NAVAL SCIENCE AND TECHNOLOGY

FUTURE FORCE™

VOL. 6, NO. 4, 2020

NAVAL STEM ADAPTS TO NEW CHALLENGES

SOFT SKILLS WILL POWER THE WORKFORCE OF THE FUTURE

INDIAN HEAD INVESTS IN EMPLOYEES WITH ITS OWN UNIVERSITY

EDUCATION, TRAINING, AND STEM

VOLUME 6
#04
2020

FUTURE FORCE

NAVAL SCIENCE AND TECHNOLOGY MAGAZINE

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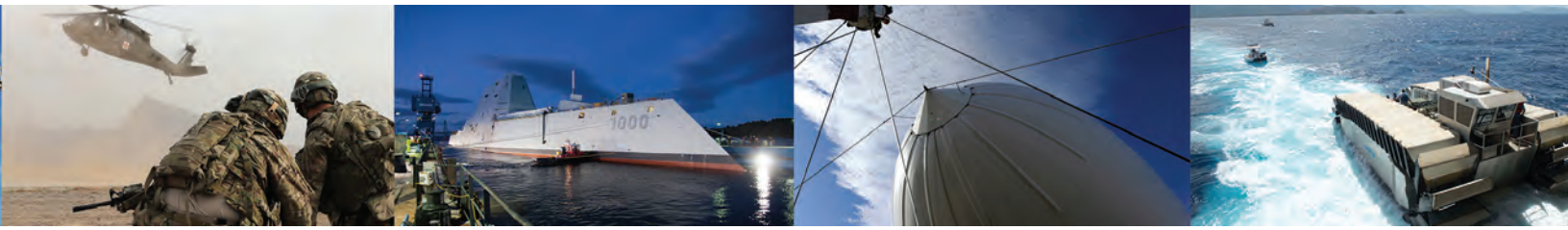

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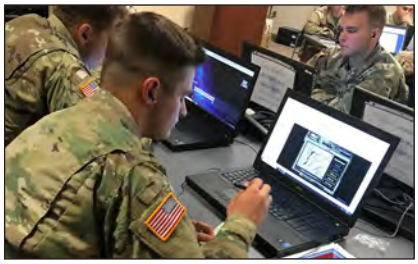

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Future Force is a professional magazine of the naval science and technology community. Published quarterly by the Office of Naval Research, its purpose is to inform readers about basic and applied research and advanced technology development efforts funded by the Department of the Navy. The mission of this publication is to enhance awareness of the decisive naval capabilities that are being discovered, developed, and demonstrated by scientists and engineers for the Navy, Marine Corps, and nation.

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Front Cover: Illustration by Jeff Wright.

SPEAKING OF S&T

By James "Hondo" Geurts

Photo illustration by Joseph Bullinger

I believe in the ability of STEM (science, technology, engineering, mathematics) to change a child's life for the better. This conviction is personal for me, since I'm a product of STEM—though it wasn't called that when I was growing up in the 1970s.

When I was in the third grade, I learned how to write code on an old-fashioned computer using paper punch cards. I loved it and was intellectually challenged and fascinated by the act of computer programming. I even created code for a simple video game. It wasn't much—a ski slalom course, and you used the computer cursor to move the ski poles left and right.

My game's graphics were downright primitive, and the action was slow. It was a far cry from today's fast-paced, hyper-realistic titles, such as "Call of Duty," but it fueled my obsession for computers and technology. I eventually earned an Air Force ROTC scholarship and graduated from Lehigh University with a degree in electrical engineering, and have enjoyed a three-decade career in military science and technology.

My story underscores the importance of STEM to the Department of the Navy (DoN)—and the necessity of developing a steady talent pipeline for the naval workforce. If the Navy and Marine Corps want to maintain their competitive advantage on a global scale, we need the skills of all Americans, regardless of race, gender, or socioeconomic background. We need to encourage students to get involved with STEM at the earliest age possible.

To accomplish this, Naval STEM is embarking on a journey of change. In light of the existing COVID-19 pandemic, and the national focus on addressing racial inequality, the DoN is revitalizing Naval STEM to adapt to changing times and expand the opportunities available to students. All with an eye toward increasing diversity and inclusion. Critical to this endeavor is aligning various naval stakeholders—such as systems commands and warfare centers—to strengthen existing partnerships and build new ones.

That's why this issue of *Future Force* you're reading is so important. It showcases the diverse efforts the DoN is implementing to meet the challenges facing the Naval Research Enterprise.

Stories in this issue cover numerous compelling topics, including an in-depth feature about new and expanded outreach initiatives within Naval STEM, including Naval Horizons and the Naval Research Enterprise Internship program; collaborations involving stakeholders such as the Office of Naval Research, the DoN Historically Black Colleges and Universities/Minority Institutions program, and the NavalX Agility Cell; and education and training programs for aspiring naval scientists and engineers.

These are just some of the exciting STEM-related developments happening within the Navy and Marine Corps. Although it is hard to view the current pandemic and societal unrest in a positive light, there is a silver lining. Disruption allows for greater agility. It presents an opportunity for the DoN to reinvent outdated processes and procedures among Naval STEM stakeholders. By cultivating a more unified workforce, the DoN can emerge from these crises stronger and more resilient.

I encourage you to share your ideas and inspirations on how to enhance Naval STEM. Send your feedback to the Naval STEM Coordination Office at Naval_STEM@navy.mil. Together, we can take Naval STEM in an exciting new direction.

Secretary Geurts is the Assistant Secretary of the Navy for Research, Development and Acquisition.

EDUCATION, TRAINING, and STEM

Now more than ever, the Department of the Navy is seeking new ways to connect people—inside and outside the sea services, during their careers and before—to science, technology, engineering, and mathematics: STEM.

►► By Thomas B. Curtin and Daniel Deitz

Photo by Alan Antczak

THE AUTONOMOUS UNDERWATER VEHICLE STUDENT COMPETITION

By Thomas B. Curtin and Daniel Deitz

ESTABLISHED IN THE 1990S, "ROBOSUB" COMPETITIONS HAVE HELPED THOUSANDS OF STUDENTS OVER THE YEARS TO CONNECT WITH ENGINEERING, OCEAN SCIENCE, AND THE NAVAL COMMUNITY.

Scanning the technological horizon 25 years ago, Office of Naval Research (ONR) Ocean, Atmosphere, and Space Science and Technology Department (also known as Code 32) program managers perceived the potential for scalable robotic platforms to meet the challenges of ocean sampling and maritime surveillance. To realize this potential, a new generation of ocean engineers would be needed. To help fill this need, Code 32 pioneered the Autonomous Underwater Vehicle Student Competition (AUVSC) in 1998. The first competition was held in Panama City, Florida, with a single task of programming an autonomous vehicle to traverse through a set of underwater gates. After several years in Panama City, the event moved to Orlando, Florida, Annapolis, Maryland, and, most recently, to San Diego, California.

The AUVSC, or "RoboSub," spawned similar competitions in Europe and Asia and, beginning in 2008, a competition for autonomous surface vehicles ("RoboBoat"). Tasks have grown in complexity. To date more than 600 teams have participated in AUVSC, providing thousands of students with the experience of attempting a set of tasks requiring underwater navigation, sensing, manipulating, and autonomous control. Alumni of the competition can be found throughout the workforce today as Navy laboratory researchers, systems engineers in industry, autonomous underwater vehicle operators, teachers, and entrepreneurs of new start-ups.

Goals and Benefits

The AUVSC is an annual competition in which students learn and practice system engineering, exercise creative problem solving, forge collaborative relationships, and develop interest in autonomous underwater vehicles. AUVSC benefits both competitors and sponsors. Student competitors learn:

- System engineering design involving multidisciplinary, problem-solving teamwork
- Competitive/collaborative balance in accomplishing goals
- Underwater autonomy measured by specific tasks
- Hands-on engineering skills meeting the challenges of a maritime environment
- Documentation/presentation skills and peer networking similar to technical conferences
- Application of new technologies not yet incorporated into academic curricula
- The value of collaboration in refining ideas and testing prototypes.

Sponsors and organizers learn:

- Trends in robotic software operating systems and applications
- Trends in robotic hardware driven by 3D printing and cross-domain components
- Measures of autonomy determined by task design and diversity of performance
- Inventive designs driven by unbiased minds and limited budgets
- Best practices for attracting engineering talent to maritime autonomy
- The identity and motivation of next-generation engineers with interest in autonomous maritime vehicles.

Autonomy

A distinguishing feature of the AUVSC is its focus on underwater autonomy. Autonomy is characterized by independent, adaptive behavior. Measures of a vehicle's autonomy include its own ability of sensing, perceiving, analyzing, communicating, planning, decision-making, and acting, to achieve its goals as assigned by its human operator(s). Autonomy can be ranked into levels based on mission complexity, environmental difficulty, and the degree of human-robot interaction required.[1]

The overall mission in each competition consists of a number of tasks with varying degrees of difficulty (and associated points) that must be performed autonomously. Given a specific set of tasks, one approach to operating an autonomous vehicle effectively is to employ robotics experts to program a set of behaviors they consider optimal. Another approach is to aggregate the independent programming decisions of a diverse group of competing engineers, thus capitalizing on the wisdom of the crowd.[2] The AUVSC provides an opportunity to exercise this latter approach in an extremely cost-effective manner.

The essence of autonomy is decision-making. "Bringing new members into the organization, even if they are less experienced and less capable, actually makes the group smarter because what little the new members do know is not redundant with what everyone else knows," writes Stanford researcher James March. "The effect does not come from the superior knowledge of the average new recruit. Recruits are, on average, less knowledgeable that the individuals they replace. The gains come from their diversity."[3] The ability to accomplish a task may improve by using a more effective unorthodox approach or by becoming more skillful using a conventional approach. The steady growth of AUVSC has provided the large number and diversity of competing teams that unlocks the value to be found in using different approaches (breadth of knowledge). The baseline of autonomy programming skills has risen very little over the long history of AUVSC, indicating that diversity is not a factor in performance gains using conventional approaches (depth of knowledge).

To extract maximum value from the wisdom of the group, the collegial nature of the competition must be carefully maintained. This paradoxical balance between competition and cooperation has been the impetus of advancement in both modern science and long-term innovation. "Knowledge is a peculiar commodity that does not get used up as it is consumed, but

rather becomes more valuable when distributed," according to the late sociologist Robert Merton. "In science, one's private property is established by giving its substance away through open publication."[4]

Two universal characteristics of innovation (versus invention) are extensive trial and error and collaboration.[5] Students who participate in AUVSC quickly learn that persistent trial and error is necessary to get a machine to work reliably underwater; they also learn the value of shared knowledge in the process. The productive tension between collaboration and competition creates a tangible energy that is a hallmark of AUVSC; indeed, its very culture. Students who have experienced and appreciate this culture have a head start in becoming the scientists, engineers, and innovators who will make a difference in the future.

Initial AUVSC missions consisted of tasks demonstrating a vehicle's capability to navigate a well-defined course and perform basic maneuvers. Missions in subsequent years have been derived incrementally from the previous year's experience, with tasks added to include in-situ decision-making and some intervention (e.g., dropping objects). In recent years themes have been adopted to add narrative coherence to the tasks and provide identity to the annual events. While this evolution has been successful in attracting teams, it has not been constructed in the context of a comprehensive autonomy framework. Future plans include identification and ranking of a benchmark set of tasks according to their autonomy merit and logistical feasibility. In contrast to the first AUVSC in 1998, there is now an international community fielding similar competitions with common interest in task design.

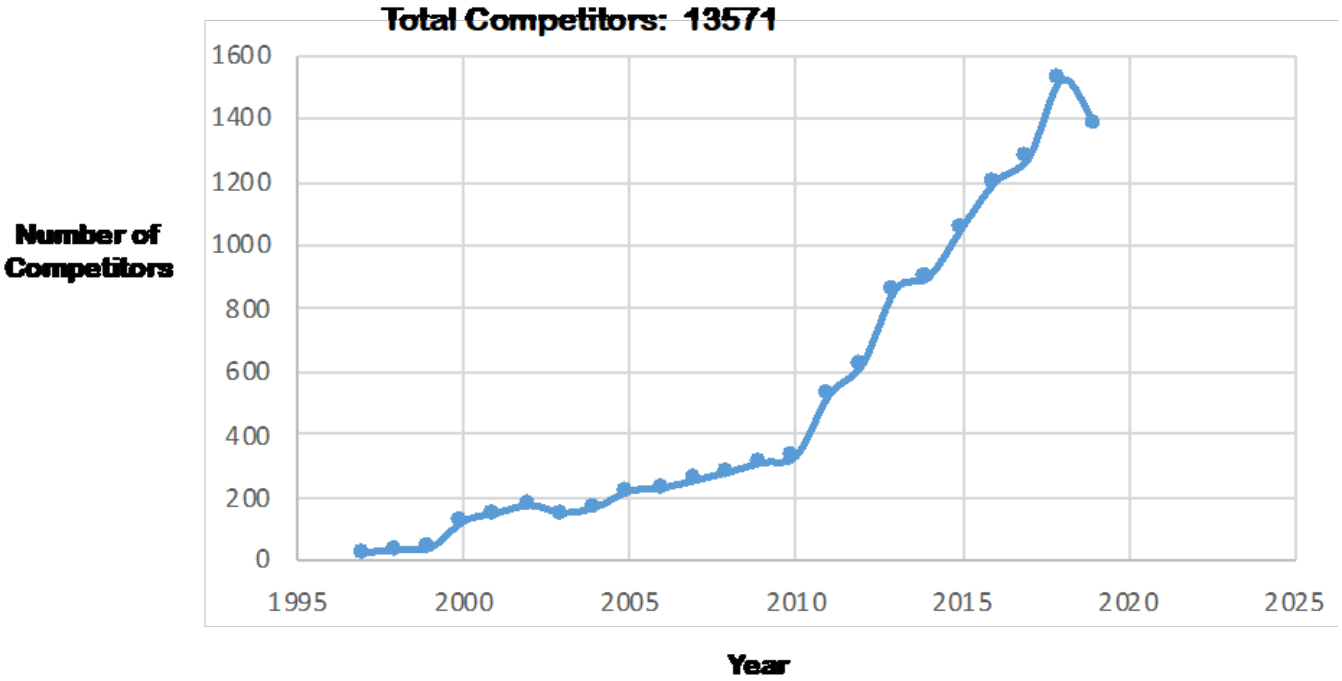
Robotic Competitions

Since AUVSC's inception 23 years ago, the world of robotic competitions has expanded immensely. To avoid misconception, mapping the lineage of AUVSC is useful. In general, robotic competitions test machine performance with defined rules of play. At least four major types of competitions can be identified:

- Learning exercises designed to teach system engineering through task accomplishment
- Grand challenges that push performance envelopes with extreme objectives
- Games in which robots compete against each other simultaneously to score points
- Combat in which robots battle against each other to disable the opponent.

Robots in each type of competition may be autonomous or under human control. Autonomous robots primarily test programmed behaviors and independent adaptability, whereas those under human control test operator skill and the human-machine interface.

Some competitions use a common vehicle for all participants, primarily testing the strategy, tactics, and skills of the operator. For example, in the Maritime RobotX Challenge ONR provided each team with a standard wave-adaptable modular vehicle built by MAR, Inc., as a common surface platform.[6] Others allow free-form vehicles, which tends to heavily weight the design and performance



Participation in the Autonomous Underwater Vehicle Student Competition has grown steadily since its inception in 1998. The competition has been highly successful in teaching multidisciplinary system engineering and providing student employment opportunities.

of the vehicle itself. A middle ground that tests both design and skill uses a constrained free-form vehicle. Vehicle dimensions dictate the size and location of the competition arena. AUVSC requires a body of water large enough to field several underwater tasks, yet small and accessible enough for task performance to be observed and judged conveniently. To provide more options for viable venues, AUVSC vehicles have been constrained in size and weight, but have otherwise been free-form.

Advances in technology continue to support more compact designs with their associated ease of deployment and manageable operation in affordable venues. These trends are driven by advances in smart phone technology; 3D printing; small, efficient brushless motors; miniaturized inertial and GPS navigation units; inexpensive cameras; multispectral electromagnetic and acoustic sensors; high-energy-density batteries; digital radios; wi-fi bandwidth; open-source software; and libraries of downloadable applications. These trends are likely to continue. A highly capable underwater vehicle can now be constructed in a form factor not much bigger than a cell phone or tablet computer. As the size of a vehicle decreases, teams are challenged to be creative in their designs. Large, expensive components are eliminated, thus leveling the playing field. Multiple vehicle solutions to accomplishing tasks become feasible and attractive. In-water testing becomes easier and available in more places, thus increasing reliability. Useful toolboxes are more affordable and more likely to be available. The cost of shipping and associated potential damage, especially for international teams, is greatly reduced. To capitalize on all these advantages, future plans include limiting vehicle weight to a maximum of 23 kilograms in accordance with National Institute for Occupational Safety and Health lifting guidelines.

Conclusion

AUVSC has been successful in creating a generation of scientists, engineers, and entrepreneurs who understand the value of teamwork, diversity, and trial and error. Although in-water performance is the most heavily weighted factor, teams are also scored on a written paper, design creativity, website, and short video. Besides system engineering, they learn to manage travel, logistics, and fundraising. In recent years, the number of registered teams has exceeded 50. The five teams with the highest scores receive awards typically ranging from $5,000-7,000 for first place on downward. Clearly money is not the motivating factor in seeking to excel.

What is the recipe for the success of the AUVSC? A number of factors contribute. The competition is designed to be challenging but enjoyable. This balance has been achieved by combining the vision of ONR program managers with imaginative logistical support of key people from the Association of Unmanned Vehicle Systems International (AUVSI), subsequently the AUVSI Foundation, and now RoboNation. The competition technical director formulates the rules, interfaces with the teams, sets up the tasks on-site, and orchestrates the week-long event that has many moving parts. AUVSC has been fortunate to have two outstanding technical directors over its long history, providing creativity and continuity. Judges play an important part in both the static and in-water phases of the competition, ultimately deciding on the final scores. AUVSC has been fortunate to have an outstanding cadre of judges over its long history, all volunteers and experts in their fields. Many judges have participated for decades, providing consistent precedents. The judges have also provided valuable feedback to the teams on the design and execution of their vehicles.

The collegial culture of the competition often propagates with many teams setting up outreach programs at their schools to promote science, technology, engineering, and mathematics (STEM) to other students or local K-12 schools. The nature of a student competition is turnover. Successful teams have well-designed succession plans that include transfer of engineering knowledge to new members. They also understand the importance of trial and error, and include many hours of in-water testing in their development plans. Students graduate and go on to contribute professionally in their fields and grow the technology base. The event provides access to top researchers in the field, as well as interactions with Navy personnel who provide insight into applications of naval interest. Sponsors often preferentially employ former competitors due to their hands-on experience. Some of today's leaders in naval technology and in industry were competitors 20 years ago. Among today's competitors will be the leaders of tomorrow.

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Dan Deitz is currently a program manager at ONR responsible for a number of autonomous underwater vehicle programs that are the beneficiaries of AUVSC investment.

MAXIMIZING LIGHTBULB MOMENTS

By Rear Adm. Lorin Selby, USN, and Mr. Jimmy Smith

Shutterstock photo by Alessandro Pintus

NAVAL STEM—SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH—IS POISED TO MAKE A GREATER IMPACT THAN EVER WITH NEW PARTNERSHIPS, NEW IDEAS, AND NEW INITIATIVES THAT WILL HELP MORE STUDENTS HAVE THOSE MOMENTS THAT CHANGE LIVES.

Many people have been lucky enough to have been a part of a special school program, or had pivotal moments in their education, or worked with a particular teacher, that made "the difference." In those moments, we had an experience that inspired us so much that it literally changed our lives. In all of these cases, something gave us a direction we might not have considered before, or confirmed a feeling that we already had, and pushed us to pursue a passion.

Some call it the lightbulb moment.

These lightbulb moments happen, ideally at least, throughout our education, and into adulthood. In elementary school, we make new discoveries that ignite childhood interests and intellects. In high school, we find inspiration from various places that helps guide our choice of college and major, or a trade, or which military service.

Even at age 18 or older, the inspiration doesn't stop. In fact, it becomes more real than ever, because now, young folks are starting to really buckle down and think about a career. Even in an era when statistics show younger workers changing careers far more than in previous decades, the things we learn as young adults are integral to who we become, both personally and professionally.

As the chief of naval research, and the Navy's director for small business programs, we know how important it is to be inspired. And we know how critical it is to have the best possible workforce supporting the US Navy and Marine Corps in the years ahead—a workforce that is motivated, bright, and interested in topics involving STEM.

Let us state it up front and in unmistakable words: Strong Naval STEM efforts are critical to America's future, and are a matter of national security.

We in Naval STEM are laser-focused on this topic, and putting down a marker: We will support multiple new approaches to encourage and reimagine what Naval STEM is and can be. We will leave no stone unturned as we widen our outreach to include all segments of America's diverse mosaic.

We will provide that lightbulb moment for America's schoolchildren, teen students, undergrads, and graduate students, across all racial, economic, and gender boundaries.

In the end, we proudly declare that revitalized STEM efforts are not only a pragmatic necessity for national success, enabling the Navy and Marine Corps to meet warfighting challenges—but also a reflection of who we are as a nation.

Before getting to some of the exciting efforts going on in Naval STEM, let's look honestly at the challenges we face as a nation when it comes to STEM. In this era of Great Power competition, we cannot avoid this truth: Competitors and potential adversaries are advancing technological capabilities once only held by the United States and our allies. In a few cases, they are ahead of us; in many more cases, they are approaching parity. When that happens with a trusted partner nation with a history of responsible behavior on the world stage, it's simply a friendly challenge.

When nation-states that have demonstrated hostility to a safe and stable global commons attain technological capabilities that threaten peace, however, complacency is not an option.

It's unquestioned that our nation achieved its standing in large part because of significant technological advances. We are proud to say that naval technology, specifically, has played a critical role in American victories and national successes. It was naval technology advances in radar and torpedoes, for instance, that proved pivotal in World War II. In subsequent decades, naval science played a crucial role in advanced timekeeping that made possible the Global Positioning System that the world depends on today. Navy-sponsored research has mapped the ocean floors and made possible satellite capabilities that were once the stuff of imagination. Today, we continue to deliver incredible breakthroughs in fields such as directed energy, artificial intelligence, autonomy, and quantum capability.

The "other guys" also have bright, motivated scientists and engineers as well. In fact, they are putting just as much emphasis on science and engineering as we are. Perhaps more. The decreasing numbers of American children embracing these fields shows that we face significant challenges. Consider just these few statistics:

- A report published in August 2019 by the Institution of Engineering and Technology, titled "Inspiring the Next Generation of Engineers," says that interest in science fell 10 percent among 9-12 year olds, interest in design and technology fell by 12 percent, and interest in computing fell by 14 percent
- According to a 2018 Pew Research report, Blacks and Hispanics remain underrepresented in the STEM workforce relative to their share of the workforce as a whole
- A Congressional Research Service report in 2018 noted that "concerns remain about persistent academic achievement gaps between various demographic groups, STEM teacher quality, the rankings of U.S. students on international STEM assessments, foreign student enrollments and increased educational attainment in other countries, and the ability of the U.S. STEM education system to meet domestic demand for STEM labor."
- A 2019 survey by Junior Achievement found that 9 percent of girls ages 13-17 were interested in a career in science, tech engineering, or math—down from 11 percent the year before
- A 2018 Junior Achievement USA survey of 13-17 year olds showed boys' interest in STEM dropped by 12 percentage points
- A Bureau of Labor Statistics report in 2015 states, "Economic projections point to a need for approximately 1 million more STEM professionals than the U.S. will produce at the current rate over the next decade if the country is to retain its historical preeminence in science and technology."
- While dated, consider this statistic: According to an article by Bill Bennett and David Wilezol, by 2009, the total number of college students grew by more than 50 percent since 1985—but the number of students majoring in mathematics and statistics remained virtually unchanged. In fact, more students were studying visual and performing arts than computer science, math, and chemical engineering combined.

And the examples continue.

There are some bright spots, however. Statistics indicate that at the university level, for instance, STEM interest is actually on the rise. Data in 2016 by the National Center for Education Statistics found that the share of STEM degrees actually rose in almost every state between 2010 and 2016. We take heart from these and other positive stats, but heart alone won't win the battle to inspire and reimagine the future.

It will take inspired programs and renewed commitment to reach new and more diverse groups of students (and hence gain new ideas and perspectives)—and, frankly, additional funds.

At the Office of Naval Research (ONR) and the Navy Office of Small Business, and across the Naval Research Enterprise, we are proud to have started some of the most serious reimagining of Naval STEM programs in many years. It's our charge to think not just of where we are today, but where we need to be in 10, 20, or 50 years.

Some of our efforts include:

- We are leading the way in adapting to the challenges of the COVID-19 era. Some people feared that with social distancing and the prohibition on conferences, field trips, and even classes and seminars—all of which depend on face-to-face interactions—Naval STEM would simply be on ice. After all, the reasoning went, how could students interact with their mentors? How could they go to see Navy facilities that would excite their minds and inspire career ideas? We refused to adopt that philosophy. Instead, we reimagined how we conduct our STEM business. That includes: innovative, world-class digital internship programs; remote and virtual field trips; and revitalization of existing programs
- We have revamped, refunded, and reimagined the Naval STEM Coordination Office, which is managed by ONR on behalf of the Department of the Navy. This new emphasis includes placing a Senior Executive Service leader at the helm, and encouraging the Naval STEM team to think outside the box, to dare to ask "what if?" and to collaborate with partners across the Navy, Marine Corps, industry large and small, and academia.
- We have taken a hard look at our diversity efforts in STEM. The intent had always been good, but the facts at the end of the day indicate we must do better to reach more diverse groups of students. For us, looking through our science-and-technology and small-business lenses, this is common sense. Throughout history, some of the

Students attend a virtual class presented by Naval Information Warfare Center (NIWC) Atlantic scientist Marcus Schoultz. Naval STEM has quickly adapted to the requirements of the new virtual learning environment of the COVID-19 era.
Photo by Joseph Bullinger

greatest innovations have come about by individuals who didn't see things the exact same way. It is fresh perspectives that will be key to America's continued tech dominance. If we miss out on students because of gender, age, race, geographic origins, sexual orientation or any other differences. We are missing out on resources vital to our nation's success.

Even more than that: If we miss out on reaching all demographics, we're ignoring what makes America such a great and unique nation. The slogan on our currency is *E Pluribus Unum*—"out of many, one." We are committed to that slogan in Naval STEM.

- We have connected Naval STEM with the Historically Black Colleges and Universities/Minority Institutions (HBCU/MI) program. Recognizing that some of the most important efforts in STEM occur at the university level—and welcoming the challenge to do better to reach more diverse demographics—we have reimagined a new STEM and HBCU/MI partnership. It's a natural synergy, and each program, composed of smart, dedicated people working to reach America's future leaders and workforce, will benefit and help each other see over and around obstacles to inspire young Americans across all demographics.
- We have reinvigorated and reimagined STEM programs, including two programs—the Science and Engineering Apprenticeship Program (SEAP), and the Naval Research Enterprise Internship Program (NREIP)—and increased their virtual segments to reach increasing numbers of high school, undergraduate, and graduate students through unique, real-world naval internships. That growth has taken place even in the midst of the COVID era. With Teams, Zoom, and phones that take better pictures than some of the best cameras in days gone by, there is no reason to stand down. Indeed, there are more reasons to hit the accelerator.
- We have launched a groundbreaking new virtual internship initiative called Naval Horizons. This program is truly exciting. The idea is to conduct fun, interesting interviews with scientists and engineers about what they do in fields such as artificial intelligence, additive manufacturing, lasers, and many other cutting-edge fields. The students watch the video and write a short, two-page paper on how this inspired them, describing how these fields might look and be used in the future. After they've done that short paper, they get a $200 stipend. Our first batch of nearly 20 videos went live in October 2020, and will reach 3,000 students. We will ramp up the second round, which is intended to reach 10,000 students.
- We have convened a group of retired senior executives from across the Department of Defense, industry, and academia to share their wisdom, experiences, and perspectives on how to address Naval STEM challenges. This talent pool is a unique source of ideas—and because these experts are retired and hence relatively unfettered by bureaucratic constraints, they are truly thinking outside the box, and have already brought exciting new vision and ideas to the STEM table.

Taken together, we know we already are making a difference and revitalizing Naval STEM. We also know this is just the start of a truly never-ending campaign to find the bright minds that will help ensure America's Sailors and Marines in the future have the absolute best workforce in the world behind them.

Like the students joining in the Naval Horizons internships, we're trying to imagine the future. In truth, none of us can say with certainty what lies ahead. We can give our nation its best chance to remain the world's best hope, however, by upping the ante in the STEM contest. Because it is a contest. It's a contest with our potential adversaries to ensure the technological edge remains with the United States. It's a contest to show we can inspire hearts and minds of young students and older mentors and leaders—and to remind ourselves of what we're capable of when we strive together.

The nation cannot falter in this matter of national security.

We will succeed.

About the authors:

Rear Adm. Selby is the chief of naval research.

Mr. Jimmy Smith is the director of the Navy's small business office.

James F. Geurts, assistant secretary of the Navy for research, development and acquisition, left, joins Dr. Delores M. Etter, professor emeritus, Southern Methodist University, as they present the 2017 Dr. Delores M. Etter Top Scientists and Engineers Award for Emergent Engineer Investigators to Dr. Richard Ordonez during a ceremony at the Pentagon. Photo by John F. Williams

NAVAL STEM ADAPTS TO NEW CHALLENGES

By Warren Duffie Jr.

THE DEPARTMENT OF THE NAVY HAS A LONG HISTORY OF SUPPORTING SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) EDUCATION. THOSE EFFORTS ARE REACHING OUT TO—AND CONNECTING—MORE PEOPLE THAN EVER BEFORE.

While interning as a nanomaterials scientist at the Naval Information Warfare Center (NIWC) Pacific, Richard Ordonez received an assignment to identify substances that could manipulate the electrical conductivity of graphene for use in sensors.

Graphene, a lightweight sheet of carbon atoms, is the world's thinnest material—and among its strongest. Considered thermally and electrically superior to silicon, graphene has numerous naval applications for sensors in everything from unmanned vehicles to underwater and space communication networks.

Ordonez—who was pursuing a doctorate in electrical engineering—and his colleagues tried various material concoctions to control the electrical properties of graphene, including a blend of sugar and deionized water acting as a type of transistor. Nothing worked. Too much electrical current leakage.

Then inspiration struck Ordonez as a he prepared a cup of tea. Since the honey he used to sweeten his beverage was of a gel-like consistency, it might serve as a good dielectric (electrical insulator). Why not try?

The scientists applied tiny drops of honey to multiple graphene films and ran several electrical measurements. To their surprise, the sticky liquid performed beautifully. As a result, Ordonez and his team developed an effective method for rapidly designing, testing and prototyping next-generation devices. They also published their findings in a respected journal, Nature Scientific Reports.

Ordonez earned a patent for the design. But he also received something even better—a full-time job offer from NIWC Pacific, the naval research and development laboratory ensuring superiority in the areas of cyber, command and control, intelligence, surveillance and reconnaissance, and space systems.

"My success as a naval employee is directly tied to my experience as a naval intern," said Ordonez, who completed his doctorate. "My internship taught me how to think differently, and my Navy mentors allowed me to make a successful transition to a full-time career. It expanded my world view. I have a career that's about more than just financial gain—it's about a higher mission of protecting warfighters and our homeland."

Sharpening America's Scientific and Technological Edge

Ordonez shines as a prime example of how important the Department of the Navy's (DoN) Naval STEM (science, technology, engineering, mathematics) program is to cultivating a strong base of Navy and Marine Corps civilian and military technical employees.

On behalf of the DoN, the Naval STEM Coordination Office oversees significant investments in education, outreach and workforce initiatives—which will enable the Navy and Marine Corps to meet warfighting challenges and maintain the scientific and technological advantage in areas like artificial intelligence, cyber and unmanned autonomous vehicles.

This is vital because, in an era when technology is easier to access than ever before, potential adversaries are increasing their technological capabilities. As the National Defense Strategy notes, the United States isn't guaranteed victory on the battlefield or in the battlespace of ideas. To stay ahead, the nation must instill a love of science and technology in its youth and encourage them to pursue naval STEM careers. So Naval STEM is re-defining its outreach—incorporating virtual and remote internship activities—to adapt to the new challenges arising during the COVID-19 era.

"We're living in an age of great power competition," said Rear Adm. Lorin C. Selby, chief of naval research. "Technology moves at breakneck speed, and sustaining a technological edge is crucial to maintaining our lead on the world stage.

"To do so, we need a well-educated and -equipped naval workforce that can meet this challenge," Selby continued, "and we need them to be US citizens, so they can work on classified projects."

As part of his responsibilities, Selby also serves as the Naval STEM executive. Since assuming his role in May, he has made Naval STEM outreach a major focus, calling the workforce of the future a matter of national security. He's also intent on broadening the Navy and Marine Corps STEM outreach, finding and encouraging talented young Americans to serve their nation from across all demographics.

In short, Selby is putting Naval STEM on the front burner. For this revitalization, he's partnering with leaders such as the Hon. James Geurts, assistant secretary of the Navy for research, development, and acquisition, and Jimmy Smith, director of the DoN Office of Small Business Programs.

Sec. Geurts even contributed the foreword to this special edition of *Future Force*.

"Having a strong STEM foundation is crucial to the success of our Navy and Marine Corps, as well as the security of our nation," said Selby. "I'm proud to embark on this important effort with Secretary Geurts and my good friend Jimmy Smith."

For these three leaders, revitalizing STEM is not something to talk about for the future—it's something we as a nation need to start doing right now. As adversaries grow in technical capabilities and aggression, Geurts, Selby, and Smith know we can't afford to let talented minds here at home go undiscovered or unsupported. And as disparities between different racial and societal groups are in the spotlight, they know Naval STEM needs to be part of the solution.

The focus areas of Naval STEM programs are: to inspire, engage, and educate the next generation of scientists, engineers, and technology and medical professionals; to

employ, retain, and develop a diverse civilian and military technical workforce; and to collaborate across the Naval STEM communities and with other agencies to maximize benefits to the DoN.

A Proud Tradition of Educational Outreach

Since the end of World War II, the DoN has placed great value in educating students in the sciences. For example, in 1946—the same year ONR was created—an issue of Science News Letter spotlighted the formation of "Navy science cruisers."

A partnership between ONR and the Science Clubs of America, the science cruisers initiative allowed high school students to see naval science in action. That year, according to Science News Letter, 110 students spent five days flying in aircraft, going to sea aboard an aircraft carrier, and sailing on battleships along the Atlantic coast.

Vice Adm. Harold G. Bowen, the first chief of naval research, had this to say about the 1946 science cruisers program:

"As a result of the war [World War II] and the lessons learned, it becomes essential to our new generation to stress more than ever their education in science.

"This is necessary for several reasons: First, our country badly needs a new crop of research scientists to enable us to hold our own in the acquisition of new knowledge; second, an education in science is essential for our children to take their proper places in the new technological world; third, an education in science is essential in order that our young men will form a large reserve for national defense which will depend to a much greater extent than heretofore on science."

Nowadays, the science cruisers program no longer exists, but Naval STEM is still a vital component to sharpening the technological edge and capabilities of the Navy and Marine Corps. Current outreach efforts include:

- Naval Science Awards Program (NSAP): This Navy and Marine Corps program encourages students to develop and retain an interest in STEM. NSAP recognizes the accomplishments of eligible students at regional and state science and engineering fairs. https://www.onr.navy.mil/Education-Outreach/K-12-Programs/NSAP
- Junior Science and Humanities Symposia (JSHS) Program: A triservice (Navy, Army, Air Force)-sponsored competition promoting original STEM research and experimentation at the high-school level. https://www.jshs.org/
- Science and Engineering Apprenticeship Program (SEAP): SEAP is an eight-week high school apprenticeship opportunity at one of nearly 25 naval laboratories or warfare centers. https://seap.asee.org/
- Naval Research Enterprise Internship Program (NREIP): NREIP is a 10-week college student (undergraduate and graduate) research internship opportunity at one of nearly 30 naval laboratories or warfare centers. https://nreip.asee.org/
- Science, Mathematics and Research for Transformation (SMART): The SMART program is an opportunity for students pursuing undergraduate or graduate degrees in STEM disciplines to receive full scholarships, with an agreement of employment within the Department of Defense upon graduation. https://www.smartscholarship.org/smart
- National Defense Science and Engineering Graduate (NDSEG): NDSEG provides fellowships to support study and research leading to doctoral degrees in science and technical areas. NDSEG confers high honors upon its recipients, and allows them to attend whichever US institution they choose. https://ndseg.sysplus.com/

In addition to these efforts, Navy and Marine Corps scientists and engineers often visit school classrooms; host STEM events, academies, and other activities; and serve as judges for science fairs and various STEM-centric contests.

"Such activities not only increase awareness of naval-relevant STEM opportunities and careers," said Dr. Michael Simpson, director of education and workforce/Naval STEM. "They inspire current workers by connecting them to potential members of the next workforce—and create a research and development community that will be vibrant and productive for generations."

Ordonez from NIWC Pacific agrees. He completed multiple internships, including an NREIP, before being hired full time.

"My internships were great," he said. "I never felt like an intern, because my managers always listened to what I had to say. They encouraged me to participate in project proposals and take on challenging assignments that would help me grow professionally. I would encourage any high school or college student to keep an open mind and consider applying for a naval internship."

New Directions

Naval STEM has an admirable track record as an established talent pipeline for the naval workforce, but its outreach efforts have been based on in-person, face-to-face interactions. Such a model is difficult to maintain during the COVID-19 pandemic.

Consequently, naval leaders want to re-energize and revitalize the program by emphasizing greater virtual and remote-learning activities—to remove geographic barriers, increase the number of students reached, and bolster its commitment to gender and racial diversity.

Dr. J. D. Walsh, applied sensing and processing branch head at Naval Surface Warfare Center Panama City Division, describes components of an unmanned system to the division's 2020 Science, Mathematics and Research for Transformation (SMART) scholarship recipient, Jacqueline Jermyn, right. Photo by Susan H. Lawson

"Naval STEM is in a transformative state," said Sandy Landsberg, who is both the Naval STEM Coordination Office executive and a division director in ONR's Information, Cyber and Spectrum Superiority Department. "Global and national events are driving us to re-examine the way we do business—to improve the quantity and quality of outreach to students, educators, naval scientists and engineers, and the greater naval STEM community, including industry and academia."

James Geurts, assistant secretary of the Navy for research, development and acquisition, is spearheading this transformation in partnership with ONR and various naval laboratories and warfare centers.

"Ultimately, it is a matter of national security for the United States to fuel thriving, wide-reaching Naval STEM programs," said Geurts. "Through virtual and remote-learning activities, we can use modern communication tools to discover, engage and develop our best and brightest, from all demographics and localities."

Examples of Naval STEM's revamped outreach include:

- The NREIP internship and SEAP apprenticeships, both held in the summer, are now virtual. To increase student participation, NREIP is hosting an additional virtual engagement internship this fall. This introduces college students to the concepts of research and development—and establishes virtual mentoring relationships between groups of participants and DoN scientists and engineers.
- A new virtual initiative called Naval Horizons has been established to reach 3,000 undergraduate and graduate students online. Naval STEM is developing a series of videos covering cutting-edge naval science and technology topics. Participants are invited to watch these videocasts and then communicate their ideas about what the future of S&T will look like in the year 2040. Students who are interested will be connected with a DoN mentor to continue the conversation. Naval STEM hopes to scale the project upward to reach 10,000 students.
- Virtual initiatives by Naval STEM stakeholder

organizations. For example, the Naval Air Systems Command (NAVAIR) is designing a virtual field trip for local middle schools to explore the aircraft squadrons, test pilot school, and laboratories at Naval Air Station Patuxent River, Maryland. In addition, the Naval Information Warfare Systems Command (NAVWAR) is creating a university challenge competition on computer vision for unmanned surface vehicles.

"Holding virtual tours at naval labs and warfare centers gives us the chance to share innovative science with a greater number of students," said Selby. "We want to do things similar to NASA, which has astronauts in space taking questions from students. Maybe we could do virtual tours of the David Taylor Model Basin [at Naval Surface Warfare Center Carderock Division]. I remember being inspired by the Apollo missions and the moon landing when I was a kid. I want the DoN to inspire the current and future generations of students to consider STEM careers."

Another important step taken by Geurts to enhance Naval STEM was enlisting Jimmy Smith, director of the DoN Office of Small Business Programs, to work with ONR in this effort.

Smith's main professional role focuses on small business acquisition policy. Throughout his naval career, however, Smith has always performed additional duties promoting STEM. His passion began from a lifelong love of aviation (he earned his pilot's license at age 16)—and his work as a naval mechanical engineer was instrumental in the design and construction of *Virginia* (SSN 774)-class fast-attack submarines.

In his latest role, Smith will help build partnerships between Naval STEM and his wide network of contacts.

"My role is as a facilitator and to serve as a type of professional connective tissue," said Smith. "I'm fortunate to be well connected in the STEM community, the result of establishing numerous relationships with academia and industry over the years."

Naval Surface Warfare Center Philadelphia Division employees serve as judges during the 2018 Girl Scouts of Eastern Pennsylvania Science, Technology, and Mathematics Experience Summer Camp poster session. In 2020, the camp was run virtually through video calls with virtual presentations replacing the poster session. Photo by Keegan Rammel

A Focus on Diversity and Inclusion

The current national discussion about racial inequality is another factor fueling the re-energizing of the Naval STEM program, which seeks to attract more students from underrepresented and underserved communities.

For example, Smith and Selby are collaborating with military, academic, and industry leaders to implement a greater commitment to diversity and inclusion within STEM initiatives, to conduct outreach, and to sustain these efforts on a long-term basis.

Naval STEM also is strengthening its partnership with the DoN Historically Black Colleges and Universities/ Minority-Serving Institutions (HBCU/MI) program. The program offers various opportunities for HBCU/ MI faculty and students to work collaboratively with scientists and engineers at naval labs and warfare centers, on projects of mutual interest.

The program has three main goals: expand opportunities for HBCU/MIs to compete for grants and contracts for basic and applied research; offer scholarships, fellowships, and internships to HBCU/MI students pursuing degrees in STEM studies; and promote greater student interest in STEM degrees at HBCU/MIs.

"By reaching out to underrepresented populations, we'll gain diverse perspectives on solving naval science and technology challenges," said Anthony C. Smith Sr., director of the DoN HBCU/MI program. "HBCU/MI students and faculty are a huge, untapped asset that can benefit the Navy, Marine Corps, and the nation."

Anthony Smith also is working with leaders assembled by Jimmy Smith and Selby to incorporate greater diversity and inclusion in Naval STEM.

"Our nation is facing major challenges from COVID-19 and the larger issues of inclusivity," said Selby. "However, this is a chance for our organization to become more agile, diverse and responsive. We can overcome adversity and move the needle in a positive direction."

When the COVID-19 pandemic struck earlier this year, several of the associated administering offices under the DoN HBCU/MI program were able to adapt and modify their student and faculty initiatives to virtual formats. These include NAVAIR, NAVWAR, the Naval Supply Systems Command, and the Naval Research Laboratory.

"The virtual internships have the potential to be a game-changer," said Jimmy Smith. "When I was an intern, on my first day I was told to sit at a bench and read technical manuals. These new internships can be more interactive, engaging, and fun—and connect us with more diverse students by removing geographic boundaries."

New Naval Partners

Another way the Naval STEM program is bolstering its capacity is by partnering with two new organizations created by Geurts—the NavalX Agility Cell (known as NavalX) and Tech Bridges.

NavalX enables collaboration, accelerates the pace of discovery, learning, and experimentation, and fosters the naval workforce's capacity for innovation and agility. It gives Sailors, Marines, and DoN civilians valuable tools for solving problems and translating ideas into actionable solutions.

This allows naval organizations such as ONR to serve warfighter needs better by connecting individuals promoting innovative ideas with experts who can experiment with those ideas, invest in them, or help turn them into something tangible for the Navy and Marine Corps.

Tech Bridges is a partnership between NavalX, ONR, and all naval systems commands. Each Tech Bridge is a regional innovation hub where warfare centers, government, academia, and industry can team up and work together on technology research, evaluation, and commercialization, as well as economic and workforce development.

The hubs connect and sustain "acceleration ecosystems" in nonmilitary facilities across the DoN, fostering greater collaboration. This involves working with local colleges and universities, research institutions, start-ups, corporations, small businesses, and nonprofits, among others.

The 13 Tech Bridges are located in California, Florida, Indiana, Maryland, Rhode Island, South Carolina, Washington, and the Washington, DC, region, and London, England.

Naval STEM Deputy Director Kathleen Gately Miranda envisions a synergistic relationship with NavalX and Tech Bridges that shares awareness of opportunities, promotes local and regional STEM initiatives, and amplifies Naval STEM's message to a wider audience.

"Through increased collaboration, we will benefit from sharing best practices and leveraging everyone's expertise," said Miranda. "In doing so, we can develop and execute the highest-caliber, naval-relevant programs and initiatives."

This commitment and camaraderie among diverse Naval STEM stakeholders will infuse the DoN workforce with a steady supply of talent—replenishing its innovative spirit and ensuring the United States stays ahead of its adversaries and near-peer competitors.

About the author:

Warren Duffie is the assistant editor of *Future Force.*

STEM FOR SEAPOWER

By Vice Adm. Ann E. Rondeau, USN (Ret.)

SHIPS AT SEA AND AIRCRAFT LAUNCHING FOR THEIR TARGETS ARE THE ESSENCE OF SEAPOWER. BUT BUILDING SEAPOWER MEANS FIRST MASTERING THE POWER OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH.

US naval forces face two concurrent challenges: our thrust into the "Cognitive Era" (the melding of computational power with human operators), and an increasingly dangerous period of Great Power competition. Individually, these challenges will test our technological and intellectual prowess. Combined, they approach the threshold of existential risk.

The topic of this well-timed issue of *Future Force* addresses intellectual capital as a critical component of decisive naval capability. Education and training, focused through the lens of science, technology, engineering, and math (STEM) are vital to seapower. Indeed, they are as important as platforms or weapon systems.

This was the conclusion of the Education for Seapower report published in 2018. Adm. James Stavridis contributed to that report, observing that: "In the end, 21st century warfare is brain-on-brain conflict, and we must build our human capital and intellectual capacity as surely as we produce the best pure warfighting technology if we are going to win the nation's wars and advance its security."

At the heart of Education for Seapower is STEM. Recommendations in the report focused on increasing warfighting and STEM curricula (as well as STEM research and faculty)—not only for the pursuit of new technologies, but also to develop naval warfighters with the know-how to apply and employ technology effectively in the all-domain (cyber, space, air, ashore, and sea) battlespace of naval warfare. Maritime superiority results only when naval forces achieve dominance in all five domains.

Naval STEM, therefore, is really about "STEM for Seapower."

The Naval Research Enterprise (NRE), led by the Office of Naval Research (ONR), continues to deliver, at accelerating pace, the "S" and "T" of Naval STEM through science and technology (S&T) research, upon which every future capability depends. Scientists at the Naval Research Laboratory, and across thousands of partner institutions funded by ONR, convert research discoveries into new knowledge necessary to develop new technologies. In this way, the NRE creates the potential for our decisive edge.

To realize that technological potential, however, requires tech-savvy engineers and mathematicians—the "E" and "M" of our Naval STEM workforce—with the intellectual capacity and operational knowledge to convert the potential of S&T into warfighting capability.

It is then up to our uniformed people, hardened by operational experience and armed with STEM-focused education, critical thinking, and acute judgment, to realize the potential of game-changing technologies. Becoming thought leaders, they master technology applications and gain the knowledge to lead innovation adoption that can solve key operational and strategic problems, faster. STEM-educated leaders are also required to counter an adversary's surprise introduction of a unique technological application.

Technical and analytical understanding of the naval environment advances the quality of timely decision-making in conflict.

Put another way, the best translator of operational need to the naval S&T research community is a STEM-educated operator. This further requires engaging in the practical, competent, and solutions-focused activities of experimentation, invention, and innovation. From where do such STEM leaders come?

The Naval Postgraduate School (NPS), at the leading edge of merging technology and intellectual prowess, delivers "technological leadership"—solutions with tech-savvy leaders who know how to use them. As the catalyst for this critical fusion, NPS is interdisciplinary, classified, responsive, innovative, and secure. Together, in response to real problems identified by the fleet and force, operationally experienced students and expert faculty researchers together develop relevant solutions that combine the art and science of naval warfare to realize the full potential of emerging technologies.

NPS students know what matters, and they want to make a difference—for them, it's personal.

There is a brilliant symbiosis between NPS and ONR: NPS is education with research, while ONR, as the Naval STEM executive, is research with education. STEM-focused education and training, in partnership with research and development, enable Sailors and Marines to master and apply new capabilities at effective pace and scale. This collaborative Naval STEM partnership can and should be even more leveraged to accelerate and enhance outcomes in support of capability in the Cognitive Era.

This is the critical pathway to sustaining our decisive edge in technological capability.

This *Future Force* issue adds a clear voice at a critical juncture, emphasizing that Naval STEM can lead to technological prowess—but only when joined with education and training for intellectual prowess will the naval leaders we need emerge to create true capability from potential.

This is "STEM for Seapower."

About the author:

Vice Adm. Rondeau is the president of the Naval Postgraduate School.

Photo by MC3 Cameron Pinske

A ROBOTICS ENGINEERING CERTIFICATE FOR STUDENTS ACROSS THE NAVY

By Lyla Englehorn, Dr. Brian Bingham, Marianna Jones, Reid McAllister, and Michael Tall

THE NAVAL POSTGRADUATE SCHOOL OFFERS A CERTIFICATE PROGRAM IN ROBOTICS ENGINEERING THAT AIMS TO GIVE GRADUATE-LEVEL TRAINING IN THIS IMPORTANT CAREER AREA FOR STUDENTS WITHIN THE NAVY, WHEREVER THEY MAY BE.

The Naval Postgraduate School (NPS) provides a graduate education experience that is highly relevant for men and women in uniform, and has had success extending educational opportunities to nonresident communities. Taking advantage of the new COVID digital work environment now accessible to many levels of the Naval Research and Development Establishment (NR&DE) workforce, a new NPS robotics engineering graduate certificate leverages on-campus courses to provide a flexible, distance-learning experience for our civilian colleagues at the Navy's warfare centers. With support from the Consortium for Robotics and Unmanned Systems Education and Research (CRUSER), and developed in cooperation with colleagues at the warfare centers, this graduate-level certificate provides a technical foundation and supplemental credential for practicing engineers across the NR&DE. The certificate gives the workforce a flexible, low-residence learning experience that includes the essential concepts and skills necessary to understand, design, and operate robotic systems. Each course in the robotics engineering certificate is composed of both instruction and hands-on activities to support student learning.

Michael Tall, Naval Information Warfare Center (NIWC) Pacific battlespace awareness portfolio manager, identified a gap in robotics engineering skills in his workforce and started scanning the landscape outside of NIWC for opportunities to get his colleagues the skills they need to move ahead. "I was meeting a lot of talented people in the workforce that didn't know about unmanned systems, but they know about computer programming, embedded hardware," Tall said. "We could teach an introductory class here about unmanned systems, so they could start to make the career switch." Tall reached out to NPS associate professor Brian Bingham, who agreed to prepare a weeklong deep-dive course on robotics engineering to teach at the NIWC Pacific campus in San Diego. There was such a large demand for that initial course that they immediately scheduled more offerings.

Doug Lamb and Gerardo Gamboa of Naval Air Warfare Center China Lake helped bring the new applied trajectory optimization certificate program to China Lake in 2018, but always hoped for additional engineering courses geared toward weapons and weapon platforms. The NPS robotics engineering certificate program fills this need, and will provide a path to a distance learning master's degree for students within Naval Air Systems Command. Through Doug Lamb, Misty West-Bruna helped Bingham share information with employees at both China Lake and Pt. Mugu in advance of the certificate launch.

Chris Egan and Reid McAllister, co-leads of the NR&DE's unmanned vehicle and autonomous systems working group, also reached out to Bingham at NPS with a similar need. "We had been searching for the right institution and curriculum to advance the naval workforce's understanding and capabilities in the development, testing, fielding, and sustainment of autonomous systems," McAllister said. After Egan and McAllister had several discussions and meetings with NPS staff and faculty, it became clear that NPS was the right place to meet the Navy's need. Once Bingham confirmed that the robotics engineering certificate program was officially part of NPS's offerings, Egan and McAllister reached out across the NR&RE for potential candidates. With a response from more than 70 candidates, it was evident there was a strong demand for this type of advanced curriculum.

Robotics and autonomy are increasingly vital to naval planning and strategies. The 2018 Assistant Secretary of the Navy for Research, Development and Acquisition unmanned systems vision lays out the "strategic imperative to exploit emergent and rapidly developing unmanned and autonomous systems technologies." Concurrently, the size of robotics and autonomy programs is growing exponentially through program offices. It is critical for the NR&DE to be able to educate and retain the expertise to deliver this vision. Bingham noted that the defense focus of NPS academics make it the ideal university to provide this series of courses because warfighters require a robotics engineering education that is different from that offered to the general public.

For example, Naval Surface Warfare Center Carderock Division's primary mission is to design and integrate manned and unmanned ships, boats, craft, submarines, and large undersea vehicles. "For our robotics certificate program, one of the needs we heard from warfare centers is that often they are not just building platforms, but also are responsible for enhancing existing [defense] platforms through the development and integration of innovative payloads and missions," Bingham said. "The development and application challenges of intelligent autonomous systems for warfighting capabilities in the air, on the ground, across the sea's surface and undersea is distinctively different than those developed by companies in support of self-driving cars." McAllister said that a version of the course also will be offered at Carderock, where more than 20 workforce members eagerly await it.

Collaborating with colleagues across the NPS campus, the resulting four-class program is offered to any US military officers (both residential and not) and Department of Defense government civilians with a bachelor of science in engineering, or similar field, and experience in computer programming. To best meet the needs of the students across the NR&DE workforce, Bingham has coordinated with not just NPS faculty members and professionals within CRUSER,

Photo by Javier Chagoya

but also experts such as Mark Paulus and David Mortimore from Naval Undersea Warfare Center Keyport Division as well as Egan, McAllister, and Tall, among others. The team designed the program to help practicing engineers refresh their knowledge and skills to orient them toward working efficiently on unmanned systems projects. Tall said that the formal certificate will provide credibility to the skillset, making it easier for job recruiters to know what applicants have learned. There also is work under way to offer the NPS robotics certificate to defense contractors as well.

"We've found that folks with computer science, applied math, and physics degrees are very well prepared for the coursework," Bingham said. The program is structured to be a combination of instruction and hands-on activities, and the four classes cover computational and theoretical foundations of robotics as well as component-based software engineering to build the required skill set. The first half of the curriculum is foundational, covering important software tools (e.g., MATLAB/Simulink, the Robotics Operating System, and OpenCV) and the theoretical foundation for robotics. Applied physics and data collection complete the four-course sequence, with each course taught by a different NPS faculty member, or, in some cases, co-taught by multiple faculty members. For the hands-on portions of the course, students will travel two times to the NPS campus at Monterey, California, for a week of labs—or an alternative designed with the best interest of public health through the COVID-19 crisis.

With this certificate intended as the first step in more intentional educational offerings in robotics and autonomy, additional programs in areas such as robotics operations, machine learning for autonomy, and modeling and simulation for autonomy are currently in consideration. The first cohort began the NPS robotics certificate in early July 2020. Students nominally finish the program in one year, taking one course per quarter. Applications were due 30 March 2020 for this first offering; the current plan is to offer entry twice a year, in July and January. The July cohort includes students from across the NR&DE: Naval Air Systems Command, Naval Sea Systems Command, various warfare centers, and the Naval Research Laboratory. A cohort sponsored by Carderock Division is slated to begin the program in January 2021. Each single sponsored cohort (of at least ten students) will be tailored to meet the needs of the command and will allow instructors to cover some of the course content at the command's location.

This robotics certificate is designed to contribute to and expand the fledgling "Naval Innovation Ecosystem." As our "new normal" emerges in the COVID-19 learning and work environment, this NPS opportunity is ideally suited to meet the needs of learners throughout the Naval Enterprise. In addition to the distance learning certificate program, NPS also is planning to offer a resident version for registered NPS students in Monterey. The Monterey campus is open only for limited lab work during this COVID-19 environment, but even resident students will be served well by this timely and carefully crafted distance learning certificate.

For more information, please go to our website https://my.nps.edu/web/mae/robotics and pay special attention to the brochure and FAQ page, or email robotics.certificate@nps.edu.

Photo by Javier Chagoya

NPS students enrolled in the Physics Robotics 533 class deploy their autonomous ground vehicles on Spruance Plaza after weeks of preparation for their final project.

About the authors:

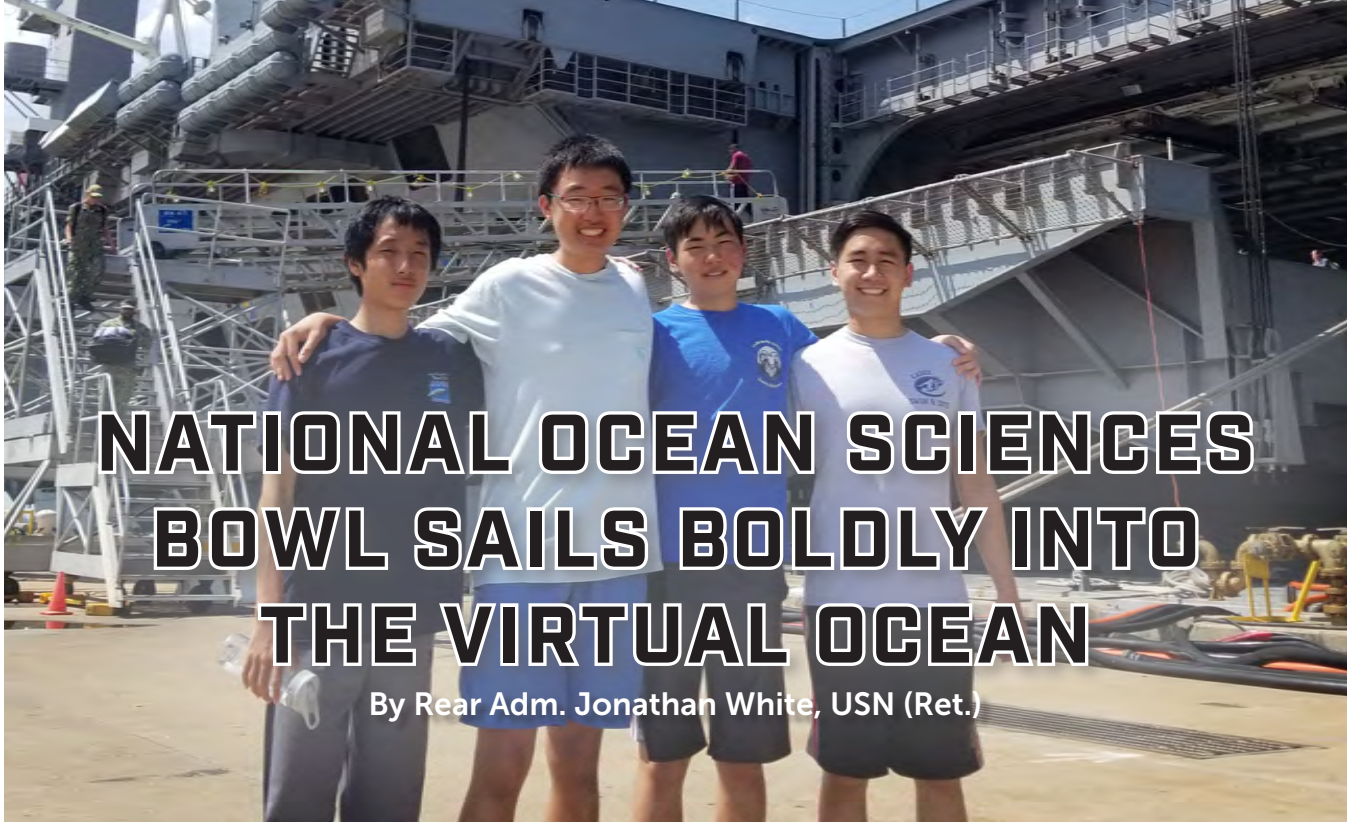
Lyla Englehorn has a research faculty appointment at Naval Postgraduate School specializing in rapid concept generation.

Dr. Bingham is an associate professor in the mechanical and aerospace engineering department at the Naval Postgraduate School.

Marianna Jones has a research faculty appointment at the Naval Postgraduate School working with several programs on campus including the Advanced Systems Engineering Robotics Laboratory.

Reid McAllister is the director of the US Navy's Integrated Unmanned Maritime Mobility Systems at the Naval Surface Warfare Center Carderock Division.

Michael Tall serves as the battleship awareness portfolio manager for the Naval Information Warfare Center Pacific.



NATIONAL OCEAN SCIENCES BOWL SAILS BOLDLY INTO THE VIRTUAL OCEAN

By Rear Adm. Jonathan White, USN (Ret.)

BRINGING TOGETHER STUDENTS FROM ALL OVER THE COUNTRY FOR MORE THAN TWO DECADES, THE NATIONAL OCEAN SCIENCES BOWL HAS BEEN ADDRESSING SIGNIFICANT GAPS IN THE NATION'S OCEAN SCIENCE CURRICULA EVEN AS IT HAS HELPED THOUSANDS TO ENGAGE WITH AND ENTER THE FIELD.

It's a bright, hot day in the Virginia summer, and four teenagers from Ladue Horton Watkins High School in St. Louis, Missouri, (shown above) are about to board an aircraft carrier, *USS Dwight D. Eisenhower* (CVN 69), for the first time and receive a tour from Lt. Cdr. R.D. Travis Wendt. They've spent the past few days in boats, salt marshes, marine labs, museums, and aquariums, meeting experts who have careers in ocean science. But why are they here? They can thank the late Adm. James D. Watkins for that.

More than 20 years ago, Watkins, former Chief of Naval Operations and chairman of the US Commission on Ocean Policy, co-created the National Ocean Sciences Bowl (NOSB; www.nosb.org) a high school-level quiz bowl competition. According to a 2018 National Survey of Science and Mathematics Education, nearly 50 percent of high schools do not offer ocean—or even environmental—science as part of their formal coursework. The NOSB addresses this gap by giving students from all over the nation a way to connect with the ocean and consider careers in ocean science and technology. These students from Missouri, who were on an award trip as the third-place finishers in 2019's NOSB national finals competition, represent Watkins' vision for the future, where ocean-based science, technology, engineering, and mathematics (O-STEM) is prevalent in education programs at all levels and enables an ocean-literate society across our maritime nation.

Watkins was a champion for ocean science and education in the United States. He began the NOSB because he understood the importance of ocean science, not only for naval advantage and national security, but for economic and environmental sustainability. He also saw the value of engaging precollege students in ocean science to meet future workforce needs. The Navy, along with other federal agencies, still champions this idea by investing in the NOSB and several other K-12 O-STEM initiatives. A lack of exposure in formal K-12 education means the ocean education pipeline doesn't begin prior to university experience or military enlistment. Thanks to Watkins' vision and the continued support of the Navy over the last few decades, there are now ocean scientists and engineers at many institutions and organizations that support naval oceanographic research and operations, and there are more in the pipeline.

Much More Than Just a Competition

The NOSB is an academic competition that begins each year at the regional level with 25 contests hosted by universities, aquariums, and other learning institutions across the United States. Students buzz in to answer multiple-choice questions

and work together to answer more challenging, collaborative questions that involve interpreting data, plots, or graphs. Teams that win their regional competition advance to the national finals competition where they vie to be the top team in the nation.

Beyond the quiz bowl, the NOSB engages students, teachers, schools, and ocean science professionals in activities throughout the year to help students build a broader and deeper understanding of ocean science than they would in a traditional classroom setting. The NOSB introduces students to the interdisciplinary nature of academic ocean science, but it also provides them with more than just answers to quiz questions: from the regional to the national level, students can participate in art competitions, write research papers, connect with peers with similar interests, receive scholarships, take part in career-mentoring events, and gain hands-on scientific experiences with actual experts in the field, all of which prepares them to lead their generation of ocean professionals. These nontraditional learning opportunities strengthen NOSB students' knowledge and understanding of marine environments while also providing them with professional development and teaching them how to solve complex problems through critical thinking and collaboration.

Approximately 2,000 students with 350 teams compete in the program each year. They are drawn to the NOSB for a variety of reasons: a drive to compete, an interest in learning about the ocean and environmental stewardship, and/or a desire to eventually work in an ocean or environmental science education or research field. Teams are formed through public, private, or parochial high schools (grades 9-12), student support organizations (e.g., Boys & Girls Clubs of America, Girl Scouts, Boy Scouts), or home school groups. Some teams enjoy the NOSB so much, they travel hours to compete at their closest regional bowl (a team in Idaho, for example, travels to western Oregon every year).

The NOSB program thrives thanks to the commitment of its 1,500 annual volunteers who: write, develop, and review competition questions; mentor students; and serve as competition officials who moderate, judge, keep time and score, and administer competition rules. These volunteers hail from local communities and may include ocean science professionals, educators, or individuals interested in challenging high school students in a fast-paced competition where they, too, can learn more about the ocean. Their participation provides students with direct engagement with professional scientists, access to expert knowledge, and advice on potential career paths.

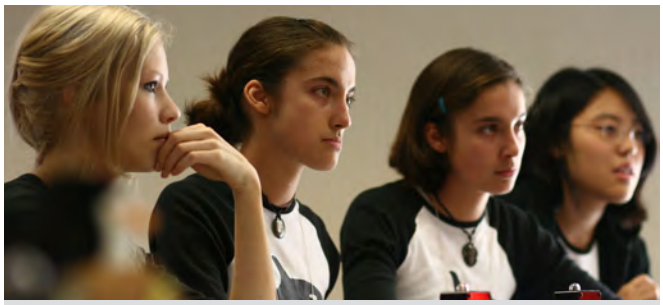
Partnerships, Community, and Ongoing Support

The NOSB began as a flagship initiative of the National Oceanographic Partnership Program, which enabled broad federal agency support—including from the Office of Naval Research—for the competition. It is managed by the Consortium for Ocean Leadership (https://oceanleadership.org/), a Washington, DC-based nonprofit organization with membership from the nation's leading ocean science, research, and technology organizations from academia, industry, and the larger nonprofit sector (including philanthropy, associations, and aquariums) and a mission that supports the national ocean enterprise, including the Navy and other federal agencies. These connections across multiple sectors of the ocean community are a key strength of the consortium and are also the foundation of the NOSB's approach to providing high school students with wide-ranging information and experiences as they chart their educational and career courses. The NOSB has grown to be a unique partnership of nonprofit organizations, academic institutions, federal agencies, and industry that provides students with direct exposure to cutting-edge ocean research and technology and connects them with university programs and potential mentors and advisors.

It only makes sense that the focus on partnerships and community have filtered down from the NOSB's creation to become one of the most unique and important characteristics of the program. The mix of community sectors represented in the program is also novel—students have direct access to research and researchers, university programs, new ocean technology and industry members, and government officials, including senior Navy leaders. These interactions have allowed the NOSB to grow as a supportive and close-knit community across the country where partners and participants benefit from shared interests and goals.

A Historically Strong Navy Connection

The Navy has been an important member of the NOSB community from its inception, serving as a program sponsor as well as a source of volunteers for question review panels and the regional and national competitions (especially the regional Hurricane Bowl in Ocean Springs, Mississippi, given its proximity to the Naval Meteorology and Oceanography Command and the Naval Research Laboratory at Stennis Space Center). In return, the NOSB helps the Navy meet its workforce accession needs by testing students on Navy-relevant ocean science topics.



Students during a 2009 competition concentrate on answering a multiple-choice buzzer question before the other team. Photo by Consortium for Ocean Leadership

To be successful, NOSB students must regularly study acoustics, waves, currents, sediment transport, beach formation, water quality, pollution, desalination, wetlands, reefs, sea level, beach nourishment and hard armoring, unmanned vehicles, seafloor spreading, sea water composition, water masses, primary productivity, and estuarine processes. Nearly 25 percent (or approximately 8,000) of competition questions from 2002-2018 covered topics taught in US Naval Academy courses. NOSB students gain a head start on understanding concepts that would assist them in undergraduate oceanography courses or in future naval military or civilian oceanographic careers. With the Office of Naval Research's support and participation, students learn about the scientific needs of and career opportunities related to the Navy.

Growing the Future Workforce—And Going Virtual

In a 2019 survey of regionally participating students, 75 percent of respondents agreed they are more likely to consider a career in a scientific field because of their participation in the NOSB, 66 percent agreed they are more likely to consider an ocean science career, and 89 percent agreed they became more aware of ocean science career options. Over the past 23 years, the NOSB has been an important workforce pathway that increases the nation's global competitiveness. To date, the tens of thousands of NOSB alums from 36 states have moved on to careers such as coordinating NOAA Exploration and Research expeditions, enforcing port security with the US Coast Guard, developing software for Bloomberg LP, designing installations for Walt Disney Imagineering, and promoting nanoscience research at the Molecular Foundry.

Hearing from students, such as one individual at Alaska's Tsunami Bowl, that "participation in the NOSB has influenced my career choice because it opened up my eyes to all the different opportunities people have in this field," confirms the need to broaden the experiences for participants each year. As we prepared for our 2020 national finals competition with the students' experience forefront in our minds, we were suddenly blindsided, like many organizations, by the COVID-19 pandemic and had to cancel the in-person event originally planned at the University of Southern Mississippi. We knew we couldn't completely cancel it—we had to go virtual. We were able to provide all our traditional finals events—a career mentoring event, a field trip experience, an opening ceremony, modified competition rounds, mock-congressional science expert briefings, and an award ceremony—all using videoconferencing software. Over the course of one week, 19 of our 23 regional winners competed in their knowledge of ocean science, explored the Galapagos, analyzed ocean-related legislation, and learned about the wealth of careers in the ocean sciences.

Going virtual highlighted the new, virtual ocean of possibilities for the NOSB to reach more students, especially those with little to no access to O-STEM programs. To do so, however, the community must continually return to Adm. Watkin's vision and work together in support of students' ocean science explorations. Doing so is in the best interest of our nation. As the need for an ocean-literate society only increases, so does the NOSB's critical role in engaging high school students in this environmentally and societally relevant field. As environmental, resource, and climate concerns continue to expand, along with the need for managing and mitigating societal, economic, and health impacts, a science-literate society will be best positioned to be able to make vital decisions. The NOSB inspires the important next generation of ocean leaders who will be addressing these issues and sets them up for success.

So what happened to that team from land-locked Missouri that toured one of the most massive and advanced products of O-STEM ever realized (the aircraft carrier *Dwight D. Eisenhower*) in 2019? They put their experiences from that summer award trip to very good use as they prepared for 2020 and successfully took first place in the NOSB's first-ever virtual finals competition. And while it was close, they were also victorious in a fun exhibition match against a team of professional scientists from Consortium for Ocean Leadership member institutions in the "Battle of the Ages: NOSBs vs PhDs," a special competition held on World Ocean Day, 8 June (https://oceanleadership.org/2020-nosb-battle/). The incredible students of today such as these are the ocean leaders of tomorrow, and with programs like the NOSB, the future of the ocean and the Navy's ocean knowledge advantage are in very good hands and minds.

About the authors:

Rear Adm. White became the president and CEO of the Consortium for Ocean Leadership following his retirement from the Navy in 2015 from his final assignment as Oceanographer and Navigator of the Navy.

POWERING THE NAVAL STEM WORKFORCE INTO THE FUTURE

By Shannon B. Turner, Dina M. Acklin, and Dr. Joseph Calantoni

HAVING PEOPLE WHO ARE EXPERTS IN SCIENCE AND ENGINEERING IS VITAL FOR THE SEA SERVICES—BUT HAVING THESE HARD SKILLS IS EVEN MORE EFFECTIVE WHEN IT'S COMBINED WITH THE ABILITY TO COMMUNICATE EFFECTIVELY, EMOTIONAL INTELLIGENCE, AND OTHER "SOFT SKILLS."

Imagine that you are a supervisor preparing for end-of-year reviews. You have two employees left to assess. The first, Charlie, gets along well with others and has a knack for presenting to customers and higher-ups, but struggles with the more technical aspects of the work. The second, Joan, needs no instruction and writes elegant code, but prefers to work alone and does not socialize with the team or outside customers. Looking at the budget, you note that you can only provide extra training to one of these two team members. Who are you most likely to send for remediation?

If you were like most supervisors in the fields of science, technology, engineering, and mathematics (STEM), you probably would be quick to assign Charlie some extra help. While it is great to be affable, you think, all team members need to have at least the same basic technical aptitude. This way of thinking, however, has resulted in a professional STEM workforce lacking in basic "soft skills," which are often cited as being the most necessary for success in any field. It is particularly relevant in STEM, where multidisciplinary work leads to the greatest breakthroughs and progress. So why, then, are we not more focused on training our workforce to have stronger soft skills?

The earliest documented definition of soft skills, found in a 1968 US Army system engineering regulation,[1] refers to "job related skills involving actions affecting primarily people and paper, e.g., inspecting troops, supervising office personnel, conducting studies, preparing maintenance reports, preparing efficiency reports, designing bridge structures."[2] More than 50 years later, managers, human resource professionals, journalists, academics, and others are still debating the proper definition of soft skills.[3] In the business sector, soft skills such as communication,

emotional intelligence, time management, and conflict management are seen as essential for success.[4] Among STEM professionals, however, soft skills have not been traditionally recognized as a key component for success, despite an abundance of research suggesting strong soft skills can both predict and produce success in life regardless of career path.

In 1918, a study by the Joint Committee on Engineering Education of the National Engineering Societies indicated that, "personal qualities such as common sense, integrity, resourcefulness, initiative, tact, thoroughness, accuracy, efficiency and understanding of men are universally recognized as being no less necessary to a professional engineer than are technical knowledge and skill."[5] The report noted that more than 94 percent of engineers participating in the study "placed Character at the head of the list" of qualities necessary "for engineering success."[6] Those "personal qualities" first cited more than 100 years ago are what we call "soft skills" today.

Another part of the problem is that we do not have a great understanding of which soft skills are in most need of development. The Naval STEM Coordination Office at the Office of Naval Research has funded a team from the US Naval Research Laboratory to assess the most commonly sought-after soft skills among our civilian and military technical workforce. The research team has developed a suite of questionnaires to quantify the soft skills of the local naval workforce at Stennis Space Center, Mississippi, examining abilities such as critical thinking, creativity, emotional intelligence, and grit. These constructs are difficult to define, and even harder to quantify scientifically, and there has been a surge of interest in being able to rigorously and objectively quantify soft skills in the same way one would assess more traditional hard skills like scientific programming or data analysis.

In STEM fields in particular, soft skills are not often expressly taught,[7] only remediated after employment.[8] Managerial and interpersonal skills training made up nearly one quarter of all employer training in 2018.[9] Because of this widespread deficiency, former engineers such as Ash Norton have made careers out of teaching fellow professionals how to improve their nontechnical skills, emphasizing that those who have a knack for recognizing and applying soft skills are often the most likely to succeed. In an interview with Forbes, Norton said, "What I've seen time and time again is that developing the 'soft skills' is dismissed throughout their [graduates'] formal training. Then, when they enter the workforce, they can't make the progress or impact that matches their technical skills because they lack communication, creativity and interpersonal skills that are required."[10]

The lack of soft skills within the STEM disciplines becomes problematic when considering the large role that engineers and computer scientists will play in the evolving Department of Defense workforce. According to Office of Personnel Management data, as of 2019 one out of every four of the 215,000 naval civilian employees occupies a STEM position. A 2017 Department of Commerce study forecasted, "STEM occupations are projected to grow by 8.9 percent from 2014 to 2024."[11] Of the nearly one million doctoral graduates in the United States today—scientists, engineers, healthcare providers, social scientists—approximately 18 percent serve in a management or administrative role,[12] those in which soft skills are particularly valuable to supervise and lead a team effectively.

Within the Department of the Navy a new group, NavalX, has been established to find new ways of connecting industry, academia, and military to solve problems more quickly and creatively. In doing so, the NavalX team focuses largely on promoting soft skills in their interactions with clients.

"You do need people who have advanced degrees, but you also need people who can manage a team," said Matt Denny, NavalX workforce engagement lead. "You can research all day long, but if you can't communicate your research, it makes it really hard to do your job. NavalX is not trying to be the next rocket scientist. Our job is to build relationships—with industry, military, government—to connect to different folks and organizations."

Billed as the Navy's "workforce superconnector," recruiting for NavalX focuses most heavily on soft skills such as empathy, emotional intelligence, communication, grit, and creativity. It is critical for workers to possess the skills for interacting with clients that improve cross-domain relationships and project success. "We have to have team members who enjoy talking with people and thrive in communication. Managing schedules, organizing projects—that can be taught," said Denny. "So we're interested in the people who already have communication skills, who can diffuse stressful situations, and who aren't afraid to be creative."

The formation of NavalX suggests a willingness on behalf of the Navy to recognize the key role of soft skills in improving the capability for the naval STEM workforce to more effectively interact with their counterparts across the Naval Research Enterprise, Navy and Marine Corps operations, and industry and academia. Better relationships will lead to more effective, targeted research and transition of technology to the fleet and operators. To understand where improvement is most needed, it is necessary to start with a solid foundation of understanding how soft skills are currently being used within our workforce.

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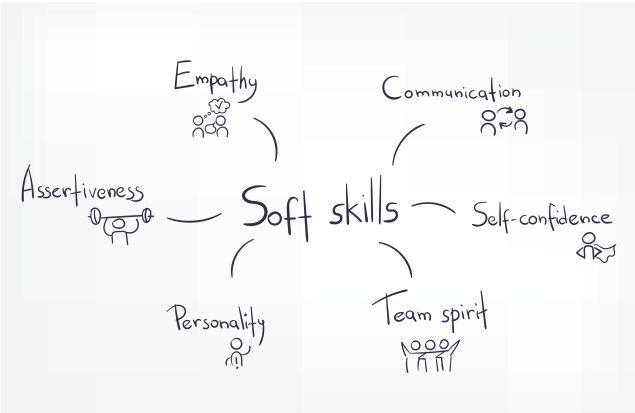

To this end, the research team at the US Naval Research Laboratory is investigating how best to promote soft skill development within specific naval STEM disciplines by quantifying the soft skills that dictate success among specific careers and workplace contexts (e.g., civilian mechanical engineers versus active-duty aerographer's mates). Using a curated suite of independent, validated assessments, the team will measure some of the most common sought-after soft skills in STEM fields. These include creativity, emotional intelligence, leadership, and critical thinking, along with a variety of other skills and personality characteristics such as charisma, ethics, and grit. In addition, the team will examine the personal and professional leadership experiences, prior military experience, and hobbies and affiliations of participants to identify individual applications of soft skills outside a work environment. Supervisory STEM professionals will also be interviewed to learn more about the role soft skills play in team building and daily management, as well as how supervisors address soft skill deficiencies in their employees or teams.

The research team expects to find correlations among existing soft skills, education levels, areas of education specialization, and Navy career paths. Of particular interest are correlations between underdeveloped soft skills among the same populations of workers. By quantifying soft skill aptitudes among the current work force and identifying those soft skills most in demand among naval STEM disciplines, the team intends for their results to guide leadership decisions regarding professional development and mentoring to the existing workforce, as well as to improve hiring practices for the workforce of the future. In this way, the Navy can work toward optimizing professional development and training opportunities provided to workers to target the growth of specific soft skills.

Study results also can be applied to developing soft skills in our future workforce, guiding K-12 lessons and activities embedded with the notion that academic rigor is not the only key to success in STEM. Understanding the value of soft skills will affect how students view their interactions among their peers and how critical those interactions may be for their future success. By incorporating into naval STEM activities the interpersonal soft skills STEM students often see as inconsequential or ambiguous, we can change their attitude toward the hazy human aspect into a measurable, effective technical instrument to be used in their quest to become professional scientists and engineers.

The project team began data collection in July 2020.

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SECURING DIGITAL TRANSFORMATION PROGRESSION WITH HYBRID TRAINING

By Stephen Pease

NEW TRAINING TECHNIQUES THAT COMBINE AN IN-PERSON PRESENCE WITH COMPUTER-BASED LEARNING NOT ONLY MIGHT BE THE RIGHT WAY TO TRAIN FOR THE TIMES WE LIVE IN—IT MIGHT JUST BE THE MOST EFFECTIVE WAY TO TRAIN PERSONNEL IN THE FUTURE.

As technology continues to evolve, so does the need to evolve the methods used to deliver critical training in the Department of Defense (DoD). Managers and employees both place a high value on training that is relevant, provides essential knowledge, and can be completed in the shortest time possible. Employees that desire to stay in front of technological trends strive to learn new information while managers push to produce results. Challenges arise when training is not sufficient, outdated, uninteresting, or delivered in ways that do not excite the workforce to take action. To advance capability, the workforce of the future must advance training methods that keep pace with each breakthrough and innovation.

This article will review existing methods of training, highlight some of the drawbacks of these methods, and provide a comparison between existing methods and new "hybrid" training methods. It is hoped that the information provided here will serve as a call to action for training professionals, and provide specific steps that can be implemented to improve the relevance and efficiency of trainings offered in the DoD.

The Old Ways

Death by PowerPoint

Recently, a training was offered on a subject that has been of great interest to the DoD—model-based systems engineering—that garnered immediate interest. This training was advertised with the keywords "hands on," and upon arrival, students found a fully functional computer at each seat, adding credibility to the "hands on" element. The introductory PowerPoint was illuminated on screen with the welcome and agenda. After the introduction and general welcome, the presenter moved into the first section, then the second section, and the third. Eight hours later, the PowerPoint presentation concluded. This is not hands on training; this is a PowerPoint presentation, and nothing more. The presenter was able to follow the standard PowerPoint commandment of "Thou shalt not use a dark background, small font, or large walls of text," which could have made the experience even more unbearable than the original false advertising. PowerPoint is not all doom and gloom, and it can be a powerful tool. It certainly serves a purpose, and is a necessary element for rapid ingestion of

information for awareness and possibly as a refresher, but PowerPoint does not provide hands-on training.

On-the-Job Training (Sink or Swim)

On-the-Job training provides the hands-on element by immersing an employee into an environment in a typical master-apprentice setting. This can be a worthwhile method for many learners because they see results first-hand. They can ask direct questions, try the newly learned method themselves, and get feedback instantly in most cases on their performance. Typically, the training comes from a more senior person who has performed the work and has a good grasp on how things operate. The senior person will typically have the apprentice shadow him or her through a workday and then slowly hand off responsibilities as the apprentice is able to perform the work. Drawbacks of this kind of training revolve around a few key areas. First, rapid technology change leaves the new and senior employee without any idea how to manage new methods, updates, physical components, interconnections, coding, or interoperability with legacy systems. Second, potential problems arise when both master and apprentice incorrectly assume accuracy in the work. This can lead to employees operating on the "way we've always done it" principle. This can stifle creative thinking in the workforce, and make implementing new technologies and ideas more difficult as well as more expensive.

Computer-Based Training

Bringing employees closer to rapid education goals, computer-based training can offer on-screen, hands-on simulations, or environments that re-create the actual software, hardware, or systems that require training. New systems can easily mock up their new interfaces to allow trainees to investigate features and functions, typically in a limited sense, and offer validation through final examinations. The shortfall with this method lies in the evident limitation of asking questions, leaving students to receive information in a one-sided experience. This experience lacks the human element, which provides guidance to wayward students that inadvertently become lost in material. Without the ability to ask questions and receive clarity, students risk losing retention of key points critical to successful grasp of the material. Without the ability for clarification, trainings can quickly become frustrating for those trying to grasp a unique concept or new information. In addition, a potential problem is the desire to "click through and get it done." The essence of computer-based training is the ability to get the training done quickly, and many times employees will take this to heart, clicking through as quickly as the software allows and not retaining anything.

Better Training Methods

Online Interactive Training

Two forms of hybrid training discussed here allow students to remain engaged and learning at the forward edge of technology. The first type of hybrid training that has received praise and resulted in decent success for retention and interactivity is computer-based training that remotely adds the live instructor element. Many forms of degree programs are held online using a collaborative environment software that allows PowerPoint, chat windows, interactive questioning over live microphones, and simulated environments where students can practice with oversight. As the technology provides better templates, instructors will stand up interactive classes with ease, speaking directly to the subject at hand. Environments that are direct representations of the training content compartmentalize for each student allowing building, exploring, troubleshooting, and true hands-on training with expert oversight from a live instructor monitoring from his or her station. The slight drawback is the online communication wedge created between student and teacher. One-on-one assistance can be difficult in these situations and sometimes prevented by the design of the software. The next solution addresses this and sets the computer and online environment as a tool in the training interaction.

Hybrid Cloud Training

The second and most effective type of hybrid training brings the instructor back into the physical classroom with the added benefit of computer-based training. For this method of training, there is an expert instructor that stands up an environment existing on the cloud, allowing students to all access the same content for training, while having the in-person direct assistance and one-on-one availability. As new technology releases, new training material follows in stride. In addition, training can be opened up beyond the unclassified level provided the proper security procedures are in place, removing most, if not all barriers to training our workforce. There is a large demand signal for this type of training as evident in a recent deep learning course offered at Naval Information Warfare Center Pacific, which filled within 30 minutes. In fact, by the time "the class is full" announcement went out roughly an hour later, an additional 40 potential students found they would need to wait for the next class. This method also strengthens the workforce through communication and networking. These types of training encourage cross-functional team problem solving,

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The tradition of Department of Defense briefing presentations—the proverbial "death by Powerpoint"—has long been acknowledged as a poor method of conveying meaningful information.

in-person, where employees can witness each other's strengths first-hand and even result in new ideas. When coupled with the value of rapid standup, this training has a return on investment not met through traditional methods.

Hybrid Training is the Future

The hybrid cloud, in-person training method requires adoption and as it becomes more available and common, an increase in interest and engagement in development of new skill sets will follow. To help our workforce be the drivers of digital transformation, preparation to field questions on training with content that may not be easily searchable or accessible is paramount. More scientists that engage in training on complex technology will find success at determining the best solutions and pathways for development. Roadblocks to success occur without personnel who understand and know how to operate new technology. By making the training more accessible, as well as more "fun," many more will find interest and gravitate toward it rather than begrudgingly train because they receive instructions to do so.

Employees in the community find value in understanding alternate technologies in something than their own focus area, which tends to lead to innovation and creativity. Managers and leadership can find humility with a hands-on understanding of difficulties that come with their employee's technology and facilitate better decision making and planning. To reach the command goals of moving into a fast-paced, digitally focused training architecture that strives to build tools keeping our warfighters eons ahead of adversaries, adoption of leading edge methods will make training more palatable, enjoyable, and critical to winning the fight and dominating the physical and cybersecurity realms.

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NEW eBOOK TECHNOLOGY CAN TEACH KIDS ABOUT ARTIFICIAL INTELLIGENCE

By Dr. Karen Cooper

A NEW TYPE OF INTERACTIVE eBOOK BEING DEVELOPED BY THE NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION IS PROMISING AN ENHANCED EDUCATIONAL EXPERIENCE.

The Navy has long recognized the need to cultivate science, technology, engineering, and math (STEM) programs to grow the defense technical base. The Naval Air Warfare Center Aircraft Division (NAWCAD) has established an office dedicated to that goal: the Strategic Education Office (SEO). The SEO supports STEM programs both inside and outside of the center, from workforce-focused, graduate-level engineering down to K-12 programs and community outreach.

The K-12 and outreach efforts target school-aged children to introduce them to STEM technical competencies important to the Navy's mission. One example is a new project, funded through a grant from the Office of Naval Research, to design a "smart" eBook on artificial intelligence (AI) for middle- and high-school students. AI is a complex topic of increasing importance to the Navy's future. Most school-aged learners have probably heard of AI, but many may not be entirely sure what it is or how it works. The project's goal is to introduce the topic in an engaging way, allowing students to grasp the basics of AI and stimulating their desire to learn more.

The SEO is leveraging a separate Department of Defense research effort to develop the eBook. The Advanced Distributed Learning (ADL) initiative, under the Office of Secretary of Defense, has spearheaded a project called "Personalized eBook for Learning" (PeBL, https://peblproject.org) to expand the functionality of eBooks with new interactive features and data-tracking of learner interactions. The SEO has partnered with Eduworks, the creators of the PeBL specification and authoring tools, to help the Navy integrate this new technology to power the AI Primer.

About PeBL

With PeBL, the ADL initiative is developing the next generation of eBooks, enabling personalized and collaborative learning experiences. A PeBL eBook has two fundamental differences from a traditional eBook: it is interactive and adaptive, allowing instructors to create tailored experiences for different learners; it also can track and log learner interactions, which can be aggregated and analyzed to provide indications of individual and class progress.

PeBL's functionality is enabled by EPUB3, the latest electronic publication standard adopted by the International Digital Publishing Form. EPUB3 adds support for HTML5 and JavaScript, which allow the incorporation of video, audio, and interactivity into eBooks. The PeBL project expands on EPUB3, specifically with the addition of extensions, which are portable pieces of JavaScript, HTML5, and Cascading Style Sheets that can incorporate video, audio, and other interactive design elements into eBooks. Many extensions can be embedded, including knowledge checks, customized content, shared notes, discussion areas, interactive "ask an expert" features, content morphing, and polling. These features enhance engagement with the eBook material while expanding the pedagogical opportunities for educators and subject-matter experts who design the content.

Current eBook capabilities are little more than print shown in an e-reader. Basic eBooks lack the ability to interwork with or control other components of a learning experience. In addition, they provide limited adaptivity, content brokering, and personalization opportunities. As a mobile connected platform, eBooks have the unrealized potential to support more pedagogical approaches than traditional books, including experiential, problem-based, dynamic, and social learning.

PeBL eBooks are instrumented with xAPI (the Experience Application Programming Interface), which is a technical specification for encoding and transmitting data about learner interactions—in this case, with the eBooks. As learners progress through an eBook, xAPI data records are captured and sent to a learner record store. This store can contain thousands of records on an individual over time, from low-level interactions, such as eBook page turns, to high-level outcomes, such as course completions. These data can be aggregated, analyzed, and turned into visualizations to create meaningful insights about a learner's activity so both teachers and learners can improve their educational experiences.

PeBL technology is consistent with the ADL initiative's designs for the Total Learning Architecture (TLA), a uniform approach for integrating current and emerging learning technologies into an interoperable Department of Defense learning services ecosystem. The TLA includes a digital learning data strategy, data and software interoperability standards, specifications for microservices, specifications for technology architecture implementations, and recommendations for business rules and governance. As the TLA concept proceeds toward department-wide implementation, PeBL is included among the prototype

Photo by Karen Cooper and Judy Katz

capabilities being tested in the ADL initiative's latest TLA "reference implementation" (basically, an exemplar prototype, similar to a model home in a real estate analogy).

Access to PeBL's technologies and prototype eBooks will be available to defense users through a Learning Technology Warehouse (LTW, https://apps.usalearning.net/), another project of the ADL initiative. The LTW will offer PeBL and other TLA resources in a software-as-a-service offering or for full transition into an existing technical enclave. For PeBL, the LTW provides a route for hardening its technologies from a cybersecurity perspective and proving scalability to larger enterprise systems. This includes the development of server-based components such as individual/shared libraries (bookshelves) and an enterprise bookstore where learners and instructors can find and access different eBooks.

Within the LTW, the PeBL package will contain a complete set of all software and documentation needed to install, configure, and create eBooks. The package will include a full set of source code for both the server and client as well as an authoring tool suite. The documentation includes an installation guide, getting-started and user guides, architectural and other technical documentation, authoring guides, and xAPI implementation information. When complete, PeBL will be a fully downloadable eBook application freely available to all government users.

The PeBL project also has produced an authoring tool: a plugin that works with Adobe's InDesign platform. Creating PeBL eBooks can now be done by instructors, instructional systems designers, and other content experts rather than just software developers. Using InDesign with the plugin, designers can import or create content, drag and drop the extensions into the content, and export custom PeBL eBooks.

In January 2018, a PeBL evaluation exercise tested the feasibility and stability of the platform. Held at Quantico, Virginia, participants included instructional designers, instructors, and other stakeholders with a vested interest in PeBL. Multiple Marine Corps commands received iPads and user accounts to experiment with PeBL independently and with each other. The experience provided valuable feedback, and this promoted the development of PeBL authoring tools.

In November 2019, researchers at Fort Sill, Oklahoma, conducted a usability study to gather empirical evidence on the utility and engagement of the PeBL content versus static eBook content. The results of the test showed higher levels of engagement and greater overall learning outcomes for the PeBL users.

The AI Primer

Creating the PeBL AI Primer eBook is a 12-month effort. The eBook prototype is expected to be complete sometime between late 2020 and early 2021 with subsequent rollout for an initial classroom test and student feedback. Following a successful test of the pilot, NAWCAD may be able to extend the opportunity to additional schools in the southern Maryland area.

The AI Primer will be available for iPads, tablets, and browsers. Currently, NAWCAD has purchased 31 iPads, suitable for 30 students and one instructor. The AI Primer will be designed to have separate interfaces for students and the instructor.

Beyond these first 12 months, the Office of Naval Research grant has options for multiple extensions, including plans for additional eBooks, as well as creating a learner record store and tools to render data visualizations of the eBook interaction data. These visualizations will be designed to measure pedagogically relevant factors, such as student engagement, class progress, and overall course effectiveness.

Education in the Future

Technologies are advancing at an ever-increasing rate. It is imperative that we make better use of learning technology to teach about advanced technologies. Applying new capabilities and techniques to education, especially for early grade levels, can help the Navy—as well as the government more broadly—to maintain a skilled workforce.

PeBL, as part of the TLA, has previously been empirically tested to show evidence of improved engagement, learning, and retention. This AI Primer project is a step toward applying contemporary learning technology and associated learning analytics into middle- and high-school classrooms. This should help build a pipeline of inspired students, ready to use innovative educational tools as they progress toward higher-level studies and STEM careers.

About the author:

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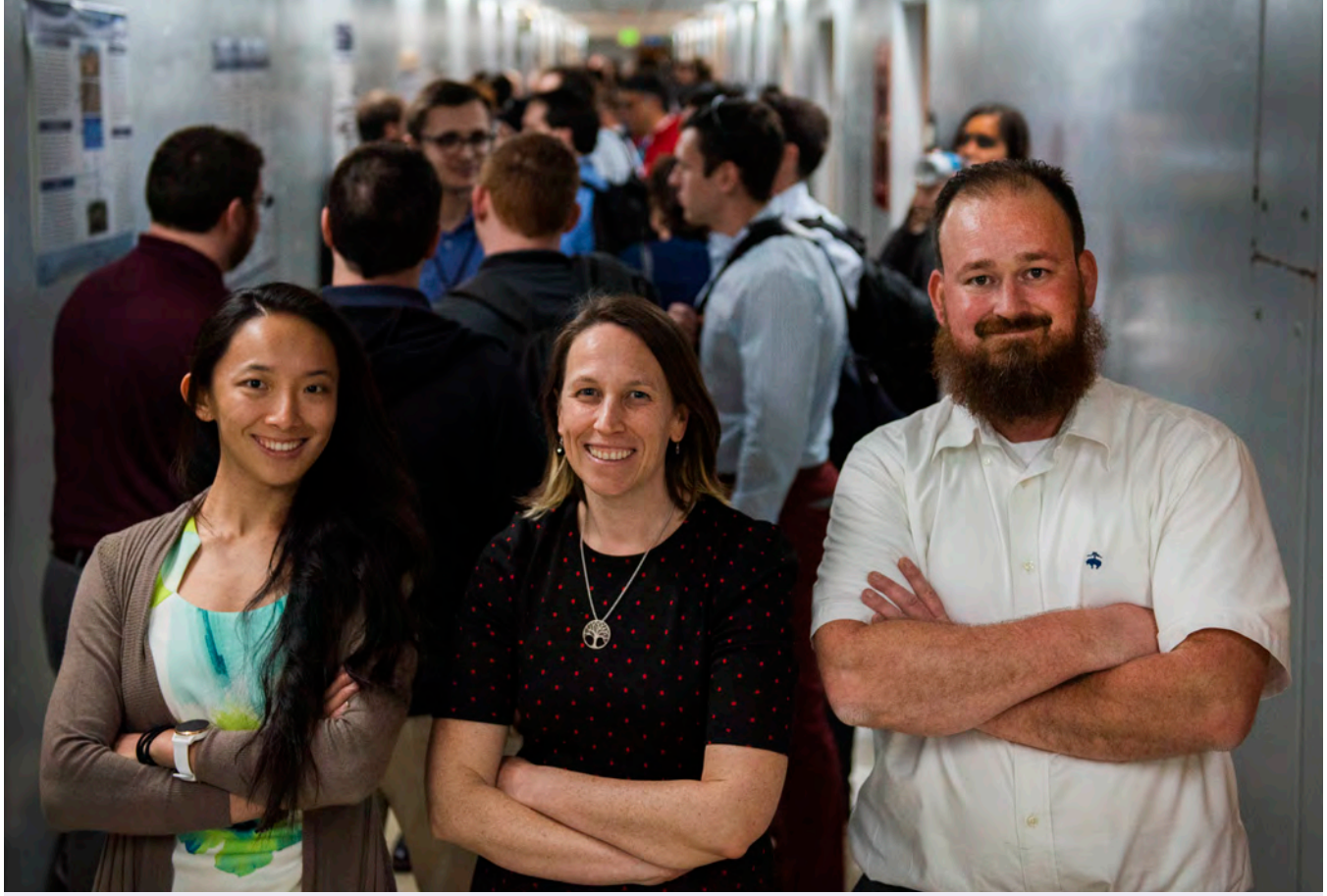
Photo by MCC Charlie White



Left to right: workshop co-chairs Nicole Isoda and Katie Rainey, and poster session chair Gary Williams.

WORKSHOP FOSTERS COLLABORATION ON MACHINE LEARNING

By Nicole Isoda and Dr. Katie Rainey

THE FOURTH NAVAL APPLICATIONS OF MACHINE LEARNING WORKSHOP HELD EARLIER THIS YEAR AT NAVAL INFORMATION WARFARE CENTER PACIFIC BROUGHT TOGETHER DEPARTMENT OF DEFENSE RESEARCHERS TO BUILD PARTNERSHIPS AROUND AN INCREASINGLY IMPORTANT TECHNOLOGY AREA.

There is growing excitement about the possibilities offered to the defense sector by advances in artificial intelligence. The Naval Information Warfare Center (NIWC) Pacific hosted the fourth annual workshop on Naval Applications of Machine Learning (NAML) to highlight efforts to bring machine learning approaches to bear on these possibilities. The workshop was held on 24-27 February 2020 in San Diego, California.

It is crucial for the Navy to be engaged in machine learning research to ensure that the sea services' unique challenges and applications are addressed. In contrast to most commercial applications, the applications to which the Navy hopes to apply artificial intelligence solutions might involve nontraditional data types, need to operate in a disconnected communications environment, and expect to interact with humans in a highly stressful and safety critical

setting. It is important for the Navy to be able to develop its own solutions, as it cannot expect to buy solutions to some problems off the shelf. The Navy recognizes the need to develop its community of scientists and engineers in this technology area, in partnership with industry and academia.

Goals of the Workshop

One of the workshop's goal was to provide training opportunities to Navy researchers. Department of Defense (DoD) researchers often have experience working in specific domain areas and with particular types of data. Many of these researchers, however, have not worked with machine learning. Machine learning promises to enable advances in these different domains. This year, lunch-and-learn sessions and tutorials on neural networks and other topics gave researchers the opportunity to learn about machine learning techniques, how to implement them, and their current uses in industry.

Another goal was to promote collaborations between government, industry, and academic researchers around technical topics crucial to Navy needs. DoD research often happens in stovepipes, without awareness of who else is doing related work, even at the same organization. The NAML workshop aimed to present a cross-section of machine learning research being done at Navy and other DoD laboratories and across various application areas in an effort to inspire discussions and collaborations between the attendees. Discussion sessions and poster sessions provided unstructured time for people to talk about their work and ideas. Many attendees were not researchers, but represented operational military organizations or companies. They were able to share with researchers their perspectives on application areas.

The final goal of NAML was to discuss challenges on both the technical and the operational sides of naval applications. Many active-duty service members attended the workshop both to learn about future technology in development and to contribute their perspective as potential users of the technology. The workshop also highlighted some of the challenges that are unique to military applications and data. This awareness will help researchers who may be familiar with machine learning but not with certain application areas to address research gaps towards these applications.

The Navy has many big challenges, and machine learning has the potential to help meet some of them and realize significant savings in terms of money and lives. A single person will not meet these challenges alone, however. The NAML workshop brought together a broad audience of researchers, end users, and other stakeholders for military applications of machine learning to discuss relevant technology challenges.

Workshop Overview

The first and second days of the four-day workshop featured keynote talks as well as short technical talks. Poster sessions were held on these days as well. Most talks and posters discussed current research projects in support of the Navy or other defense organizations.

The third and fourth days of the workshop consisted of restricted and closed sessions to discuss topics that could not be opened to the full audience. There was also a poster session on the third day for those who could attend the restricted talks.

Short tutorials were held during lunch on the first, second, and third days of the workshop, and a dedicated tutorial session was held on the fourth day. These tutorials were provided primarily by industry representatives to demonstrate capabilities and special application areas of machine learning across different domains.

Throughout the workshop, some attendees met in smaller groups to hold discussions for ongoing or potential areas of research. Many of these groups were started at previous NAML events and continue to meet at NAML each year to further their collaborative efforts.

Over half of the workshop's 500 attendees represented Navy or other DoD research and development laboratories. Other participants came from other military and government organizations (including representatives from outside the United States), federally funded research and development centers (such as national labs), academic institutions, and commercial companies. In total, the workshop included 84 talks, 97 posters, and 7 tutorial sessions.

The agenda was built with the assistance of a team from NIWC Pacific and other DoD organizations who reviewed abstracts, selected presentation topics, and chaired speaker sessions. The general chairs of the workshop were Katie Rainey and Nicole Isoda, both from NIWC Pacific, and the poster session was chaired and organized by Gary Williams, also from NIWC Pacific.

Keynote Talks

Several keynote talks were given by current and former members of the DoD community. Brett Vaughan, Navy chief artificial intelligence officer and artificial intelligence portfolio

manager at the Office of Naval Research, delivered the first keynote. Col. Randy Pugh, senior Marine representative and associate dean of research at the Naval Postgraduate School, gave another keynote. A third keynote speaker from the DoD was Harry Dreany from the Marine Corps Warfighting Laboratory. Retired Navy Rear Adm. Brian Losey, now a general partner at Shield AI, delivered a keynote on the use of artificial intelligence for maneuverability.

Two additional talks covered yet more diverse topics. Dr. Gert Cauwenberghs, a professor at University of California, San Diego, was the opening keynote for a special session on neuromorphic computing. Dr. Carey Priebe, professor at Johns Hopkins University, discussed machine learning theory and methods from a statistical perspective.

Technical Presentations

This year, the short technical talks presented throughout the week were very diverse in topics and application areas. In addition to the well-studied topic areas of autonomy and computer vision, there were also several talks on neuromorphic computing and tracking.

As the Navy continues moving towards the use of systems of autonomous agents, it is important to understand how those agents could work together to accomplish an objective. David Hattori-Messing of Leidos presented "Contextual Dependencies for Autonomous Role-switching Strategies" to discuss the inspiration of beehive roles, responsibilities, and behavior when facing dynamic contexts.

Computer vision is an extremely active area of research, but unlike many commercial applications, Navy applications of computer vision often deal with scarce datasets. Daniel Hogan of In-Q-Tel CosmiQ Works summarized a case study on the effects of data quantity in his talk "How Much Data Does Geospatial Deep Learning Need?: A Case Study."[1]

Neuromorphic computing is an emerging topic throughout the machine learning community. Catherine Schuman of Oak Ridge National Laboratory presented several case studies for an improvement to applications of spiking neural networks3 in her talk "Evolutionary Optimization for Neuromorphic Systems."[2]

The topic of target tracking is of great interest and importance to the Navy as well as the greater defense community. Maximilian Rodger of the Surrey Space Centre at the University of Surrey presented "Classification-Aided Data Association of Synthetic Aperture Radar (SAR) and Automatic Identification System (AIS) Datasets for Space-based Maritime Surveillance," an extension of his prior work with these datasets.[3]

Impact and Future Plans

Machine learning is especially applicable to information warfare, the center of NIWC Pacific's mission. The machine learning community at NIWC Pacific began hosting the NAML workshop four years ago to improve collaboration between different parts of the community, to increase awareness of the technology, and to close the gap between challenges and solutions.

Since its inception, the NAML workshop has provided a unique networking experience for Navy researchers and experts working in different aspects of the Navy mission. Each year, attendees are exposed to new technologies, familiar techniques applied in novel ways, and challenges yet to be overcome shared by colleagues tackling different naval problems. The workshop also heightens the profile of the work being conducted at the warfare center, and increases awareness of how other subject matter experts across the field are working on related challenges. Given the increased investments the DoD is making in artificial intelligence, it is imperative that its scientists and engineers come together to discuss their work and how to reach its future goals. The NAML workshop fosters collaboration and helps researchers see how their technology can be used in domains outside their expertise and how it applies to a broad range of Navy applications they may not have considered.

The next NAML workshop is anticipated to be hosted virtually in spring 2021 because of the impacts of COVID-19.

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Photo by Ahn Nuzen

(From left to right) Kathleen Miranda (NIWC Pacific), Theresa Garcia (San Diego State University), Yolanda Tanner (NIWC Pacific), and Capt. Mel Yokoyama (NIWC Pacific).

BUILDING STEM SUCCESS THROUGH EDUCATIONAL PARTNERSHIPS

By Yolanda Tanner

AN EDUCATIONAL PARTNERSHIP BETWEEN NAVAL INFORMATION WARFARE CENTER PACIFIC AND SAN DIEGO STATE UNIVERSITY HAS BEEN A PRODUCTIVE EFFORT FOR BOTH INSTITUTIONS IN PROMOTING SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS EDUCATION.

Prior to 2014, science, technology, engineering, and math (STEM) outreach efforts at the Naval Information Warfare Center (NIWC) Pacific included a range of K-12 activities and summer internship and fellowship, such as the Naval Research Enterprise Internship Program, the Science and Engineering Apprenticeship Program, the Historically Black Colleges/Minority Institute Program, and the Summer Faculty Research programs.

In 2014, the center established a postsecondary outreach program to aid in STEM retention through partnerships. The rationale was simple: if more undergraduate students (especially from under-represented communities) remain in a STEM major, it potentially increases the population of degreed undergraduates available to develop a diverse, technologically advanced naval science and engineering workforce.

With a specific goal, NIWC Pacific's postsecondary STEM outreach found its place and purpose. In 2015, the program facilitated the formal signing of an educational partnership agreement between NIWC Pacific and San Diego State University, a renowned Hispanic-serving Institute.

Educational partnership agreements commonly address broad topics such as faculty collaborations, resource sharing, and exposing students to opportunities. When an agreement approaches its termination date, a question usually surfaces: what did it accomplish? This article is a retrospective snapshot of how research informed practice and transformed outreach strategies. It views the five-year agreement from a STEM outreach perspective of various challenges and leverages the Triple Helix model of government, academia, and industry.

National Challenges

The STEM pipeline serves as a framework representing the progression of students that traverse precollege and higher education systems before entering the STEM workforce.[1] In addition, based on the attrition of those within the STEM pipeline, many observers portray it as "leaky" and typically reference characteristics such as race, ethnicity, gender, and major as factors.[2] For example, women, African Americans, and Hispanics who declare STEM majors as undergraduates are less likely to remain in those majors.[3] A relationship may exist between the underrepresentation of women, African Americans, and Hispanics within the STEM workforce where the majority of STEM workers are degreed in science or engineering.[4]

When viewing STEM inequities in relation to national and workforce percentages, historically underrepresented populations lack proportional representation in the STEM workforce when compared to the overall population.[5] In line with population-to-workforce comparisons, existing studies indicate underrepresented minorities account for approximately 30 percent of the US population and 13 percent of the science and engineering workforce.[6]

Nationally, STEM extends from educational systems into the workforce. Losses of undergraduate, graduate, or doctoral students before degree attainment can negatively impact sectors who employ STEM degree holders. Sectors often include the federal government, for-profit businesses, nonprofit organizations, state or local governments, and precollege to four-year educational institutions.[7]

Department of Defense Challenges

When comparing gender and ethnicity among those who are female, African American, and Hispanic, the Department of Defense (DoD) sector of the federal government lags behind the overall STEM workforce sectors in all three categories.[8] In efforts to create a degreed, diverse STEM workforce, defense laboratories face three unique challenges. First, National Security Council policies require adherence regarding US citizenship.[9] Because of this constraint, defense laboratories are unable to capitalize on gross increases of STEM degree recipients across the university system.

Second, developing a degreed diverse STEM workforce is dependent on the STEM higher education pipeline. Census data indicate that among undergraduate STEM degree recipients, 43 percent were nonforeign-born. Of this group, 83 percent were Caucasian. For every 100 degreed undergraduate STEM students, approximately seven percent are nonforeign-born women and minorities.[10] Third, the defense laboratory workforce is aging. Half of the naval civilian workforce is retirement eligible in the year 2020, thus increasing the imperative to create a diversify the science and engineering workforce while simultaneously replacing it.[11]

The combination of stringent citizenship requirements, a STEM undergraduate degreed pool where the majority of candidates are potentially ineligible, a significantly homogeneous undergraduate pool, and a wave of retiring employees creates considerable problems for defense laboratories in the development of a diverse, degreed STEM workforce. Emphasis on retention, persistence, and degree attainment of historically underrepresented undergraduates in STEM builds a broader talent pool, which simultaneously can increase diversity in the defense workforce.[12]

Higher Education Challenges

When considering STEM in higher education, one can view retention and persistence in the context of undergraduate STEM entrants who either left higher education before attaining a degree or certificate, or those who remained in college but switched to a non-STEM major. At the undergraduate level, approximately 28 percent of the student population entered a STEM major. Within six years, however, 48 percent of undergraduates either exited the major or college entirely before STEM degree attainment. Overall, 65 percent of African Americans and 50 percent of Hispanics leave STEM majors. In comparison with Caucasian and Asian STEM undergraduates, 48 and 32 percent, respectively, exit STEM majors.[13] Collectively, underrepresented populations leave STEM majors at a higher rate than their Asian and Caucasian peers.[14] When taking into account collegiate students who exit or leave the major, STEM and workforce capacity can potentially increase through the retention of disadvantaged and underserved populations already existing in the STEM pipeline.

Research-Informed Decisions Challenges

Establishing and developing a diverse STEM education outreach-to-workforce program is challenging as each organization must consider its priorities across the STEM outreach landscape. Research at the national, DoD, higher education, and local workforce levels were used to inform the decision and target areas of emphasis within the postsecondary outreach program. We understood that the STEM solution needed to extend beyond the notion that increased volume in the primary years of education would adequately compensate for STEM pipeline leakages. In focusing on underserved undergraduate STEM degree conferral, three benefactors included government,

industry, and academia. A synergistic partnership approach would provide for entities to work on efforts that support mutually beneficial interests. NIWC Pacific and San Diego State agreed that joint efforts would include: partner collaborations, strategies, and research-based practices to facilitate STEM degree attainment in efforts to deepen the science and technology talent pool needed to develop a diverse STEM workforce.

Technology Transfer and the Triple Helix Model

Since its inception in 1950, the National Science Foundation has been promoting the progression of science and engineering on behalf of national interests related to the economy, leadership, and national security. In addition, the foundation and DoD continues to fund and partner with research universities and other external entities toward the creation of knowledge or products. In 1980, the federal government enacted the Bayh-Dole Act providing a uniform policy across government agencies to address ownership and licensing, which contended that providing a blanket permissions mechanism—now known as technology transfer—for individuals who conducted federally funded research to apply for patents would accelerate commercialization.[15]

At NIWC Pacific, technology transfer promotes innovation and creativity and serves as an essential pathway to move Navy innovation from lab to market and, ultimately, to warfighters.

The concept of technology transfer has a basis in the "Triple Helix" model, which comprises three entities, academia, government, and industry. Each member is an independent and autonomous helix with the ability to intertwine with one another for common and mutually beneficial purposes. In theory, the goal is to bring together universities, industry, and government with the objective of technology transfer and transition. Whether technology transfer, technology transition, or innovation, the Triple Helix is an action-oriented model, as independent entities not only establish partnerships to accomplish specific objectives but indicate how or what each organization will contribute to achieve particular objectives.[16]

A Model for STEM Outreach

The Triple Helix proved beneficial in STEM outreach efforts between NIWC Pacific and San Diego State since the model was familiar to and used to some extent by the two partners. In line with technology transfer, STEM outreach requires innovative approaches. Within the construct of the Triple Helix, both technology transfer and STEM outreach require that organizational members work throughout various levels of the organization in capacities that are both hierarchical and functional.[17] In addition, the Triple Helix requires that partners form horizontal relationships and hybrid structures for both long- and short-term ventures.[18] NIWC Pacific postsecondary outreach incorporated the Triple Helix model in dealing with the center's government, academia, and industry partners. Through consensus, partners identified the overlapping objective of increasing STEM access to students underrepresented in STEM career fields. The overlapping intersection provides context, a specific area of focus with a targeted intention, and an opportunity for partners to identify and leverage individual and collective resources and capabilities to accomplish particular tasks and objectives.

In adopting this type of model for postsecondary STEM outreach, organizational operators must be representatives inside and outside the organization whose roles explicitly incorporate the objectives and whose responsibilities include the implementing efforts based on action. While a form of the Triple Helix model may exist in the technology transfer office, the same organizational points of contact can prove insufficient as members in the partner organizations may not have the dual role of knowledge or products in addition to undergraduate retention.

In using the Triple Helix model for STEM postsecondary outreach, we concluded that partner organizations needed to provide representatives with the ability, authority, and programmatic responsibility of developing and implementing STEM programs or initiatives on behalf of their organization.

Five Years Later

Recently, the first educational partnership agreement between NIWC Pacific and San Diego State expired. During the five years of the agreement, we have positively affected thousands of students underrepresented in STEM careers (veterans, military-affiliated, women, and minorities) and conducted 44 outreach events in conjunction with the university and affiliated partners. Efforts have included:

- Competitive grant award San Diego State University Advancing Navy STEM Workforce through Educational and Research (ANSWER) for $750,000 by the Office of Naval Research Naval STEM Education to Workforce
- Increasing STEM awareness of naval careers through

internships, lab tours, discussion panels, and leadership conferences

- University feedback that increased the number of students applying to our internship, workforce, and technical services programs
- STEM volunteers aiding in STEM identity development
- Hands-on workshop and soft skills development to hone contemporary workplace skills
- Precollege STEM awareness expansion through collective efforts with Math Engineering Science Achievement (MESA)
- MESA alliance partners, San Diego City College and Southwestern College, contributed to the initiation of the STEM Student Employment Program at the former with future expansion at the latter
- 105 interns and fellows have conducted summer research with our scientists and engineers
- 100-percent increase in summer faculty research.

STEM university research targeted toward entering undergraduates in conjunction with research laboratories or industry and higher education partnerships can potentially aid in student collegiate retention, closing the transition gap between degree matriculation and employment, and diminishing the gap between teaching and practice.[19] For NIWC Pacific postsecondary STEM outreach program, with the incorporation of research, an educational partnership agreement, and the Triple Helix model, we were able to engage partners mutually interested in underserved undergraduate retention and the development of a diverse science and engineering workforce.

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Photo by Ryan Hanyok

STEM PROGRAM SAILS ABOVE AND BELOW THE WATER AT CARDEROCK

By Charlotte George, Haley Kirby, and Lydia Weyrich

WITH BIG EVENTS SUCH AS THE INTERNATIONAL SUBMARINE RACE AND LOTS OF OTHER OPPORTUNITIES FOR PROSPECTIVE ENGINEERS AND SCIENTISTS, THE NAVAL SURFACE WARFARE CENTER CARDEROCK DIVISION IS A LEADER IN THE NAVY'S STEM OUTREACH.

The Navy supports a broad range of educational outreach programs through partnerships and collaboration with schools and agencies, as well as internship opportunities and professional development training to encourage students and teachers of all ages to gain awareness in the science, technology, engineering, and mathematics (STEM) career fields.

The Department of the Navy's STEM programs are deliberate investments in the current and future workforce, which enhance the Navy and Marine Corps' ability to meet present and future warfighting challenges.

Naval Surface Warfare Center (NSWC) Carderock Division's STEM and outreach programs align with the needs of local students and educators with the aim to inspire and engage, and eventually to employ. Located in West Bethesda, Maryland, NSWC Carderock Division sees students and educators from Maryland, Virginia, and the DC area. In some cases, however, students come from around the world.

The International Submarine Race

STEM programs at NSWC Carderock Division focus on connecting disciplines and emphasizing 21st-century skills—such as creatively solving problems and collaborating with others on a team.

NSWC Carderock Division is host to the International Human-Powered Submarine Races (ISR). Teams representing schools from across North and South America, Europe, and the Middle East build human-powered submarines. The week-long contest, held in NSWC Carderock Division's 3,200-foot David Taylor Model Basin and sponsored by the Foundation for Underwater Research and Education, inspires and encourages students to explore different STEM disciplines.

All the way from Montclair, New Jersey, Tyler Nedzi found herself spending the summer not only as a Naval Research Enterprise Internship Program (NREIP) intern at Carderock, but also the University of Michigan ISR team captain for the 15th ISR in June 2019.

When Nedzi toured the University of Michigan before beginning her freshman year, she had no idea it would have such an impact on her future. During her visit, the tour guide took Nedzi through the building that housed the project teams, which featured the University of Michigan human-powered submarine project. As an avid scuba diver, seeing a project with such a large diving aspect intrigued Nedzi.

"I saw that it was a scuba-diving project, and I was like 'Oh, that's really cool,' but then I even found my major through this project—naval architecture—I didn't know it existed," Nedzi said.

From then on, Nedzi knew what she wanted her major to be, and what she wanted to spend the next four years of her life pursuing. Nedzi joined the team her freshman year and has participated every year since.

Under the mentorship of Rachel Jacobs, a chemical engineer in Carderock's wastewater management branch, Nedzi spent two summers as an NREIP intern at Carderock while simultaneously being involved in the ISR.

During her internships at Carderock, Nedzi said she has bettered her engineering skills, and also enhanced her leadership skills through the guidance of Jacobs. Nedzi said she intends to pursue a graduate degree before then applying to work at Carderock.

For Carderock, one of the goals at ISR (held in June every other year) is to recruit students for STEM jobs. The STEM and outreach program director for Carderock, Charlotte George, was a contestant when she attended Florida Atlantic University.

"ISR was a life-changing experience for me that exposed me to other Department of Defense opportunities," George said. "This event gives us a large pool of potential employees, and we hope to snag some of them. It's our 'gateway' event."

Giving Students a Taste of Engineer Life

Students visit NSWC Carderock Division to participate in interactive tours of the Navy's premier laboratory for ships and submarines. Some partnering schools that implement naval STEM projects in their classrooms will participate in competitions when they visit. One of Carderock's hands-on, project-based engineering programs, SeaPerch, allows students to build their own remotely operated underwater vehicles.

NSWC Carderock Division provides SeaPerch construction training sessions with classroom teachers who then work with the students in the classroom, either during the school day or as part of special after-school engineering clubs.

During the construction of their SeaPerch, students learn to use a variety of tools and equipment, including PVC pipe cutters, wire strippers, soldering irons, and multimeters. The scientists and engineers assist the students through all stages of construction, helping them wire and waterproof their motors, teaching them how to wire the switches and power cables in their control box, and assisting them as they troubleshoot their SeaPerch.

A culminating field trip to NSWC Carderock Division or to a public pool gives the students the opportunity to test their SeaPerches. During a SeaPerch "competition," the students maneuver their remotely operated vehicles through obstacle courses and recover objects from the bottom of the pool.

NSWC Carderock Division hosts many SeaPerch events throughout the academic school year and, in turn, is able to give young students a brief but meaningful exposure to the life of an engineer.

The First Department of Defense Einstein Fellow

NSWC Carderock Division's STEM and outreach program sought out the expertise of a teacher to create naval STEM content (geared at K-12) that connects multiple disciplines, emphasizes 21st-century skills, and promotes naval research and technology.

"We wanted to look at our programs through the lens of an educator and learn the realities of implementing STEM in the classroom," said George.

The US Department of Energy Office of Science's Office of Workforce Development for Teachers and Scientists manages the Albert Einstein Fellowship program, now in its 29th year of operation. It provides a unique opportunity for accomplished K-12 STEM educators to apply their extensive classroom knowledge and experiences to their host offices to inform federal STEM education efforts.

In 2019, NSWC Carderock Division joined the list of sponsoring agencies for the fellowship program, which includes Oak Ridge Institute for Science and Education, the National Science Foundation, the Library of Congress, NASA, and several US congressional offices. NSWC Carderock Division selected the first Einstein Fellow for the Department of Defense, Deborah Reynolds, a STEM educator in the Pittsburgh school system.

Reynolds has more than 25 years of teaching experience as a STEM and gifted educator. She started her teaching career in 1986 upon receiving a B.S. in biology from Stephen F. Austin State University. She is passionate about providing students with STEM opportunities beyond the classroom and encourages students' participation in numerous STEM competitions, challenges, and other project-based learning opportunities. This passion led Reynolds to pursue an M.Ed. in curriculum and instruction with a STEM emphasis from Concordia University in

2015 and a School Principal Certification (K-12) from Point Park University in 2018. Most recently, she was announced as the Pennsylvania Association for Education Communications and Technology 2020 Outstanding Teacher of the Year.

For the past year, Reynolds has been working with the Carderock STEM team.

"Naval Sea Systems Command [NAVSEA] STEM has so many wonderful and relevant programs for students and educators to get engaged," said Reynolds. "As I have traveled around the country to different NAVSEA commands, I have had the opportunity to meet the wonderful NAVSEA STEM teams that are in place at each site. These enthusiastic coordinators are constantly developing unique efforts in order to engage their local community."

During her time with NSWC Carderock Division, Reynolds has provided valuable insights about the use of STEM programs in the classroom, such as how teachers find new activities, the struggles to implement them in the classroom (whether it's administrative or personal), and national education issues. In an effort to remove barriers to adoption, NSWC Carderock Division is aligning all of its activities to national standards. They also reviewed their materials to ensure they can be easily accessed and understood by a teacher.

"We are working together on a coordinated effort to develop a one-stop NAVSEA STEM tab where educators and students can access naval-relevant STEM content and learn more about getting involved through the many different pathways," said Reynolds.

Carderock's STEM and outreach program aims to strengthen the STEM workforce pipeline through outreach by inspiring student's interest in STEM through hands-on, accessible application of naval STEM fundamentals, provide practical experiences to engage students and teachers of all ages to "learn by doing," and educate the next generation with foundational skills and knowledge needed to pursue advanced STEM education and careers.

"We impact thousands of students across the nation every year in our efforts to inspire, educate and engage learners of all ages in naval-relevant STEM subjects," said George. "Working with the Albert Einstein Fellowship program has broadened our understanding of what it takes to teach STEM in the classroom. We are excited to roll-out new open-ended challenges that will promote students' ingenuity and creativity."

The new STEM content developed this year in collaboration with Reynolds is intended for use by any naval STEM coordinator. Next year, NSWC Carderock Division will host another Albert Einstein Fellow to build on the work that Reynolds started, to continue creating new STEM education programs and tools and initiate new partnerships with the academic community.

The Albert Einstein Fellowship program is growing within the Department of Defense, with the addition of two new sponsors. In addition to Carderock, the Manufacturing Technology Program Office and the Department of Defense STEM Office, both a part of the Office of the Undersecretary of Defense for Research and Engineering, have selected fellows for the 2020-2021 academic year.

The three incoming Einstein fellows come from K-12 schools across the country and represent diverse teaching backgrounds—with expertise in science, engineering, computer science, and mathematics. Federal agencies and Congressional offices will benefit from fellows' real-world experiences as educators. In return, Einstein fellows will gain understanding of the role of the federal government in the US education enterprise, knowledge of resources available to students and educators, and broader perspectives on national education issues that can be applied to the classroom or to leadership positions in their districts or elsewhere.

About the author:

Charlotte George is the STEM and outreach program director for Naval Surface Warfare Center Carderock Division.

Haley Kirby works in Naval Surface Warfare Center Carderock Division's STEM and outreach program.

Lydia Weyrich was a Naval Research Enterprise Internship Program intern during the summer of 2019 at Naval Surface Warfare Center Carderock Division and is a 2020 graduate of The Ohio State University.

Photo by James Travassos

UNIVERSITY PROGRAM YIELDS BIG WINS FOR THE NAVY

By Susan Farley

THE NAVAL ENGINEERING EDUCATION CONSORTIUM, A PROGRAM ESTABLISHED BY NAVAL SEA SYSTEMS COMMAND, BRINGS TOGETHER COLLEGE STUDENTS IN AN ARRAY OF FIELDS TO WORK ON PROJECTS AT THE NAVY'S WARFARE CENTERS.

Developing an innovative, knowledgeable technical workforce is a challenge for any organization; for the Navy, that challenge is intensified as global power competition requires it to be well ahead of the curve at all times. Cultivating a pipeline of highly motivated and technically creative engineers and scientists is of utmost importance to the Naval Sea Systems Command (NAVSEA). One challenge is that many of the technology areas specific to naval applications are not part of the traditional college curriculum. A collaboration between Navy commands and academia could be the solution, so NAVSEA established the Naval Engineering Education Consortium (NEEC) as a way to immerse college students into the technical fields associated with Navy ships and submarines.

NAVSEA implemented the NEEC program at the command's 10 warfare centers across the country with the goal to "increase and maintain a knowledge base for increasingly sophisticated technologies critical to the design and operation of complex, interrelated systems for the Naval and Defense acquisition communities."

In addition to funding the research performed at colleges and universities, NAVSEA provides Navy civilian mentors to work with the professors and students.

The students selected should be highly motivated US citizens who have an interest in pursuing full-time employment at the sponsoring Navy command when they graduate. For the Navy, the advantages include access to university laboratories, professors, and students. Navy challenges are researched, new technologies are explored, and the next generation of qualified, knowledgeable engineers and scientists have a clear path to employment.

Once the students are hired as full-time Navy civilians, they are able to hit the ground running, often working on similar projects they worked on as NEEC students. Their learning curve is reduced significantly, and they are well on their way to becoming the Navy's future technology leaders.

Phillip Caspers from Virginia Polytechnic Institute and State University (Virginia Tech) first heard about the NEEC program through his PhD advisor, Dr. Rolf Mueller and his Navy mentor, at the Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island.

"I became aware of the NEEC project toward the end of my dissertation," said Caspers. "At that time, my funding sources were drying up and I was looking to shape my dissertation topics to something that I could work on to finish my work. I heard about Dr. Mueller's project and that is what led me to NEEC. My project was to develop a robotic model where you have an in-air sonar system that is able to dynamically move its aperture and to study the information encoded by that process. The Navy lab particularly, as a student, really helped shape my work so, without the Navy lab, it's just an academic perspective."

After graduating, Caspers was hired at NUWC Newport's sonar and signal processing branch. His research at NUWC includes developing a bio-inspired broadband sonar that is based on his PhD work at Virginia Tech as well as transient detection methods using bio-acoustic sounds.

Caspers has maintained a relationship with the NEEC project that is still ongoing at Virginia Tech and has brought in additional students to assist with the research.

"NEEC is a great way to bring in quality people," said Caspers. "It is also great for the students who can get real-world experience and also, as a student it helped me to understand what the problems and interest were of the engineers and scientists at NUWC."

Carlos Javier is also a new employee at NUWC Newport. He attended the University of Rhode Island, earning his bachelor's, master's, and PhD in mechanical engineering, focusing on both computational solid mechanics with an emphasis on soft biological materials and experimental solid mechanics with a focus on composite materials. He learned about the NEEC program from his professor.

"My project was titled Dynamic Behavior of Composite Structures Subjected to Aggressive Marine Environments: An Experimental and Computational Investigation," said Javier. "It focused on subjecting composite materials to sea water and ultraviolet radiation and then subjecting the weathered materials to blast loads in air and underwater."

He was hired at NUWC full time in July 2019 and has been working in the area of shock and vibrations of structures.

"NEEC provided funding for my entire PhD. Without that, I would not have been able to achieve that step in my academic career," said Javier. "Through NEEC, I was able to learn how to be an independent researcher, as well as acquire the tools needed to be a successful engineer and analyst."

James Sowinski heard about the NEEC program through an email he received from the computer science department at Indiana University. He was accepted into the program and soon began working with the Naval Surface Warfare Center (NSWC) in Crane, Indiana. His project addressed verifying integrated circuits in an automated way. Sowinski investigated popular computer vision techniques and new deep learning techniques in order to detect if an integrated circuit is counterfeited or not.

"I had previously been a teaching assistant at [Indiana] and hadn't really worked on a problem that I felt had this importance to it," said Sowinski. "I think working with the Navy lab gave it a lot more weight."

Following his work in the NEEC program, Sowinski interned at NSWC Crane and was hired full time after he graduated. His current work at NSWC Crane are follow-on efforts to his NEEC project.

"The NEEC program is a great way to get Department of Defense problems out there to the universities," said Sowinski. "It was obviously very rewarding for me and I definitely enjoyed my time and the progress that I've made since."

Harry Phillipeaux attended Florida Atlantic University, where he earned both his bachelor's and master's in ocean engineering. He was approaching the end of his undergraduate degree and looking for graduate research opportunities. He got involved with NEEC through a mentor and was assigned a research project on magnetic anomaly detection and localization techniques, specifically for maritime and mine countermeasures-type missions.

"Initially, I was doing a lot of numerical modeling and simulation in the early stages of the project," said Phillipeaux. "One of the cooler things—I hadn't really worked with a lot of hardware before then—but I had ended up taking some of the algorithms that were developed during the initial effort, and integrating them onto unmanned underwater vehicles."

Philippeaux's NEEC mentor is his current branch head at the NSWC in Panama City, Florida, so the two had built a relationship during the year and a half that Philippeaux was part of the NEEC program. Philippeaux also completed a Naval Research Enterprise Internship Program (NREIP) internship at NSWC Panama City—an experience that is strongly encouraged by the NEEC program as an opportunity to spend the summer at a Navy lab. Philippeaux's current work directly correlates to some of his work on the NEEC project.

"My line of work is a little more early type of research, so it's things that haven't been tried before. It fits in very well with what I did in grad school because it's a problem that's been around for a while but that we still need a really good solution. I've been able to be sort of creative and implement a lot of the algorithms I used in grad school," said Philippeaux. "NEEC is a really good opportunity. It led to a lot of different things that I do now. It directly impacts your career because most likely what you do for NEEC research is what is what you're going to be geared towards when you start working."

Sally Sutherland, NEEC director for the warfare centers, says one benefit of the program is that when the NEEC students are hired at the centers, they generally know what they're working on as soon as they are hired.

"Part of why we do the NEEC program is to benefit the warfare center. It's great that we go out and talk to the universities and the students are engaged," said Sutherland. "These are the kind of people that we want to bring into the warfare centers—motivated, smart, talented students, doing good work for the Navy. What the students worked on at their university directly impacts the Navy and hopefully makes the naval systems better—sonar systems, cybersecurity, unmanned vehicles—these are all really important."

NEEC started 10 years ago at the University of Michigan as a collaboration with the NSWC in Carderock, Maryland, for ship design because they were having difficultly hiring naval architects. The goal of the Navy and the University of Michigan was developing naval architects for submarine design and ship design. The program was soon adopted by other warfare centers expanding into broader technology areas. The University of Michigan contract expired in 2015 and NAVSEA permanently took over the program.

For universities and colleges, the NEEC program solicits proposals through a Broad Agency Announcement that is posted annually (usually September) on the Grants.gov website. The announcement will identify technical naval topics of interest for which universities and colleges may submit proposals. The proposals are evaluated and grants are awarded one year with options for second and third years.

Sutherland's goal is to continue to get good students coming in and making a difference for the Navy.

"A big part of NEEC is to find students who really want to work for the Navy, maybe working on something a little bit bigger than themselves," said Sutherland. "If they can see some of the work and see how it's important and they can see how they're directly impacting the Navy, then hopefully we can attract those kinds of students and support them."

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Photo by James Travassos

SENIOR CAPSTONE PROJECTS ADDRESS NAVY NEEDS

By Susan Farley

A PROGRAM AT THE NAVAL UNDERSEA WARFARE CENTER IN NEWPORT, RHODE ISLAND, LETS LOCAL COLLEGE STUDENTS TAKE ADVANTAGE OF THE CENTER'S RESOURCES TO CONDUCT THEIR SENIOR SCIENCE AND ENGINEERING PROJECTS.

For college students, a senior capstone project is a way to synthesize what they have learned and highlights their accomplishments. As the Navy builds its workforce of scientists and engineers to develop solutions to its technical challenges, it looks to academia for emerging talent. Combining Navy needs with senior capstone projects is one way to capitalize on the collaboration between Navy laboratories and academia.

The Naval Undersea Warfare Center (NUWC) in Newport, Rhode Island, works with teams of college seniors from the University of Rhode Island and the University of Connecticut on their senior design and capstone projects, providing challenges and technical mentors with the goal of hiring students as full-time Navy civilian engineers. These capstone projects address real Navy needs, including launching unmanned vehicles, machine learning, 3D printing in a dynamic environment, and variable buoyancy capsules.

With the goal of recruitment, the Office of Naval Research (ONR) supports the capstone projects as part of their science, technology, engineering, and mathematics (STEM) initiative. NUWC mentors are able to collaborate with the universities through internal investment support.

Dr. James LeBlanc, chief scientist in the Platform and Payload Integration Department at NUWC Division Newport, coordinated the mentored senior design and capstone projects taking place at both universities. To highlight the work being accomplished, he hosts project review days for students to present their briefs, receive information on NUWC employment from a human resources representative, and tour the NUWC's unique lab spaces such as the launcher facility and the survivability test laboratory.

"With these senior design projects happening between the two universities, it seemed like a great opportunity to bring them all together to present their projects, to learn from each other and to see NUWC," LeBlanc said. "If any of these students are considering coming to work for NUWC, then they need to see it. It's also a great opportunity for us to hear from them and provide feedback on their projects, which have real applications to the Navy."

Michael Accorsi, senior associate dean for the University of Connecticut's School of Engineering and professor of civil and environmental engineering, led a contingent of students.

A team from the University of Rhode Island shares information on their project on a mechanical engineering design of an underwater-launched eye in the sky, during presentations at the Naval Undersea Warfare Center Division Newport. Photo by Rich Allen

"The program has brought the idea to the forefront of students' minds that NUWC is an option for their careers," Accorsi said. "It engages students early in their decision-making process and gives them good awareness of NUWC. The UConn/URI senior design day at NUWC was a tremendous success. The day started with presentations of the nine projects, which was the first time that the students were able to see the work of all the other teams. This was very intense as each of these projects directly addresses a current Navy need and the students were highly aware of the relevance and importance of their work. It was really beneficial to them to see the large NUWC research campus and all the unique testing facilities. This really opened their eyes to how exciting it is to work at NUWC as an engineer."

"These are good projects. It's not make-work," said Dr Vito Moreno, the University of Connecticut's director of the mechanical engineer senior design program. "We look for real engineering problems that they can solve, and it's a challenge for them because it's open-ended. They also learn about the customer-supplier relationship with NUWC being the customer."

With its proximity to NUWC Division Newport, the University of Rhode Island enjoys a collaborative relationship with the command and hosts a seminar series that features NUWC engineers and scientists as guest speakers. Dr. David Taggart, from the university's department of mechanical engineering, guides students with their capstone projects.

"The objectives of the URI/UCONN Navy STEM program are to create a community of students, faculty and local Navy stakeholders and to make our engineering students aware of Navy-related career opportunities," Taggart said. "Our program includes a variety of activities including weekly seminars, field trips and undergraduate research and design experiences. The senior design experience has proven to be a highly effective mechanism for engaging students in real-world engineering problems of interest to the Navy."

In 2018, NUWC project manager Dr. Peter Hardro sponsored a senior capstone project at Rhode Island for mechanical engineering students. As a result of that effort, NUWC Division Newport brought on one of the students as a full-time engineer. In 2019, Hardro sponsored two more capstone projects in collaboration with a local small business, PowerDocks LLC, which has a cooperative research and development agreement with NUWC Division Newport. Along with NUWC's education partnership agreement with the University of Rhode Island, these agreements enabled all three parties to work together.

The "Buoy Boys" conduct in-water testing of their technology at the Narragansett Bay Test Facility. Back Row: Peter Hardro, Logan Ewing, James Dambek, Anthony Baro, PowerDocks. Front Row: Joe Kearney, Ian Millspaugh. Photo by Rich Allen

At the time of the senior capstone project, Hardro was also director of the 2019 Advanced Naval Technology Exercise, an event designed to promote innovation and collaboration across government, industry, and academia. In 2019, Hardro invited one of his Rhode Island teams to perform in-water testing of PowerDocks' technology during the exercise. Two students from that team were then hired as full-time engineers at NUWC Newport.

"I thoroughly enjoyed all of the senior design and capstone project briefs and was absolutely impressed with the scope of the projects undertaken and significant progress that has been made in just two semesters," Hardro said. "As a mentor, I typically struggle with defining reasonable bounds to the problem to ensure it is manageable within the timeline of the class. I tend to ask for a lot with the expectation that we may need to cut back, but time after time the students rose to the challenge. This year, one of the teams was able to design and prototype a complete full-scale system. I am pleased to see that their initiative and effort has progressed to the point that we were able to include them as part of [the 2019 exercise]."

As a result of the connection through the Senior Capstone Project, PowerDocks continues to work with Rhode Island students on developing technology, most recently focusing on a buoy that harvests wave energy for power.

"Working here has given me exposure to a wide variety of work and I am always finding new opportunities to learn and grow," said Ian Millspaugh, a former Rhode Island student and current NUWC Division Newport engineer. "I have been able perform a wide variety of work including drafting, design, validation, experimentation, simulation, and analysis. I recently started on a project that involves coding and machine learning, which is completely new to me. I have also completed several classes through NUWC University that have helped give me a more diverse knowledge base. I think NUWC is full of great opportunities to become a better engineer and I am very happy that I was able to join the team here."

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Photo by Matthew Poynor

INDIAN HEAD INVESTS IN EMPLOYEES WITH ITS OWN UNIVERSITY

By Holly Dodds

FOUNDED IN 2019, NAVAL SURFACE WARFARE CENTER INDIAN HEAD DIVISION'S "INDIAN HEAD UNIVERSITY" IS HELPING TO ACCELERATE THE TECHNICAL TRAINING OF ITS PERSONNEL.

The global COVID-19 pandemic has caused workplaces to mandate working remotely with the implementation of maximum telework. While employees have adapted their work schedules to the new normal, other workplace functions also needed to adapt. Naval Surface Warfare Center (NSWC) Indian Head Division recently launched six live virtual courses, with another 10 courses under consideration, within Indian Head University (IHU).

NSWC Indian Head officially launched IHU for employees in September 2019. The platform provides employees with a one-stop shop for all training needs and includes a streamlined training request process for employees.

"The concept of IHU was to establish a formal and effective operating structure that allows our workforce the ability to easily access, understand, and sign up for learning, development, and educational opportunities," said Michelle Hinkle, NSWC Indian Head Workforce Development Branch head.

The IHU concept and brand began in 2016 when NSWC Indian Head technical director Ashley Johnson challenged deputy technical director Amy O'Donnell to revitalize the command's technical rigor. Technical rigor renewal was necessary as a foundation for assuring increased execution with discipline and proficiencies that was to come with the new strategic plan development. O'Donnell researched Department of Defense and industry technical organizations, and searched for best practices she could apply to her renew technical rigor approach. In the architecture plan she submitted, as was approved for implementation starting October 2016, she found the best results were achieved when the organization deliberately invested in enhancing specific employees' proficiency for their specific fields and specialties, especially focused on unique knowledge and processes that the workforce must master for the organization's success.

"At that time, the term training in the command was associated negatively with only compliance issues and the

workforce did not necessarily think of it as knowledge they needed to succeed in their career areas," O'Donnell said. "I knew for technical rigor to succeed and to implement this into our rollout program, I needed to brand for proficiency. This was much more focused on the workforce doing their specific area of execution better and we wanted that to be clear and different."

While meeting with other organizations, O'Donnell observed many had structured an internal "university." In the same fashion, she branded the technical rigor proficiency as "IHU." Structured for scientists and engineers, IHU comprises a typical college program with 100-, 200-, 300-, and 400-level courses, as well as elective and advanced focus area opportunities.

"It's not solely about courses. It also includes experiences, similar to how a student internship functions, we implement rotation programs for all our new science and engineering hires to complete early in their career," O'Donnell said. "There are electives, clubs, other activities, and optional things people can do. When fully implemented there will be technical concentrations and additional advanced degrees for employees' applied areas."

By 2017, the term IHU had taken off beyond just technical rigor. The command embraced IHU and hired a dedicated chief learning officer to stand up the entire effort. According to O'Donnell, once the IHU idea was developed, the first question was, "Where do we start with addressing the workforce proficiency needs?" After surveying leadership, IHU began its offerings with command new hires. The 100-level Technical College basic ordnance technology (BOT) course was the first structured course and implemented even before IHU's official launch last year. The 100-level basic Indian Head processes (BIP) course followed next. IHU provides both courses to each new technical hire within their first 12 months of onboarding. These two courses, along with a rotation within their first four years, complete their 100-level initial proficiency needs. Today, IHU is composed of four distinct colleges: Technical, Leadership, Business, and General Studies.

The Technical College's structure enhances the proficiency and knowledge of the science, engineering, and technical competencies, as well as the unique processes this workforce must master in the areas of project management, systems engineering, safety, and quality.

The Leadership College is primarily for employees just starting their careers, looking for mid-career advancement, or ready to move into senior leadership positions. The development of leadership competencies plays an important role in personal engagement and career progression and this college includes programs and information to support a leadership journey.

The Business College is the central learning and development resource for employees working and interested in the areas of business, contracting, financial management, comptroller, and corporate operations.

Lastly, the General Studies College provides information and resources to support learning and development programs for all employees, including academic tuition assistance, Defense Acquisition Workforce Improvement Act certification, employee rotation program, individual development plans, mentoring, and supervisory training.

"We are currently working on Phase II of IHU, which includes the development of the certification and requirements page for each college," said Angie Amen, IHU lead. "Each IHU college will list the certifications and requirements for positons within their competency areas."

According to Hinkle, IHU offers several benefits that were unavailable before its implementation. "IHU offers a new streamlined training enrollment process. Employees no longer use Enterprise Resource Planning to create ad hoc training requests," Hinkle said. "Prior to IHU, employees would enter their own ad hoc training requests. Having the Workforce Development Branch create all the requests has significantly improved their timeliness and accuracy."

Since the successful implementation of IHU, the university has received more than 2,600 training enrollment requests and offered approximately 220 training course sessions.

"Due to the ease of registering for classes, there has been a substantial increase in the number of training requests received," Hinkle said.

IHU's first virtual course, an instructional course on Microsoft Teams, had nearly all of its seats filled, leading to the university offering additional courses through the platform.

"Since there are no in-person trainings scheduled in the near future, we looked back at our needs assessment to find a solution," Amen said. "Right now the live trainings hosted in Microsoft Teams are a real win-win."

The command's Workforce Development Branch is researching ways the program can host more live courses and trainings for IHU. As society steers away from gathering in groups, virtual training is becoming a much more viable outlet.

About the author:

Holly Dodds is a public affairs specialist for Naval Surface Warfare Center Indian Head Explosive Ordnance Disposal Technology Division.

Photo by Naval Information Warfare Center Pacific

COLLABORATION WITH ACADEMIA PROMOTES RIGOROUS RESEARCH

By Robert Tanner, Paul Shigley, Clare Morton, and Dr. Mark Nissen

A PARTNERSHIP BETWEEN THE NAVAL INFORMATION WARFARE CENTER PACIFIC AND THE NAVAL POSTGRADUATE SCHOOL IS SENDING STUDENTS TO A NEW DOCTORAL PROGRAM IN INFORMATION SCIENCE.

There are many reasons why a Navy lab would encourage its workforce to strive for higher education: to meet organizational benchmarks, to diversify its educational portfolio, or to strengthen the rigorous research needed for future technology development. The sense of urgency to invest in even more doctorates, however, has increased over the past few years because of renewed threats from adversaries and the recognition from senior leaders that our civilian and military workforces are the key to success.

"Our obligation, our mission to the Navy and the nation is to deliver and provide warfighting systems and ships to the men and women of the country to never allow them to be in a fair fight," said Jim Smerchansky, the executive director of the Naval Sea Systems Command (NAVSEA), at the High Velocity Learning Summit in 2018. "Our obligation to our workforce is to provide meaningful work and the right tools they need to be successful." An ongoing study for the Department of Defense shows preliminary indicators that our military universities, such as the Naval Postgraduate School (NPS), might be the best value in total cost, return on investment, and workforce retention.

In 2017, Dr. Steve Russell and Dr. Wadad Dubbelday—the former chief technical officer and deputy chief technical officer, respectively, at the Naval Information Warfare Center (NIWC) Pacific—recognized the need for the naval laboratory to focus its efforts on the development of its workforce and promoting the benefits of continued education among the civilian workforce, with a focus on higher education in information sciences, artificial intelligence, machine learning, data science, and more. The command highly encouraged and supported the pursuit of higher education in years past, but the recognized need in light of the current environment reinvigorated the effort. Through partnerships with local universities and military academia, the laboratory was able to provide a wider breadth of education in areas of importance to the center.

One such partnership was unique in its nature. NPS, located in Monterey, California, has been a valuable partner in the research and development domain and has partnered with NIWC Pacific on many research and development efforts. After reviewing multiple organizations to provide consulting, training, or education to develop science and technology management expertise, Russell

determined that NPS had the unique combination of similar mission and purpose, and an understanding of the defense working capital environment. In addition, NPS has been a significant partner when it comes to educating the civilian workforce.

This thought process is being revealed in an ongoing Department of Defense study conducted by Dr. Johnathan Mun on the return on investment from the department's investment in graduate education for military officers. The preliminary data indicate that military institutions of higher education have a lower total cost than their civilian counterparts. Other early indications are that graduates from these programs provide the department a return on investment in academic research greater than that of their contemporaries educated at civilian equivalents. Furthermore, graduates of military education programs exhibited a higher retention after 17-22 years. While these findings are derived from military officers' performance, they can be generalized to the defense civilian science and engineering workforce, which confronts defense-related research more often than their military counterparts and have potentially longer career opportunities—often 30-to-40-year spans.

In 2017, because of the close relationship with faculty at NPS, a back-of-the-napkin idea quickly became reality. Within just a couple of months, the concept of developing a doctoral program in information sciences in which prospective candidates from San Diego, and elsewhere, could attend became a reality. The initial cohort of ten students began their studies in the latter part of 2017, quickly immersing themselves in the field of information sciences. A second cohort would soon follow in its footsteps, solidifying the bond between the two naval organizations.

As the information sciences department at NPS describes itself, "[Information sciences] broadly encompasses the design, implementation, use, promotion and evaluation of organizations, processes and systems associated with knowledge, information, data and communication. It includes areas of concentration in information systems, information technology, information warfare, information operations, and command and control." The field encompasses a wide variety of areas that are of particular interest to the Navy and Department of Defense as a whole.

The program provides students the ability to engage with professors on a daily basis, both through distance learning and on-site studies. Some of the core studies are on the methodologies employed when conducting academic research that are of utmost value to a naval research and development laboratory. The program's flexibility allows for students to work full time within their projects while still working on their academic studies. In addition, the ability to correlate their academic studies with their program and project requirements further assists in reinforcing the subject matter learned.

To date, the partnership between NIWC Pacific and NPS has developed doctoral students that are focusing on areas such as trust in autonomy, cyber security, knowledge transfer and sharing, and command and control, among others. The symbiotic relation between the two organizations has reinforced the need for continued partnerships throughout the Department of Defense educational system and academia as a whole. The information sciences department at NPS has been able to expand its student base, further its educational curricula, and add to its prolific scholarly journal portfolio. NIWC Pacific has furthered the education of a group of employees dedicated to the laboratory's vision that will employ the skills learned in the program to apply rigorous research methodologies within the projects and programs in which they reside.

Educational partnerships such as the one between NPS and NIWC Pacific remain a largely untapped resource. The opportunities that exist are plentiful and can further reinforce the capabilities of both the civilian and military workforce, enabling our workforce and warfighters to maintain the competitive advantage over our adversaries, near and far.

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Photo by John Williams

DIVERSITY IN NAVAL STEM: THE POWER OF SOMEONE BELIEVING IN YOUR POTENTIAL

By Anthony C. Smith Sr.

THE DEPARTMENT OF THE NAVY'S HISTORICALLY BLACK COLLEGES AND UNIVERSITIES/MINORITY INSTITUTIONS PROGRAM IS TAPPING INTO UNDERSERVED COMMUNITIES—SUCH AS THESE HIGH SCHOOL STUDENTS IN HAWAII—TO REACH TOMORROW STEM PROFESSIONALS.

Growing up in Houston, Texas, I wasn't a very good student in high school, especially in science and math. Then, during my sophomore year, I met two teachers who expanded my intellectual and, ultimately, professional journey.

My biology teacher, Ms. Sigee, saw potential in me, telling me I had the ability to be a "great science guy"—and that it didn't matter where I came from. My math teacher, Mr. Nguyen, said I had a natural aptitude for numbers and equations.

They were the first to say I could go far studying math and science. That idea never entered my mind before.

Their encouragement made a huge impression on me, a kid from an underserved neighborhood. I started to think there was a bigger world for me through education. I eventually earned a biology degree from Texas Tech University and have enjoyed 20 years of Navy service—uniformed and civilian—in various science and technology roles.

My success is a testament to the power of someone believing in your potential. This inspires me each day in my job as director of the Department of the Navy's (DoN) Historically Black Colleges and Universities/Minority Institutions (HBCU/MI) program—and in my new role collaborating with military and civilian experts striving to bring more diversity to the Naval Research Enterprise (NRE).

The Value of the Program

The program enables HBCU/MI students to work with scientists and engineers at naval labs and warfare centers.

The program has three primary objectives: expand opportunities for HBCU/MIs to compete for grants and contracts for basic and applied research; offer scholarships, fellowships, and internships to HBCU/MI students pursuing degrees in science, technology, engineering, and mathematics (STEM) studies; and promote greater student interest in STEM degrees at HBCU/MIs.

Reaching out to underrepresented populations benefits the Navy and Marine Corps in numerous ways. These students offer diverse, unique approaches to solving naval science and technology challenges. They're fascinated by naval technology and are eager to participate in the full spectrum of internships and fellowships available. And they're patriotic—a significant number of them enter the naval workforce and make a career of it.

That's why the James Geurts—assistant secretary of the Navy for research, development and acquisition—wants to help the DoN HBCI/MI program expand its impact by partnering with the DoN Naval STEM program.

It's part of a larger initiative by Geurts to reinvigorate

Naval STEM in response to the challenges rising from the COVID-19 pandemic and larger national conversations centering around racial inequality. This effort—which emphasizes increased virtual and remote-learning activities—harnesses the talents of the DoN HBCI/MI program, Naval STEM, the Office of Naval Research, and naval laboratories and warfare centers.

Working Toward Greater Diversity and Inclusion

I'm honored to play a role in this transformation by marshaling the unique experiences and perspectives of military, academic, and industry leaders. Chief of Naval Research Rear Adm. Lorin Selby and Jimmy Smith, director of the DoN Office of Small Business Programs, recruited these leaders to meet regularly and hash out ways to remove geographic barriers to learning, to increase the number of students reached, and to foster a greater commitment to diversity and inclusion within Naval STEM.

Much of our outreach inspiration comes from the National Aeronautics and Space Administration (NASA). For decades, NASA has performed outstanding STEM outreach to students, including through its own educational TV channel and live broadcasts of launches, landings, and other events.

A prime example is NASA's current Artemis program—which aims to land the first woman and the next man on the Moon by 2024. To promote Artemis, NASA offers students and educators a fascinating array of lesson plans, seminars, contests, and other activities spotlighting the future of space exploration. All of it is designed to inspire future astronauts, scientists, and engineers.

The leaders I'm working with want to come up with similar outreach efforts for the Navy and Marine Corps—something with a cool factor similar to the Blue Angels flight demonstration squadron. We're collaborating with the chief of naval information to create our own compelling content.

This could include videos of research being done at the David Taylor Model Basin (located at Naval Surface Warfare Center Carderock Division and used to test ship designs) or the test pilot school at Naval Air Station Patuxent River. Students also could cheer on a team while watching live streams of the Navy-sponsored International Submarine Races and RoboSub and RoboBoat competitions.

In addition to overseeing the creation of engaging content, we're also pursuing the following efforts, each informed by our principles of diversity programming, meaningful outreach, and sustained engagement:

- Establish STEM networks nationwide, particularly in fleet concentration areas such as Norfolk, San Diego, and Hawaii. To bolster diversity and inclusion, we first need to make students aware of Naval STEM. For example, take the underserved and underrepresented students populations in the Washington, DC, region. They live near the Pentagon, the Naval Research Laboratory, and Carderock—yet many of them have no idea about what Naval STEM is or what the Navy and Marine Corps do. We need to remedy that.
- Educate students, parents, and teachers about STEM-related activities, internships, scholarships, and other related opportunities. We also will highlight how HBCU/MIs can serve as feeder programs leading students to Naval STEM and the naval workforce.
- Identify enthusiastic mentors from within the Navy, Marine Corps, and throughout the NRE—people who want to cultivate and encourage future generations of STEM professionals. While it's valuable if these individuals come from similar backgrounds as the students they mentor, that isn't necessary. The most important qualification is a desire to serve and share their knowledge, insight, and experience.
- Bolster partnerships with scientific organizations such as the National Science Foundation, US Department of Energy, and FIRST Robotics competition.

I'd like to close this article with a personal story about the importance of promoting Naval STEM. A few years ago, I met an ambitious student named Devan, who attended an HBCU and was interested in internship opportunities. I advised him to consider those offered by the DoN HBCU/MI program and Naval STEM. He did, and landed an internship at the Naval Facilities Engineering Command location in Washington, DC.

It was a life-changing experience for Devan. He saw naval technology and processes at work first-hand. He benefited from experienced and thoughtful mentors, and he developed a stronger professional network. Devan is now in graduate school and looking forward to a career in the naval workforce. His is an inspiring story. Hopefully, we can find more Devans and create more stories like his.

About the author:

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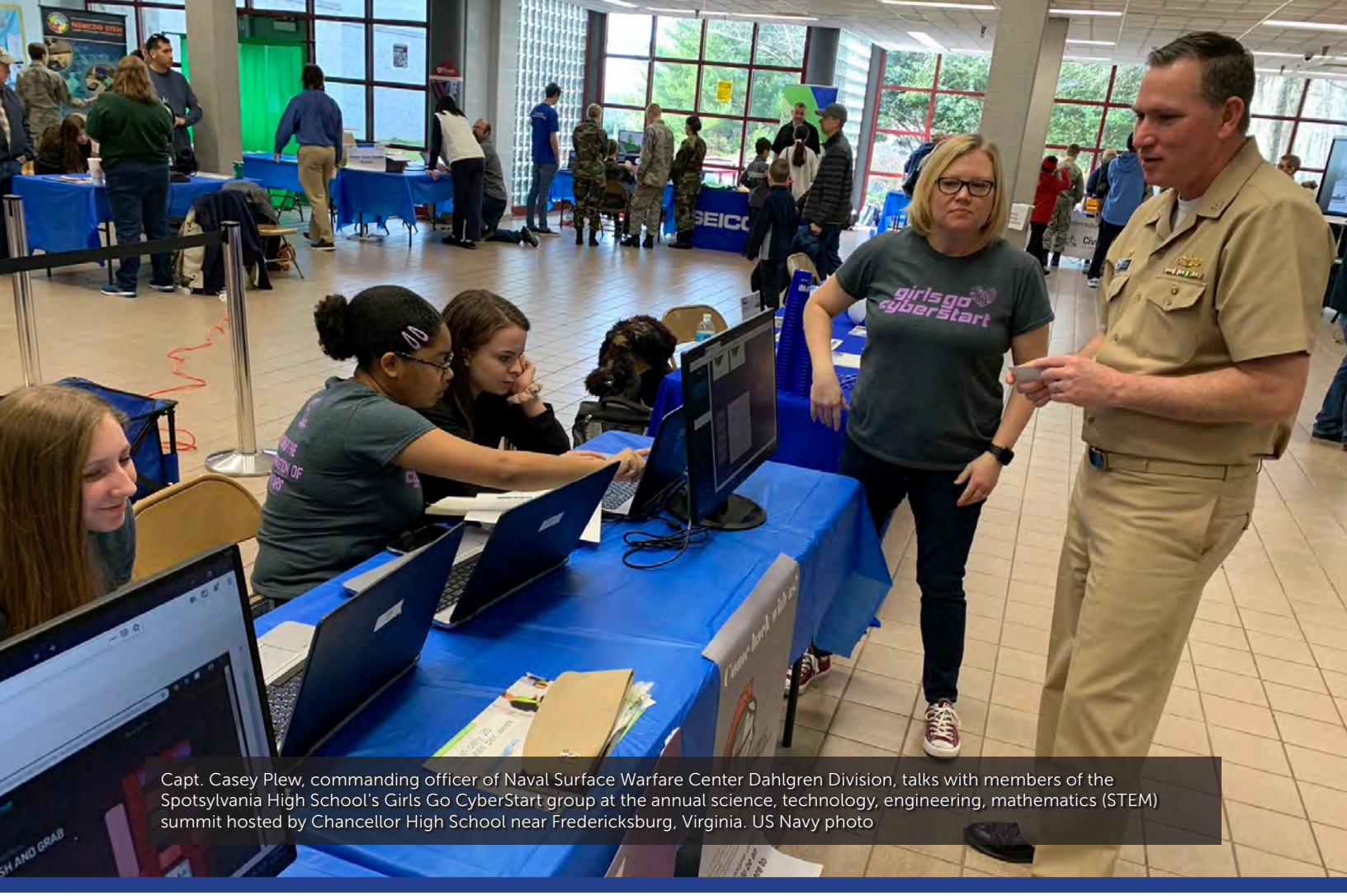

Capt. Casey Plew, commanding officer of Naval Surface Warfare Center Dahlgren Division, talks with members of the Spotsylvania High School's Girls Go CyberStart group at the annual science, technology, engineering, mathematics (STEM) summit hosted by Chancellor High School near Fredericksburg, Virginia. US Navy photo

FUTURE FORCE is a professional magazine of the naval science and techology community published quarterly by the Office of Naval Research.

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