WINTER 2022

BENEATH THE SURFACE

UNDERSEA WARFARE ACADEMIC GROUP'S NEWSLETTER • NAVAL POSTGRADUATE SCHOOL

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Pictured left to right: Dr. Anu Kamurag (N45/LMR), MIDN Bonnie Tom (USNA Intern), Dr. Kevin B. Smith (NPS and Chief Scientist), Dr. Paul Leary (NPS), Becky Hoag (NPS-PAO), and Dr. Nick Durofchalk (GA Tech)

USW RESEARCH FIELD TEST

Autonomous Systems and Acoustic Vector Sensor Systems

In August, various Naval Postgraduate School (NPS) faculty were able to participate in field testing of autonomous systems and acoustic vector sensor systems out in Monterey Bay. The goals of the tests included an evaluation of sensor performance near shelf breaks and the ability to track various signals of interest from distributed systems. Elements of the work were supported by the Office of Naval Research, the NPS Naval Research Program (NRP), and Los Alamos National Labs.

The NRP-funded portion of the August test was overseen by the Navy's Living Marine Resources (LMR) program based in Port Hueneme. NPS faculty will participate in the LMR program review in mid-November to report on the work done and continuing efforts.

NPS also recently acquired new hardware that will support cutting edge research in support of operational challenges. Professor Derek Olson in the Department of Oceanography recently accepted delivery of a Staple Toolkit system from NSWC-Carderock, which will be used by LCDR Joel Harding in his thesis work to study the impact of environmental variability and uncertainty on predictions of sonar performance. This system was acquired through support by OPNAV N97 and the efforts of RADM (ret) Jerry Ellis. In addition, Professor Paul Leary in the Department of Physics just received two new Slocum gliders from Teledyne-Marine. These systems are now part of our Undersea Sensing Systems Lab, and will help support future data collection events for numerous student theses. The lab also expects to receive new directional acoustic sensors and autonomous platforms for testing.

LEARN MORE
Email Dr. Kevin Smith at **kbsmith@nps.edu**

FROM THE CHAIR

Prof. Kevin B. Smith, Chair, Undersea Warfare Academic Group

Welcome to the inaugural edition of the Naval Postgraduate School's Undersea Warfare newsletter. As Chair of the Undersea Warfare Academic Group at NPS, I am pleased to report on the numerous USW-related activities on-going across campus.

NPS Leadership continues to strongly support the USW curriculum and its interdisciplinary program. NPS President Rondeau (VADM, USN ret), with support from the USW group, hosted a visit by RDML Richard Seif, Commander, Undersea Warfighting Development Center. During his visit, Admiral Seif provided a classified brief to the USW students and faculty, highlighting the technical challenges we currently face and encouraging our officer students to align their thesis efforts towards addressing those challenges. Follow-up from his visit is on-going, I will be visiting UWDC after attending the NDIA USW Symposium (the "clambake") at the end of October.

At the end of September, I met with RDML Douglas Perry, Director Undersea Warfare Division, N97 and BGen David Odom, Director of Expeditionary Warfare, N95. Both offices support the USW curriculum at NPS and provide flag level oversight of the educational skill requirements of our naval officer students. Both visits were productive, and we continue to look for ways that our education and research can support the security needs of our Sailors and Marines working in the USW-domain.

Also, in mid-November, two NPS submarine officer-students and I attended the Naval Submarine League Symposium in Crystal City, Arlington, Virgina. This was a great opportunity for us to highlight the USW-relevant work being done at NPS to those in the submarine force.

As part of our weekly Menneken Lecture series, the USW Academic Group recently hosted Mr. Xavier Harris from the Submarine Learning Center out of Groton, Connecticut. Mr. Harris presented some of his primary submarine operational sonar training material to a group of students and faculty. This was very well received, as it helped bridge the connection between the theory being taught in the classroom and the real-world applications of our understanding of acoustic phenomena in the oceans.

Finally, I am pleased to report that the Undersea Warfare Academic Group has a newly renovated office suite in Spanagel Hall at NPS. RDML (ret) Rick Williams (the N95-sponsored Chair for Expeditionary and Mine Warfare) officially on-boarded as an NPS employee and has moved into the spaces. RADM (ret) Ellis will be retiring at the end of this calendar year, and his replacement will also have an office in the suite, along with our Executive Assistant, Mr. Brian Hafemeister. A guest office will also be available for those visiting NPS to present at our Menneken Lecture series.

I look forward to an exciting year of student and faculty USW-related research at NPS. We hope this USW newsletter will help keep you up to date on the latest information on our various efforts.

CONNECT
Email Kevin Smith at **kbsmith@nps.edu**

TEAM UPDATES

USW Welcomes Dr. Kai Gemba

The Undersea Warfare group at NPS would like to welcome Dr. Kai Gemba, a new tenure-track faculty member in the Department of Physics whose area of research will support USW-related theses at NPS. Professor Gemba comes to us from the Naval Research Laboratory, where he has been studying methods of using passive acoustic detection of sources of opportunity to investigate features in the environment that can impact sonar performance.

Dr. Kai Gemba

ADIMIRAL'S NOTE

RADM (ret) Jerry Ellis, OPNAV 97 Sponsored Chair for USW

The past few months have been filled with teaching Undersea Warfare courses and a return to in-person meetings. Some highlights from this year and reflections on upcoming activities on USWAG and upcoming related activities:

During the summer and fall quarters this year, I taught the classified (SECRET/NOFORN) course "Undersea Warfare—Yesterday, Today, Tomorrow". The course is attended by Undersea Warfare students (submariners, aviation, and surface warfare officers), submariners and Bowman Scholars in various other programs. They continue to impress me both in their performance and very positive attitude. The U.S. Navy will benefit greatly from their service.

Additionally, I developed an unclassified version of the above USW course for our international students. Although international attendance is currently low, the students work hard and enjoy the studies and presentations. I think it is a big plus in supporting and strengthening our relationship with our partner nations.

I worked with NPS leadership to fund a booth for the Submarine League Annual Symposium. It was manned by members of the Northern California Chapter of the Naval Submarine League, many of which are NPS faculty and students. This was a great opportunity for the students, the submarine force, and NPS. Hopefully those of you that attended the symposium were able to visit the booth and talk to the group there. They enjoyed their interaction with leaders in the community. I will try to continue this practice in the future for submarine related conferences.

Since the COVID-19 pandemic resulted in the cancellation of the NPS Submarine Birthday Ball for the last two years, we are starting to plan for the ball to happen this coming year. We want to make it very special. The NSL Chapter here is already discussing it and we will start making great efforts after the start of 2022.

Lastly, as many of you know, I will be retiring at the end of this year (on December 31) after 62 years of continuously working for the Navy. It has been quite an adventure and I have enjoyed it very much and would do it all over again and not change a thing. I will miss the Navy, but it is probably the "right" time. My relief was selected, but as of writing the name is not releasable. I am very happy with the selection and look forward to seeing his contributions to the NPS USW program.

CONNECT
Email Jerry Ellis at **wgellis@nps.edu**

Naval Postgraduate School students USN LT Elliot George (pictured left) and USN LT Weston Patrick (pictured right) at the Submarine League Annual Symposium in Crystal City, Arlington, Virginia.

USW PROJECTS IN MOTION

RDML (ret) Rick Williams, the OPNAV N95 Sponsored Chair for Expeditionary and Mine Warfare

The NPS USW program routinely works with departments across campus to find and support USW related projects for research by students and faculty. As the Expeditionary and Mine Warfare (EMW) Chair for N95 at NPS, I help facilitate access to resources for faculty research and student theses and provide subject matter expertise on Department of Systems Engineering capstone projects.

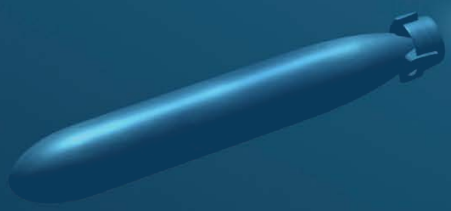
The nine-month capstone project, "Modeling and Simulation of Offensive Denial Mining," was completed in June 2021. The academic advisers for the project were Professor Paul Beery and Prof. Tony Pollman of the Systems Engineering Department, and I served as a project adviser and Subject Matter Expert (SME). Students were distance learning civilians from NUWC Newport (2), NSWC Dahlgren (1), and NAWC Patuxent River (1).

The students researched the NAVSEA developed "Modeling and Simulation Tool" (MAST) as a tool that might provide utility in the modeling and simulation of offensive mining events. The research was moderately successful and did several successful mining events for both aircraft and UUVs. Suggestions are included in their report for further refinements to potentially improve MAST's utility.

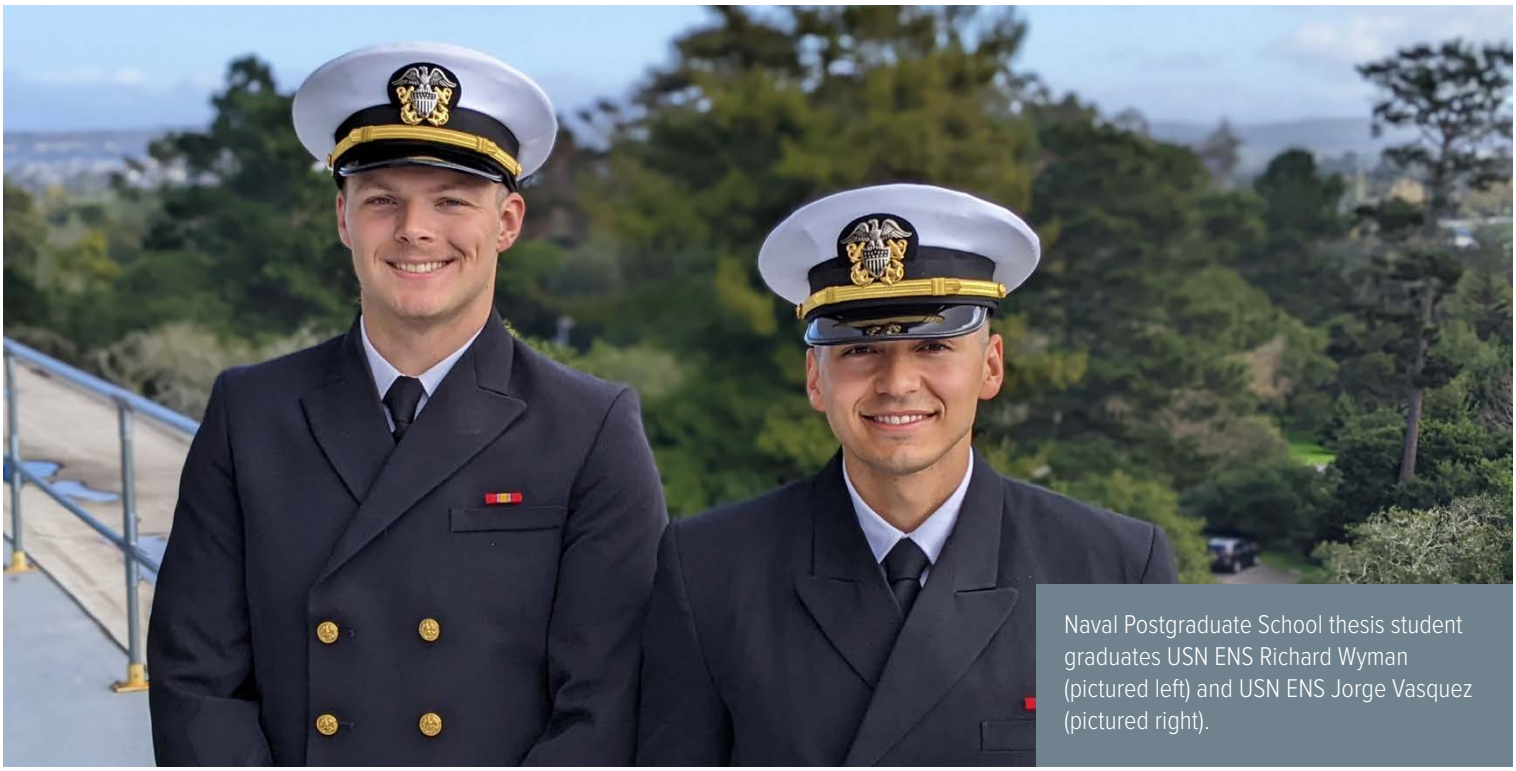
The project results were presented to NPS Systems Engineering faculty and interested students, interested industry and laboratory persons, and sponsors from NSWC, Panama City. They will also be presented at the next International MIW Technology Symposium in Monterey tentatively scheduled for May 2022.

Earlier this year, I presented a question from U.S. Fifth Fleet to Professor Isaac Kaminer and Prof. Sean Kragelund of the Mechanical and Astronautical Engineering Department. Namely, how should MCM operators best employ the wide variety of unmanned vehicles and sensors that were coming online. They leveraged algorithms for solving optimal control problems with uncertain parameters that had been recently developed at NPS and UC-Santa Cruz with CRUSER and ONR funding. By modeling the performance of various unmanned vehicles and sonars used for mine hunting, they could generate optimal search trajectories for a given MCM scenario. For time—or resource—limited search, this method produced trajectories that outperformed conventional lawnmower patterns. Their approach was also used to solve "inverse problems" to identify optimal vehicle and sensor configurations for autonomous vehicle teams. Additional research determined that this optimal motion planning framework was suitable for implementation on unmanned vehicle autopilots. This year, NPS and SMWDC-MIW jointly proposed a new NRP study topic that was selected for FY22 funding, "Clandestine Mine Countermeasures Optimization for Autonomy and Risk Assessment." This study will investigate novel methods for conducting clandestine MCM with multi-vehicle teams to identify safe routes for naval forces. A main objective for this year's effort is to analyze data from recent Mine Warfare Readiness and Effectiveness Measuring (MIREM) test events.

CONNECT
Email Rick Williams at **rdwillia@nps.edu** for more on expeditionary and mine warfare.



2021 Thesis Graduates



Naval Postgraduate School thesis student graduates USN ENS Richard Wyman (pictured left) and USN ENS Jorge Vasquez (pictured right).

The NPS Undersea Warfare curriculum offers students the opportunity to study the fundamental principles that apply to the design, performance, and employment of sensors, unmanned vehicles, and tactics in the undersea environment. The program combines electrical and mechanical engineering, mathematics, oceanography, physics, and operations research into a multi-disciplinary program of study. This unique curriculum permits students to select a degree program based on personal interests and undergraduate education, providing more in-depth study in a specific area. In calendar year 2021, students graduated with degrees in Physical Oceanography, Physics, Applied Mathematics, Electrical Engineering and Engineering Acoustics. No matter the degree, students are required to relate their thesis back to Undersea Warfare. Below is a listing of student research for our CY2021 graduates:

LT Kristen Ainslie (MS Operational Oceanography): Formation and Destruction of Arctic Thermohaline Staircases

LT Jack Brault (MS Physics): Quantum Key Distribution Laboratory Demonstration

LT David Kramer (MS Physical Oceanography): Maneuvering a Submerged Object: Effects on Wake Dynamics and Persistence

LT Hwanhee Lee, Korean Navy (MS Physical Oceanography): The Interaction of Wakes Generated by Submerged Propagating Objects with the Turbulent Subsurface Mixed Layer

ENS Thomas Reeder (MS Applied Mathematics): Analysis of a Similarity-Based Approach to Positively Affect Mentor-Mentee Relationships Among Service Members

LT Yi-Fan Shen, Taiwan Navy, (MS Engineering Acoustics): Accelerated Noise Interferometry-Based Passive Acoustic Characterization of the Littoral Ocean

Maj Dexter Tan, Singapore Navy, (MS Physical Oceanography): Application of Time-Reversal Mirror to Passive Remote Sensing of the Ocean

ENS Jorge Vasquez (MS Electrical Engineering): A Minimalist Design for AIS Cyber-Security in Voyage Networks

ENS Richard Wyman (MS Engineering Acoustics): Experiments in Passive Suppression of Low-Frequency Broadband Underwater Sound

ENS Jared Young (MS Engineering Acoustics): Investigation of Acoustic Characteristics and DB Reduction of Microsphere-Based Paneling on Diving Wetsuits

LEARN MORE

Visit Calhoun—Naval Postgraduate School's digital repository for research materials and institutional publications—for more about USW student research at **https://calhoun.nps.edu**

Mr. Xavier Harris (pictured in front) presented to USW students and faculty at the Menneken Lecture Series.

USW EVENT SPOTLIGHT

Menneken Lecture Series Presenters

The Menneken Lecture series is named in honor of Carl E. Menneken, the Naval Postgraduate School's first Dean of Research. The lecture series has been running since 1996. Attendees are Undersea Warfare (USW) students and faculty. The student body is primarily US Naval officers from submarine, surface, and aviation communities.

The USW Academic Group recently hosted **Mr. Xavier Harris from the Submarine Learning Center** based in Groton, Connecticut. Mr. Harris presented some of his primary submarine operational sonar training material to a group of students and faculty. This was very well received, as it helped bridge the connection between the theory being taught in the classroom and the real-world applications of our understanding of acoustic phenomena in the oceans. Below are some of our most recent presenters:

Dr. Charlie Loeffler from the Applied Research Laboratories with the University of Texas at Austin presented *Development of Sonars, Signal Processing Techniques, and Their Employment Earliest Days to Now.* This talk briefly discussed the development of sonar systems and their associated processing techniques through a number of system generations. It described the status and approaches of implementing today's systems. Lastly, it provided insights on the development and employment of combinations of sonars on different platforms.

Donald Brutzman, Ph.D., LCDR USN (Ret.) gave a presentation titled *Extending Effective Tactical Range of Surface-Search Radars through Coordinated UAV Scouts.*

While a Navy Lieutenant at Submarine School, Rear Admiral John J. (Joe) Ekelund USN (Ret.) developed an import concept for determining target range using passive sonar sensors. This capability revolutionized anti-submarine warfare (ASW). Adaptation of the widely known Ekelund Range algorithm holds further potential to enable passive bearings-only target-range determination for unmanned air vehicles (UAVs). Careful sensor measurements while computing crossed-bearing intersections can improve target motion analysis and tracking while maintaining UAV stealth. This concept is part of Network Optional Warfare (NOW) investigations to improve Naval force capabilities. Modeling, simulation and ongoing NPS field experimentation (FX) offer valuable opportunities for fleet-relevant student thesis research.

Mr. Theo Goda, Ice Exercise (ICEX) Program Manager, from Undersea Warfighting Development Center Arctic Submarine Laboratory spoke about *Ice Exercise (ICEX): Supporting Arctic Training, Research, and Submarine Operational Readiness.*

The Navy's Arctic Submarine Laboratory (ASL) led the development of systems for submarines to safely operate in the Arctic under the pack-ice. As Arctic conditions change, ASL continues to enhance its capabilities through the Ice Exercise (ICEX) program and its supporting drifting ice camps to ensure there is a safe venue to conduct submarine tactical development, capability development, torpedo evaluations, and to validate operational readiness of the submarine Force in the Arctic. In recent years, the ice camp has evolved to support environmental research, joint service and combined military training, and technology development. The ice camp typically hosts over 150 participants over a four-week period on the drifting sea ice.

LEARN MORE

Email Dr. Kevin Smith at **kbsmith@nps.edu** for more information about the Menneken Lecture Series.

USW RESEARCH UPDATE

Undersea Remote Sensing Program

Estuarine studies have rightly focused on geological, thermodynamic and hydrodynamic parameters, such as depth, width, bottom composition and morphology, water temperature and salinity structure, tides, current profiles, turbulence and sediment transport. As the US Navy continues to invest heavily in autonomous systems, understanding the impact of the riverine and estuarine environments on autonomous operations and acoustic system performance is key to mission success. The unique hazards of the estuarine environment demand that we understand the fine-scale environmental dynamics in order to support comprehensive environmental assessments to develop strategy and tactics. When correlated to the conventional parameters, acoustic parameters provide an enhanced capability for persistent monitoring of activities of interest in denied areas and will improve autonomous system performance.

The multi-year Undersea Remote Sensing program, funded by the Office of Naval Research (ONR32LO), consists of a series of field experiments in the Columbia River, Connecticut River, James River and Mobile Bay estuaries. The acoustical approach includes using simple, small acoustical instrumentation to collect acoustical data in the estuarine environment for analysis and modeling. The acoustical characteristics are correlated to traditional riverine observational parameters, the analytical interpretation of which is corroborated with acoustic propagation models. Specifically, the spectral sensitivity of these acoustical-environmental correlations, the temporal and spatial scales of variability, and the impact on signal coherence as a function of time, frequency and range are examined with the ultimate goal of translating the findings into operationally relevant recommendations for future operations and autonomous acoustical system design.

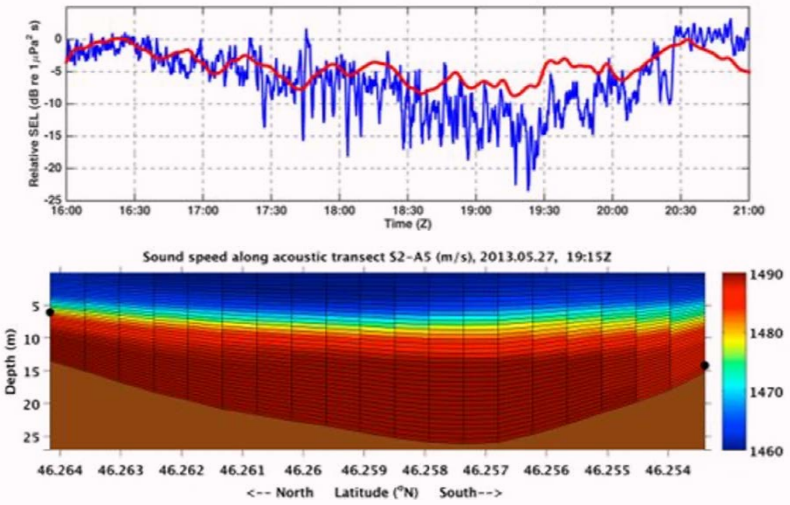


Fig. 1 The top panel shows relative Sound Energy Level (SEL) decreasing 15 dB during a 2 ½ hour period as the high-soundspeed salt wedge enters the Columbia River Estuary. The second panel shows the position of the salt wedge (in terms of sound speed) relative to the acoustic source and receiver at the time of observed minimum SEL. The significant decrease in SEL is due to 3D acoustic refraction over just 1.36 km range, induced by the salt wedge as it advances upriver during flood.

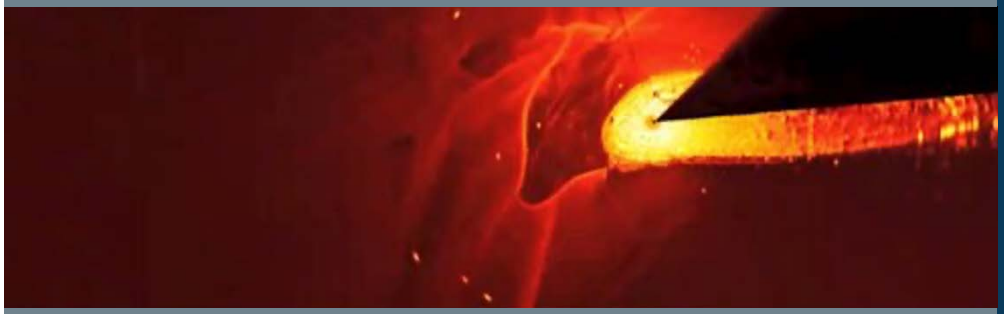


Fig. 2 X-band radar backscattered energy showing sea surface features during ebb at the mouth of Mobile Bay in May 2021. The radar system was located at Fort Morgan; the sea surface features appear as curvilinear highlights due to scattering by the rough surface at the fronts between salt and fresh water masses. Breaking waves inject bubbles at these fronts; the resulting bubble plumes often fill the water column to the bottom. The complex and highly dynamic acoustic waveguide created by the rough surface, the bubble plumes and the strong sound speed gradients between the two water masses presents a very challenging environment for autonomous navigation and acoustic communications systems.

LEARN MORE

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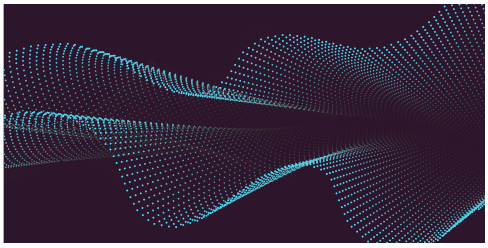
In Brief



NEW MASTERS COHORT BEGINS

In July 2021, a new cohort in the Curriculum 535 Underwater Acoustic Systems, which includes distance-learning students from various US Navy Warfare centers as well as an active-duty Navy officer, started their studies toward Master of Engineering Acoustics and Master of Science in Engineering Acoustics degrees.

NEW CERTIFICATES APPROVED

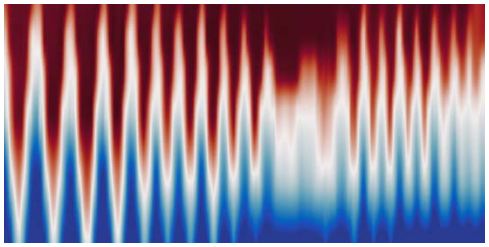
A proposal for three new academic certificates in Fundamentals of Engineering Acoustics, SONAR System Applications, and Underwater Acoustics has been approved by the NPS Deans and Chairs. Each certificate's course of study is based on three intensive, quarter-long courses and will be available for resident and distance-learning students. After final approval by the NPS Academic Council, the certificate programs will be offered to NPS students seeking to deepen their knowledge of USW applications of acoustics and to the wider USW community.

UNDERWATER ACOUSTIC RESEARCH

An NSF-sponsored work on underwater acoustics applications of time-reversal mirror, which is based on thesis research by Maj. Dexter Tan (Singapore) and research by USW faculty, presented as an invited lecture in the special session *Time Reversal Acoustics* at the 181st Meeting of the Acoustical Society of America held in Seattle, Washington in November and December, 2021.

REMOTE SENSING RESEARCH

In his MS thesis entitled *Accelerated Noise Interferometry-Based Passive Acoustic Characterization of the Littoral Ocean,* LT Yi-fan Shen (Taiwan) demonstrated that acoustic characterization of the seabed over kilometer-scale ranges can be achieved, without employing any controlled sound sources, by using time series of ambient noise as short as 10 minutes. It is a much shorter noise-averaging time than reported previously and a big step toward operational applications of acoustic noise interferometry for passive remote sensing of the ocean.



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