2021

Applied Physics Laboratory

UNIVERSITY OF WASHINGTON

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.

Scientific discoveries

Engineering innovations

Solutions for regional, national, and worldwide problems

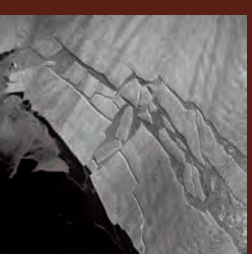
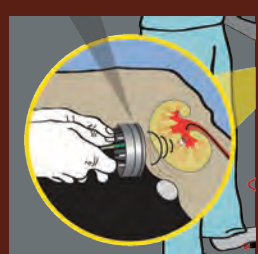
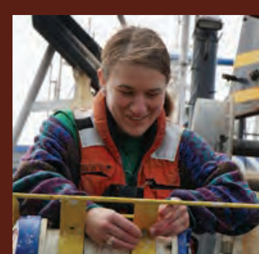
contents

community, flexibility, success

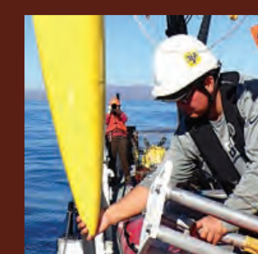
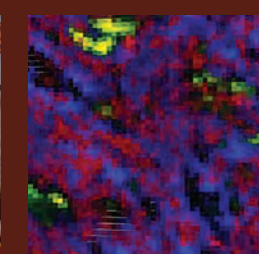
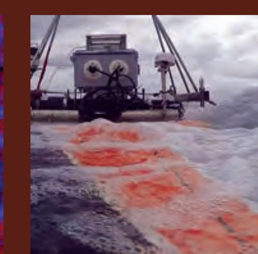
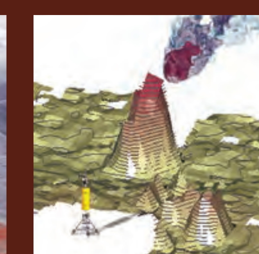
Nearly two years ago now, we pulled together as a community in the face of an unknown future. I am proud to report that APL-UW met the challenge head-on. Mitigating the initial impacts of the pandemic was difficult, but perhaps more challenging has been the past 12 months as the goal posts have been pushed back again and again. We've adapted continuously to these ever-changing realities while remaining steadfast in our commitment to fulfill the needs of our research sponsors and University of Washington community.

Flexibility in the moment has long been the cornerstone of our success — conducting research in the field, especially at sea, and in laboratories. Adopting that philosophy in our day-to-day operations has allowed us to remain extraordinarily productive. We have delivered on our current research efforts and continue to successfully propose new basic and applied research.

I am optimistic that we will find a normalcy that puts the pandemic behind us. That new normal may be fundamentally different than past practice, but at its center will be a point of consistency — to overcome all obstacles in the way of collective success. I know APL-UW staff will continue to seek, find, and implement those pathways to success. Our people make APL-UW a really amazing place!



progress reports

new discoveries and advances in ongoing research + development programs

ACOUSTICS · OCEANOGRAPHY · OCEAN ENGINEERING · ELECTRONIC SYSTEMS · POLAR SCIENCE · ENVIRONMENTAL REMOTE SENSING · MEDICAL + INDUSTRIAL ULTRASOUND · AIR-SEA INTERACTIONS · CLIMATE SCIENCE

tracking a warm jet in a cold ocean

In September 2018 a team aboard the R/V *Sikuliaq* tracked a 100-m-thick wall of warm, fast-moving water pouring into the Beaufort Sea during a **Stratified Ocean Dynamics of the Arctic (SODA)** research cruise. Last summer they published results of their high-resolution observations detailing how the freight train of heat meandered, slipped under a cooler, fresher surface layer, and then broke up into closely spaced warm patches lurking at depth.

With shipboard instruments, autonomous vehicles, and surface drifters, researchers followed the warm water jet as it evolved. They now report that early in the subduction process the ocean was losing a lot of heat to the atmosphere, which is expected in the Beaufort Sea in mid-September, but as the warm jet was squeezed deeper below the surface, heat fluxes from the ocean to atmosphere decreased dramatically. They conclude that only a small portion of the jet's total heat content was lost to the atmosphere. Nearly all was subducted, sequestered at depth, stirred, and spread into the Beaufort Sea basin. Persistent SODA measurements by moored instruments over 100 km away detected warm water pockets at depth, even months later when the ocean was completely ice covered.

These data and analyses provide critical insight to the physics governing subduction, stratification, mixing, and vertical heat transport at small scales in the western Arctic that are not currently resolved by regional sea ice forecasts and climate models.

skimming through puddles on a tropical ocean

A modified stand-up paddleboard with a meter-deep instrumented keel was towed for over 200 hours far outside the wake of the R/V *Roger Revelle* during the second **Salinity Processes in the Upper Ocean Regional Study (SPURS II)**. Deployed to coincide with the many intermittent bursts of showers in the tropical eastern Pacific, the Surface Salinity Profiler (SSP) collected a novel set of salinity, temperature, and turbulence data before, during, and after freshwater input to the ocean's surface.

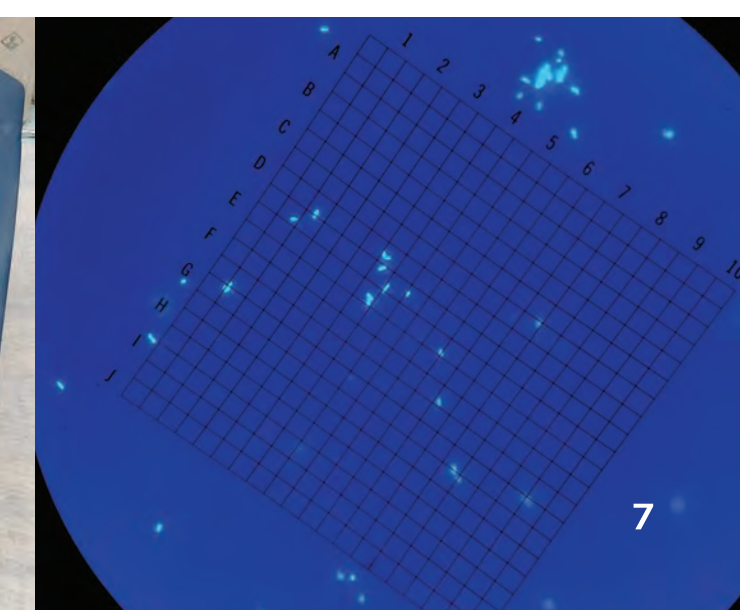
Principal Oceanographer **Kyla Drushka** and oceanography graduate student **Suneil Iyer** assessed the formation, persistence, and erosion of rain-formed fresh lenses under a wide range of conditions, and report a complex interplay of wind, waves, rain, stratification, and mixing. The high-resolution observations and their analyses of the patchy and widely varying events are aiding researchers' efforts to understand how freshwater inputs are spread into the regional sea surface salinity signal that is measured by satellite-borne sensors.

A new version of the SSP, one that is jet powered and programmed to survey autonomously, will be deployed in the Arctic next year. Druska leads an effort to measure the fresh surface layer created as sea ice melts during summer. The persistence of a stratified fresh layer near the ice edge may inhibit upward mixing of warmer, deeper layers, shielding sea ice from further oceanic melt, and preconditioning the ocean for autumn sea ice growth. The upcoming field campaign to capture the formation of sea surface salinity anomalies and evolution of stratification may improve the sensitivity and accuracy of salinity products derived from satellite remote sensing — measurements that are challenged by the Arctic's cold water and sea ice.

bacteria + biosignatures at icy extremes

Polar microbiologists **Karen Junge** and **Erin Firth,** sea ice physicist **Bonnie Light,** and colleagues have teamed to study the liquid water trapped in the pores and channels of sea ice and the organisms capable of surviving in this super cold and salty environment. The team designed experiments with the well-studied, cold-adapted microorganism, *Colwellia psychrerythraea*, exposing it to temperatures as low as –10°C and salinities four times saltier than seawater. Whether fed or starved for many months, *C. psychrerythraea* survives, remains metabolically active, and grows in the brine channels of sea ice. They also report how many cells remain viable under various experimental conditions, how much DNA the organisms make, and how many and which proteins they synthesize.

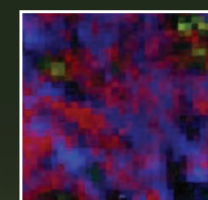
Now, with funding from the **NASA Exobiology Program,** the team is subjecting cold-adapted microorganisms to temperatures as low as –196°C for as long as one year. Pushing extremophiles into conditions beyond what they would ever experience on Earth serves as an analogue for the extreme cold environments of icy planets or moons in the solar system. Their work to isolate metabolism-specific proteins that indicate growth and survival may guide a future robot's search for biosignatures of microbial life on distant icy worlds.



Perseverance seeks evidence of past life with PIXL

With the exclamation, "Touchdown confirmed!" broadcast from mission control at the Jet Propulsion Laboratory, Senior Principal Physicist **Tim Elam** and millions of people around the world celebrated the safe landing of *Perseverance* after its 300-million-mile journey to Mars. As planned, *Perseverance* parachuted down into Jezero Crater, which at least once in the past was filled by a lake and retains a delta formed by outflowing water.

As the self-identified 'chief spectroscopist' of the Mars rover mission, Elam's analyses of data collected by PIXL – the Planetary Instrument for X-ray Lithochemistry – puts him front and center in the search for evidence of ancient life on Mars. After the February landing the science mission began in earnest. Several rocks have been targeted for close inspection and samples collected and cached for eventual return to Earth on a future mission.



Perseverance uses a tool on its robotic arm to abrade the surface of a targeted rock. Then PIXL can interrogate the newly revealed surface with its X-ray beam. Elam explains that he contributes two interpretive components to PIXL data streaming back from Mars: converting PIXL emission spectra excited by its X-ray beam to elemental composition – the rock's chemistry – and mapping the elements distributed on the surface. In one of the early samples PIXL identified over 20 elements in a 3 x 3-mm target area.

Elam's interpretations are then shared with the vast science team dedicated to analyzing the rock's origins and composition. Looking at PIXL's element map and focusing on the salt grains flecked in one of the samples, the team has posited that this particular volcanic rock likely spent a considerable amount of time underwater, where the salts percolated through the rock's pores and were then trapped when the lake dried.

Biosignatures – fossil evidence of past biologic processes in Jezero Crater – would be the ultimate finding, but until cached samples are returned to Earth for close examination such determinations are challenging. For now, PIXL and its companion instruments on *Perseverance* are providing greater insight than ever before about the Martian surface.

image: NASA/JPL-Caltech

precise undersea navigation for persistent gliders

Collaborative efforts among Principal Engineer **Sarah Webster** and colleagues at the Woods Hole Oceanographic Institution last year resulted in successful field tests of an acoustic navigation system for Seaglider. A low-power sensor improves the accuracy of Seaglider's undersea position calculations by an order of magnitude and could enable the vehicle to spend more of its time and energy making observations in deep ocean volumes of interest to oceanographers.

Seagliders fly underwater by changing buoyancy mechanically to dive and ascend on shallow glide paths. They stay on course by dead reckoning between GPS position fixes obtained at the surface during each dive cycle or, when operating under sea ice and denied the surface, by receiving acoustic signals from infrastructure-intensive subsea beacons.

During field experiments off the California coast, a surface beacon transmitted position information to Seaglider at regular intervals. An acoustic modem and precision timing and attitude sensors integrated on Seaglider used the one-way travel time calculation to determine the glider's position relative to the beacon.

In upcoming experiments planned for 2022 in the Gulf of Mexico, a single uncrewed surface vehicle will support two gliders surveying a region of interest. The navigation sensors draw very little energy and enable gliders to forego frequent trips to the surface so that limited stored power is expended on persistent, long-term observations of the deep ocean interior or seafloor.

arctic's 'last ice area' not immune to summertime melt

Perhaps the most dramatic observation of global climate change is the diminished sea ice cover in the summertime Arctic. Scientists long thought that the Arctic's 'Last Ice Area' – north of the Canadian Archipelago and Greenland where cold temperatures and onshore winds and currents pile up large reserves of the Arctic's oldest, thickest sea ice – would endure, even in a warming climate.

In August 2020 the German Icebreaker *Polarstern*, guided by satellite images that showed extensive open water and low sea ice concentrations, transited the Wandel Sea north of Greenland at the end of the MOSAiC expedition. Where was the sea ice? What caused the record low ice concentration in 2020? Is a warming climate now imperiling the 'Last Ice Area'?

Using satellite data and sea ice model experiments, APL-UW polar scientists **Axel Schweiger, Mike Steele,** and **Kristin Laidre** collaborating with Canadian colleagues reconstructed what happened during 2020 and report a prognosis for the 'Last Ice Area'. Sea ice in the region was actually thicker in the spring of 2020 than in previous years, but unusual weather – several strong wind events – early in the melt season pushed sea ice out. During summer, without a thick, protective cover of sea ice, solar radiation was absorbed by the ocean and then high wind events in early August mixed the accumulated heat upward, melting even more ice.

Based on their experiments, the scientists attribute about 20% of the record low sea ice concentration of 2020 to the initial conditions, that is, the long-term thinning trend driven by the warming Arctic, and attribute 80% to the weather events. They warn that summer sea ice concentrations in the Wandel Sea will now vary more from year to year and that given the right atmospheric conditions, the 'Last Ice Area' is poised to melt again.

photo: Melinda Webster, the Ice Watch program.
Photo collected as part of the international Multidisciplinary drifting Observatory for the Study of the Arctic Climate (MOSAiC) with the tag MOSAiC20192020 and the Project_ID: AWI_PS122_00.

fracturing antarctic glacier accelerates toward sea

Laboratory glaciologists **Ian Joughin, Daniel Shapero, Ben Smith,** and colleagues report that Pine Island Glacier, Antarctica's largest contributor to sea-level rise, has accelerated in the last several years coinciding with dramatic calving events captured by satellite remote sensing. Using an ice flow model, the researchers link the breakup and 19-km retreat of the ice sheet's leading edge to an observed 12% speedup.

The ice shelves of West Antarctic glaciers have been thinning for decades as a warming ocean erodes them from below. They are on a path toward irreversible collapse, but earlier studies had forecast that this process would likely play out over hundreds of years.

The rapid breakup of Pine Island Glacier's ice shelf, where one-fifth of its area was calved between 2017 and 2020, cannot be attributed to melting and thinning. Rather, the model studies reveal that the glacier's acceleration and breakup go hand-in-hand — increased internal forces are tearing the glacier apart. Now, researchers think it's possible that the collapse of the glacier's ice shelf could occur over the coming decades, not centuries.

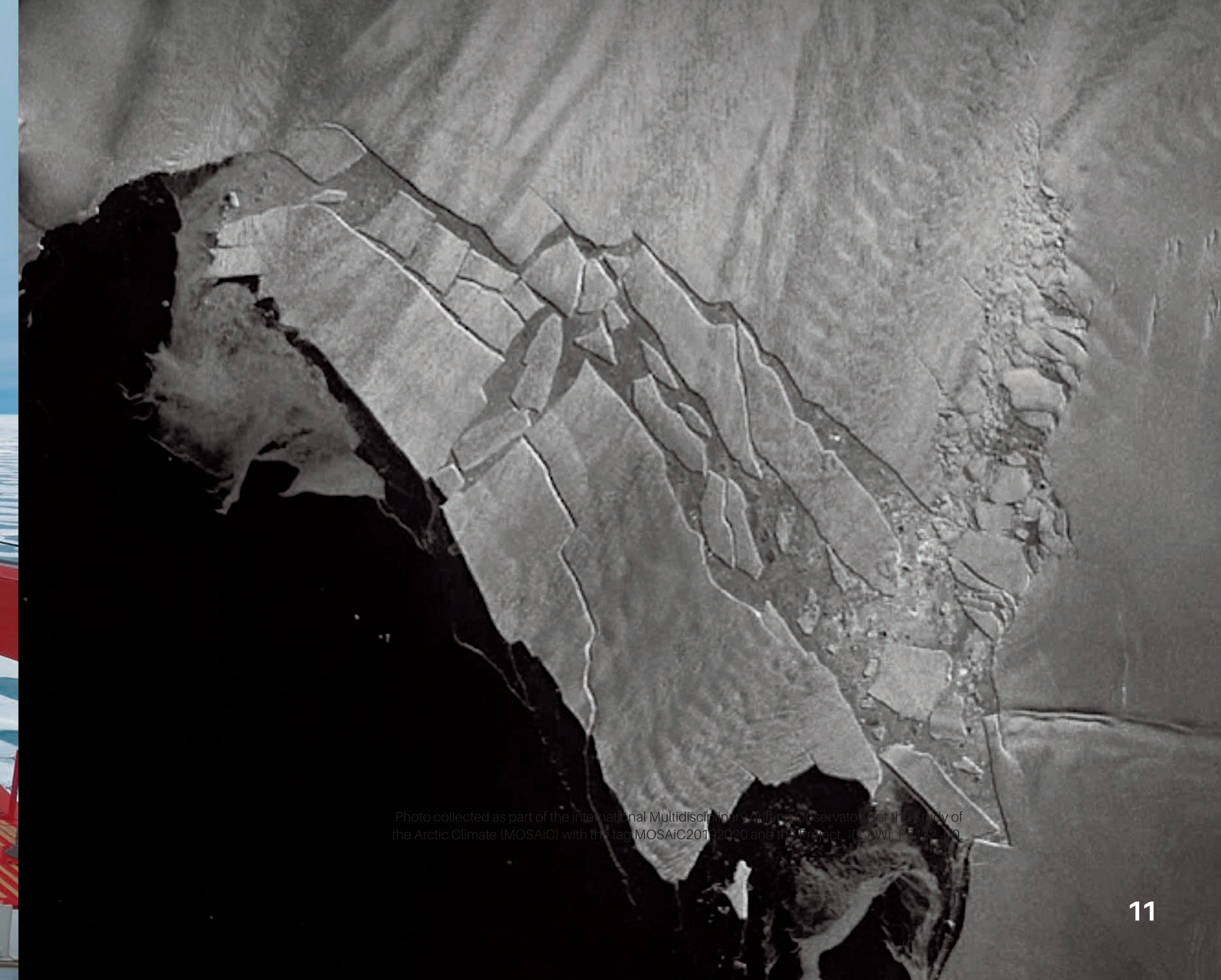


Photo collected as part of the international Multidisciplinary drifting Observatory for the Study of the Arctic Climate (MOSAiC) with the tag MOSAiC20192020 and the Project_ID: AWI_PS122_00.

IVAR — second generation

Recent developments have extended the depth and duration of the Laboratory's Intensity Vector Autonomous Recorder. IVAR records four channels of acoustic data continuously — one for acoustic pressure and three associated with an accelerometer to measure acoustic particle velocity, thus sensing the direction of recorded sound. The second-generation system can be lowered to 500-m depths for as long as 10 days.

As previously reported, IVAR was used to characterize acoustic propagation in an area 100 km south of Martha's Vineyard, where a large swath of the seafloor is covered in thick, sound absorbing mud. Seabed properties are inferred from IVAR's recordings of a passing ship, explosive sources, and even marine mammals. IVAR has since been deployed in acoustic reverberation experiments, where it made extremely interesting observations: source pulse and echo intensities arrive at the instrument in opposite directions, and as they collide they momentarily cancel each other. Most recently, IVAR was back at the great mud patch on the New England shelf to complete a pilot study in preparation for the 2022 **Seabed Characterization Experiment.**

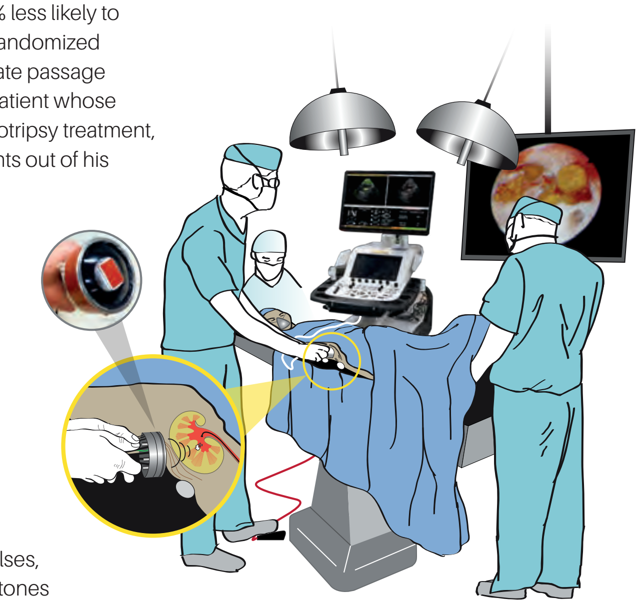
Project leads **Peter Dahl** and **David Dall'Osto** note that they continue to improve their methods to analyze vector acoustic data, discovering new and unanticipated properties of sound and the seabed with the system.

IVAR was developed under an Office of Naval Research DURIP, a DoD–university partnership to support invention of instruments needed to conduct cutting-edge research.

more patients treated with ultrasonic therapies

A urologist, holding an ultrasound probe against a patient's skin, can now image, fragment, and push kidney stones to relieve painful obstructions and hasten their natural passage, all while the patient is awake and feeling no discomfort. Investigators at the APL-UW **Center for Industrial + Medical Ultrasound** and their multi-institutional collaborators who developed an ultrasonic treatment system for kidney stone disease have now reported exciting results from several ongoing clinical trials at the fall 2021 meeting of the American Urological Association.

In one randomized controlled trial that has followed subjects for up to 5 years and who had asymptomatic stones removed surgically from the kidney, patients are over 75% less likely to require another surgery or return to the emergency room. In another ongoing randomized controlled trial, ultrasonic propulsion, instead of surgery, is being used to facilitate passage of small, asymptomatic kidney stones from patients. For one case reported, a patient whose stubborn kidney stone fragments would not pass months after shock wave lithotripsy treatment, the transcutaneous 'leaf blowing' effect of ultrasonic propulsion swept fragments out of his kidney's lower pole and facilitated their natural passage within hours.



Nineteen subjects were recruited into the first study of burst wave lithotripsy — the transcutaneous application of focused, cyclic ultrasound pulses. Patients were about to undergo surgical intervention to treat their kidney stones but were first treated with burst wave lithotripsy. Administered with a handheld probe, the ultrasonic treatment fragmented 65% of total stone volume to less than 2-mm fragments in less than 10 minutes per stone with only minor tissue injury monitored by ureteroscopic video.

In another study 20 awake patients presenting to a kidney stone clinic or hospital emergency department with painful, obstructing ureteral stones were treated with ultrasonic propulsion and burst wave lithotripsy. Stone motion was observed in most cases, some stones were fragmented with the burst wave pulses, half of the patients had near-immediate reduction in pain, and nearly all acute stones passed within 3 days of the procedure.

acoustics experiments address sonar performance

Early 2020 experiments at the Naval Undersea Warfare Center, Division Keyport test range in Dabob Bay focused on collecting acoustic propagation and reverberation data under rough and calm sea surface conditions. While APL-UW acousticians **Todd Hefner** and **DJ Tang** have worked to understand how the waves generated during episodic winter storms impacted acoustic measurements, they also discovered that surges of freshwater outflow from area rivers during these heavy rain events could also be a strong driver of acoustic variability within the bay.

Now, in a collaboration with Laboratory oceanographers **Ramsey Harcourt** and **John Mickett,** the team is exploring whether freshwater inputs have a similar impact on acoustic propagation along the Washington coast. A preliminary analysis of ocean modeling and acoustic simulation studies has prompted the Office of Naval Research to fund an 8-week experiment on the Washington shelf next summer. This effort will explore the freshwater impacts on acoustic variability and seek to improve ocean models of the processes that could ultimately enhance the Navy's ability to predict sonar performance in such coastal environments.

prototype tech for modular hydroacoustic stations

For several years APL-UW engineers have collaborated with the Comprehensive Nuclear-Test-Ban-Treaty Organization (CTBTO) Hydroacoustic Team to improve the sustainability of International Monitoring System hydroacoustic stations. Now, the technology that would enable a proposed modular solution for these stations – a prototype cable latch designed by engineers **Geoff Cram, Mike Harrington,** and **Derek Martin** in collaboration with CTBTO and fabricated by APL-UW machinists – has completed initial qualification testing. The stations listen always and everywhere for violations of the Comprehensive Nuclear-Test-Ban Treaty. Most are comprised of two sets of three hydrophone nodes on the seafloor cabled in a continuous string. In the current configuration, damage or failure anywhere along the triplet string – the hydrophone riser assemblies or inter-node cables – would require complete recovery for replacement or repair, and then redeployment.

APL-UW engineers proposed a modular solution so that individual component failures could be addressed by a ROV on the seafloor. The prototype cable latch would serve as the connecting point between triplet components in a modularized station. Its robust and effective design includes a cable termination assembly and plate to resist and transfer to the latch frame the combined bending movements and tension loads during deployment. During underwater qualification testing the latch's retention cables were cut with a manual tool that is functionally identical to a tool onboard a ROV. With cables cut, the latch arms open to clear the moment resisting plate/termination assembly, which can then be lifted from the latch, thereby simulating ROV operations on a service mission to a modular hydroacoustic station node.

gateway to the arctic

three decades of observations in the bering strait

Moored instruments have been deployed in the Bering Strait since 1990 to measure the Pacific water flowing north into the Arctic Ocean. Last summer APL-UW oceanographers reported that the three-decade record indicates that the flow is increasing and the waters are warming and freshening.

The program to monitor the sole oceanic gateway between the Pacific and Arctic was begun in 1990 by (retired) APL-UW oceanographer **Knut Aagaard** and a multi-institutional team. Since 2000, Senior Principal Oceanographer **Rebecca Woodgate** has been a lead investigator and almost always aboard the program's service cruises every summer to recover the previous year's moorings, deploy their replacements, and conduct hydrographic surveys. Senior Oceanographer **Cecilia Peralta-Ferriz** joined the program in 2018, bringing a satellite remote sensing perspective to the work. Despite the COVID-19 pandemic, program operations continued in 2020 and 2021, though with modifications.

Because of safety concerns, Woodgate's science team did not join the crew aboard the R/V *Norseman II* in 2020. She notes, "We shipped the moorings with as many parts as possible connected and there were color-coded instructions for the crew." The researchers and ship's crew have collaborated successfully for many years, and with a high-speed Internet connection to the ship they used group text and video call apps to maintain immediate and face-to-face communication during critical operations. The crew deployed the replacement moorings, but it had been decided that the previous year's moorings would not be picked up because it is a more complex effort. Woodgate admits this was a bit of a gamble, but it paid off and all of the moorings (and their data) were retrieved successfully in summer 2021, extending the time series into its 31st year.

These continuous observations in the Bering Strait document the influence of Pacific waters on the Arctic and their variability in a warming climate. The relatively warm Pacific inflow triggers sea ice melt in the western Arctic, pumps one-third of the total freshwater input to the Arctic, and is a major source of nutrients for arctic ecosystems. Woodgate and Peralta-Ferriz report that the total Bering Strait transport has increased by more than 50% since the 1990s, the summer waters are 2–4°C warmer, and the winter waters are now even fresher than during summer.

photo: Katy Christensen, UW

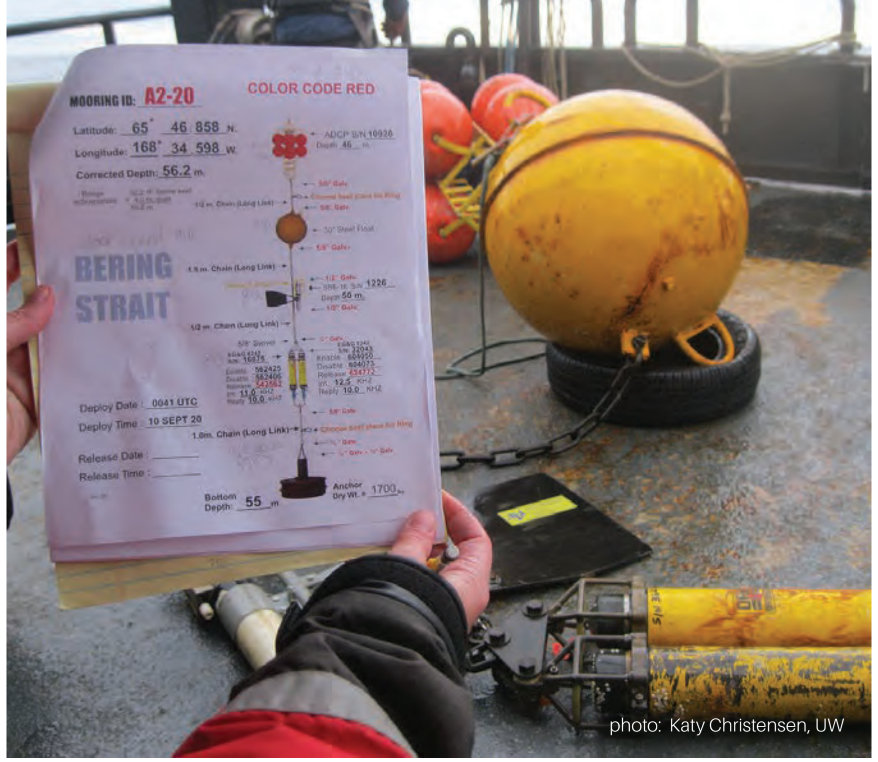


photo: Katy Christensen, UW

"The temperature changes in recent years are expected in a warming climate… earlier warming, later cooling, adding up to a longer warm water season," explains Woodgate. "We didn't expect that the flow would speed up, but it has, and the winter freshening is the most intriguing part of the record."

The long-term trend of increasing flow through the Bering Strait is driven by the Pacific-to-Arctic 'pressure head', which results from the somewhat enigmatic sea surface height difference between the oceans that pushes waters northward. Previous work by Peralta-Ferriz and Woodgate combined the moored time series with satellite ocean bottom pressure data and a modeling study to show that changes in arctic atmospheric circulation are a dominant influence on flow variability. Winds in the East Siberian Sea are, in effect, pushing water away from Bering Strait, thus lowering the sea surface height and increasing the pressure gradient that pulls water through the gateway.

As well as increasing in transport, the waters are now warmer by degree and duration. The annual mean temperature has increased from 1° to 3°C. In the early 1990s, the annual mean was often below 0°C, but since 2014 all the annual means have been positive. Woodgate adds, "This is a remarkable change if you think about it in terms of distance from the freezing point, around –2°C." When observations began the water flowing past the moorings usually warmed to over 0°C in mid-June, but now that temperature threshold is crossed in May. Likewise, the first day that water returned to below 0°C used to happen in November, but now it is delayed until mid-December.

This longer season of warm water pouring through the Bering Strait triggers earlier and greater sea ice melt in the Chukchi Sea. Woodgate and Peralta-Ferriz note that Bering Strait oceanic heat transport now melts the equivalent of 1–2 million square kilometers of 1-m-thick sea ice per year, a value that has doubled since 2000. They also warn that we should expect an amplification of this effect. Earlier open water conditions now common in the Bering Strait and Chukchi Sea coincide with maximum solar heat input during late spring and summer, creating a positive feedback to add heat to the ocean. And while solar radiation input is limited by the season, oceanic heat can continue to inhibit sea ice growth even when the sun's energy is weak and the atmosphere very cold during fall.

The researchers stress how strange the flow through the Bering Strait has been in recent years. The most unusual observation is that waters flowing from the Pacific in winter are now fresher than in summer. Since 1990, annual mean salinities have increased by about 0.5 practical salinity units, "… and that's quite a lot," exclaims Woodgate. The erasure of seasonal variability in the salinity signal, however, "… changes everything I've been teaching oceanography students for decades about the strait," she adds. Sea ice growth creates cold, salty water, while ice melt creates fresh water, so during freezing months the flow should be more saline and during melting months, fresher. She suspects that the fresh water can be attributed to increased river runoff and glacial ice melt into the Gulf of Alaska that is carried by a coastal current to the strait. Over the decades, mooring measurements detected 'freshwater events' during winter, but these events now dominate to the point of erasing the winter salinity signal entirely.

The remarkable winter freshening suggests that Pacific waters are entering the Arctic about 50 m shallower than before. It is likely that they no longer refresh the cold layer that has served as a protective barrier between the sea ice and the warmer, denser Atlantic water layer below, and the nutrient-rich Pacific water is now deposited closer to the surface. The three-decade-plus record of observations in the Bering Strait will aid future collaborative research needed to understand the impacts of increasing heat and freshwater fluxes from the Pacific on arctic climate and ecosystems.

team members: REBECCA WOODGATE, CECILIA PERALTA-FERRIZ, JIM JOHNSON, ROBERT DANIELS, KATY CHRISTENSEN (UW), JOHN GUTHRIE, LARAMIE JENSEN (UW), KAY RUNCIMAN

sponsor: NATIONAL SCIENCE FOUNDATION

POSTDOCTORAL RESEARCHER LARAMIE JENSEN AND OCEANOGRAPHIC ENGINEER ROBERT DANIELS ABOARD R/V *NORSEMAN II*, 2021.

JENSEN IS MAKING MEASUREMENTS OF TRACE METAL AND NUTRIENT CONTENT DURING THE 2021 BERING STRAIT HYDROGRAPHIC SURVEY TO INVESTIGATE ARCTIC CIRCULATION AND BIOGEOCHEMISTRY.


photo: Jim Well, R/V *Norseman II*

cabled array data

a trove for acousticians

APL-UW engineers were principal partners in the design and installation of the Ocean Observatories Initiative Cabled Array and lead the engineering team each summer on a cruise to maintain and expand the observatory's capabilities. Commissioned in 2015, the OOI-CA is the world's largest undersea observatory. The high-power, high-bandwidth network hosts more than 150 scientific instruments and provides a 24/7/365 portal for scientists to access near-real time data to study deep and coastal ocean processes.

shimmering hydrothermal vents + seeps

COVIS, the **Cabled Array Vent Imaging System,** developed by APL-UW ocean engineers, is one of the instruments added to enhance the OOI-CA since commissioning. A tripod base and 4-m tower support COVIS's dual-frequency (200 kHz and 400 kHz) multibeam sonar that is mounted on a triaxial rotor. Plugged into an OOI-CA node, COVIS stands amid the ASHES hydrothermal vent field in Axial Caldera at about 1500-m depth. Since 2018 COVIS has been monitoring hydrothermal venting from sulfide chimneys and seafloor fissures on the active volcano, which is predicted to erupt with the next five years.

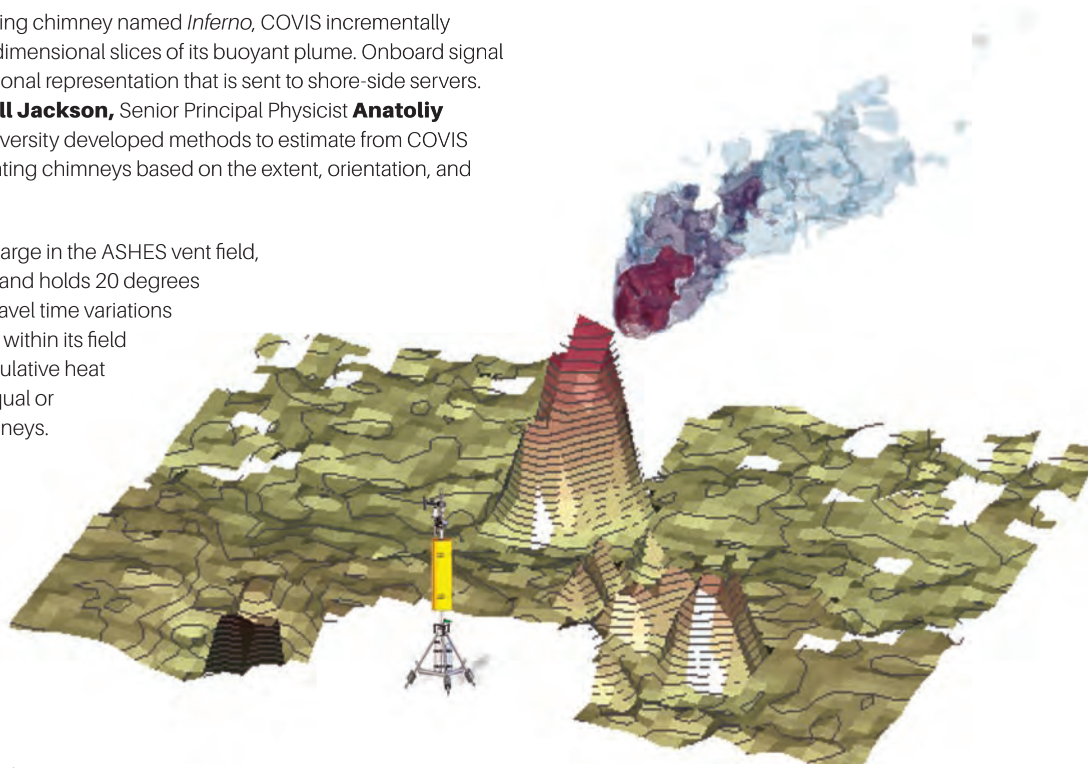
Acoustic remote sensing is a natural tool to monitor hydrothermal venting because the temperature fluctuations due to the mixing of hydrothermal fluids with seawater scatter and distort the sound waves. Senior Acoustician **Guangyu Xu** suggests an analogy: "We can see the shimmering of air above hot asphalt on a sunny day even though the air is transparent because the temperature fluctuations create a visible signal." Likewise, COVIS's sonars detect sound scattering and distortion caused by the turbulent mixing of hot hydrothermal discharges and the cold ambient seawater.

photo: UW/NSF-OOI/CSSF

"Like any remote sensing technology, we need ground truth data to calibrate our observations."

— Guangyu Xu

Standing about 10 m away from a venting chimney named *Inferno,* COVIS incrementally pitches its sonar head to capture two-dimensional slices of its buoyant plume. Onboard signal processing constructs a three-dimensional representation that is sent to shore-side servers. Xu, Principal Engineer Emeritus **Darrell Jackson,** Senior Principal Physicist **Anatoliy Ivakin,** and colleagues at Rutgers University developed methods to estimate from COVIS data the volume and heat flux from venting chimneys based on the extent, orientation, and vertical velocities of plumes.



To map the diffuse hydrothermal discharge in the ASHES vent field, COVIS points the sonar at the seafloor and holds 20 degrees below horizontal, detecting acoustic travel time variations due to the variable water temperatures within its field of view. It is hypothesized that the cumulative heat output from these diffuse flows may equal or exceed the focused venting from chimneys.

The team is developing model simulations that predict acoustic backscatter signals relative to certain amounts of heat from the seafloor. They are aided by colocated OOI-CA and autonomous measurements. "There are several seafloor temperature sensors within the COVIS range of view," notes Xu. "Like any remote sensing technology, we need ground truth data to calibrate our observations." He and colleagues report that their acoustic observations match well with the locations of diffuse flows detected during a seafloor survey with temperature sensors. The verification of COVIS observations opens the possibility of developing acoustic methods to estimate the hydrothermal heat flux at ASHES before, during, and after the next eruption.

discovery driven by data

The density and reliability of data streaming to shore from scientific echosounders plugged into the OOI-CA are critical to Senior Oceanographer **Wu-Jung Lee,** who is developing machine learning methods to chart the distribution, abundance, and movement of mid-trophic level sea creatures. "Cabled Array echosounder data are always very high quality," explains Lee, adding, "Working on new data analysis methods requires consistent, robust data." Lee, Senior Oceanographer **Emilio Mayorga,** and **Valentina Staneva** from the UW eScience Institute founded the Echospace Group, where researchers with diverse backgrounds and expertise are developing computational methods and open source software to join the analysis of acoustic observations and ocean environmental variables.

“Working on new data analysis methods requires consistent, robust data.”

— Wu-Jung Lee

Echosounders allow researchers to infer the type and number of animals – acoustic scatterers – from the sounds transmitted to and bounced back from objects in the water column. Traditionally, echosounder surveys have been conducted from a ship, but now the instruments are deployed on moorings and autonomous vehicles, which has created a glut of data that overwhelms data processing methods that often rely on human experts to visually inspect, label, and analyze.

Lee and Staneva developed a methodology to extract dominant patterns automatically and describe their variation using data from an upward-looking echosounder integrated on the shallow profiler mooring of the Coastal Endurance Array. From the moored platform suspended at 200-m depth, the echosounder records the daily vertical, synchronized movement of creatures rising to the surface at dusk and returning to depth at daybreak, as well as other patterns that do not follow the same movements. They report that their data-driven method automatically removes noisy outliers from the echograms and builds a comprehensive representation of the animal aggregations engaged in these different vertical movement behaviors. Lee emphasizes that their machine-learning approach, “… succeeded in finding the dominant patterns in the data without making any prior assumptions about the type of scatterers or sources of interference.”

Now, the group is working to apply the same pattern analysis approach to the high-density physical and chemical data collected by other instruments on the mooring. “Connecting environmental observations with the bioacoustics to determine temporal correlations is a high, but attainable, goal,” adds Lee.

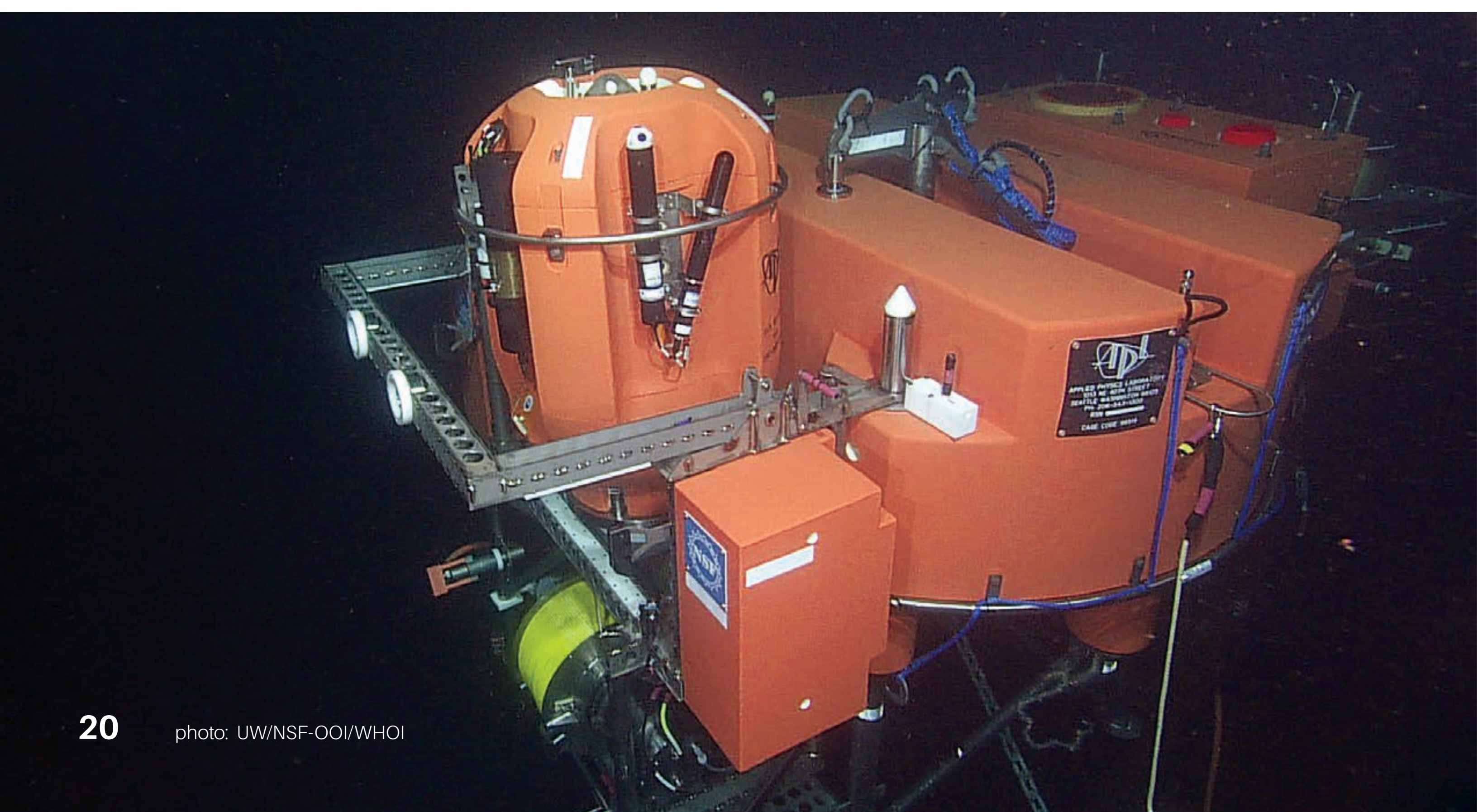


photo: UW/NSF-OOI/WHOI

pandemic quiets shipping noise

Hydrophone recordings from an OOI-CA station on Hydrate Ridge, about 87 km offshore Newport, Oregon, show a marked decrease in shipping noise in early 2020, coinciding with the beginning of the COVID-19 pandemic. The low-frequency recordings at this station have been nearly continuous since Cabled Array commissioning in January 2015, so Senior Principal Engineer **Peter Dahl** and Senior Acoustician **David Dall’Osto** were able to pinpoint the clear departure from previous years’ mean noise levels beginning around 1 March 2020 and trace the persistence of the decreased noise through the summer. Adding a wrinkle to analysis of this time series is that a seasonal reduction in noise is out of phase with ship traffic. That is, noise levels are lower in summer when traffic is greatest.

Dahl initiated his inquiry into the pandemic’s possible effects on underwater noise in the Northeast Pacific by approaching Senior Principal Engineer **Mike Harrington,** who serves as the OOI-CA’s chief engineer. “Mike recommended the hydrophone data from this station because there are no noise sources from nearby instruments on the array, and it’s been recording continuously for over five years,” notes Dahl. The station is also situated within north–south coastal shipping lanes and likely detects noise from ships on routes connecting Pacific Northwest and Asian ports.

The researchers report that the low-frequency noise of shipping traffic was reduced by 1.6 dB in the spring of 2020 relative to the means of the previous five years. To corroborate that this decrease was due to the economic downturn and reduction in container ship traffic caused by COVID-19, they aligned maritime automatic identification system data and shipping container metrics over the same period since 2015. The noise reduction in early 2020 correlates roughly to the nearly 20% fewer vessels sailing routes within listening distance to the Hydrate Ridge station.

A clear seasonal pattern emerges from the hydrophone time series. Low-frequency noise is 2–3 dB less in summer than in winter, which is out of phase with the number of vessels, and moreover, is greater than the quieting effect of the pandemic. Dahl explains, “With summer warming, sound speed near the surface increases, so the ability to transmit sound to long ranges, particularly that generated by ships near the surface, is reduced.” The hydrophone recordings capture this annual seasonal effect plus the subtle change in low-frequency noise in spring and summer 2020 caused by the pandemic’s impact on vessel traffic.

apl-uw team members: PETER DAHL, DAVID DALL’OSTO, MIKE HARRINGTON, DARRELL JACKSON, ANATOLIY IVAKIN, WU-JUNG LEE, GUANGYU XU

sponsors: NATIONAL SCIENCE FOUNDATION; OFFICE OF NAVAL RESEARCH; UNIVERSITY OF WASHINGTON COOPERATIVE INSTITUTE FOR CLIMATE, OCEAN AND ECOSYSTEM STUDIES

harnessing marine energy

Purpose built for marine energy research and development, the Laboratory's R/V *Russell Davis Light* was busy on Lake Washington in 2021. Efforts at APL-UW span the range from basic research to design and engineering for at-sea power applications, and are driven by collaborations with faculty and students in the College of Engineering, postdoctoral researchers, and APL-UW professional engineering staff.

Ongoing projects include laboratory testing and field deployments of wave and tidal energy converters, advancing ocean microgrid and vehicle recharge systems, and developing environmental monitoring platforms for marine energy sites. R/V *Light* supports turbine testing at scales that bridge laboratory studies to commercial markets, and after significant upgrades in late 2020 is now equipped with acoustic systems research infrastructure.

deep dives into an ice sheet

Melt probes can descend through hundreds of meters of glacial ice using modest electrical power. These platforms show great promise to make novel observations within and beneath ice sheets. Because melt probes are logistically light, they allow researchers to reach deep into ice sheets at a fraction of the cost of conventional drilling methods.

Senior Principal Physicist **Dale Winebrenner** leads the Ice Diver research and development program at APL-UW. Successful tests of the probe on the Greenland Ice Sheet earlier this year have moved the team a step closer to their goal of exploring polar subglacial lakes. These are some of the last places on Earth left unexplored and there are at least 400 in East Antarctica alone. Reaching their depths under the ice sheet is presently so difficult and expensive that it happens only very rarely. "Our Ice Diver is designed to descend to the lakes and be brought back to the surface," explains Winebrenner. "Retrieving lake water samples and preventing pollution of these pristine environments is a completely new development in melt probe technology."

Antarctic lakes beneath kilometers of ice are likely the closest analogues on Earth to seas beneath the icy crusts of Europa and Enceladus in the outer solar system. Stretching to the goal of distant world exploration will require technological refinement and rigorous, repeatable scientific tests. "We don't know what lives in the earthly lakes, nor the ways organisms can 'make a living' in a geochemical sense there," adds Winebrenner. "But we have to find out if we want to plan expeditions to distant icy moons searching for signs of life."

At Greenland Summit Station, some 3200 m above sea level at the apex of the Greenland Ice Sheet, an APL-UW engineering team of **Ben Brand, Justin Burnett,** and **Madison Pickett** sent an Ice Diver over 100 m deep into the ice. At that depth the probe retrieved water samples and was then recovered to the surface. This is the deepest any melt probe has explored an ice sheet and returned successfully from a sampling mission.

Through the first 12 hours of Ice Diver's descent, and to a depth of over 60 m, the meltwater produced by the hot-tipped probe was absorbed laterally into the surrounding firn and did not accumulate in the hole above. With ice temperatures near –30°C, water in the borehole would quickly refreeze, trapping Ice Diver and preventing its recovery to the surface. As they continued deeper the team observed meltwater retained in the hole, but they were prepared.

An earlier numerical investigation had shown that antifreeze injected into the melt hole above the diving probe at a rate determined by probe diameter, descent rate, and temperature could prevent refreezing and avoid clogging the hole with slush. They began injecting methanol above Ice Diver and proceeded for over 12 more hours to the final depth of 103 m, feeding the probe's tether down through the antifreeze/water mixture. Ice Diver was recovered without resistance, and even 36 hours later sent down into the borehole and retrieved again successfully. "We have validated a simple antifreeze injection strategy in the field at temperatures characteristic of large parts of the Greenland and Antarctic ice sheets," Winebrenner notes.

Also validated are the team's methods to collect samples of englacial meltwater free of microbial contamination, which have been developed by collaborator **Jill Mikucki,** microbiologist at the University of Tennessee, Knoxville. Prior to deployment, Ice Diver's outer surfaces were cleaned with hydrogen peroxide. At the maximum dive depth, peristalic pumps, autoclaved tubing and sample bags within the Ice Diver's shaft body collected 120 ml of meltwater according to design. Immediately upon recovery to the surface, tests were conducted to detect microbial contaminates. Adenosine triphosphate assay results indicate that the probe surfaces were below the threshold of cleanliness limits established by the NASA Mars Science Laboratory.

COLDEX

With new funding announced in late 2021 from the National Science Foundation, the Ice Diver team is part of a plan to search for the oldest ice on Earth. They will develop expendable probes to dive several kilometers into the ice in the Allan Hills region of Antarctica. This instrument development effort and projected field research season in 2022–23 is part of a multi-institutional campaign to retrieve a continuous ice core dating back 1.5 million years and preserving traces of the planet's climate history.

Classical ice melt probes maintain connections with their electrical supply on the surface through wires spooled inside the vehicle that unwind during descent into the ice. By design, water in the melt hole above the probe refreezes. The Ice Diver team developed a classical melt probe and sent it 400 m into the Greenland ablation zone back in 2014.

The new version of deep diving expendable probes will include a laser source and optical sensors to quantify the number of dust particles trapped in layers of glacial ice. During colder, past epochs the atmosphere was dustier. The oldest ice is likely to reside in patches near the bottom of the ice sheet. The probes, sampling ice age based on its dustiness, will be sent on missions to find these patches in the survey area, thus identifying the most promising sites to core drill the most ancient ice on Earth.

Winebrenner, several UW glaciologists, and colleagues from institutions around the U.S. are banding together to advance understanding of the Earth's climate history within the new **Center for OLDest Ice EXploration. COLDEX** was created in 2021 by a National Science Foundation grant. The survey mission will be completed in the first 5 years, with deep ice core extraction planned for the second 5-year period.

sponsors: NATIONAL SCIENCE FOUNDATION, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

apl-uw team members: BEN BRAND, JUSTIN BURNETT, TIM ELAM, MADISON PICKETT, DALE WINEBRENNER

A sustained, coordinated effort is underway to study the initiation, maintenance, and transport of harmful algae blooms (HABs) on the Washington coast. APL-UW researchers are integral partners in the design and production of observing technologies, data services, and communication networks to understand HAB dynamics and mitigate their impact.

co-design of networked systems

for coastal surveillance + research

Pseudo-nitzschia spp., a phytoplankton that can produce the neurotoxin domoic acid, blooms in coastal waters every year. When large blooms and their toxins come ashore the negative effects are widespread— the threat to human health, the economic toll of closed fisheries and depressed recreation and tourism, the aftermath of poisoned seabirds and marine mammals, and the upset of deep cultural traditions for coastal tribal communities.

High-frequency observations are needed to capture the patchy HAB outbreaks in dynamic, coastal waters. Since 2016 such observations have been enabled by the Environmental Sample Processor (ESP). This robotic 'lab in a can' biosensor, developed at the **Monterey Bay Aquarium Research Institute (MBARI)**, takes in water samples and runs molecular diagnostic tests to detect and quantify harmful algae and toxins. Senior Principal Oceanographer **Jan Newton** explains that the ESP, "... is capable of processing biological samples autonomously... a job that traditionally had been done by humans in a lab, either aboard a research vessel or on shore."

An APL-UW team led by Senior Oceanographer **John Mickett** and Principal Engineer **Nick Michel-Hart** collaborated with the **NOAA Northwest Fisheries Science Center,** that owns and operates the instrument, and MBARI to integrate the ESP into a purpose designed, subsurface, moored platform. They equipped it with a stored power supply for 60-day deployments to span HAB 'seasons'. A pump and 30-m intake hose samples the upper 1–2 m of water where HAB cells and toxin concentrations are greatest. A tethered surface buoy supports two-way communications with a shore-side data server. With the Laboratory's novel subsurface mooring design the robotic lab is isolated from surface wave motions, experiences minimal tilt and acceleration that could upset its onboard reagents, telemeters sample results in near-real time, and is deployed throughout periods when HAB outbreaks are most likely.

photo: Stephanie Moore, NOAA Fisheries

The robust ESP mooring has been deployed for the past five years as a sentinel about 20 km off the Washington coast, sited strategically between the Juan de Fuca Eddy – a known HAB initiation site – and Washington coastal beaches with important tribal and recreational razor clam fisheries. If harmful algae and toxins are spun out of the eddy and transported toward the beaches, the ESP sample results are available nearly immediately to coastal managers, who can then apply resources to ramp up testing on beaches or announce harvest closures.

Two autonomous oceanographic and meteorological observatories, also managed by the Laboratory and the **Northwest Association of Networked Ocean Observing Systems (NANOOS),** are moored nearby. Recently a research team combined this rich trove of colocated environmental measurements with three years of ESP observations, satellite data, and coastal ocean circulation models to report on HAB dynamics and their variability on the Washington shelf. One surprising finding is that HABs and their toxins are not exclusively transported from the Juan de Fuca Eddy. Coastal-trapped internal waves, undulating through the ocean interior as they propagate, lift density surfaces on the shelf. This vertical transport of deep, nutrient-rich waters to the euphotic zone triggers blooms. Moreover, these waves can be generated by atmospheric events originating far from HAB initiation sites on the Washington shelf.

"The breakthrough was the ESP itself, but without ocean engineering expertise to place it offshore, the instrument wouldn't be an effective tool. Without the data service, we wouldn't have near-real time analysis and response. And without relationships with coastal managers, the information wouldn't be transferred. A network of individuals, who have built and sustained trusted partnerships, makes it all work."

— Jan Newton

This past summer two more observing platforms – moorings with near-bottom oxygen sensors and profiling current meters – were deployed on the coast and added to the portfolio of assets served by NANOOS. The **Quileute Tribe Natural Resources** program initiated a collaboration with APL-UW to build, deploy, and maintain the moorings to improve responsiveness and better understand the occasional development of low-oxygen zones that threaten their Dungeness crab fishery. These hypoxia monitoring moorings fill a data gap in the coastal observation network and, like the ESP, have a surface buoy to support two-way communications with the NANOOS data server.

The Quileute Tribe's investment in mooring development was made possible by the disaster relief compensation received after the massive 2015 spring HAB outbreak that stretched up and down the West Coast, causing prolonged closures of fisheries. Due to a persistent oceanic heat wave in the Northeast Pacific, that severe and widespread HAB event is a harbinger of the future. "The Quileute Tribe was one of the original NANOOS partners," notes Newton. "Together we are developing and deploying systems to gather data to guide coastal management decisions and to support ongoing research so that we may better anticipate the impacts of accelerating climate change on coastal waters."

partners in the co-design and deployments of the ESP mooring:

ERIC BOGET, NICK MICHEL-HART, KEITH MAGNESS, DEREK MARTIN, JOHN MICKETT, JAN NEWTON, TROY TANNER, KEVIN ZACK (APL-UW)

STEPHANIE MOORE, NICK ADAMS, VERA TRAINER (NOAA Northwest Fisheries Science Center)

GREG DOUCETTE (NOAA Center for Coastal Environmental Health and Biomolecular Research)

PARKER MACCREADY (UW Oceanography)

IVORY ENGSTROM (McLane Research Labs)

JAMES BIRCH, BRENT ROMAN, SCOTT JENSEN (Monterey Bay Aquarium Research institute)

QUILEUTE NATURAL RESOURCES

OLYMPIC COAST NATIONAL MARINE SANCTUARY

The Applied Physics Laboratory advances the education mission of the University of Washington. Our scientists teach in academic departments, advise student thesis and dissertation projects, and mentor aspiring independent investigators focused on careers in research.

APL-UW scientists teach, advise, and mentor scores of students across the academic spectrum of our world-class research university every year — from undergraduate oceanography and mechanical engineering majors, to those pursuing graduate degrees in over a dozen disciplines, to postdoctoral scholars whose career interests align with the Laboratory's areas of expertise.

Over 40 Laboratory scientists hold faculty appointments in UW academic departments, principally in the College of Engineering and College of the Environment. Graduate and undergraduate students pursuing UW degrees are entrained into their advisors' sponsored research projects, where they gain applied research experiences beyond the classroom and build professional support networks.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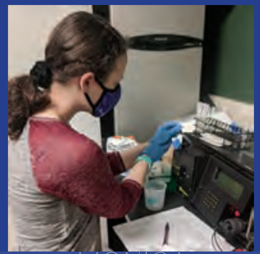
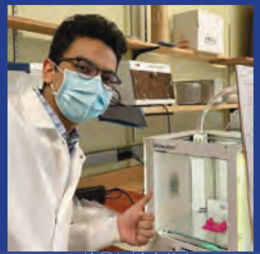

MONICA


BRENNAN


MEGAN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We recognize with pride every year the graduate students who earned advanced degrees and the APL-UW scientists who served as their research and thesis advisors.

graduate students, degrees earned, thesis titles, and apl-uw advisors

Pratik Ambekar, Mechanical Engineering, M.S., 2021
Design, Fabrication, and Characterization of a Microfluidic Device for Ultrasound Based Cell Sorting
Thomas Matula and Oleg Sapozhnikov

Laura Crews, Oceanography, M.S., 2020
Meltwater Advection Hastens Fall Freeze-up: Observations from the Beaufort Sea in 2018
Craig Lee

Ting Lai, Bioengineering, Ph.D., 2021
Beamforming Approaches for Ultrafast Nonlinear Ultrasound Imaging
Matthew Bruce

Megan Morrison, Applied Mathematics, Ph.D., 2021
From Worms to Wars, Modeling and Controlling Networked Dynamical Systems
Michael Gabbay

next generation of scientists + engineers

mentoring engineering excellence

At the end of the 2020–2021 academic year, seniors in the UW Department of Electrical + Computer Engineering presented results of their capstone research projects in the **ENGINE (ENGineering, INnovation, and Entrepreneurial) Showcase**. This culmination of the undergrads' education tests their skills in collaborative systems engineering, project management, and working on real-world, industry-sponsored projects.

Taking the first prize among 40 competitive ENGINE teams was the one co-sponsored and co-advised by Booz Allen Hamilton, APL-UW, and the Naval Undersea Warfare Center, Division Keyport. For their project the students developed an autopilot system for a human powered submarine to counter the problem of vehicle roll during high-speed, pedal powered, straightaway travel.

APL-UW mentors to the ECE student team were mechanical engineers **Cassandra Riel** and **Benjamin Maurer**. Principal Electrical Engineer **Payman Arabshahi**, also an Associate Professor in ECE, serves as the department's liaison with industry partners.

• • •

Riel, her colleagues **Laura Lindzey** and **Madison Pickett** from the Laboratory's Ocean Engineering Department, and Mauer also mentor the **UW Human Powered Sub Team**. The UW team grabbed many of the top honors at the spring 2021 International Submarine Races, a biennial design competition for human powered underwater vehicles hosted by the Naval Surface Warfare Center, Carderock Division.

This past spring there was no in-person, in-water competition at the naval test facility, but teams competed virtually with their designs. They were judged on a series of four written reports, each detailing a specific subsystem, and a live operational problem solving challenge via Zoom. The UW team was awarded top prize in three of the design categories: human factors engineering design, the future submarine technical and design challenge, and maneuvering and control design, plus first place in the operational problem solving challenge.

"The team is one of the best opportunities for students to get challenging, hands-on engineering experience. Especially for aspiring ocean engineers it's a fun, weird, and gratifying way to learn. By mentoring the team, I stay connected with the joy of discovery that inspired me to pursue a career in engineering."

— Cassandra Riel

at-sea applied research experience

Undergraduates **Megan Clements** and **Colleen Ames**, aeronautics + astronautics and mathematics majors, respectively, conducted at-sea experiments aboard the UW's R/V *Rachel Carson* during their summer internship advised by oceanographers **Andy Jessup** and **Chris Chickadel**.

With support from the Washington NASA Space Grant Consortium's Summer Undergraduate Research Program, Clements and Ames were entrained in a research program to test infrared radiometer and camera technologies to take the temperature of the ocean's very surface layer — the ocean skin temperature. The students spent several weeks learning about the infrared remote sensing technologies and how the observations are processed to estimate heat fluxes between the ocean and atmosphere across the skin layer.

During the week at sea, data were collected with 'gold standard' infrared systems as well as those comprised of simplified and miniaturized instruments that do not require research vessel support. The students' data analyses and final presentations assessed the performance of the alternative systems to address the overall project goal of deploying accurate ocean skin temperature sensing systems on uncrewed surface vessels that could increase data coverage of the world's oceans at relatively low cost.

apl-uw undergraduate internship program

Early in 2021 APL-UW leadership, human resources personnel, and a dedicated group of scientists conceived a new undergraduate internship program that, despite the pandemic, was launched in the spring.

The program is creating access to applied research and engineering experiences for UW undergraduates, and helping them realize that a career in research is possible and achievable. Internship organizers are partnering with the University and other local institutions to identify and engage with student groups that include first-generation college students, underrepresented minorities, and women. The paid, 10-week internships align with the students' quarterly academic schedule and focus on hands-on education experiences to inspire and advance academic and professional careers in STEM disciplines.

undergraduate interns, apl-uw advisors

Edgar Santos Aguilar, Earth + Space Sciences
Yak-Nam Wang, Center for Industrial + Medical Ultrasound

Kamran Kazemi, Atmospheric Sciences and Data Science
Emilio Mayorga, Center for Environmental + Information Systems

Alejandro Martin-Villa, Mechanical Engineering
Peter Gaube, Air-Sea Interaction + Remote Sensing Department

Monica Santiago, Mechanical Engineering
Jan Newton and Roxanne Carini, Ocean Physics Department

Jiovany Soliman, Mechanical Engineering
Thomas Matula, Center for Industrial + Medical Ultrasound

• • •

Brennan Hunt, Physics and Applied Physics
Joshua Lee, Human Centered Design + Engineering
Aubrey España, Acoustics Department

The five students in the inaugural spring 2021 cohort were recruited through a partnership with the UW-hosted Pacific Northwest Louis Stokes Alliance for Minority Participation program — funded by the National Science Foundation to build academic and social support networks for underrepresented minority students. They participated in a range of research experiences, from collecting ocean observations, to improving lab instrumentation, to analyzing mountain snow data. Their spring internships were capped by Zoom presentations in early June.

Kamran Kazemi, now a senior in atmospheric sciences and data science, joined in spring to work with Senior Oceanographer **Emilio Mayorga** and Principal Research Scientist **Anthony Arendt** on Arendt's NASA-funded project to improve understanding of snow depth variability in mountainous regions by engaging with the community, including backcountry professionals and recreationists, to gather snow observations.

Working entirely remotely, Kamran participated in regular multi-institution team calls and discussions, building an appreciation for scientific collaborations. He expanded his skills in open-source data science using the Python programming language and Jupyter computational notebooks and applied these skills to assess the quality of the citizen science data. Kamran's successful spring internship was extended into a full-time summer internship. Now he has transitioned into a student assistant position, where he is completing the initial data assessment and will contribute to broader data analysis that will culminate in a peer-reviewed publication.

Midshipman **Joshua Lee** and Officer Candidate **Brennan Hunt,** both part of the UW Naval ROTC program, spent the summer quarter learning about new technology developed at APL-UW – the Multi-Sensor Towbody (MuST) – to address a real-world naval problem of detecting and classifying hazardous objects on the seafloor with sonar. Advised by Principal Physicist **Aubrey España,** Lee and Hunt advanced step by step through the MuST mechanical components, how it is deployed in an operational scenario, how the classifier system works, and how to interpret the sonar data. Their summer internship experience was capped by a day of at-sea tests with MuST in Lake Washington, followed the next day by a formal presentation and a dockside open house for MuST, where they described the system to Laboratory staff visitors.

"I am grateful to the interns we had in this first NROTC cohort… for rolling with the punches and kicking off this program in the middle of a pandemic."

— Aubrey España

Despite the many challenges posed by the ongoing COVID-19 pandemic, the overall financial health of the Applied Physics Laboratory remains strong. Many institutions experienced a decrease in their ability to engage in research, but APL-UW was able to respond quickly and create safe research environments, thereby reducing the impact of the pandemic on our research and, by extension, our financial well-being.

The total grant and contract funding for FY2021 was over $67.6M, representing 217 distinct awards. This represents a decrease of 13% from the record total in FY2020. The overall decrease was due to changes in funding from the U.S. Navy, NAVSEA, NSF, and DARPA. Though less total funding was received than the prior year, the U.S. Navy remains the largest sponsor of Laboratory research and development, representing more than 51% of all awards received in FY2021. Support from non-Navy federal sponsors remains strong, with significant increases from NOAA and the DoD. In October 2020 the Laboratory received its fully executed NAVSEA contract, continuing the valued partnership between APL-UW and NAVSEA that has spanned over 75 years. Under this new contract 15 task orders totaling $16.8M have been awarded to date.

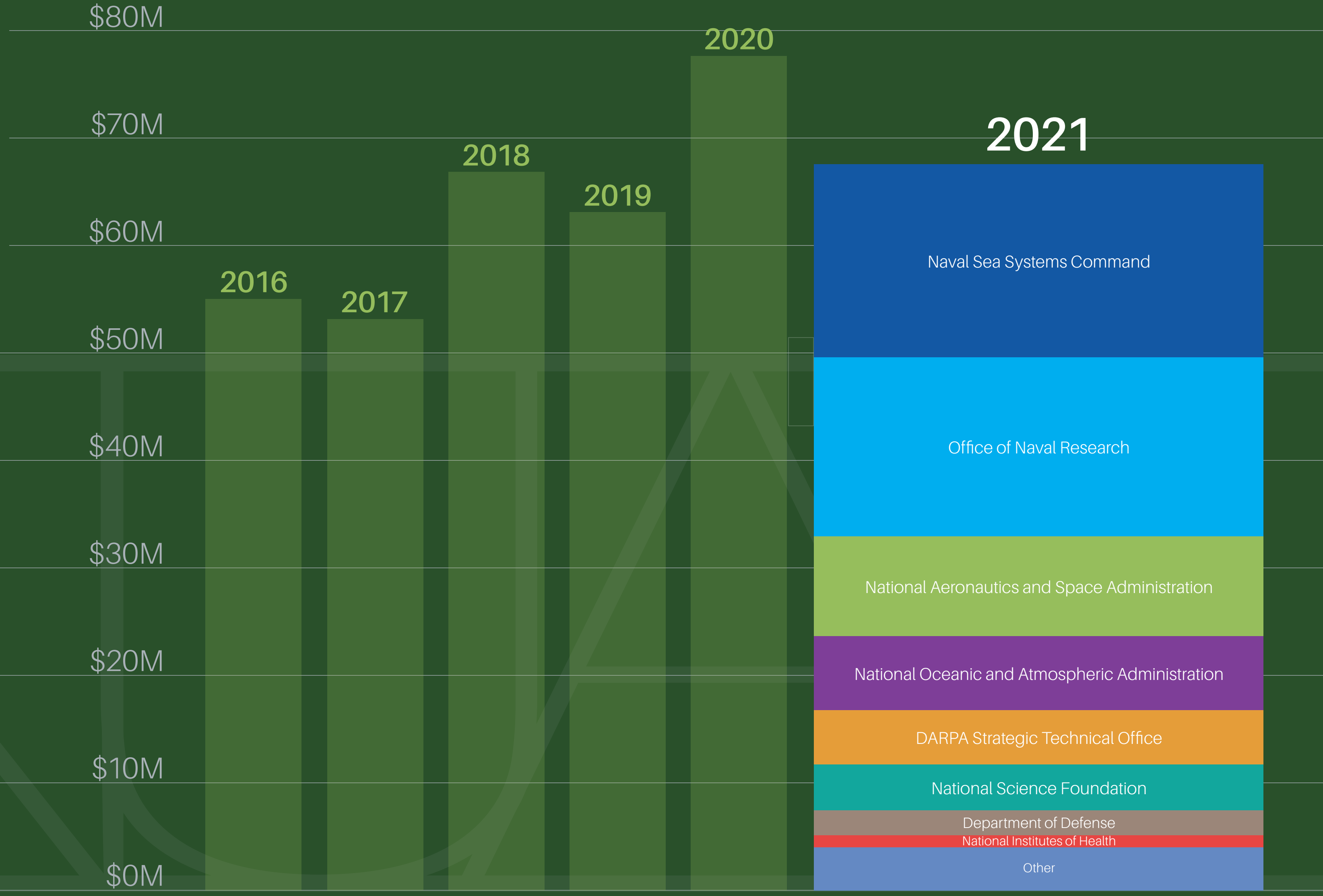
Prorated Direct Cost, Fee, and Indirect Cost revenues result from research funding received and allow the Laboratory's leadership to make strategic investments in APL-UW staff and facilities. Prorated Direct Cost revenues, which support administration and facilities, grew 2.8% over the same period last year. These revenues are being used strategically to support the growth of research at the Laboratory by investing in people, facilities, and security. Discretionary budgets, Fee and Indirect Cost, are now forward funded, in contrast to the past practice of allocating revenues as earned. The change in budget allocation enables the Laboratory to make more informed decisions about how to manage these funds. For example, now APL-UW research departments have greater flexibility in using these funds to support their unique departmental needs. The discretionary funds that have not been allocated directly to research departments are deployed to support growth in facilities and information technology infrastructure, to recruit postdoctoral scholars, and to buoy diversity, equity, and inclusivity initiatives — all advancing the Executive Director's vision.

The Interdepartmental Independent Research + Development Program, launched in early 2020, has fostered an increase in multidisciplinary efforts across APL-UW's research and technical departments. Two proposals were funded during the second year of this program resulting in collaborations across six of the eight research and technical departments. The Technical Staff Development Program has been expanded to provide funding for all staff to refresh and build new skills. The program has supported proposals that range from specialized engineering workshops to contract negotiation certification programs. A total of twelve proposals were funded during the second year of this program, with expenses totaling $44K.

Work continues to replace a critical APL-UW facility — our dock for the research vessel fleet on Portage Bay. Engineering reports are completed and a request for proposals has been issued by the University of Washington. A vendor will be chosen in early 2022 with installation to follow.

financial health

annual total awards



THE UNIVERSITY OF WASHINGTON COMMUNITY OF STUDENTS, FACULTY, AND STAFF RETURNED IN FALL 2021 TO IN-PERSON LEARNING, SCHOLARSHIP, RESEARCH, AND PUBLIC SERVICE ON THE SEATTLE CAMPUS.

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LEADERSHIP CHANGES AT THE LABORATORY AND UNIVERSITY DURING 2021: CHRIS CHICKADEL, JAMES GIRTON, DAVID KROUT, AND BONNIE LIGHT NOW LEAD THEIR RESPECTIVE DEPARTMENTS AND MARI OSTENDORF WAS NAMED UW VICE PROVOST FOR RESEARCH.

leadership

laboratory

KEVIN WILLIAMS	Executive Director
WARREN FOX	Deputy Executive Director
• • •	
CHRIS CHICKADEL	Chair, Air–Sea Interaction and Remote Sensing
JAMES GIRTON	Chair, Ocean Physics
MIKE HARRINGTON	Director, Electronic and Photonic Systems
TODD HEFNER	Chair, Acoustics
DAVID KROUT	Director, Environmental and Information Systems
BONNIE LIGHT	Chair, Polar Science
THOMAS MATULA	Director, Industrial and Medical Ultrasound
NICK MICHEL-HART	Head, Ocean Engineering
• • •	
BEN ADAMS	Facility Security Officer
KATIE AVRIL	Director, Information Technology
MARIA CARD	Director, Human Resources
DIAN GAY	Director, Resources and Facilities
AUTUMN SALAZAR	Director, Business and Finance

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