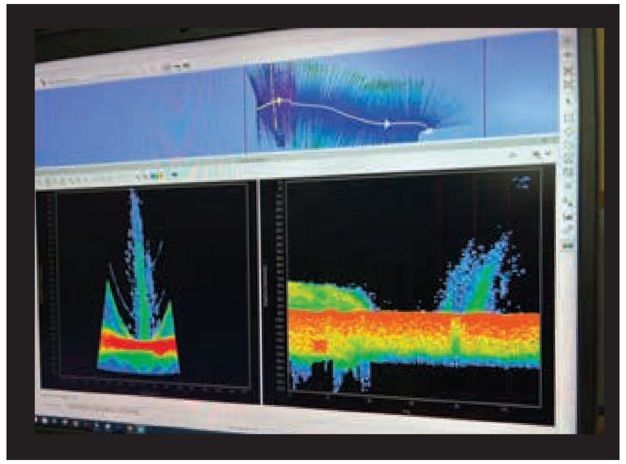
OCEAN DRONES SEEK AND MEASURE METHANE PLUMES

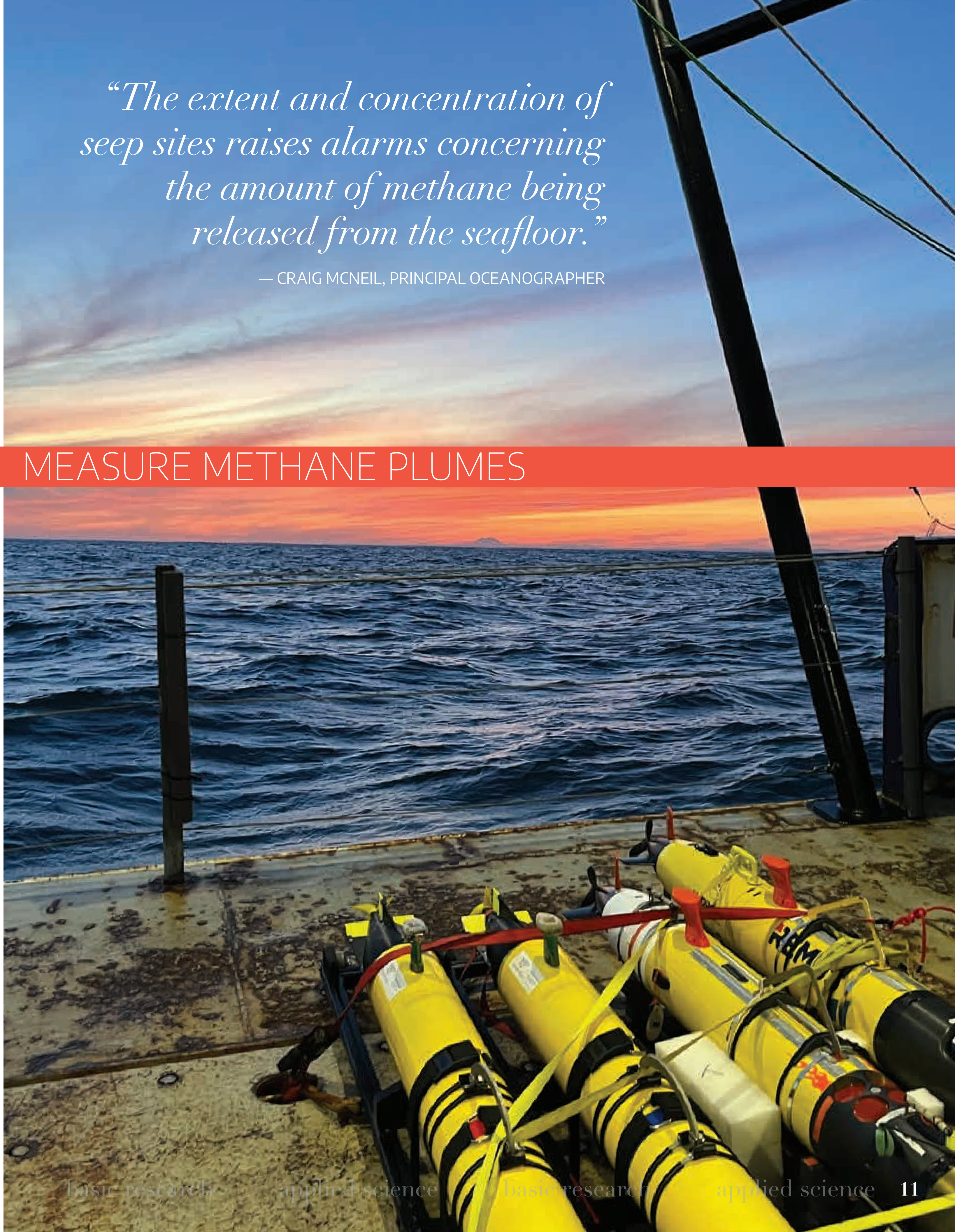
“Sending the run command. Three, two, one, go.” Aboard the R/V *Rachel Carson*, Principal Oceanographer Craig McNeil commands an autonomous undersea vehicle (AUV) to dive. “It’s the first time in the experiment we’ve been able to get three of them in the water. We should be collecting lots of good data.”

Equipped with high-resolution imaging sonars and dissolved gas sensors, the vehicles are on missions to characterize plumes of methane rising from seafloor sources up through the water column. Methane, a powerful greenhouse gas, resides in the deep sediment layers of the seafloor and can, under certain conditions, migrate upward and be released as bubbles into the overlying ocean. Methane seep sites on the Cascadia Margin, stretching offshore from Vancouver Island to Northern California, are ubiquitous, with at least several thousand discovered so far. “The extent and concentration of seep sites discovered by our NOAA colleagues raised alarms concerning the amount of methane being released from the seafloor,” says McNeil, “… and that’s why we’re pursuing this research.”

At what rate does methane enter the water column, and how often does a bubble plume rise all the way to the ocean surface? How do the tides or geological phenomena affect methane release and dispersion? At sea, the team uses shipboard sonars to locate a seep site, then they deploy the fleet of AUVs. With smart, adaptive sampling algorithms to seek the rising bubbles, the vehicles fly so as to ensonify the buoyant plume in three dimensions. The intensity of acoustic backscatter — the reflection of sonar signals off the bubbles — is used to estimate the amount of methane released at the site.

With support from NOAA Ocean Exploration, the team is working to achieve a high-density characterization of hundreds of individual methane seep sites along the Cascadia Margin with the AUVs. “With these data,” explains McNeil, “… we can extrapolate regional methane fluxes from wide-ranging surface ship surveys.”





“The extent and concentration of seep sites raises alarms concerning the amount of methane being released from the seafloor.”

— CRAIG MCNEIL, PRINCIPAL OCEANOGRAPHER

MINIATURE WAVE BUOYS DROPPED IN PATHS OF FEROCIOUS HURRICANES

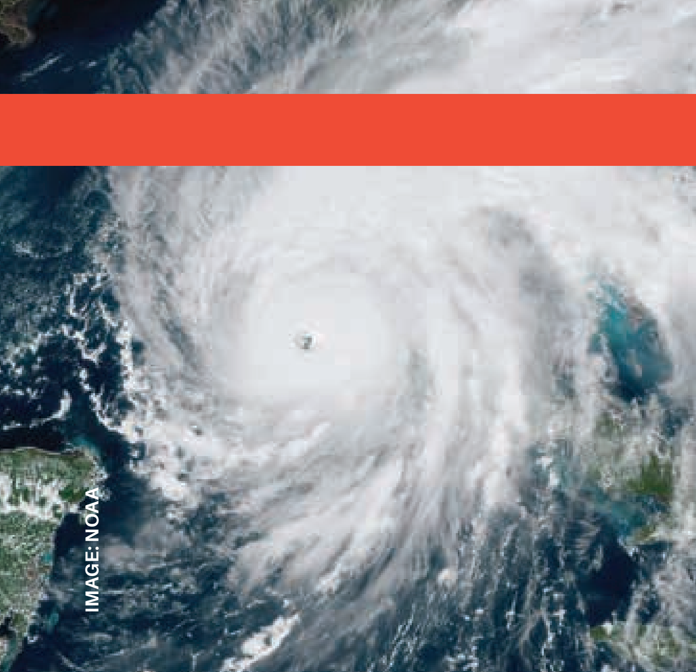
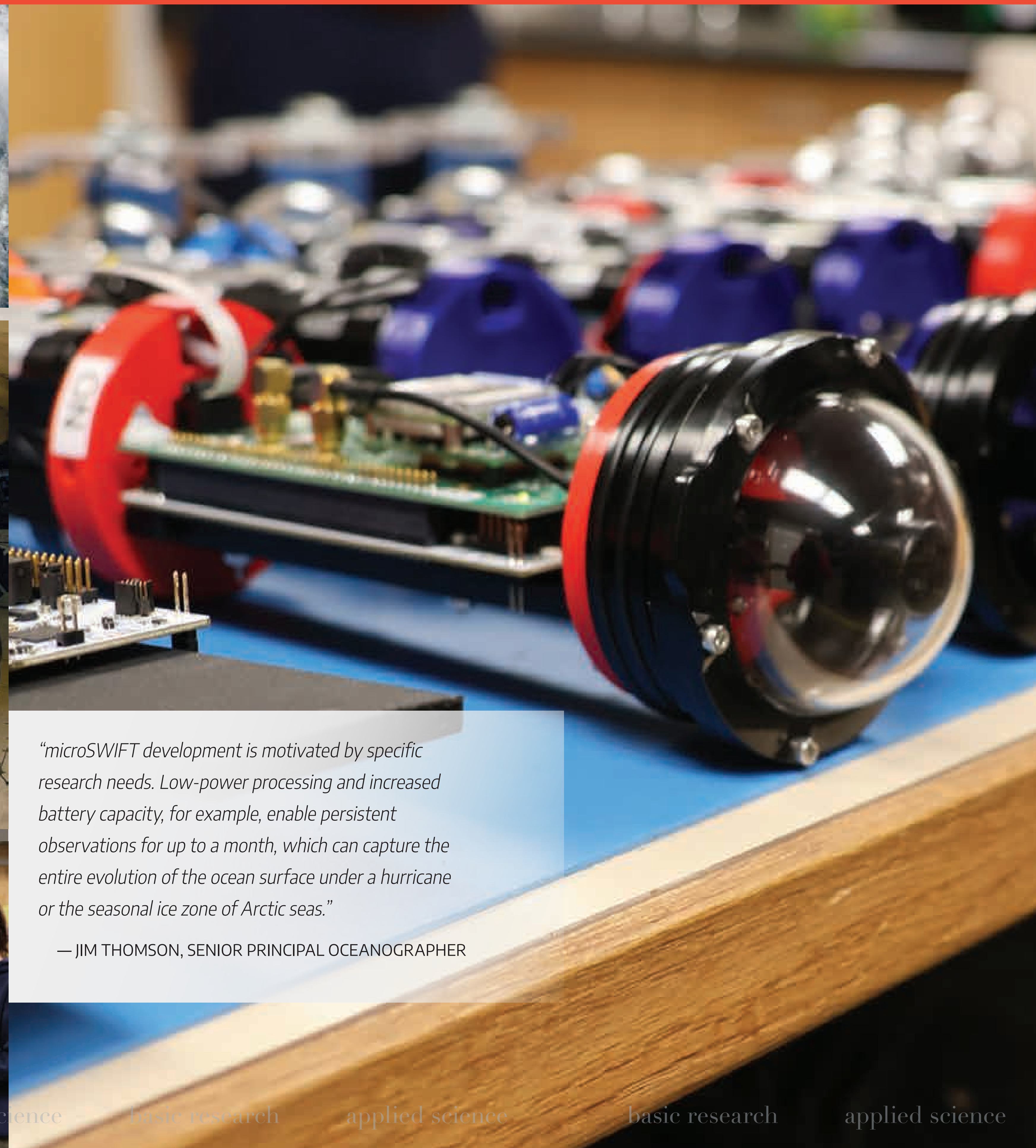


IMAGE: NOAA

IMAGE: NRL Scientific Development Squadron



"microSWIFT development is motivated by specific research needs. Low-power processing and increased battery capacity, for example, enable persistent observations for up to a month, which can capture the entire evolution of the ocean surface under a hurricane or the seasonal ice zone of Arctic seas."

— JIM THOMSON, SENIOR PRINCIPAL OCEANOGRAPHER

Hurricane Ian, a Category 4 storm, hit the heavily populated areas near Fort Meyers, Florida, on 28 September 2022 with damaging winds and a catastrophic storm surge. Exactly two days before landfall, UW Civil and Environmental Engineering graduate student **Jacob Davis** was called to join a Naval Research Laboratory Scientific Development Squadron mission to drop drifting wave-monitoring sensors from their aircraft into the ocean ahead of the hurricane's forecasted path.

Five of the drifters were microSWIFTs — miniature, expendable surface-floating instruments developed in Senior Principal Oceanographer **Jim Thomson**'s lab and deployed in arrays to study coastal wave dynamics. "The microSWIFTs deployed in Hurricane Ian are the original version," explains Davis, "... just repackaged into a new, longer hull for improved hydrodynamics and more space for batteries to extend the buoy's sampling life on the ocean surface."

An APL-UW team including Davis and Thomson is one of ten funded by the National Oceanographic Partnership Program to better understand and forecast the coastal impacts of hurricanes. While track and intensity forecasting has improved, there remains uncertainty about what happens on land above mean sea level when a major storm comes ashore. Observations of the evolving wave field under a moving hurricane are key. Waves themselves are a major part of the total storm surge and they roughen the ocean surface, giving the wind more 'grip' to push against, piling up water along the coast.

Analysis of data collected by the microSWIFTs and other wave buoys under Hurricane Ian provides new insight on the 'steepness' of the waves, which had been studied previously only in low-to-moderate wind speeds. "That work showed that wave slope increases proportionally to wind speed, but our data reveal that wave slopes eventually reach a maximum," remarks Davis. "At the very high wind speeds of hurricanes, waves are breaking constantly, with whitecaps injecting spray and foam into the air–sea interface beneath the hurricane." This finding parallels knowledge of air–sea drag coefficient saturation at extreme wind speeds, and provides a benchmark to include the ocean wave component in coupled atmosphere–ocean models used to forecast hurricane intensity.

For the 2023 hurricane season, the APL-UW team staged next-generation microSWIFT buoys with the NRL squadron and the NOAA Hurricane Hunters, who fly and deploy instruments directly into the storm. Buoys were dropped into hurricanes Idalia and Lee.

PERSISTENT OBSERVATIONS IN THE ARCTIC OCEAN

Understanding the variability of the Arctic ocean–ice–atmosphere system and predicting its evolution over days, weeks, and seasons requires year-round observations spanning a range of spatial and temporal scales. Numerical models of the system are of great value, but require observations for initialization, assimilation, and to inform how the simulations represent unresolved physics. Nowcasts and forecasts must have data delivered in near-real time, which is especially challenging in polar regions, where sea ice blocks access to satellite services.

To address these challenges and to support U.S. Navy missions in the ice-covered Arctic, the Office of Naval Research has directed efforts to develop mobile observing capabilities composed of ice-based gateway nodes, to bridge the ice–ocean interface, and an array of complementary autonomous platforms, including gliders, floats, and fast undersea vehicles. Networking these components together with long-range acoustic navigation beacons and acoustic communication technologies enables controlled, coordinated, and cooperative sampling and data relay for the platforms operating under the sea ice.

The Arctic Mobile Observing System (AMOS) array operates as a cloud of drifting and mobile autonomous systems. Its modular nature means that it can be scaled to fit a range of tasks, and because most of the individual elements are small and light, the array is flexible logistically, which is crucial for Arctic operations.

A multi-institutional team has pursued simultaneously technology development and scientific research into atmosphere–ice–ocean dynamics in the central Beaufort Sea since 2019. Laboratory oceanographers **Craig Lee**, **Jason Gobat**, and **Luc Rainville** have each served as chief scientist aboard annual research cruises to deploy and recover long-endurance autonomous platforms, ice-based instruments, and moorings.

“The AMOS team has achieved fully autonomous year-plus missions by SGX gliders under the sea ice and multiyear drifts of the Ice Gateway Buoy – Heavy,” recounts Lee. “We also successfully implemented very low-frequency, long-range underwater acoustic navigation and demonstrated networked, cooperative operation among many autonomous systems.” The technical capabilities have enabled scientific discovery. Lee explains, “These observations have illuminated how sea ice meltwater pools on the ocean’s surface impact the small-scale patterns of sea ice freeze up, as well as how open water leads and sea ice mobility modulate momentum transfer from the atmosphere to the ice-covered upper ocean.”

IMAGES: Briana Carter, U.S. Coast Guard

“The AMOS team has achieved fully autonomous year-plus missions under the sea ice.”

— CRAIG LEE, SENIOR PRINCIPAL OCEANOGRAPHER

FROM THE BEACH TO THE SEA AND BACK AGAIN

Taking in a seaside view, swimming at the beach, or boating — most of us experience only the first few kilometers of the ocean closest to shore. For oceanographers, the nearshore region is fascinating in its complexity, defined by spatially heterogeneous dynamics and nonlinear interactions among many physical processes. A collaborative group of scientists centered in the Laboratory's Air-Sea Interaction and Remote Sensing (AIRS) Department is dedicated to understanding the physics driving the exchange of material — heat, gases, sediments, nutrients, biota, and pollutants — from the shore, through the surf zone, on to the inner shelf, and back again, and to developing novel technologies and approaches to make observations in this challenging environment.

In 2020 Melissa Moulton received an Office of Naval Research Young Investigator Program (YIP) award that supports scientists showing exceptional promise for doing creative research and to encourage their teaching and research careers. Since, she has pursued applied research to forecast coastal exchange from remote sensing observations, and continued work on the fundamental physics of nearshore dynamics with National Science Foundation support. These projects entrain students at all levels, from undergraduate interns to postdoctoral researchers, seeding the next generation of scientists in the field.

exchange expressways

Water pushed ashore by breaking waves wants to return to the ocean. Where there is a gap between breaking waves, water is funneled through that gap, creating a seaward jet — a rip current. Where a channel cuts through a sandbar, the water pushed ashore will use it to escape back to the sea. These bathymetric rips are well-studied, and a known dominant mechanism of nearshore exchange. "AIRS researchers, our collaborators, and students are finding innovative ways to discover more about rip currents," remarks Principal Oceanographer Melissa Moulton.

From above, rip currents appear as plumes of sediment-laden water moving offshore, with small, bright breaking waves at their edges. They can persist for hours to days and AIRS researchers questioned whether water density — temperature and salinity — influences rip current behavior. Gaining insight from height, the team, as part of an ONR Departmental Research Initiative, mounted visible light and infrared thermal cameras to a small aircraft flown over a stretch of California coast with bathymetric rip currents. Thermal images reveal a surf zone often much cooler or warmer than the ocean immediately offshore owing to variations in water depth, solar heating, wave dissipation, and mixing. Measured in units of surf-zone width — the distance from the shoreline to where waves start to break — the team discovered that the offshore extent of warm rip current plumes is about one surf-zone width greater than cool plumes, with the warm seaward ejections spreading across the surface and the cool plumes slipping below the surface and spreading in different patterns. Postdoctoral researcher Walter Torres is using numerical models to study these dynamics. "It turns out that these features have a lot in common with river plumes," says Torres. "It's been fruitful to bring in theoretical concepts from the estuarine and river plume literature that have not been applied to wave-driven outflows like rip currents."

From height the researchers also observed surf zone eddies that behave like rip currents, forming episodic jets that move material offshore. Transient or "flash" rips are generated where waves approach the shore from slightly different directions, forming complex patterns of breaking. As the waves crest and break, the edges shed vortices. Pairs of positive and negative vortices can join, spinning up a transient rip current. Irregular, directionally spread wave fields are ubiquitous on the coast, but they are a challenge to predict and observe, so this active area of research has been conducted in a wave-making laboratory and on supercomputers.

back to the laboratory

At Oregon State University's wave simulator, paddles can be tuned to produce waves crossing the basin toward the 'shore' at angles up to 30 degrees. The controlled laboratory setting — uniform bathymetry alongshore, absence of background currents, and repeatable conditions — isolates wave and eddy dynamics. Counting, measuring, and recording waves with remote sensing technologies and in-water instruments, the team quantified individual wave properties and characterized the relationships between directional spread, breaking wave patterns, and forces driving surf zone eddies. Experiment results are reported in Christine Baker's dissertation, completed in 2023, and papers published recently in the peer-reviewed literature. They show that as directional spreads increase, the wave crests shorten and the number of crest ends increase. More crest ends generate more eddies and thus more flash rips and cross-shore exchange.

The team also discovered a saturation effect. Observations in the basin and subsequent computer model runs show that eddy generation reaches a plateau and may even decrease as directional spread continues to increase. "This is counterintuitive to the prevailing theories described in the literature," says Emma Nuss, a civil and environmental engineering graduate student. "There must be some unaccounted physics." Nuss is reanalyzing the trove of data and looks forward to applying wave basin findings to nearshore water quality and ecosystem studies, and to ongoing work to improve rip current forecasts for beachgoers. The latter is a collaborative effort involving undergraduate student Audrey Casper and researchers at NOAA.

broad applications

Recently, Moulton led a multi-institutional effort to create a taxonomy of nearshore processes, gathering the latest science, all the underlying physics, and defining equations. "The YIP award allowed me to collaborate with biological and physical oceanographers to develop a framework to translate exchange processes into an indicator of connectivity between the beach and offshore that will be useful in a broad range of applications." Step by step, the framework guides users to consider the importance of exchange mechanisms — winds, stratification, waves, rip currents, and diurnal heating and cooling — and the behavior of particles — dissolved nutrients, sediments, larvae, oil, and plastic. Solutions estimate the exchange velocity for particles that maintain a depth due to swimming or buoyancy, and an exchange spread for particles without enough swimming speed or buoyancy to counteract turbulence.

Now Moulton is excited to apply these theories with forecasters studying oil spills, harmful algal blooms, water quality, and marine debris, as well as search and rescue operations. "I've been thrilled to see that this work is of interest to a broad community and can't wait to see where it leads."

ULTRASONIC SHOCKS DISRUPT PANCREATIC TUMOR DEFENSES

L to R: Research Scientist **Stephanie Totten**, Principal Research Scientist **Yak-Nam Wang**, Research Associate Professor **Tatiana Khokhlova**, and Postdoctoral Scholar **Randall Williams**

Innovative devices and methods are showing promise to enhance the delivery of drugs to fight pancreatic cancer tumors. A collaborative team of researchers at the Laboratory's Center for Industrial and Medical Ultrasound and colleagues at the UW School of Medicine has developed a system to deliver pulses of high intensity focused ultrasound into the body to create clouds of oscillating gas bubbles that bombard the tumor's defenses and sensitize it to chemotherapy. Experiments performed in fall 2023 are the team's first steps toward demonstrating the capability to permeabilize tissue with their novel image-guided ultrasound system.

Pancreatic cancer is difficult to diagnose early. Overall survival rates are about 40%, but only 3% if the cancerous cells have metastasized. The tumors are extremely dense and permeated with collagen fibers that create great pressures inside the tumor, inhibiting vascular development and decreasing perfusion. These characteristics render the tumor difficult to infiltrate with chemotherapeutic agents administered systemically.

Recently, the research team reported successful experiments in a mouse model of pancreatic cancer where repeated, weekly ultrasound treatments, combined with systemic drug administration, were well tolerated, created persistent physical changes, and disrupted the tumor's immunosuppressive microenvironment. Their key to disrupting the pancreatic tumor's armor is using millisecond-long pulses of high intensity focused ultrasound to induce cavitation throughout the tumor tissue. During the pulse, the rarefaction part of each acoustic cycle applies a large tensile stress on the tissue. This stress pulls on nanometer-sized gas bubble nuclei present in soft tissues and expands them into micron-sized bubbles that grow repeatedly and then collapse violently. Controlling the parameters of ultrasound delivery — frequency, peak positive and negative pressures, and duration of the pulse — is crucial to initiate cavitation reliably in tissue.

Acoustic cavitation in combination with ultrasound contrast agents, such as microbubbles or nanodroplets, has been studied extensively and used over the past decade to promote drug delivery to many types of tumors. Cavitating microbubbles create small pores in cell membranes, opening a conduit to enhance drug delivery. Microbubbles, however, tend to remain confined to the vasculature or perivascular space, so they don't work well in tissues with poor perfusion such as pancreatic cancer tumors. The team developed a system to overcome these limitations by inducing cavitation without the need for ultrasound contrast agents.

In the study with mice, genetically engineered to form pancreatic tumors spontaneously, the effects of cavitation — jostling and cracking of tissue throughout the tumor — were confirmed by histology. Further, the research team observed that ultrasound-based cavitation disrupts another important component of pancreatic tumors — hyaluronic acid, which forms complexes with water to make an impenetrable, gel-like substance. Cavitation breaks the hyaluronan bonds, increasing permeability. The team also discovered that cavitation short circuits the genetic code tumors use to resist chemotherapy and stimulates "good" immune cells to attack the tumor's immunosuppressive defenses. For all these reasons, they conclude that ultrasound treatment sensitizes the tumor to chemotherapy and opens a window for effective immunotherapy.

> *"Producing proliferating cavitation without the need for ultrasound contrast agents is a promising approach for image-guided drug delivery enhancement."*
>
> — RANDALL WILLIAMS, POSTDOCTORAL SCHOLAR

The mouse model of pancreatic ductal adenocarcinoma mimics closely the biology of human disease, but the hardware geared to treat mice is very different than would be used in humans. To that end, the team engineered a powerful driving electronics system based on an open platform ultrasound imaging machine, Verasonics, made by a local company, to operate a dual-mode linear ultrasound array. Designed by the team and fabricated at Sonic Concepts, another local company, the 64-element array integrates therapeutic and imaging ultrasound capabilities, providing a full view of the treatment region and simplifying operations for researchers and future clinicians. Balancing the technical issues of integrating therapy and imaging modes, the team ensured the system images centimeter-scale anatomic landmarks and is optimized to initiate cavitation at a depth of 3–6 cm in tissue, which is appropriate for noninvasive treatment in humans.

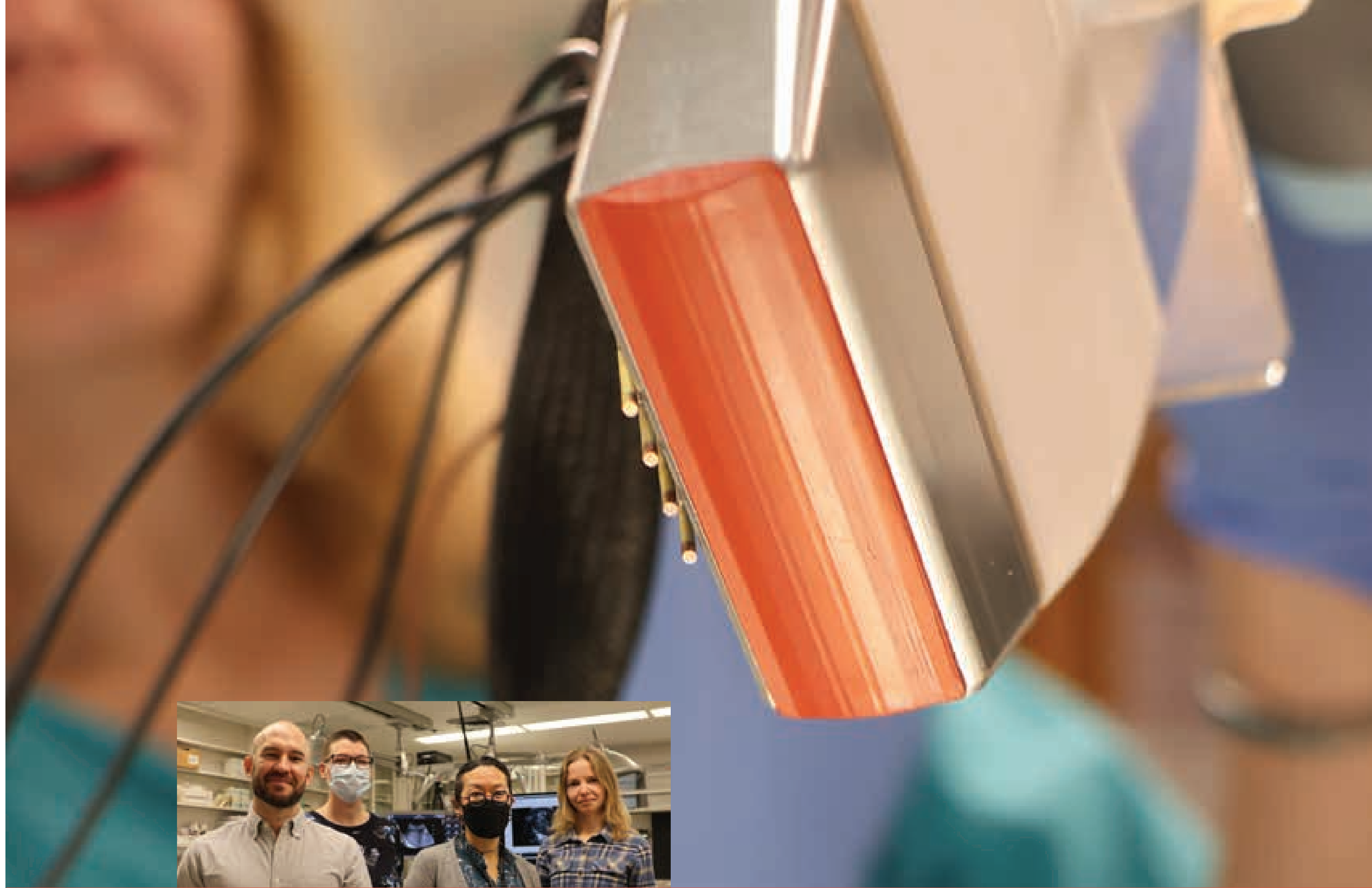
The array's acoustic output was characterized through a combination of hydrophone measurements, acoustic holography, and numerical simulations. "The first week I arrived at APL-UW," notes Williams, "... the array was delivered from the manufacturer and I began characterization experiments." Various configurations of pulsed focused ultrasound beams were tested in tissue-mimicking gels, producing a range of cavitation behaviors. Near the cavitation threshold, sparse stationary bubbles are generated by each pulse, but as the peak negative acoustic pressures are increased, smaller offspring bubbles form adjacent to the parent bubbles. These proliferating clusters of bubbles are known to cause greater tissue disruption than the growth and collapse of isolated, stationary bubbles. As peak pressures increase further, proliferating cavitation behavior becomes more pronounced with bubbles fanning out laterally and axially, increasing the number and spatial density of bubbles in the cavitation cloud.

"Think of it as little groups of bubbles pushing their way through the tissue."

Interestingly, bubble proliferation was discovered to be dependent on nonlinear propagation effects. That is, at moderate to high intensity, areas of compression in the ultrasound wave propagate slightly faster than areas of rarefaction, which transforms a smooth sinusoidal wave into a sawtooth wave with a sharp shock front within the focal area of the beam. The interaction of this shock front with pre-existing bubbles promotes their rapid growth and initiation of offspring bubbles in front of them, eventually growing into a cloud. Beams with longer focal areas tend to produce shock waves at lower intensities, and the team leveraged this effect when designing the new array.

During recent in vivo experiments, ultrasound imaging, in both brightness and power Doppler modes, was used to guide and monitor the treatment area and the intensity of cavitation activity. To aid visualization, power Doppler encodes in color the variability of the backscattered acoustic signal from the transient cavitation cloud. A passive cavitation detection technique — listening for the acoustic emissions from the oscillating bubbles — provided researchers further information about treatment efficacy. "It is the gold standard for cavitation detection, but it doesn't provide information about the bubbles' spatial distribution, which is what the power Doppler does really well," adds Williams.

The recent experiments were a success. The Verasonics system captures and records the acoustic signals backscattered from the target tissue over the course of the treatment. The team is now analyzing these data to develop metrics relating cavitation behavior to tissue disruption observed in histological slides. Future work will integrate these metrics into a protocol that clinicians can use to guide treatment based on real time feedback.



multidisciplinary collaborations @ CIMU

Enhancing drug delivery by disrupting tumor tissue with inertial cavitation is an example of research programs at the Laboratory's Center for Industrial and Medical Ultrasound that ultimately intend to reach clinical trials in humans. These are complex problems requiring expertise from many fields and areas of practice.

"All these contributions are equally important. We are fortunate to have all available here at the Laboratory and University."

— TATIANA KHOKHLOVA, UW SCHOOL OF MEDICINE

Team members bring understanding of the physics of ultrasound propagation and bubble dynamics, ultrasound device design and characterization, signal and image processing and real time imaging guidance, tissue and tumor biology and immunology, and clinical experience treating pancreatic cancer patients — oncology, interventional radiology, and surgery.

Small, relatively inexpensive buoys are catching waves and putting critical ocean observations directly into the hands of people in coastal communities who need the data most. The Backyard Buoys project provides opportunities for Indigenous and other coastal communities to make ocean observations in support of their local blue economies: maritime activities, food security, and coastal hazard protection.

The project, funded by the National Science Foundation Convergence Accelerator, is a collaborative effort among U.S. Integrated Ocean Observing System (IOOS) regional networks, people in remote and underserved coastal communities, and an ocean sensor company. Together, they are working to democratize local ocean wave measurements and provide a solution to the hurdle of observing technologies that are too expensive to purchase and too complicated to sustain.

BACKYARD BUOYS

"We are helping communities establish their own wave buoy programs, and we are co-designing tools that put the wave data in the palms of their hands in a way that's understandable and actionable."

— ROXANNE CARINI, SENIOR OCEANOGRAPHER

The project has an ambitious goal to provide buoys to communities in American Samoa, the Republic of the Marshall Islands, Hawaii, the Pacific Northwest, and many Alaska locales. Despite the very different environments for each coastal community, there are common concerns, needs, and solutions. Co-design is the unifying principle. Coastal communities have full autonomy over their wave buoys, and their unique histories and cultures inform their participation in the Backyard Buoys project. In 2023, buoys were deployed by members of the Alaska Eskimo Whaling Commission and their community members at Point Hope, Wainwright, and Utqiagvik to monitor conditions during the open water season. And here in Washington, test deployments were made by the Quileute Tribe off La Push and Quinault Indian Nation south of Taholah. These buoys are providing much needed wave data even throughout high current and storm events.

The project's success to date is leveraged on existing partnerships within each IOOS regional association — academic institutions, governments, tribes, and community scientists — to identify needs and reach into Indigenous and other remote coastal communities.

Convergence Accelerator funding for Backyard Buoys was first awarded in fall 2021 and then again when the project was selected for Phase 2 funding in fall 2022. The first year was all about building trust, strengthening partnerships, and co-developing stewardship plans with communities. "The exciting part of this project is seeing the partners working together in the field, with knowledge transfer, and knowing this new capacity will provide lasting aid to communities," notes Senior Principal Oceanographer Jan Newton. More buoy deployments, the release of a smartphone app, and education activities spanning summer camps to an undergraduate waves and tides course are planned for 2024.

"What appeals to us about the project is that it's collaborative, community-led, and community-driven."

— LESLEY HOPSON, ALASKA ESKIMO WHALING COMMISSION EXECUTIVE DIRECTOR

"This project has the ability to bridge local Indigenous knowledge and scientific data collection, making the information needed for safety decisions more accessible and relevant to our community."

— FUIAVA BERT FUIAVA, SAMOAN VILLAGE CHIEF AND NATIONAL PARK SERVICE, AMERICAN SAMOA

IMAGE: Holly Kent, AOOS

A NEW HOME PORT FOR THE APL-UW RESEARCH FLEET

"This dock and our vessels are mission critical for APL-UW."

— KEVIN WILLIAMS, EXECUTIVE DIRECTOR

With the cutting of a blue satin ribbon, Executive Director Kevin Williams welcomed a large gathering of APL-UW staff and friends to celebrate the Laboratory's new dock for our research vessels. Williams remarked: "This facility upgrade is a once-in-a-lifetime event. The previous served naval research for 70 years and now we are affirming many more decades of continued service."

A hallmark of APL-UW is our ability to conduct ambitious research programs in the field, especially at sea. Before novel sensors, instruments, vehicles, and observing platforms can be deployed in oceans around the world, APL-UW scientists and engineers often conduct extensive testing in Lake Washington, Puget Sound, and coastal Washington waters using our research fleet. "We can't go to the ocean if we don't test our equipment. This dock and our vessels are mission critical for APL-UW," says Williams. As supporting infrastructure for APL-UW research, the investment in this facility underscores the commitment of the Laboratory's leadership to sustain core competencies and strategize for future growth.

The grand opening celebration in July was the culmination of dauntless efforts that began in late 2020 when the Laboratory's facilities and business teams initiated the project's design and funding plan. The new dock has an improved connection to shore and increased load-bearing capacity so larger scale equipment can be staged and on/off-loaded to vessels safely. Its proximity to Laboratory and University classrooms, laboratories, and storage and staging facilities ensures seamless transitions of research equipment and personnel to and from experiments at sea.

INNOVATIONS BY INTERDISCIPLINARY TEAMS

Executive Director Kevin Williams established a competitive program in 2020 to stimulate science and engineering collaborations across the Laboratory and foster nontraditional, multidisciplinary working groups. Winning proposals are funded internally to advance the team's research and development efforts and to strengthen their chances to win support for their ideas from government sponsoring agencies.

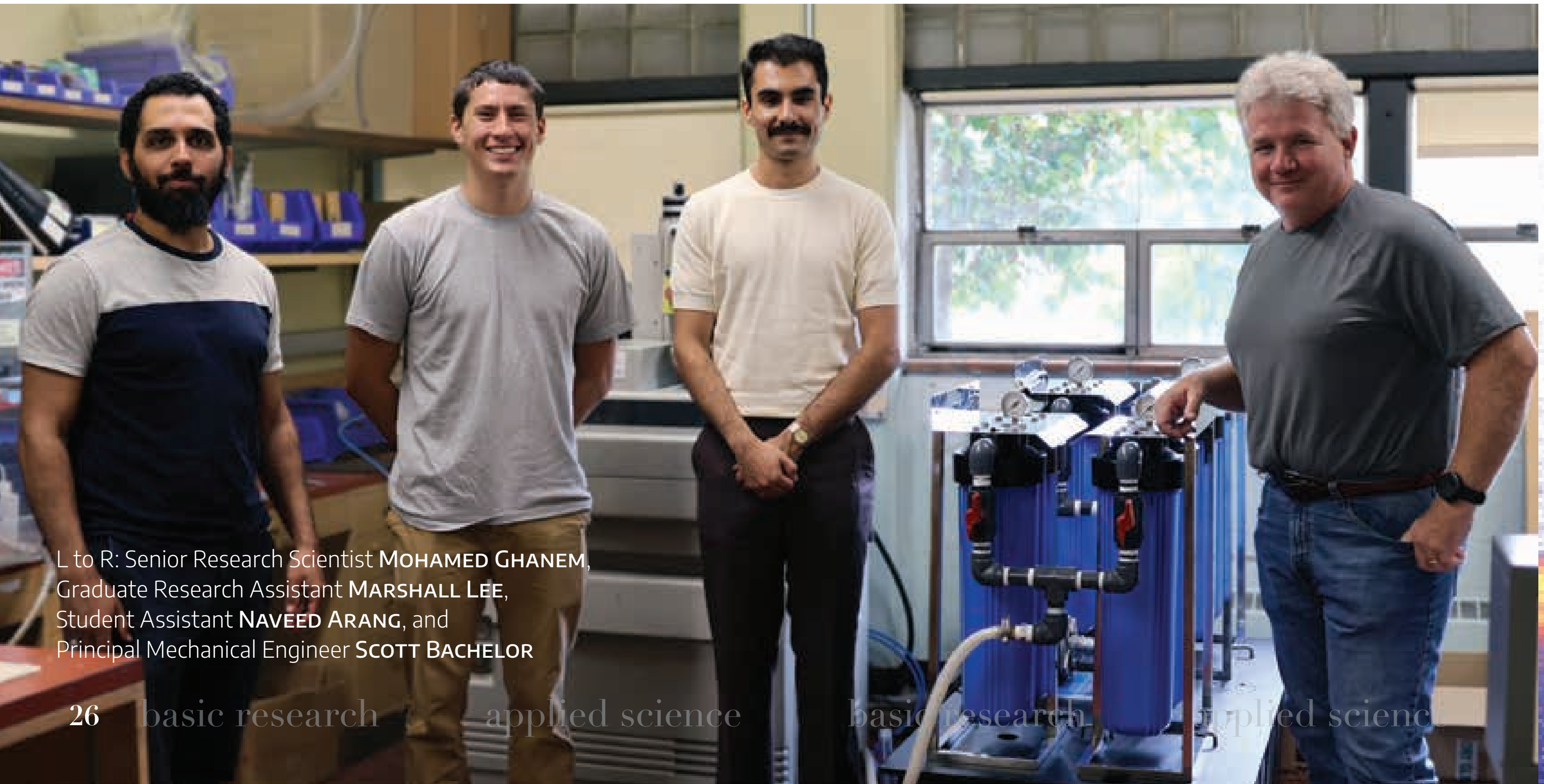
transducer fabrication technology exchange

Two teams of investigators, one that transmits acoustic energy into the ocean and the other into the human body, are solving transducer design and fabrication problems, adding capabilities to support future Laboratory projects. Curved and linear one-dimensional transducer arrays are the mainstay of diagnostic ultrasound and sonar operations. Curved, two-dimensional arrays are required for ultrasonic therapeutics, but their use has been limited to research settings because they are expensive, custom devices.

Center for Industrial and Medical Ultrasound researchers have demonstrated the noninvasive manipulation (trapping, steering, pushing) of objects in the human body, most notably to treat kidney stones, using a 256-element transducer array. The Transducer Center for Excellence in the Environmental and Information Systems Department makes linear, curved, and planar transducers rated for full ocean depth sonar and underwater sensing applications.

The teams have joined their capabilities — to fabricate sensors that operate reliably at extreme pressures in harsh environments and to characterize, simulate, and control multi-element arrays in research and clinical settings. The goal is to produce their own 256-element array with geometrical focusing absent a lens (which attenuates acoustic energy) and independent output control of each element (to steer the acoustic beam or change the beam's shape).

The workgroup has made progress, developing a numerical method to populate a topologically close-packed flat or curved array of transducer elements on any arbitrary surface, and simulating various acoustic output levels to establish the electrical demands of the system. They have developed techniques to arrange and attach piezoceramic elements on non-flat surfaces, and shown that their approach reduces cost, speeds fabrication, and results in an array that is robust and serviceable. Any part of the array can be accessed, repaired, or replaced with ease.



L to R: Senior Research Scientist Mohamed Ghanem, Graduate Research Assistant Marshall Lee, Student Assistant Naveed Arang, and Principal Mechanical Engineer Scott Bachelor

simplify, amplify echosounder measurements

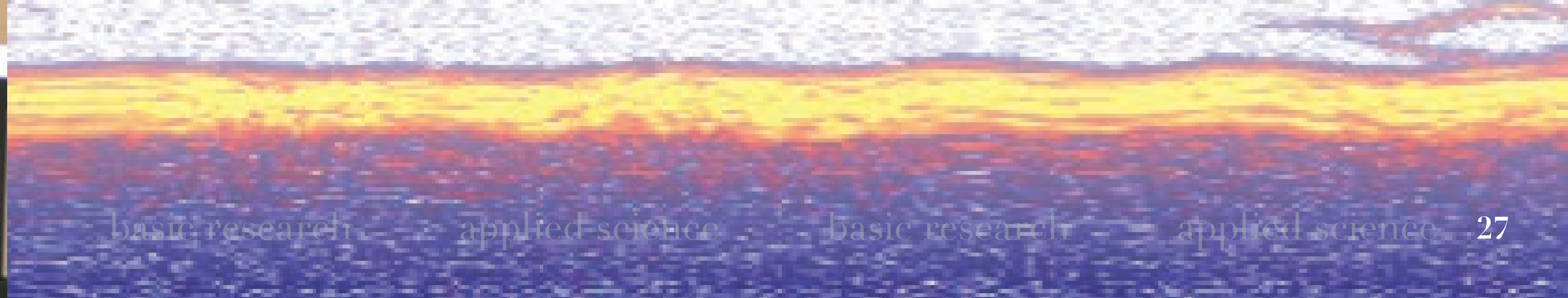
With the successful deployment of swarms of small spar buoy instruments, a collaborative team is a step closer to realizing a distributed sensor network to observe zooplankton and fish at scales and resolution not possible previously. APL-UW researchers and their external partners are developing BobberNet — an integration of a low-cost sonar with proven mechanical, electronic, and cellular communications components developed by Laboratory engineers. The goal: a network of cloud-connected echosounder floats delivering large-scale, real time observations of mid-trophic biological phenomena to advance ecological research in coastal regions.

Scientific echosounders are a mature technology used to measure the distribution, abundance, and movement of marine organisms in the water column. However, their components are expensive (especially transducers and electronics) and with few instruments in the water, they can miss biological phenomena that evolve sparsely and rapidly in dynamic coastal environments. Senior Oceanographer Wu-Jung Lee had the idea for BobberNet and is collaborating with the Ocean Engineering Department led by Principal Engineer Nick Michel-Hart, and with biological oceanographers and the Washington Department of Fish and Wildlife. "We believe that numerous, widely distributed, low-cost systems can provide more useful ecological data than scientific quality instruments, even if the data from each instrument are lower quality" explains Lee. "For many biological phenomena, the spatial and temporal coverage of the observations is often more critical than the quality of each sample."

As conceived, BobberNet could be applied to two science questions important to the sustainability of marine resources in Puget Sound. Here, the survival of larval herring and salmon smolts relies on their ability to feed shortly after their marine emergence. A swarm of echosounder floats could determine where and when zooplankton are most abundant, giving researchers and conservationists a forecast of fish recruitment success. A BobberNet flotilla could also detect Pacific herring spawning and hatching events, informing follow-on stock assessments.

Each BobberNet float is a lightweight, self-contained package, alleviating the logistical hurdles of scientific echosounder integrations with various platforms. In the prototypes, a golf-ball-sized, 'castable' recreational fishing sonar is fit to the end of a Laboratory-developed spar buoy, which houses a simple computer board to orchestrate sonar operations, organize the data, and communicate with the cloud. There, in virtual space, a mission file for each float controls sampling behavior and allows a user to make adaptive modifications based on the most recent data.

Proof-of-concept deployments with a network of four floats have characterized platform stability against wave motion, the power needs for various sonar and communication operation configurations, sonar quality in different water depths and with various bottom vegetation, and communication with cloud resources. "It works!" exclaims Lee. She acknowledges, however, that the prototype sonar has signal to noise limitations. The team is now focused on developing a sonar in house to enable scientifically valuable measurements by BobberNet.



next generation of scientists + engineers

Advancing the education mission of the University of Washington has been a central tenet of the Laboratory since its founding. APL-UW scientists teach, advise, and mentor scores of students at our world-class research university every year — undergraduate and graduate students in science and engineering disciplines, and postdoctoral scholars whose career interests align with the Laboratory's areas of expertise.

Beyond UW academic programs, Laboratory staff inspire and train students and educators at every level. Notable examples shared in this Annual Report include classroom enrichment experiences on landfast sea ice for middle-schoolers (p. 29) and an intensive, week-long internship with high-school students (p.30), who are on paths toward academic and professional careers in science, technology, engineering, and mathematics.

Polar scientists funded by the National Science Foundation to understand how microplastic particles move through the sea ice–ocean system in the Arctic are engaging with educators to craft a new high school science and math curriculum module based on their research methods. They are confident that their motivating concerns about microplastic pollution will translate to students' interest to understand and quantify this real-world problem. For the past two years, the APL-UW team has hosted summer workshops at the Laboratory to share expertise with teachers and to co-create classroom lessons and lab experiments that can be tested during the school year. Because microplastic exchange in the sea ice–ocean system is a multidisciplinary problem, it is open to a wide range of standards-based learning activities. The team's efforts will achieve their broadest impact when a curriculum module is distributed through a national student-scientist-teacher association.

Individually, APL-UW scientists mentor, advise, and provide hands-on research opportunities to undergraduate students. Now, with the kickoff of a summer internship program in 2023 (p. 32), capacity to inspire and train students has increased dramatically. Interns were selected from applicants who are undergraduates in STEM disciplines and from historically underrepresented groups. Sustained success of this program holds promise to grow and diversify the oceanographic research community and workforce.

APL-UW is a premiere launching pad for early career scientists. Postdoctoral scholars pursue research and training across the Laboratory's areas of expertise — ocean acoustics, physical and biological oceanography, polar science, and ultrasound physics (p. 37). With guidance from their APL-UW mentors, postdocs hone their academic talents and expand expertise through multidisciplinary collaborations, they gain professional experience as principal investigators, build a support and resource network, and develop the soft skills of grant writing, field experiment planning, and leadership (p. 39).

STEM ON ICE

An interactive classroom was set up on the shorefast ice near Utqiagvik, Alaska, for about sixty 8th grade students in the spring of 2023. The field trip for Hopson Middle School students enhances a component of their curriculum focusing on sea ice and climate change science taught from diverse perspectives.

Divided into small groups, the students rotated through four sea ice learning and experience stations: (1) Indigenous knowledge, (2) biology, (3) remote sensing, and (4) measurements of local weather, snow, and sea ice conditions. Demonstrating the many observing technologies and presenting the science concepts far from classrooms and any other permanent structures required the close collaboration of the Hopson 8th grade teachers, researchers from APL-UW and the University of Alaska Fairbanks, and logistics support from UIC Science. "The team was crazy effective," says Senior Principal Scientist Ignatius Rigor. "We've all worked together before, so we already know everybody's strengths and areas of expertise."

Rigor adds that Station #1, staffed with local whaling captains and elders, "... was by far the most popular with the students." There they learned the many Iñupiat terms to describe sea ice and how to know the difference between safe and dangerous ice. Ice cores drilled by students at Station #2 were examined closely for signs of biota living on the bottom surface and in brine channels. Two more stations demonstrated the methods and technologies used by scientists to take in situ measurements and how it is possible, from vantage points high above, to observe the frozen surface and to distinguish among bare ice, flat snow, snow dunes, and ridged ice — and how they change over time.

The field trip was a great success and now younger students are excited for the chance to participate as 8th graders. With support from the local community, Rigor and the multi-institutional science team are working to sustain the interactive sea ice learning experience as an annual event.

IMAGES: Ben Evans, MIT Lincoln Laboratory

ENCOURAGING YOUNG ENTREPRENEURS

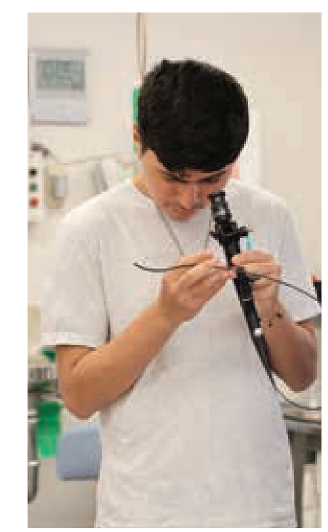
Seven eager and entrepreneurial high school juniors arrived in Seattle in June for a week-long immersive learning experience coordinated by Center for Industrial and Medical Ultrasound researchers. These students, who traveled across the country from Pahokee, Florida, have a long-standing relationship with the CIMU scientists and engineers — beginning with a robotics competition they entered in 2018 as middle-schoolers.

Under the tutelage of Brad Sokol, who worked in medical device development before becoming a science teacher, the students were participating in an after-school robotics club and entered the regional LEGO League Robotic Competition. Teams were asked to address a technical or medical problem faced by humans on extended space missions. When they set to work researching the issue, they chose to address astronauts' kidney stones, a problem more likely to develop in space.

Further research into the topic brought them in touch with a CIMU team. "The students discovered us as experts in kidney stone treatment research in the context of long-duration space missions," explains Senior Principal Engineer Mike Bailey. "Our idea of acoustic propulsion began in 2009, and our team had just begun clinical trials in humans and spun off a company to commercialize the technology when the students began their research." Bailey adds that the students' solution proposed for the competition was elegant and scientifically sophisticated — creating a vortex sound source to generate vigorous bubble action either to dislodge or break a kidney stone.

Based on this success, Pahokee teachers and CIMU researchers wanted to continue the collaboration, but the COVID-19 pandemic postponed plans for the group to visit Seattle until this past June. Their week was filled with hands-on demonstrations of experimental and commercial technologies, instruction in patent applications and medical device regulations, as well as brainstorming discussions about current scientific research such as the physiological effects of ultrasound applied to the brain.

Now in their senior year of high school, most of the students are planning to pursue further education and careers in science and engineering. Many are using their week-long immersion in entrepreneurial thinking to write college admission essays. Mr. Sokol, commenting on the benefits of the four-year relationship, says, "We helped expand our students' horizons — how big they can dream and what they can accomplish."



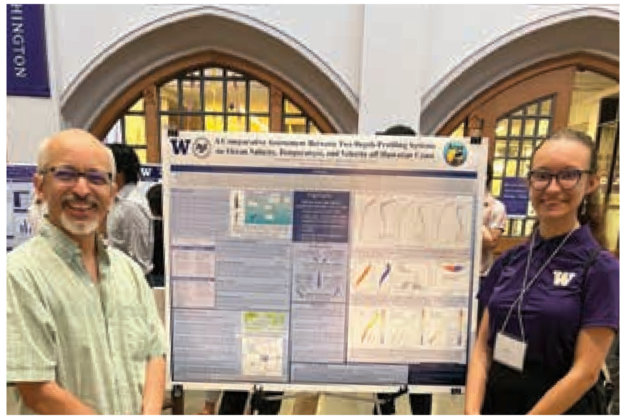
"It's a once-in-a-lifetime opportunity that I never thought I'd have."

RESEARCH EXPERIENCES FOR SUMMER INTERNS

A cohort of college undergraduate interns now has a clearer picture of themselves as future ocean scientists. In its inaugural year, 11 students participated in the rigorous, yet fun, Diverse and Inclusive Naval Oceanographic Summer Internship Program — DINO SIP.

The internship program is made possible by funding from a Department of the Navy / Office of Naval Research initiative to develop an inclusive and diverse oceanographic workforce. Winning the grant was a catalyst for the commitment of internal Laboratory funds and University of Washington support to establish DINO SIP. Joining APL-UW in January as our STEM Development Program Coordinator, **Amanda Labrado** had only a few months to design and begin implementation of a comprehensive experiential learning program for students who often face barriers to learning opportunities beyond the classroom. She announced DINO SIP in the spring and set out to recruit college students pursuing studies in STEM fields who are from historically underrepresented groups: ethnic minorities, first generation college and LGBTQ+ students, military veterans and their families, and disabled persons. Over 40 students responded to the call for applicants.

> *"These students are so curious, intelligent, and driven. Being able to help them along their academic and professional journeys inspires me."*
>
> — AMANDA LABRADO, STEM DEVELOPMENT PROGRAM COORDINATOR



"I couldn't have done this all myself," says Labrado. "Many APL-UW researchers stepped up by reviewing applications, serving on the selection committee, and volunteering as mentors." When students arrived in June they were enrolled in a seminar course led by the UW Office of Undergraduate Research focusing on professional development lessons. At APL-UW the interns were teamed with expert mentors to work on project-based research problems, provided peer-to-peer support and community-building activities, and exposed to tools and resources to navigate a path toward a career in ocean sciences.

"I'm really excited about this awesome opportunity. It levels the playing field for a lot of us."

"The mentorship, the academic experiences, and the social opportunities... I feel like I've gained a new family. I will definitely be recommending DINO SIP to others."

"This is my first internship. It's super fun and I've learned so much about how to do research."

Projects ranged across APL-UW areas of expertise: physical and biological oceanography, instrument design, fabrication and testing, as well as acoustic and image-based remote sensing of ocean and terrestrial environments. "Mentors did a great job ensuring the projects were reasonable in scope, feasible, and would generate data to analyze and results to present," explains Labrado.

During the two-month internship, students learned to measure salinity, temperature and depth, as well as phytoplankton, zooplankton and dissolved oxygen from a research vessel; they collaborated with each other to solve problems posed by their research topics; they wrote abstracts and technical briefs, designed posters, and presented results publicly to the APL-UW and University communities with enthusiasm and confidence.

Students who had never conducted research before excelled in the program and a small number are continuing to work with their mentors during the academic year. "I witnessed a tremendous amount of growth in each student over the summer," says Labrado. "I know they will go on to do amazing things."

"Oceanography is something that really interests me, and back home in Texas there isn't an option to study it."

Over 40 Laboratory scientists hold faculty appointments in University of Washington academic departments, principally in the College of Engineering and College of the Environment. Students pursuing UW degrees are entrained into their advisors' sponsored projects, where they gain applied research experiences beyond the classroom and build professional support networks. Every year we recognize the students who earned graduate degrees and the APL-UW scientists who served as their research and thesis advisors.

GRADUATE STUDENT ACHIEVEMENTS

Christine Baker
Civil + Environmental Engineering, Ph.D., 2023
Surfzone Vorticity Dynamics in a Directional Wave Basin
Melissa Moulton

Tyler Cox
Atmospheric Sciences, Ph.D., 2023
Atmospheric Heat Transport: Variability, Trends, and the Role of Orography
Aaron Donohoe

Erica Escajeda
Aquatic + Fishery Sciences, Ph.D., 2023
The Ecology, Sonic Environment, and Acoustic Occurrence of Subarctic Baleen Whales in the Bering Strait Over a Decade of Change
Kristin Laidre

James Stadler
Oceanography, M.S., 2023
On Estimating and Validating Surface Wave Spectra from EM-APEX Profiling Floats
Barry Ma and James Girton

Katie Sullivan
Electrical + Computer Engineering, M.S., 2023
Using an Off-The-Shelf Rigid Gripper to Grasp Objects of Different Strengths and Compliances
Aaron Marburg and Howard Chizeck

Zhihua Zheng
Oceanography, Ph.D., 2023
Impact of Surface Waves on Turbulence in Ocean Surface Boundary Layers: Observations and Scaling
Ramsey Harcourt and Eric D'Asaro

The Laboratory supports postdoctoral scholars showing outstanding potential to establish independent research careers with a two-year fellowship. **Science and Engineering Enrichment and Development (SEED)** scholars have research goals aligned with Laboratory areas of expertise and receive mentoring from APL-UW principal investigators. SEED fellows make significant contributions to the Laboratory's success and often become long-term additions to our science and engineering staff.

SUPPORT FOR ASPIRING INVESTIGATORS

IMAGE: Katy Christensen, UW

Polar chemist Laramie Jensen's recent research experience includes observations of the warming, freshening, and changing supply of nutrients transported to the Arctic Ocean through Bering Strait. Her plans for the SEED fellowship are to pursue higher resolution sampling of the gateway to understand the supply, distribution, and variability of trace metals to the Arctic. Trace metals, while often in very low concentration in the surface ocean, are essential micronutrients for phytoplankton growth.

"I sampled trace metals opportunistically during a July 2021 NSF-funded cruise in Bering Strait," explains Jensen. "I found remarkably large spatial variations in metals and macronutrients taken along four transects." Her results demonstrate the strong coupling of water mass origin and metal content in Bering Strait. Surprising, however, was her discovery that nutrient-poor waters were high in trace metals while nutrient-rich waters were low.

Over the next two years Jensen proposes to investigate the unexpected dichotomy between nutrients and trace metals on seasonal and interannual time scales by joining her Polar Science Center mentors Rebecca Woodgate and Cecilia Peralta Ferriz on planned cruises in Bering Strait. She has developed a pumping method driven by the ship's air supply that uses plastic tubing, capsule filters, ropes, and weights lowered over the side to collect water samples, rather than a traditional rosette with Niskin bottles. Samples from multiple depths are collected in less than 10 minutes per station, fitting within the cruise's high-speed hydrography program.

The fellowship also provides opportunities for lateral career growth and new interdisciplinary collaborations. “I hope to apply new chemical insights to traditionally physical oceanography process studies,” says Jensen. Two mature observing programs led by APL-UW investigators are natural extensions. For the Davis Strait gateway observatory, trace metal analyses could be leveraged to tease apart the relative modification from rivers and glacial melt that these waters undergo during transit from the Arctic to the North Atlantic. And in the heavily populated Puget Sound region, Jensen is developing techniques to collect metal and nutrient samples from moorings deployed in the region’s major basins to understand how ship and river inputs, as well as water residence time, affect potential metal toxicity.

IMAGE: Mike Rathibhan, R/V *Norseman II*

IMAGE: Katy Christensen, UW

FUTURE LEADERS, ALL ABOARD!

For one week in June 2023, postdoctoral scholar Astrid Pacini and 13 other early career scientists sailed from Seward to Nome, Alaska, aboard R/V *Sikuliaq*. With seven mentors, the group spent the time aboard learning and practicing all the skills needed to fill the chief scientist role on a research cruise.

The National Science Foundation, in partnership with the University–National Oceanographic Laboratory System (UNOLS) and the Arctic Icebreaker Coordinating Committee, organized the early career chief scientist training cruise with the goal of helping a cohort of diverse researchers gain the skills and confidence to request, plan, and lead scientific surveys on UNOLS vessels in the Arctic.

“We talked extensively about how to advocate for the well-being of everybody sailing and how to foster safe and respectful working environments.”

“The trip was an incredible opportunity to learn how to be a chief scientist, including methodologies for cruise planning, best practices for pre-cruise logistics and team-building, at-sea communication, and post-cruise documentation and data sharing,” remarks Pacini. Mentors, the ship’s Captain and marine technicians, and a community observer led workshops ranging across topics of sea ice navigation, *Sikuliaq*-specific capabilities, Arctic geopolitics, community engagement and co-production of knowledge, and environmental compliance. All participants served a 24-hour shift as co-chief scientist and gave talks about their research to foster collaboration.

Prior to joining the Laboratory’s Polar Science Center in fall 2022 as a NSF Office of Polar Programs Postdoctoral Fellow, Astrid logged extensive seagoing experience pursuing her high-latitude oceanographic research. Expeditions have taken her to the Labrador and Irminger seas, Baffin Bay, and, she recalls, “… a memorable winter storm-chasing cruise in the Nordic Seas,” to observe active deep convection conditions. The June training cruise was her second opportunity to work on *Sikuliaq*. For five weeks in November and December 2022 she was part of a team deploying a mooring and surveying the freeze-up period in the Beaufort and Chukchi seas.

The training is of immediate value to Pacini. Research plans during her fellowship at APL-UW focus on the air-ice-ocean interactions in the marginal ice zone and seaward of the ice edge in the Arctic. “This training helped me understand all the responsibilities and work behind the scenes. It will help me support chief scientists on future cruises.”

IMAGES: Lloyd Pikok, UIC Science

IMAGE: Djordje Zlatanovic/The Seattle Aquarium

Congresswoman Pramila Jayapal, whose district includes Seattle, toured APL-UW to meet researchers, handle some innovative technology, and announce a newly funded community initiative:

$1.5 million is going to the University of Washington to support an ecosystem ocean profiling buoy network to help understand climate changes that impact coastal economies, cultures, and communities, and help Seattle address sea level rise.

— social media post (3 July 2023)

Over the next two years APL-UW is leading an effort to design, build, and make operable a moored, biogeochemical, ocean profiling buoy network for high-resolution, full water column measurements throughout Puget Sound.

In U.S. coastal communities, climate change, population growth, and natural factors have caused ecological stressors such as depleted oxygen, corrosive waters, and extreme swings of temperature (marine heat waves) and salinity (droughts or flooding).

EQUITY AND ECOSYSTEM HEALTH

Initiative funding supports advanced technologies to sample water characteristics at higher vertical and temporal resolution and more efficiently than ever before, designed by Principal Engineer **Dana Manalang** and Senior Oceanographer **John Mickett**, and to share data in real time to all affected communities via NANOOS, the Northwest Association of Networked Ocean Observing Systems, led by Senior Principal Oceanographer **Jan Newton**.

A local small business will manufacture floats fitted with biogeochemical sensors. The floats use changes in their buoyancy to plunge to the seafloor and rise to the surface on regular intervals, all while remaining tethered to a moored buoy that supports meteorological sensors, data management hardware and software, communications, and a power supply.

The robotic floats are replacing a profiling sensor package attached by cable to a mechanical winch, which is prone to failure and requires frequent maintenance in the saltwater environment. This upgrade to a moored buoy network, which has operated in all the major basins of Puget Sound for 15 years, will increase water quality profiling frequency, and simplify deployment, recovery, and maintenance. Further, because the technology is more reliable and cost-effective, it allows for an expansion to more communities.

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