OBSERVE

FLIGHT TRAINING
FOR COGNITIVE
DOMINANCE

BUILD LIKE
A BOSS

A LEARNING LAB
FOR DECISION
SUPERIORITY

ACHIEVING DECISION SUPERIORITY

ACT

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OFFICE OF NAVAL RESEARCH
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Future Force

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Front Cover: Illustration by Jeff Wright.

SPEAKING
OF S&T ►► By Rear Adm. Lorin C. Selby, USN

Welcome to a new edition of *Future Force* Magazine, where the focus is always on the world of naval science and technology (S&T), and how S&T is the catalyst for present and future naval dominance. I've been leading the charge since I came to the Office of Naval Research (ONR) to promote the idea we need to reimagine naval power—that we can't continue to do things as we've done them since the end of the Cold War. The world has changed dramatically since then, in no small part because of the almost ubiquitous spread of cutting-edge technology and new capabilities to friend and foe alike. This means we have to be more flexible in our processes, more imaginative in our vision, and more agile in all things related to our programs and platforms, to ensure continued naval superiority—and to stay one step ahead to ensure safety and stability in the global commons. In business or in combat, complacency is dangerous.

Reimagining naval power can bring to mind dramatic images like directed energy weapons, or swarming autonomous unmanned aerial vehicles, and it's true new capabilities such as this are going to help our warfighters now and in the future. But to get to those marquee platforms, we need to reimagine how we can dominate the battlespace. Which absolutely means we need to invest intellectual and fiscal capital into new ways to achieve decision superiority. In fact, when I informed the command of my top priorities recently, decision superiority was one of the four I chose to emphasize. (The others are point defense; creating a strategic hedge to complement our large-platform fleet; and building a great future workforce through Naval STEM and Historically Black Colleges and Universities and Minority Institutions.)

Dominance in the cognitive domain is critical. As I told the Naval Research Enterprise team recently: As the cyber and physical domains become increasingly intertwined, it is clear the advantage will go to the competitor who can utilize digital tools, to include analytics and artificial intelligence, to distill information and data into actionable decisions that are richer and faster than the adversary. To facilitate, ONR is crafting programs to maintain operational dominance in the cognitive domain.

You will see several stories in this edition on naval research designed to facilitate decision-making for commanders and crew alike, including ways to sift through the ever-growing mountain of data that new satellites and sensors are providing. As we advance these decision superiority programs, we are not only providing our Sailors and Marines the tools they need to do the job in the modern world, but meeting senior-level guidance as well, including the Interim National Defense Strategy, and directives from the Chief of Naval Operations.

I am proud of the men and women across the Naval Research Enterprise—those in uniform and civilians alike—for the great and innovative work they are doing to advance our efforts. All of it helps keep our Sailors and Marines safe on ship or shore or in the sky.

Rear Adm. Selby is the Chief of Naval Research.

ACHIEVING DECISION SUPERIORITY

Decision-making in moments that matter depends on two elements. First, there is the matter of quality: it is a good decision? Is it the right decision for this moment? Is it the best one under the circumstances? Second, there is the matter of time: was it fast enough? Or, alternatively, was enough time taken to make the right decision? Achieving decision superiority over adversaries will mean employing training, doctrine, and practice that master both of these elements.

HOW WE GOT HERE

▶▶ By Colin E. Babb

BUILDING A SCIENCE OF
DECISION-MAKING

TRAGEDIES IN THE PERSIAN GULF IN THE 1980S PUT MODERN CRISIS DECISION-MAKING INTO SHARP FOCUS. FOR DECADES AFTERWARD, THE OFFICE OF NAVAL RESEARCH HAS SUPPORTED TECHNOLOGY TO AID IN MAKING DECISIONS—BUT IT HAS SUPPORTED BASIC RESEARCH IN THE NATURE OF DECISION-MAKING FOR EVEN LONGER.

In May 1987 and July 1988, the frigate USS *Stark* (FFG 31) and cruiser USS *Vincennes* (CG 49) respectively were involved in separate incidents in the Persian Gulf that clearly illustrated the problems—and high stakes—involved with modern military decision-making. In the former, the ship was hit by an Iraqi Exocet missile, resulting in 37 dead and 21 wounded Sailors; in the latter, the cruiser accidentally shot down an Iranian civil airliner, resulting in the deaths of 290 people. In both cases, decision-makers aboard each vessel had minutes to decide how to respond to incoming information. The high speeds of contemporary aircraft and weaponry, the frustrations of state-of-the-art sensors (i.e., apparently precise data with not always precise interpretation), and the tense environment of ongoing regional conflict all combined to create situations in which human decisions had tragic consequences.

In the aftermath of these two incidents, the US Navy accelerated its efforts to provide science and technology solutions to support decision making, and in the more than three decades since has increasingly looked toward sensor automation and fusion, artificial intelligence, and machine learning for successful outcomes. This was not the beginning, however, of the Navy's interest and investment in the science of decision-making. The Office of Naval Research had been supporting basic research and laying the foundation for decision-making science for decades. Two notable principal investigators, psychologists Daniel Kahneman and Amos Tversky, would become pioneers in the field of behavioral economics, earning one of them (Kahneman) a Nobel Prize in 2002 (Tversky had passed away in 1996).

Both men were born in British Palestine and would spend their adult lives in the new state of Israel. Both also would receive undergraduate degrees from Hebrew University, and both would serve in the Israel Defense Force—in the same psychology field unit (a series of coincidences that also would connect them to ONR). Here, however, the similarities ended. Michael Lewis—who recently wrote a book on the relationship between Kahneman and Tversky, The Undoing Project—observes that their personalities were worlds apart. Kahneman was quiet and self-critical, and Tversky was the life of the party and an intimidating intellect.

"It was as if you had dropped a white mouse into a cage with a python," Lewis writes, "and come back later and found the mouse talking and the python curled in the corner, rapt."[1]

The core of Kahneman and Tversky's work represents a corrective to traditional psychology and economics, both of which posit that humans operate from a baseline presumed to be rational, the so-called homo economicus. A central claim of the two psychologists is that people generally aren't that effective at accurately analyzing situations where probability is involved, either by misplaced intuition or back it by using statistics with too-small sample sizes. In order to make sense of complex situations, and to facilitate making judgments in those situations, humans use mental short cuts—or heuristics. These short cuts often are based on experiences, either personally or socially based, that don't accurately reflect the reality of the situation. "Their work on randomness—how people see random sequences as not random and see patterns where none exist—you see this everywhere," said Lewis. "You see this in people getting a reputation for being really great with money, you see it in people getting a reputation for being really great at picking hits in the movie business, or picking baseball players in the draft. Many of the things around us have a random component; a lot of luck involved. The human mind doesn't see the luck, it sees the pattern and this is one of their first great insights."[2] Their other major theory, prospect theory, posits that people are more averse to losses than they are attracted by potential gain.

Their military experiences in the Israeli army in particular would shape and drive their research, which in turn made their ideas of increasing interest to those involved in crisis decision-making. Kahneman and Tversky problematized the very foundation of military thinking—that crisis moments call for "gut calls," intuitive decisions based on personal experience or inaccurate data that may or may not have any relevance to the crisis at hand.

Kahneman and Tversky came to the attention of ONR because of the efforts of its London office during the 1960s to observe and report on Israel's psychology program. In a series of at least six reports, from 1961 to 1973, ONR London personnel shared the results of their visits to Israel intending to look at a range of programs, both civilian and military. The reason for these visits and their focus was simple, according to Joseph Zeidner in his 1969 report: the nation had a distinctly high quality of psychology research. "All of the previous reports," he writes, "have stressed the remarkable range of studies and the sophistication and vigor of the professional community." Both Kahneman and Tversky are mentioned, as members of the faculty at Hebrew University, in Zeidner's report. As reservists, however, both men also were members of the Israel Defense Force's field psychology unit, also a major topic of many of the London reports, and both men would see service in the Yom Kippur War in 1973. This shared dual experience in academia and the military would have a profound effect on their shared work.

One of their first ONR-supported efforts would also appear in 1973, a technical report entitled "Judgment under Uncertainty." The program manager for this work was Martin Tolcott, the head of ONR's engineering psychology programs. In an issue of Naval Research Reviews in 1971, Tolcott stated that the aims of the overall program were "to generate new knowledge about human performance in the kinds of systems typical of current and future naval operations, and to develop improved ways of organizing, processing and presenting this information so that it may contribute to the design of more effective naval systems."[3] The connection between Tolcott and the two Israeli researchers would be long and fruitful and continue even after the former left ONR; as a contractor, Tolcott helped organize a major symposium on decision research in 1987 that included Tversky as a speaker.

In the fall of 1988, during hearings dealing with the aftermath of the Iran Air Flight 655 disaster, the history of the Navy's investment in decision science—and the perception that the service had abandoned it during the 1980s—figured prominently in congressional testimony. Several experts testified that while research support from the Navy in decision-making science had been vigorous in the 1970s, it had declined in the 1980s. "The military services in general, and the Navy in particular, have not been very big supporters or very constant supporters of research on group problem-solving, judgment, and decision making," said Richard Nisbett, a professor of psychology at the University of Michigan. In subsequent testimony, Steven Zornetzer, director of the Life Science Directorate at ONR, made clear that this picture was inaccurate. While research support for individual decision making had declined in the early 1980s, support for team decision had increased. Kahneman and Tversky were among the 13 principal investigators supported by ONR throughout the 1980s—indeed, this was their most fruitful period of work that would eventually earn a Nobel Prize.

In the aftermath of this inflexion point, research would shift again toward the incorporation of technology in decision aids. For the past three decades, ONR has focused its decision support program on projects that maximize knowledge and information management using artificial intelligence and machine learning aids. Going forward, research is focusing on unmanned systems, foundational science in analysis and prediction, and C4I technologies. Dealing with the stresses of making decisions in times of conflict remains a formidable challenge. In this issue of Future Force, our contributors outline current research efforts that seek to ameliorate and overcome the stresses of decision-making and, ultimately, to achieve decision superiority.

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NAVAL AVIATION TRAINING NEXT:
THE MODERNIZATION OF FLIGHT INSTRUCTION

By Lt. Cmdr. Todd Seech, USN, and Lt. Cmdr. Michael Natali, USN

BEHIND THE HIGH TECH—SUCH AS THIS PROTOTYPE T-45 SIMULATOR—THAT IS TRAINING TODAY'S NAVAL AVIATORS IS A FOUNDATION OF EMPIRICALLY BASED PRINCIPLES HELPING TO BUILD THE COGNITIVE DOMINANCE FOR TOMORROW'S FIGHT.

Innovation is under way at Naval Air Training Command (NATRACOM), where leaders are reimagining the meaning of cognitive dominance in the defense domain. On first look, NATRACOM's physical spaces resemble many tech-focused organizations moving to modernize their processes, with high-end, commercial-off-the-shelf hardware being deployed alongside purpose-built software and artificial intelligence (AI) agents to maximize efficiency. Underneath the realistic cockpit renderings, adaptive AI air traffic controllers, and extended reality flight simulators, however, lies a bedrock foundation of empirically based training principles that guide the new initiative—known as Naval Aviation Training Next (NATN)—that is developing aviators with the cognitive dominance necessary for the fight of the future. By basing core elements in scientifically sound practices instead of merely adding new technology, NATN provides the promise of outlasting other "innovative" programs while also enacting impactful change across the Naval Aviation Enterprise and even beyond to the entire Department of Defense.

Necessity and Invention

There is a rich history of defense innovations born directly from capability gaps, ranging from Great Britain's use of radar systems to deter a larger German Luftwaffe during the Battle of Britain (i.e., the Dowding System) to the US Army Air Forces' development of pressurized cabins to allow the higher, longer, and more dynamic flight profiles of the subsequent Jet Age. NATRACOM shares this heritage in a fashion common across many defense organizations: Excessive production times and resource use are limiting mission achievement and require action. These catalysts for change were perhaps less romantic than the wartime examples provided above, but they constitute momentous obstacles to maintaining defense operational and cognitive readiness.

Lengthy aviation production timeframes are not a Navy-specific problem nor are they a transient issue. In a recent report to the Congressional Armed Service Committee, the Office of the Under Secretary of Defense for Personnel and Readiness highlighted significant production shortfalls across each service from 2013-2018, including a 2,000-pilot shortage in the Air Force in 2018 that equated to approximately 20 percent of its pilot billets being vacant (2019). Then-Secretary of the Air Force Heather Wilson went so far as to say that the manning problem would "break the Force."[1] Taking account of the department-wide personnel gap, the military services estimated the need for a total of 75,000 new military pilots to be produced over the next 20 years.

The report gave special acknowledgement to the difficulties in timely production of jet pilots. On the Navy side, this issue is indeed persistent, as can be noted in Table 1, which outlines the time-to-train for Navy pilots broken down by fleet airframe. Measured in average total years from reporting to preflight indoctrination to the completion of Fleet Replacement Squadron training, the metrics are staggering. At times-to-train in excess of five years for some pipelines (not including accession training times), this constitutes a major problem that could go beyond filling empty entry-level billets, as it delivers mid-to-senior level O-3s to the fleet who have not completed initial leadership tours. This follow-on effect may start a cascade of potentially negative consequences related to Navy career opportunities, leadership pipelines, quality of life, job satisfaction, and ultimately retention, further exacerbating operational and cognitive readiness problems.

Considering the metrics above and more in the Office of the Under Secretary of Defense for Personnel and Readiness report, it is clear that the pilot manning problem is persistent, pervasive, cross-service, and inter-industry. Swift and significant changes to training are thereby warranted and, fortunately, this necessity is proving to be the mother of novel training invention.

Time to Train (years)
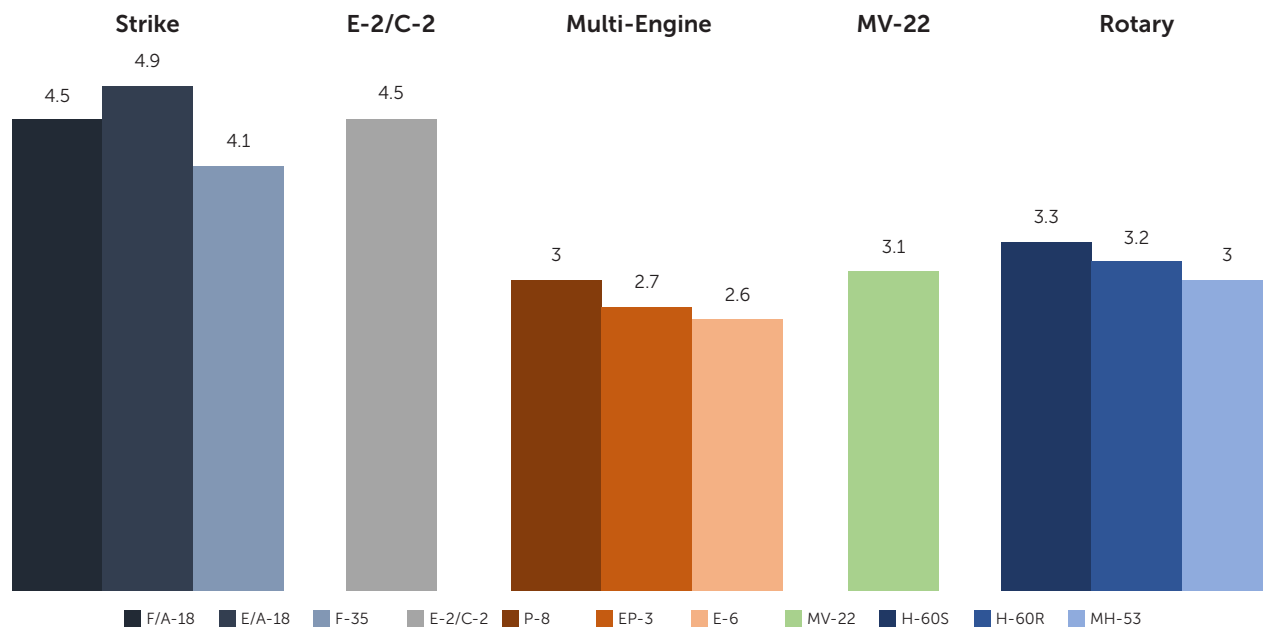
Time-to-train for Navy pilots produced between May 2021 and April 2022 by fleet aircraft platform. These data do not include any preceding accession training (such as Officer Candidate School or Academy attendance).

Phoning a Friend

In the Office of the Under Secretary of Defense for Personnel and Readiness report, the Air Force was spotlighted more than any other service. To its credit, though, it had not been idly standing by as the issue mounted. On the contrary, Air Force leadership undertook a slew of initiatives to train and retain pilots, including providing additional incentives and bonuses, implementing "fly-only" career paths, recommissioning recently retired pilots, increasing career redesignation programs, outsourcing "red air" personnel, and increasing the number of pilot accessions produced by the Air Force Academy.[2] In addition, the Air Force began an experimental program—known as Pilot Training Next (PTN)—that intended to be an incubator for high-risk, high-reward educational practices that could disrupt the military's, at times, archaic methods.

PTN was the brainchild of then-Air Education and Training Command commander, Lt. Gen. Steve Kwast, whose leadership focused on the idea of a "learning next" philosophy, of which he said: "[It is] the art of innovation, where you let people have the freedom, and the money, and the authority to try and tinker like [the] Wright brothers did in the bicycle shop to see what's in the realm of the possible without being anchored to the past."[3] Provided with local freedom to design its curriculum and significant funding to explore modern technologies such as low-cost virtual reality simulators, PTN was tasked with exploring the realm of possible for reducing time-to-train while maintaining necessary graduate skill proficiency. Taking a holistic approach, PTN included physical training,

physiological monitoring, and even a saltwater sensory deprivation chamber, thereby exploring the "what, why, and how" of how to improve flight training. This "shotgun approach" to human performance research also highlighted the Air Force's commitment to Kwast's call for innovation and the removal of long-standing training practices that persisted because of lengthy histories instead of empirical support (i.e., "this is how we have always done it" thinking). With this approach, the majority of the inaugural PTN class completed training in 2018 in four months.[4] Compared to the multiyear process that training had ballooned to, this significant reduction in time-to-train provided the promise of a combination of faster pilot production times and better training outcomes, sending waves through military aviation training across the services.

The Navy watched its somewhat eccentric sister-service closely, evaluating how best to optimize its own processes. PTN offered solutions—faster training and improved cognitive readiness—to resolve a shared issue among the services, but the resources and logistics necessary to replicate success across all flight training was untenable and, admittedly, never intended. PTN was designed to determine the possible, and so the next step was to identify which features could be distilled into usable improvements capable of integration across all flight training. Since PTN Class 1.0 was completed in 2018, the Navy closely coordinated with the Air Force as it continued to work diligently to maximize efficiencies, scale the program to its numerous training units (e.g., Project Bonzai, Undergraduate Pilot Training 2.0 and 2.5), and further tailor experiments to meet the Air Force-specific mission.

Three and a Half Guiding Principles

Through its PTN program, the Air Force dared to ask, and test, what was possible, and now it was time for the Navy to take the lead on training innovation. With a great deal of the exploratory work completed by the Air Force, the Navy focused on synthesizing the lessons learned and applying scientific principles from cognitive, learning, and training psychology to add a foundational structure to its own program. This work led to the introduction of the Navy's research-supported "Three and a Half Guiding Principles" that would serve as governing philosophies for NATN development, design, procurement, and implementation:

1. ***Competency-Based Training***
   For NATN, competency-based training encompasses two major shifts in focus from the legacy method: the general behavioral skillsets and competencies to be a successful aviator are emphasized instead of fixation on technical skills that are unique to a single airframe; and students progress through training at the speed they are able to learn and demonstrate competence, accelerating through areas where they excel, allowing more time to focus on areas needing improvement. For the first shift, NATN showcases greater student engagement and ownership in their own training, focusing on critical thinking and decision making in ever-changing situations, as well as mission planning and understanding mission objectives. For the second shift, it is understood that task competence can be demonstrated in different timeframes by different students based on their individual inherent abilities and previous experiences, falling in line with the well-documented research on maintaining optimal arousal levels to maximize performance.[5] Combined, these two "competency-based" components culminate in NATN's conviction that better aviators will be produced when student pilots take ownership over their own idiosyncratic requirements for task repetition, time to demonstrate mastery, and speed by which they progress through training. In NATN, this notion of "speed" is operationalized and enabled through event "validations" (previously known as "proficiency advances"), which are events that are bypassed based on established task competence in similar previous events. This NATN policy has the remarkable quality of improving student learning and cognitive readiness (using optimized engagement and focus on skills for success agnostic of aircraft) while simultaneously saving resources in the form of student and instructor time as well as the significant aircraft use costs.

2. ***Cyclical Learning***
   NATN is designed to provide practice for all skillsets throughout the entirety of the syllabus, cycling back to previously learned skills for repetition in lieu of the traditional, more sequential approach, in an overall effort to combat skill decay. An exhaustive investigation of military aviation training skills stressed that novice aviator skill loss over the period of eight months is substantial (approximately 18 percent across skills) and consistent across almost all students.[6] The report also highlighted that flight tasks requiring high degrees of integration among cognitive, procedural, and control components (e.g., operations into/out of airports in adverse conditions, basic instrument maneuvers under the hood) are extremely susceptible to rapid decay without practice. Therefore, the NATN approach to syllabus flow is a more dynamic, cyclical skill growth model, moving away from the linear, block development found in legacy syllabi. For example, while legacy syllabi train one skillset to proficiency before moving to another through sequential and compartmentalized stages, the NATN syllabi focus on integrated difficulty levels—that is, the focus is on an integrated, realistic flight experience that builds all skills together from the ground up. The cyclical learning is fully realized in NATN's entirely new portion of training—the "Mission Stage"— in which instructors are given substantial freedom to mimic the fluctuating flight conditions and mission profiles of the real-world operational environment. By integrating all skillsets and mimicking operational situations, it allows students to practice and learn how to make critical decisions related to the mission, thereby making autonomy and self-sufficiency a cornerstone of training.

3. ***Cohesive Cohorts***
   Class size has long been a focus of educational research. While numerous government initiatives have focused on the simple metric of student-to-teacher ratio, contemporary studies have found that the issue is far more complex and requires the consideration of multiple key variables when attempting to optimize pupil performance.[7] Some elements that improve student performance above and beyond class size have included increased peer tutoring, increased variety

Project Corsair students have access to T-45 virtual reality devices to practice skillsets on their own as well as during instructor-led syllabus events. Naval Air Warfare Center photo

of media from which content is communicated, and student-led small group training.[8] To date, legacy naval aviation training has not addressed these issues and the notion of a "class" has merely been a demarcation of training start date. The Air Force, however, has long used the concept of "flights," or small student cohorts that have more structured interaction (such as consistently shared events), and in doing so has tapped into some of the research-supported benefits mentioned above. Seeing the results from PTN and recognizing how flights resembled Navy fleet squadron cultures, NATN has adopted this idea as a core concept of the program. NATN now groups all students into small, cohesive cohorts called "detachments," or "dets," with structured characteristics intended to capitalize on the research literature, including their own: local leadership (i.e., det-specific officer-in-charge), physical spaces and training hardware, and instructor pilot cadre. This arrangement allows for maximal local autonomy and instructor familiarity with specific student needs, which promotes and facilitates Principle 1, Competency-Based Training (through event validations and optimal customization of mission stage events to meet specific student needs), while also ensuring confident selection of students for specific advanced training pipelines. The guiding principle of cohesive cohorts is a force multiplier for the others and has received near universal acclaim from instructors and students in early iterations of the program.[9]

3.5. Technology

PTN and NATN have both received international recognition for their use of technology to revolutionize applied training. Indeed, technology is ubiquitous throughout the programs, including the use of: electronic kneeboard tablets to replace paper-and-pencil-based kneeboards; the full range of extended reality (i.e., mixed, augmented, and virtual) to build specific task trainers; artificial intelligence agents to demonstrate and evaluate flight performance and communication with air traffic control; a variety of purpose-built software programs that provide improvements to the way students brief, fly, and debrief; 24/7 access to training hardware and content; deep analytics of student performance, physiology, and resource utilization. These new technologies, however, have too often taken the center stage over the true innovations happening in training. It is vital to the success of these programs that technology is recognized as merely a means to an end; that is, the variety of media and contexts that technology provide exists solely to enable competency-based training, cyclical learning, and cohesive cohorts. For this reason, we intentionally refer to technology as "half" of a guiding principle.

This Happened Yesterday

NATN is moving fast. The guiding principles and new technology described above are inherently prospective, and therefore often lack the substance necessary to convey the magnitude of change that has already occurred and will continue in the coming months. To dissuade readers from mistaking this program as a "long shot" that may fade as its champions rotate from their current posts, a brief state of the program is warranted. For orientation, NATN itself is an umbrella term for the group of projects replacing the various phases of NATRACOM training:

• Project Avenger: Named for the World War II-era Gumman TBF Avenger, this project will replace legacy primary training (i.e., introductory flight training in the

Three T-6 Texan II aircraft with Training Squadron (VT) 2 at Whiting Field, Florida, prepare for flight operations, Photo by Lt. Michelle Tucker

T-6B Texan II) by fiscal year 2025. Three cohorts have already completed the new syllabus and cohorts are ongoing at both of NATRACOM's primary training wings. Using the guiding principles described above, the first class progressed to key milestones (such as solo flight) 25-percent faster, did so in 14-percent fewer flights, completed the entire program 8.5-percent faster, and performed at or above legacy-trained peers in their advanced training platforms.

- Project Hellcat: Named for the F6F Hellcat, this project will replace T-45C Goshawk intermediate strike training with the T-6B, capitalizing on its newer, more advanced avionics systems to provide 8-10 dynamic flights to students bound for advanced strike training. This project better prepares students for the faster and more dynamic jet environment in a more cost-effective aircraft.
- Project Corsair: Named after the Vought F4U Corsair, this project is the replacement for advanced strike training in the T-45C. Project Corsair has begun its first two inaugural classes, one at each jet training wing, and leverages the 3.5 guiding principles of preceding programs. Scaling will occur over the next several years until it completely replaces legacy strike training.
- Additional Programs: Rotary, multiengine, flight officer, and aerial vehicle operator training pipelines also are developing their own projects that embrace the NATN philosophy and will replace their respective legacy training in the next decade.

This methodical, iterative approach to full-scale deployment allows the Navy to identify and implement improvements before making a total shift, with each class and syllabus building on lessons learned from the previous ones. NATN philosophy can serve as a roadmap from which to innovate and improve further; it is far from perfected, but is a remarkable improvement on the status quo.

Future Proofing Our Warfighters

According to NATN Director, Commander Drew Corey, the goal of NATN is "to produce a more capable and self-sufficient aviator, proficient in a dynamic and fluid environment, and to do so more efficiently than we do today." Not only geared to solve the manning problem, NATN is working to give our aviators the cognitive dominance necessary for the high-end fight of tomorrow. Recognizing that training students to operate a specific platform in a specific context is shortsighted, NATN utilizes training methods—not static content—to achieve cognitive dominance in warfighters, including optimizing performance through individualized training, mimicking real-world operations through cyclical training, and reliance on team peers for guidance.

As NATRACOM moves forward with this paradigm shift, it will rely heavily on the expertise, experience, and esprit de corps of its uniformed and civilian subject matter experts to ensure that innovation never comes at the expense of Navy culture. More true now than ever are former Chief of Naval Operations Admiral George Anderson's words: "The

Navy has both a tradition and a future—and we look with pride and confidence in both directions." NATN brings Naval Aviation tradition into the modern age.

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ANTX
PROMOTES COLLABORATION, DELIVERS SOLUTIONS

By Capt. Edward Lundquist, USN (Ret.)

AS THE PACE OF WARFIGHTING ACCELERATES, THE NEED TO SENSE, DECIDE ACCURATELY AND ACT DECISIVELY AND RAPIDLY BECOMES MORE CRITICAL. ADVANCED NAVAL TECHNOLOGY EXERCISES ARE HELPING TO ACCOMPLISH THAT GOAL.

Advanced technology exercises (ANTXs) are conducted by the Naval Research & Development Establishment (NR&DE) and hosted at the various naval warfare centers around the country to, as the ANTX homepage states, bring industry, academia, and government research and development organizations together to "align technical innovation with operational needs," and "evaluate the utility of new technologies before decisions are made on investment priorities."

ANTX, a series of demonstrations sponsored by Navy and Marine Corps organizations, displays new technology in settings comparable to real-life operational environments and assists senior leaders in assessing and prioritizing technologies. It also brings participants and observers representing very different technologies and unique approaches together to form teams that can address warfighter needs and warfighting technology gaps.

The Naval Air Warfare Center Aircraft Division's (NAWCAD) 2021 ANTX featured more than 20 emerging warfighter technologies at its Naval Air Station Patuxent River headquarters.

"We're focused. We typically look for a problem that we get from the fleet, and then we go after it and attack that problem," said Tony Schmidt, director for rapid prototyping and experimentation at NAWCAD.

"We look for capabilities that can help us solve this problem, and who within our warfare centers, or outside of the fence line, can do this—whether it's industry or academia—to get the right smart people to go do that work. So we actively look for the means and the experts and the capabilities that reside across the waterfront and outside of the Navy," said Schmidt. "We're looking for technology to get out to the warfighter and providing that forum for DoD, industry, and academia to participate and showcase capabilities and how they would interface with a warfighting environment."

Teams and projects were brought together based on skill sets, capability, and infrastructure. Each of the participants brought unique capabilities and new technology that were evaluated in an operational environment.

Schmidt said the Navy and Marine Corps distributed maritime operations and expeditionary advanced base operations concepts have created a need for new ways to provide logistic supports to a widely distributed force afloat and ashore. That led to the Navy's Blue Water logistics unmanned aerial system concept of delivering material using commercially-available unmanned air vehicles to prototype a long-range, naval ship-to-ship and ship-to-shore cargo delivery system. The system was tested aboard USS *Gerald R. Ford* (CVN 78) during ANTX 2021.

Teaming for Success

"Our location and partnerships at this busy port have built a great laboratory to study problems relevant to the Navy and impact every aspect of the maritime industry and marine environment, from crewing to maintenance to maritime security," said Alan Jaeger, the research and technology applications manager at the Naval Surface Warfare Center Port Hueneme Division and director of the Ventura Tech Bridge and FATHOMWERX Lab. "We recently hosted the Advanced Naval Technology Exercise/Coastal Trident 2021 event to witness and demonstrate new and better ways to ensure maritime domain awareness and port security," said Jaeger. "This program supports our innovation pipeline as a low-risk way to get capabilities into a representative environment so we can learn and adjust quickly."

The Navy and its industry partners, both small and large, all benefit. "Through our growing ecosystem, promotion of divergent thought and neutral facilitation, we have created a dynamic platform to deliver a high rate of return for all participants," said Jaeger.

Coastal Trident (CT) 21 encompassed more than 50 projects and 35 topics, and included more than a dozen live exercises occurring over a six-month period culminating in demonstrations held onsite in September. Participants examined the operational and technical capabilities of port and maritime security organizations to counter asymmetric threats to the nation's marine transportation systems and their associated personnel, operations, and critical infrastructure.

In many cases, these demonstrations brought partners into teams that have previously never worked together. In one such event, a team consisting of Atlas North America of Yorktown, Virginia; Marine Arresting Technologies of Tarpon Springs, Florida; Spotter RF of Provo, Utah; and ION of Houston, Texas, collaborated to provide a solution to the issue of enforcing a maritime security and safety exclusion zone, and slowing or stopping a vessel from entering that restricted area without damaging the boat or harming its occupants. The system was able to sense activity, make decisions and quickly affect outcomes.

According to Bob Murphy with Atlas North America, the companies had all independently applied to ANTX 2019 in Newport. "We attended the industry day, where they encouraged companies to partner. Dave Gentle of

ION called me afterwards to talk about how we could collaborate. It was an 'aha!' moment where I could see that we could be of more benefit to the government for us to demonstrate a system-of-systems solution rather than to independently demonstrate our own systems.

"We developed two basic scenarios—above water and underwater—and each scenario had at least several excursions to it that we employed during the demonstration," said Murphy. "We all had our individual objectives where we wanted to demonstrate our technology and system capability, and we had a top-level objective for the entire demonstration, with our various solutions that we were offering to counter the over-arching problem. The lower-level objectives were system specific, while the top-level objectives focused on a high probability of intercept."

The sonar demonstration showed a lot of clutter around the target. "This wasn't an artificial test environment. We were dealing with actual real-world conditions," said Gentle.

ION has a long history of building and networking underwater sensors and survey systems for seismic exploration in support of the oil and gas industry. "Those technologies—acoustics, hydrodynamics sensing, telemetry, and undersea cables—all of those are relevant to the Navy. They're dual-use technologies," said Gentle. "So, we wanted to see how we could explore that market with the US Navy. We made our proposal to participate in ANTX, and they came back and said, 'Well, that sounds quite interesting. We'll take you on.' And that was the start of it for us."

For ION, working with the team was mutually beneficial. "Each of us had our own test objectives, and together we had a top-level objective of a high level of intercept" said Gentle. "We've shown that we can use this technology to deliver countermeasures against threats such as divers, [unmanned underwater and aerial vehicles]. We have the sensing, [command and control], and countermeasures that are smart enough to defeat modern threats."

"All of our individual systems are mature TRL [Technology Readiness Level] 9 technologies, but as a system of systems, we were at a much lower technology maturity level," said Murphy. "With our test at CT21, we can now claim at least TRL 6 as an integrated system because we've successfully tested it in field experimentation."

Matthew Searle, chief technology officer with Marine Arresting Technologies (MAT), agreed. "We demonstrated that we can have a port security package that works."

"ANTX CT21 allowed us to plan our own exercise and [concepts of operation] as well as providing Navy assets to use as targets and launch platforms," said Searle. "I think this is fairly unique."

Searle said that by putting together an entire kill chain, the team was able to demonstrate a system of systems with each part in proper context. "We conducted one exercise to counter a UUV [unmanned underwater vehicle], using a portable Atlas Cerberus sonar—that was being remotely operated via a WiFi hotspot from the UK—which communicated with ION's Marlin software and gave targeting data to a tablet on the patrol boat allowing us to precisely intercept the UUV, supplied by UUVRON1, with the MAT Stingray net mounted aboard a Navy High-Speed Maneuvering Surface Target [HSMST]. If allowed, we could, in theory, have used the HSMST unmanned but port regulations needed the vessel to be manned."

Another demonstration connected a Spotter RF radar to ION's Marlin command and control system and provided targeting data to the unmanned aerial vehicle (UAV) to deploy the MAT arresting line autonomously.

The Spotter RF C550 perimeter surveillance radar detected and tracked a target and passed information to the command-and-control hub developed by ION, which used their Marlin platform technology to plan and execute the missions for the UAV. The UAV was fitted with a command-initiated device that discharged an arresting line in front of the vessel at the precise time and location computed by the hub. The radar data enabled a constantly updated solution. The drone flew in front of the target and deployed the arresting line, which slowed the target boat. The UAV can be recovered and the system reloaded for subsequent missions.

An exercise with the Coast Guard's Maritime Security Response Team-West was leveraged to conduct ANTX experiments with wearable sensors and remote physiological monitoring at Port Hueneme. NSWC Port Hueneme Division photo

Searle said the team is already looking ahead. "Next year we would like to combine the radar and sonar data," he said, "allowing us to use a UAV to intercept subsurface targets."

Demonstrating Progress

At an ANTX, the technology, integration, and collaboration can vary from simple to complex, and can be advanced to a higher TRL in successive years.

For example, in 2017, General Dynamics Mission Systems and General Dynamics Electric Boat demonstrated multiple mission command, control, and communication capabilities connecting Bluefin Robotics' UUVs and a UAV with a simulated AN/BYG-1 submarine combat control center ashore. A Stackable Air-powered Launch System (STAPLS) designed for use aboard submarines also was used. The goal of the General Dynamics demonstrations, which took place during Naval Undersea Warfare Center Division Newport's ANTX 2017, was to provide available solutions to the communications challenges of operating in a contested, undersea environment.

The team demonstrated capabilities for real-time, two-way communications from the AN/BYG-1 control center to change the Bluefin SandShark UUV's mission, using an Aerovironment Blackwing UAV while the SandShark was operating in the water. The team also launched both a SandShark and a Hammerhead canister containing the Blackwing from two platforms: a Bluefin-21 medium-weight UUV, and then from a STAPLS launcher designed by General Dynamics Electric Boat. In another demonstration, the SandShark communicated with a simulated undersea communications network composed of an acoustic communication node connected to a fiber-optic cable that relayed information from the SandShark back to the AN/BYG-1 through a surface buoy.

The following year, the General Dynamics team leveraged "big picture" theatre-level planning tools to enable cross-domain command, control, and communications of manned submarines and UUV systems. The ANTX 2018 demonstration employed real-time mission communications with a land-based, theatre-level planning command center and a submarine's tactical-level command center responsible for tasking the https://gdmissionsystems.com/products/underwater-vehicles/bluefin-21-autonomous-underwater-vehicleBluefin-21 and Navy UUV mission assets.

During Newport's ANTX 2019, a General Dynamics Mission Systems-led team demonstrated cross-domain,

ANTX 2021 was the culminating event of the exploration phase of the Tactics and Technology Exploration and Experimentation method. The exercise involved the Marine Corps Warfighting Laboratory, the Navy Warfare Development Command, the Naval Information Warfare Center Atlantic, and the Naval Surface Warfare Center Crane Division. Photo by Joseph Bullinger

multilevel command, control, and communications capabilities using manned and unmanned assets, which included a Bluefin-9 UUV, a SeaTrac unmanned surface vehicle and a shore-based simulated submarine combat system, a simulated surface combatant combat system, and a simulated mission operations center. The demonstration also provided real-time 3D visualization and communications using General Dynamics' secure 4G LTE wireless broadband network. According to a General Dynamics statement, "the demonstration offered technology solutions to address the challenges of communicating among multiple platforms in contested environments, from high-level operation planning to tactical mission execution."

ANTX provides unique opportunities to stakeholders. The hosting warfare centers can immerse themselves in new technology in their relevant areas of responsibility and can engage with new and existing industry and academic research partners. Both large primes and small entrepreneurial businesses can be exposed to specific warfighter requirements, and work with actual end-users in a realistic operating environment not otherwise available to them. And the ultimate customer—warfighters—can see witness technologies and solutions that will enable better decision making and more effective operations. ✈

About the author:
Capt. Lundquist writes on naval, maritime, and defense issues, including developing science and technology for warfighters.

CREATING A
LEARNING LAB
TO MAINTAIN
DECISION SUPERIORITY

PHYSICAL SYSTEM

SOCIAL SYSTEM

CYBER SYSTEM
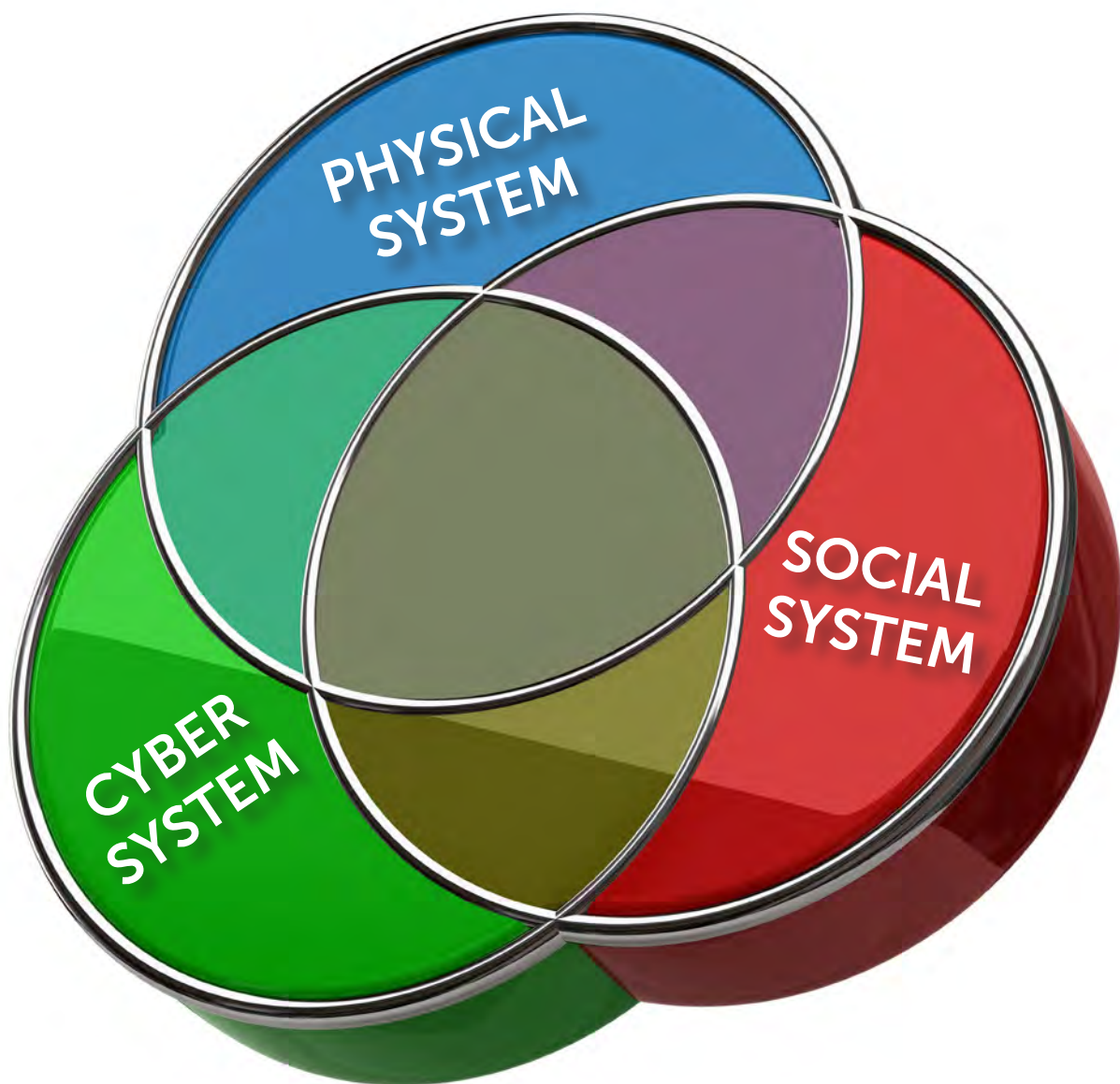
By Dr. John Wood, Dr. Jon Wade, and Rick Gessner

A PARTNERSHIP BETWEEN NAVAL INFORMATION WARFARE CENTER PACIFIC AND THE UNIVERSITY OF CALIFORNIA SAN DIEGO IS BUILDING A NEW LAB TO INVESTIGATE THE INTERSECTION OF THE CYBER, PHYSICAL, AND SOCIAL AS THE REALMS OF MACHINES AND HUMANS BECOME MORE ENTWINED.

The Office of Naval Research (ONR) has established decision superiority as one of four priorities for 2022. "As the cyber and the physical domains become increasingly intertwined," says ONR in its rationale for this priority, "it is clear that the advantage will go to the competitor who can utilize digital tools, to include analytics and artificial intelligence, to distill information and data into actionable decisions that are richer and faster than the adversary."[1] As systems engineers, we the authors know it is our job not only to create systems that integrate the cyber and physical domains but also, and perhaps most importantly, integrate key personnel including decision-makers into those domains, thus creating cyberphysical social systems.

To that end, Naval Information Warfare Center (NIWC) Pacific and the University of California San Diego (UCSD) Jacobs School of Engineering have entered into a cooperative research and development agreement aimed at expanding the knowledge and improving the techniques required to engineer the cyberphysical social systems necessary for achieving and maintaining decision superiority. The principle investigators from both of the organizations that lead this agreement met at an engineering conference in San Diego. Recognizing a similarity in the topics presented, the representatives continued their discussions beyond the conference and shared their respective interests, visions, and goals. The tremendous alignment of these topics gave rise to the desire to formalize a cooperative agreement.

Goal and Benefits

The general objective of the agreement is to further the research and development of systems engineering tools and techniques that support the creation of cyberphysical social systems. The agreement integrated and enhanced existing efforts already being performed by each organization. NIWC Pacific develops cyberphysical social systems in support of Navy and national defense initiatives related to information warfare, while UCSD creates and delivers educational curricula related to the systems engineering of cyberphysical social systems. Through this collaborative effort, UCSD and NIWC Pacific will jointly establish an "Accelerated Learning Lab" to assist engineering students and practicing engineers in the creation of cyberphysical social systems. In addition, and as suggested by its title, the lab will incorporate a measurement system to accelerate the learning of which engineering tools and techniques best support the rapid development of effective cyberphysical social systems. Based on the findings, the collaborators will develop and maintain a systems engineering "guidebook" that documents a set of principles, methodologies, and tools that facilitate the creation of cyberphysical social systems.

Figure 1 graphically represents the information flow and feedback cycle of this vision. Through the execution of this vision, the authors hope to address Chief of Naval Operations Adm. Michael Gilday's desire for learning how we can "use data in a more innovative way to give us a quicker flash to bang, from decision-making to action. There is a lot of information at our fingertips every single day; it's getting the right information to the right people at the right time so you can make the right decisions faster than your opponent."[2]

Approach

The collaborators decided that in order to rapidly build and continually expand the knowledge captured in the guidebook, it would be ideal to have multiple student teams create cyberphysical systems through the accelerated learning lab each semester. The collaborators needed to develop concepts for cyberphysical social systems that mimic actual or planned Navy cyberphysical social systems that are also appropriately scoped so engineering students can create such systems in a university lab environment. After exploring multiple candidate topics, the collaborators agreed that the initial projects should be focused on controlling distributed energy resources and major energy consumers (e.g., heating and air conditioning) within a localized environment using the DERConnect testbed.[3] The collaborators also agreed that the first manifestation of these methods and tools should be executed in a three-course sequence at UCSD. These three courses will consolidate the systems engineering process into three major phases that will also set the structure for the engineering guidebook referenced above. The phases, their descriptions, and their intended outcomes are provided in the following subsections.

Concept Phase

This phase combines the contextual analysis of systems thinking to ensure social, environmental, and economic sustainability with entrepreneurial/intrapreneurial approaches to innovation that provide the foundation for the conceptualization of complex systems. Practitioners transform the definition of a problem in a technical social context to a system concept, use-case scenarios, and technical requirements using a systems-thinking, model-based approach.

The outcomes of this phase include:
- Understanding the perspectives and fundamentals relating to sustainability, environment, and economics
- Understanding total life-cycle costs, value creation, and how those translate into overall mission objectives in the context of the complete system
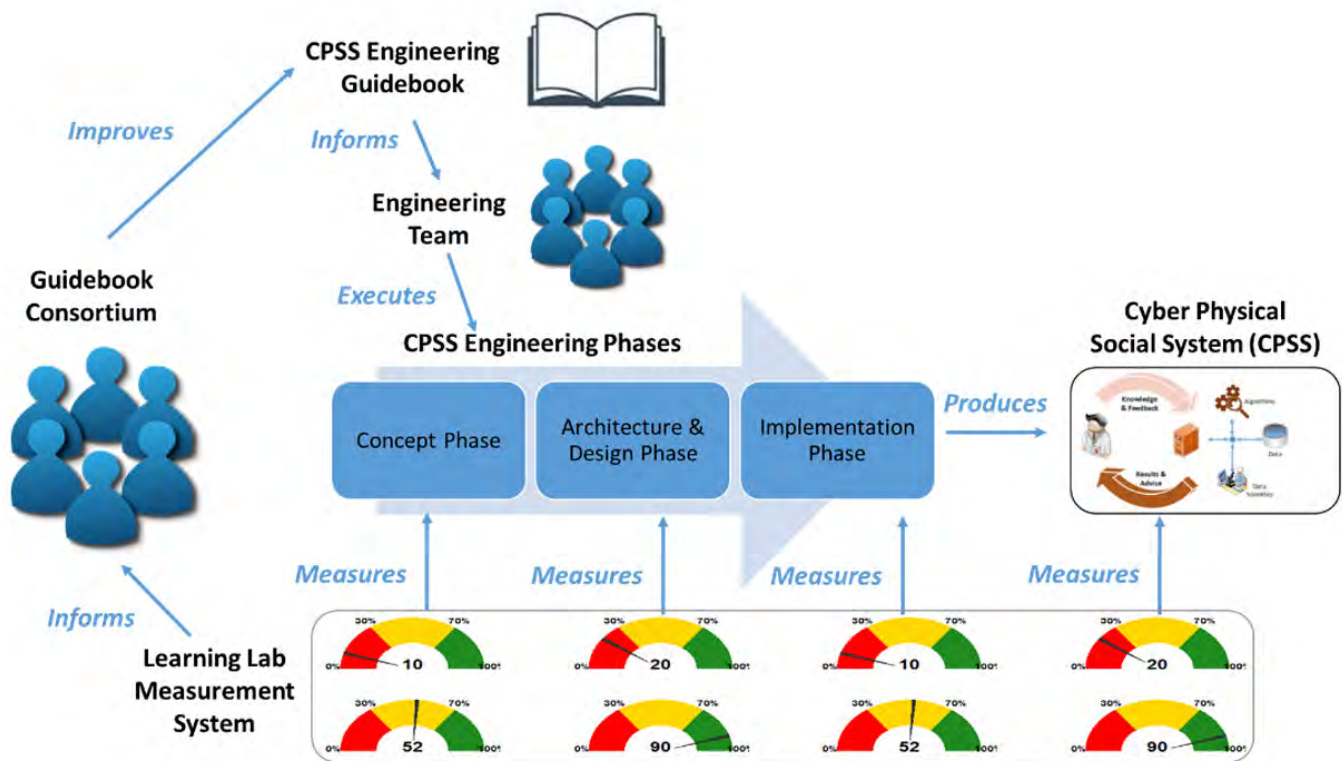
Figure 1. Operational view of the Accelerated Learning Lab for the creation of cyberphysical social systems.

through technical, operational, support, sustainment, and product management perspectives
- Creating, selecting, and testing conceptual models
- Developing a concept of operations for the system of interest with respect to the life-cycles of customers, services, and operations
- Specifying the system content using operations, use-case scenarios, and technical requirements.

Architecture and Design Phase

In this phase, practitioners will develop and represent potential architectures and then evaluate their strengths and weaknesses. To aid in this evaluation, the guidebook will include case studies that illustrate successful and unsuccessful examples, architectural patterns, and methodologies. The guidebook also will describe best practices in evaluating architectures, measuring suitability, and common architecture improvement techniques.

The outcomes of this phase include:
- Using an architecture to provide support for strategy and long-term system objectives
- Developing a holistic architectural model of a complex system and using it to assess system performance and to drive detail design
- Decomposing a complex system into components, connections, protocols, logical and physical

topologies, and constraints and tradeoffs, and defining how those elements work together to fulfill the system's purpose
- Developing a complete set of specifications for the subsystems and components of a complex system by methodically flowing requirements down from system specifications and diagramming the result in a high-level language such as the Unified Modeling Language (UML) or System Modeling Language (SysML)
- Evaluating the success and limitations of an architecture and determining appropriate improvements.

Implementation Phase

This phase explores methods for evaluating systems for correctness, efficiency, performance, scalability, and reliability. Practitioners execute product acceptance testing through an established customer requirements-oriented verification process. Leading up to product acceptance testing, practitioners will execute precursor activities including inspection, unit-level testing, and integrated system-level analysis. The guidebook will highlight the benefits of automation for tedious, time-consuming, and risky implementation activities.

The outcomes of this phase include:
- Developing a verification and validation plan to

define the balance of tests, analyses, and reviews that produce measures of evidence within the given risk tolerances and time constraints

- Developing test strategies and test cases using application-appropriate testing methods and principles to collect evaluation metrics that identify defects
- Performing simulation and physical testing, including fault injection and stress testing strategies, to measure the robustness of the system
- Performing analysis and verification measures in lieu of testing in situations where testing is not feasible
- Producing traceable analysis results and coverage measures that document the verification and validation evidence in relation to the system requirements

Next Steps

Beginning in fall 2023, UCSD engineering students will execute the phases described above in a series of three courses structured as a new specialization in an existing mechanical and aerospace engineering master's degree program. The collaborators will capture lessons learned and formalize the guidebook. The guidebook then will be issued to NIWC Pacific engineers for their use in creating cyberphysical social systems. Once again, the collaborators will capture lessons learned and use that information to update the guidebook. The collaborators intend to continue to capture lessons learned and update the guidebook as they receive feedback from UCSD engineering students and NIWC Pacific engineers who leverage the guidebook as shown in Figure 1 above. Following this process, the collaborators hope that the learning will continue indefinitely and the efficiency and efficacy related to the engineering of cyberphysical social systems will improve continually.

Through a chance encounter at an engineering conference, NIWC Pacific and UCSD were able to team up to address the emerging engineering challenge of rapidly developing cyberphysical social systems. Through this collaboration, the Navy will be able to capture lessons learned in engineering at an accelerated pace as a result of the constant flow of student projects. In the future, the Navy will be able to apply those lessons learned in the creation of systems intentionally designed to integrate decision-makers into the cyberphysical realm, thus providing the foundation for decision superiority.

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NRL DEVELOPS A
PHOTONIC COMPONENT
LIBRARY

By Nicholas E.M. Pasquini

AS MORE COMPUTING SYSTEMS SWITCH FROM ELECTRONIC TO OPTICAL, OR PHOTONIC, COMPONENTS, THE US NAVAL RESEARCH LABORATORY IS HELPING TO PAVE THE WAY FOR NEW PHOTONIC RESOURCES.

The US Naval Research Laboratory (NRL) recently provided a license to a silicon-nitride based photonic component library to The Research Foundation for the State University of New York, the administrator of AIM Photonics, a Department of Defense manufacturing innovation institute, using a novel form of intellectual property protection: the trade secret.
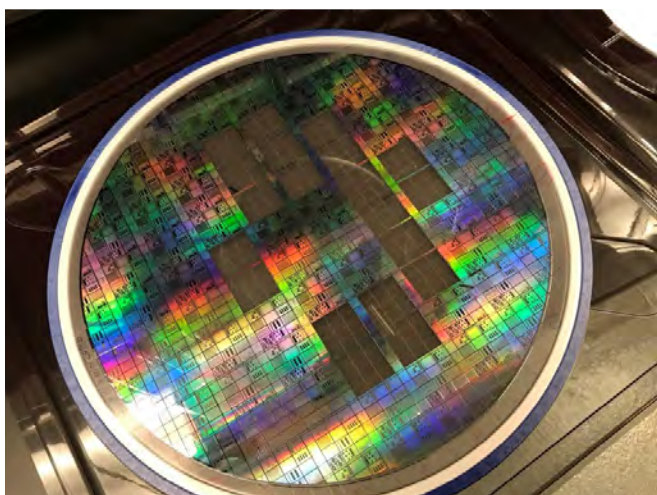
By working closely with AIM Photonics' state-of-the-art foundry, NRL's Optical Sciences Division is developing photonic components with functionalities targeting defense priorities such as analog signal processing, quantum information and computing, data remoting, and navigation and timing.

"Photonic integrated circuits have demonstrated that combining optical sources, modulators, and detectors on semiconductor chips is a winning technology," said Dr. Todd Stievater, a research physicist from NRL's Photonics Technology Branch and principal investigator. "They are already integral pieces of today's internet data centers and enable the continued scale-up of the world's flow of digital information."

This success is founded in part on process design kits, which include sets of predesigned and preverified functional components for both traditional (electronic) integrated circuits and photonic integrated circuits.

"The . . . license to NRL's component library will permit AIM Photonics to create a new [process design kit] for internal research and development by AIM Photonics customers," said Nathan Tyndall, a research chemist from the Photonics Technology Branch and co-inventor of the component library.

The Photonic Integrated Circuit Sensors program, which resulted in the creation of this intellectual property, is sponsored by the Under Secretary of Defense for Research and Engineering.

The component library is based on years of internal research at NRL focused on developing and processing silicon-nitride waveguides to support photonic integrated circuit applications. The license is an important step toward lowering the costs associated with using photonic technology for defense applications.

Silicon nitride is a glass-like material commonly used in semiconductor fabrication. In NRL's work, optical waveguides are formed in this material, which allow light to be transported across a semiconductor chip.

"'This design once; use many, many times approach' provides economies of scale for commercial applications," Stievater said. "The high, up-front labor and resource costs of [photonic integrated circuit] technology have hindered comparable development for lower-volume applications of vital interest to the Department of Defense."
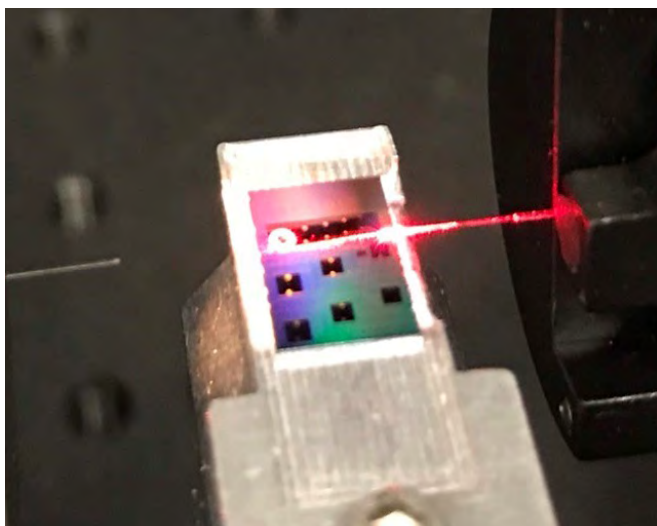
With the exception of software, the Department of the Navy has not historically used trade secret law to protect its inventions—instead opting to protect its inventions under patent law. "While patenting offers the broadest scope of protection, it is also expensive, prolonged, and requires the invention to be publicly disclosed," said Dr. Stephen Deese, a NRL Office of Technology Transfer partnership manager. "This is the first time a trade secret has been commercially licensed by the Department of the Navy and provides an additional tool to protect and license intellectual property."

Trade secret law, on the other hand, has a narrow scope of protection but is less costly, quick to implement, and by definition requires that the invention be kept secret. "Private sector companies routinely choose between trade secret protection and patent protection based on what makes sense for them," said Sean Walsh, a NRL intellectual property attorney.

NRL's intellectual property counsel explored whether the Navy could do the same thing under its existing statutory authorities. "After months of legal analysis, NRL's intellectual property counsel concluded that the Department of Navy could protect and license its inventions as trade secrets, and provided their analysis to Counsel, Office of Naval Research, who formally adopted it in March 2021," Walsh said.

NRL's Office of Technology Transfer and intellectual property counsel then built a trade secret program. "The

A 300-millimeter photonic integrated circuit semiconductor wafer made by AIM Photonics using a new low-optical-loss passive fabrication technique and components developed by the Naval Research Laboratory. The semiconductor wafer is patterned into 64 identical parts (each one called a reticle) approximately 1 inch square. US Naval Research Laboratory Optical Sciences Division photo

A 633-nanometer laser coupled from an optical fiber to a low-loss sensing spiral on a photonic integrated circuit die fabricated by AIM Photonics. The majority of photonic integrated circuit research is performed in the near-infrared, whereas these circuits are designed to operate in the visible and near-infrared. US Naval Research Laboratory Optical Sciences Division photo

culmination of that effort is this license," said Amanda Horansky-McKinney, former head of the NRL Office of Technology Transfer. "NRL hopes and expects this is the first of many trade secret licenses."

In the past few months, several other government agencies have reached out to NRL to learn about its trade secret program and to see if they could implement something similar. "NRL's trade secret program is a model for other agencies and a blueprint for government intellectual property in the future," Walsh said.

"The fab team at AIM Photonics has been working with our members, like NRL, to develop new technology platforms for specific applications such as photonic sensors," said AIM Photonics chief operating officer Dr. David Harame. "New process technologies require new [process design kits] for designers to be able to take advantage of the technology. By partnering with experts like Dr. Stievater we are able to move quickly to create and release a [kit] with their verified photonic devices."

NRL's component technologies, developed under this effort, are now available to license for companies with interests in collaborative research purposes, commercial applications, and educational partnerships. For additional information, contact the NRL Office of Technology Transfer at techtran@nrl.navy.mil. ◤

About the author:
Nicholas Pasquini is a public affairs specialist and technical writer at the US Naval Research Laboratory.

NAVAL INTERN HELPS GENERATE COST-SAVING ALGORITHM

By Samina Mondal

N RL's Naval Research Enterprise Intern Program (NREIP) intern, Liam Magargal, and a team of NRL scientists and collaborators from the University of Washington have developed novel algorithms to significantly reduce time and costs of simulating the behavior of complex multiphysics systems with machine learning. These efforts are aimed at enabling efficient, accurate, and low-cost designs of defense systems and applications.

NRL offers undergraduate and graduate students with a strong interest in scientific research an opportunity to learn under the tutelage of professionals through the NREIP. During the ten-week internship program, students work with mentors at participating Navy laboratories who help hone or further develop their skillsets. Magargal, a Lehigh University doctoral student, helped design and build computational multiphysics models and subsequently used them to generate synthetic data to train algorithms developed by the NRL and University of Washington team.

"Computational multiphysics is a field of computational mathematics and physics that enables scientists and engineers to model complex phenomena, such as modeling airflow over an airplane," said Magargal. "While these tools have become indispensable in engineering design, they are often too computationally expensive to be used in many time-critical analyses."

Dr. Steven Rodriguez, an NRL research scientist from the Computational Multiphysics Systems Laboratory who is heading the team in this effort, guided Magargal through the development of an in-house code based on numerically modeling the physics of multiphase flow with smoothed particle hydrodynamics. The tandem composed code that can be customized and user-defined to allow for physical inputs such as conductivity, density, viscosity, and other physical and computational parameters.

Magargal and Rodriguez first focused on generating training data for NRL's algorithms with simple fluid flow often seen in natural convection, such as Rayleigh-Bénard instabilities—a phenomenon that can be seen when you boil water.

"Liam focused on helping me code up a mathematical technique used to model fluids called the 'Smooth Particle Hydrodynamics Method,' or SPH for short, which was originally developed to model astrophysics," said Rodriguez. "SPH is recognized among the scientific computing community as an effective modeling tool, and has shown to be useful for problems involving different types of fluids with different densities—for example, how oil and water interact at room temperature."

This past summer, Magargal learned the mathematical framework of SPH and how to communicate these ideas to a computer to run fluid simulations and study the behavior of intermixing fluids. After modeling the Rayleigh-Bénard convection, Magargal leveraged the code to systematically generate training data for the Projection-Tree Reduced-Order Model (PTROM), the algorithm developed by NRL and University of Washington team.

"The PTROM is a class of reduced-order modeling, which is a discipline in applied and computational mathematics that aims to reduce the costs of simulating complex multiphysics systems," Rodriguez said. "It is an approach akin to machine learning, where you feed an algorithm data over a couple of different user inputs runs and the algorithm is able to predict output data of many other desired inputs it was not trained on."
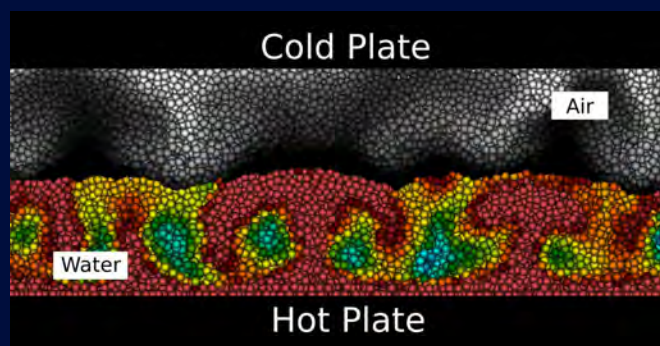
Output data of natural convection between water and air exhibiting Rayleigh-Bénard instabilities were collected to test the power of the novel algorithm, which will be employed to compute results of physics models much faster than previously possible. US Naval Research Laboratory Center for Computational Materials Science illustration

Magargal's code and data will enable the deployment of the PTROM for many query applications such as design optimization, uncertainty quantification, and control. "Using Liam's SPH code," said Rodriguez, "we can train the PTROM to learn the behavior of intermixing fluids over a few physical properties, such as different densities and viscosities. So that if we train our PTROM over the interactions of air and water, it can guess how honey and milk will interact—as a fun and extreme example."

Liam Magargal, a Lehigh University doctoral student and Naval Research Enterprise Internship Program intern, helped design and build computational multiphysics models and subsequently used them to generate synthetic data to train algorithms developed by an NRL and University of Washington team. Photo courtesy of Liam Magargal

"I was drawn to NRL because of Dr. Rodriguez and his organization's research, which involves applied mathematics and machine learning methods and how they relate to computational physics models," Magargal said. "I had a healthy amount of freedom to explore new interests while working toward an end goal, and I was excited to build skills in new areas that will be beneficial to me throughout my career."

The resulting code Magargal and Rodriguez developed is now being used to for new developments that will further extend the capabilities of PTROM algorithm.

The Office of Naval Research is offering summer appointments at a Navy lab to current sophomores, juniors, seniors and graduate students from participating schools. For more information about NREIP opportunities, please contact NRL's NREIP coordinator at: NREIP@nrl.navy.mil

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VIRTUAL REALITY
TAKES FOOTHOLD IN BATTLE MANAGEMENT SYSTEM

By Rachel O'Donnell

A TEAM AT NAVAL SURFACE WARFARE CENTER DAHLGREN DIVISION IS HELPING TO INTEGRATE VIRTUAL REALITY INTO THE BATTLE MANAGEMENT SYSTEM, A POWERFUL PROTOTYPING ENVIRONMENT FOR ENVISIONING AND BUILDING NEW INNOVATIONS.

In the 1990s, the gaming world predicted that virtual reality would be widespread by 1994. Although this prediction might have been slightly premature, the last few years have truly brought a shift in the ubiquity of this new technology. Mostly associated with commercialized products in this day and age, virtual reality (VR) has applications within the military's top projects and programs including the Battle Management System (BMS) at Naval Surface Warfare Center (NSWC) Dahlgren Division.

"BMS is consistently trying to innovate and figure out what kinds of technologies they can bring into the main line portfolio," explained BMS metrology and augmented reality/virtual reality project lead Mike Weisman. The rapid onset of commercially available headsets in the recent consumer market has created a wider avenue for maturation, stability, and predictability. "Generally, when we use VR, we look at it within three different types of applications: engineering, training, and tactical purposes."

In the engineering application of VR, Weisman and his team go to different locations, scan the environments, and use the data to create a digital twin, or virtual recreation, of the area. The result is shortened timeline from the original idea to a delivered product.

"Using VR, people can put on a headset, walk around the design and see how it would actually fit in the space, creating an immersive, 3D representation. It enhances the speed and accuracy of our designer as they create things," said Weisman.

Project lead Mike Weisman and his virtual reality team at Naval Surface Warfare Center Dahlgren Division. NSWC

As the team began to integrate the program, the program sponsor saw a unique opportunity to implement the program for operator training. Weisman and his team created and delivered the 30-millimeter virtual gun trainer, which allows operators repetition on the system that was not as easily accessible in the past.

"Now an operator can, at a reduced cost, get in there and have a full one-to-one scaling. They can walk around a full pallet. If they need to look underneath something, they have to bend down. Their bodies learn this muscle memory of where everything is," explained Weisman. "This repetition makes [the system] second nature to them as the actual hardware. By doing repetition, it becomes engrained."

A big emphasis is that the virtual trainer is not designed to replace the training, but rather help someone who needs extra time on the system. The third application of the system falls in the tactical range. Instead of creating a 3D model out of sand, the team created a virtual sand table that allows for easier postmission analysis.

"The virtual sand table makes it very easy for someone to understand what happened in a digestible way," said Weisman. To show how the system would work in operation, the team tied the virtual sand table into boat and air traffic over and through the Potomac River Test Range at Dahlgren, as well as into the base camera system. "We have aggregate data sources coming in from different places to show visually, but we've also got a framework on the backend where we can pull all this data in and display it simply together."

The development aspect of BMS plays an important role when it comes to postmission analysis. Because the data is timestamped, it can be fused with the corresponding time, which allows for flexibility and insight after a mission.

"BMS has a lot of data, whether it's from test events, models or semantics," said Dahlgren Division computer scientist Brandon Gipson, a specialist in the backend development of the application. "Putting [data] into VR extracts it in a way where it's not just ones and zeros, but you can actually see an inflight path of an aircraft or drone during a test event."

With access to the wide range of data input from BMS, the team also is able to visualize everything they have collected information on during a scenario, including the state of sensors on the platform, the measured wind direction, wind temperature, and visual tracks.

During a recent visit at NSWC Dahlgren Division, Deputy for Test and Evaluation Assistant Secretary of the Navy for Research, Development and Acquisition Rick Quade experienced the tactical sand table firsthand. Although mostly in development, the applications for VR in BMS are growing exponentially.

"The tactical application gives us a good workspace to try out a lot of things and figure out what works or doesn't work," said Weisman.

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DAHLGREN DIVISION ENGINEERS BUILDING ARCHITECTURE FRAMEWORK FOR NEW FRIGATES

By Diana Stefko

"If we desire to secure peace," President George Washington once observed, "it must be known that we are at all times ready for war." During the late 1790s, the United States commissioned naval engineers and shipbuilders to design and build large warships capable of agile maneuvering and stowing an excess amount of weapons.

With the passing of the Naval Act of 1794, Washington secured the authorization to procure the Navy's first six frigates—three-masted warships of either 38 or 44 guns. One of these vessels, *Constellation*, launched in 1797, would cement its place in the Navy's distinguished history.

The ingenuity and progressive mindsets of those early naval engineers and shipbuilders provided the necessary framework that affected this era of shipbuilding. In a similar way of those early naval shipbuilders, today's workforce at Naval Surface Warfare Center Dahlgren Division is building the framework for developing innovative combat systems and integration essential to the fleet.

In April 2020, the Department of the Navy announced the intent to build and deploy the next generation of the *Constellation* (FFG 62)-class guided-missile frigates.

A team of scientists and engineers at Dahlgren Division is helping lead the effort in developing the Frigate Architecture Framework—a cybersecurity framework composed of products, policies, and methodologies joined to form a resilient compliant network architecture. The framework provides the blueprints to integrate proven combat system products with modern cybersecurity best practices for the *Constellation* class.

The Dahlgren team draws personnel from across the center as well as collaborates with other organizations within the Departments of the Navy and Defense,

Guided Missile Frigate systems engineers Christopher Cho and Andrew Wagner are leading the effort at Naval Surface Warfare Center Dahlgren Division to provide the architectural framework and combat systems engineering methodologies for the *Constellation* class. NSWC Dahlgren Division photo

including the other Naval Sea Systems Command warfare centers and industry partners.

"We maintain constant communication, meeting with multiple teams regularly, where all combat system representatives discuss and work out the details of integration for each of the elements and to stay on track," stated Christopher Cho, a frigate system engineer from the Surface Navy Combatants Engineering and Integration Branch at Dahlgren.

The team guides system product development, driving engineering decisions that align with the new architecture construct.

"We are working with each of the combat system elements and working out all the details that are required in order to be able to integrate this successfully into a working effective combat system," said Cho.

In the coming year, Cho and Wagner will continue to support Frigate Architecture Framework efforts with the mission to implement Dahlgren-developed architecture products and processes to drive integration decisions across the combat system and platform.

By 2026, the Navy is scheduled to take delivery of the first new *Constellation*-class combatant ships.

An artist's rendering of the new *Constellation* (FFG 62)-class guided-missile frigate. Marinette Marine Illustration

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BUILDING LIKE A BOSS:
NEW SOFTWARE FACTORY MODERNIZES ACQUISITIONS

By Steve Ghiringhelli

A MULTI-AGENCY TEAM THAT REBUILT THE NAVY'S INFORMATION TECHNOLOGY SYSTEM FOR ACQUISITIONS RECENTLY RECEIVED A MAJOR AWARD FOR THEIR EFFORTS.

Naval Information Warfare Center (NIWC) Atlantic took home major honors during the 2022 Department of the Navy Information Technology Excellence Awards on 23 May, highlighting a quickly emerging Marine Corps capability that may help the Department of the Navy improve how it develops software.

For data excellence, NIWC Atlantic shared the "Leverage Data to Drive Advantage" team award with the Navy's office of Acquisition, Policy and Budget for completely rebuilding the Navy's acquisition oversight system known as the Research, Development and Acquisition Information System (RDAIS). The entire effort was led and overseen by the Program Executive Office for Manpower, Logistics and Business Solutions' (PEO MLB) Enterprise Systems and Services and Innovation Support Services (E2S & ISS).

In the individual category, NIWC Atlantic systems engineer Matt Gallucci received the "Person of the Year" award for his accomplishments as the data team's chief engineer.

Following the awards presentations, a short ceremony was held marking the sunset of RDAIS 2.0 and the official full rollout of RDAIS 3.0—the latter of which was a three-phase enterprise onboarding of all Navy, Marine Corps, and Department of Defense users completed in December 2021.

"The RDAIS 3.0 team showcased how data can be strategically leveraged to achieve acquisition agility," said Aaron Weis, Department of the Navy Chief Information Officer. "The team also embraced and showed the advantages of the 'DevSecOps' approach [to software development].

"It was an amazing thing to watch the team retire the current generation and stand up this new capability," he said.

RDAIS is the Navy's authoritative source of programmatic information on cost, schedule, and performance for all Acquisition Category/Business System Category Level I-IV and Abbreviated Acquisition Program acquisitions. It is used to account for the acquisition of every piece of gear, equipment, product, weapon system, ship, aircraft, and ground vehicle in the Navy and Marine Corps.

"The development of RDAIS 3.0 was unique with so many Navy organizations and users coming together in a cutting-edge manner as a team," said Kevin Allen, E2S & ISS program manager. Multiple Navy offices and "more than 700 functional users collaborated together using a DevSecOps Continuous Integration Continuous Delivery agile software development process. What truly makes RDAIS a success is that it leapt forward in technology and [defense] procurement as well."

The RDAIS overhaul took just over one year to complete.

"The accomplishments of our combined team have been both exciting and exhausting," said Erik Gardner, NIWC Atlantic's RDAIS 3.0 technical lead. "They executed a monumental task with little to no precedent and took personal risks to organize, behave, and think differently. I am very pleased to see how our Navy is celebrating their pioneering spirit."

Department of the Navy Chief Data Officer Thomas Sasala called the rapid development and launch of RDAIS 3.0 a significant step forward.

"It is one of the first cloud-native apps we have deployed and the first to fully embrace the [Department of the Navy] enterprise approach to data management and electronic data exchanges," Sasala said. "The RDAIS team should be commended for their forward-leaning approach, commitment to the mission and unwavering focus on the customer."

MCBOSS

The prestigious awards threw a spotlight on NIWC Atlantic's achievement as well as the vehicle that got them there—Marine Corps Business Operations Support Services (MCBOSS).

MCBOSS is a cloud-native, software-development environment that NIWC Atlantic helped develop more than four years ago at the request of Headquarters Marine Corps, whose leaders wanted software development overhauled at the enterprise level.

"The vision for MCBOSS was to provide Marines a secure, user-friendly suite of software solutions that could be quickly developed and delivered across the enterprise," said Don Yeske, head of the Expeditionary Enterprise Systems and Services Division at NIWC Atlantic, where MCBOSS was originally developed. "That meant everything from your typical office-based scenario to training and sustainment operations to the tactical edge."

In 2019, MCBOSS moved into the fast lane, after Commandant Gen. David Berger released his guidance

prioritizing a transformational shift from disconnected legacy systems to an "integrated data architecture" that treats data as a critical resource.

"MCBOSS just happened to be at the center of a strategic technological shift in the Marine Corps," said Peter C. Reddy, NIWC Atlantic executive director. "In addition to more integration with the Navy, the Commandant stressed the need for automation and removing redundant administrative processes from the shoulders of Marines.

"That's what MCBOSS seeks to accomplish," Reddy added. "Let Marines focus on warfighting, not time-consuming data entry tasks."

Importantly, MCBOSS provides a foundation for enabling "DevSecOps" (development, security and operations), a software industry best practice that pairs programmers with system administrators and embeds security every step of the way.

One of the key drivers of the DevSecOps approach is the urgent time crunch the sea services are under when it comes to developing advanced, secure capabilities for warfighters, which can take years for conventional procurements to yield.

"In reality, what you may end up with is a solution to a four-year-old problem," said Jeff Hays, Enterprise Engineering and Integration Services team lead. "By that time, the problem has changed. Actually, we may not even have that problem anymore."

In any DevSecOps environment, real-time user experience informs every facet of development. Yeske emphasized how critical it is that process or organizational filters don't stand in the way. "You can't say you're doing DevSecOps if you're not regularly and directly engaging with your users," he said.

> **"MCBOSS JUST HAPPENED TO BE AT THE CENTER OF A STRATEGIC TECHNOLOGICAL SHIFT IN THE MARINE CORPS."**

RDAIS 3.0

By November 2020, the Marine Corps had become strong proponents of the burgeoning MCBOSS software factory, even releasing a requirement that all Marines use MCBOSS—or, as a second option, any other Department of Defense-approved DevSecOps environment.

This coincided with the successful rollout of PEO MLB's Logistics Integrated Information Solutions-Marine Corps portfolio's Technical Data Management–CATALYST (TDM-CATALYST), a software development platform that will be the future backbone for all Marine Corps logistics

business operations, including streamlining data for tracking repair parts and products on MCBOSS.

NIWC Atlantic played an integral role in developing the TDM-CATALYST app.

Around the same time, the Navy asked NIWC Atlantic to overhaul RDAIS. In response, NIWC Atlantic turned to a small team of software engineers working at the command's Operational Application and Service Innovation Site (OASIS), who recommended leveraging MCBOSS.

"We knew the Navy wanted to move toward cloud computing and modernized approaches to software development," said Gardner, a founding member of OASIS. "In addition to adopting a new technology, DevSecOps requires a shift in organizational mindsets. Old mentalities have to collide with new ones. But that change in culture requires proving another way of doing business will actually deliver value."

OASIS, which got its start around the same time as MCBOSS, is an incubator of sorts for software developers who are strong believers in DevSecOps and other agile approaches to software procurement.

The unique OASIS environment is primarily concerned with nurturing a DevSecOps culture at NIWC Atlantic, "evangelizing" the message outside of the command and enabling cyber-ready capabilities throughout the Department of the Navy enterprise.

"OASIS helps software development teams leapfrog slow-moving, traditional processes to rapidly build, accredit and deliver secure apps, whether in the commercial cloud, an enterprise data center or at the tactical edge," Gardner said. "But to disrupt the status quo, you need to get down in the weeds, ask pointed questions and constantly evaluate the user's experience to confirm what is being delivered equals real value."

In the case of RDAIS 3.0, NIWC Atlantic helped the RDAIS software team—which comprised engineers in Norfolk, Washington, DC, and Charleston, South Carolina—to transition to a modern continuous integration and delivery DevSecOps team, with full access to agile acquisition pathways and approved cloud vendor security authorities at the disposal of OASIS.

Gallucci led the RDAIS 3.0 team to acquire critical contract awards in less than 30 days, an "authority to operate" in an astounding 47 days and an operational continuous integration and delivery software factory

pipeline that updates the authorization to operate and deploys application improvements weekly.

The result was the first cloud-native Department of the Navy business app developed within MCBOSS.

In the citation, the Navy praised Gallucci's "fail fast" approach that sought to measure learning, digest performance trends, and quickly respond to continuous feedback—all critical facets to maintaining the focus of a DevSecOps venture on users' experience.

Acquisition professionals using RDAIS 3.0 can now share data, quicken their decision-making, and support enterprise data analysis through the Navy's "Jupiter" enclave, which acts as a funnel to the Office of the Secretary of Defense.

Through the success of the RDAIS 3.0 effort, Yeske said MCBOSS can help change how the Navy thinks about software acquisition.

"We never imagined several years ago that Marine Corps modernization in software development would end up effecting major modernization at the [Department of the Navy] enterprise level," Yeske said.

Capt. Nicole K. Nigro, NIWC Atlantic commanding officer, called the RDAIS 3.0 release a "remarkable achievement" considering the reboot was a total tech refresh of such a large and complex system.

"The greater Navy community now understands what we have known all along—NIWC Atlantic has developed a culture of outside-of-the-box thinkers who know how processes work, which strings to pull, and what hill is worth dying on to deliver value to the warfighter using DevSecOps," Nigro said. "I'm so proud of this team and how they leveraged MCBOSS to get the job done. I know they will continue succeeding well into the future."

In addition to NIWC Atlantic, the RDAIS 3.0 Development Team award included the following analysts and policymakers at the Office of Deputy Assistant Secretary of the Navy for Acquisition, Policy and Budget Jaimie Reese: Robert Borka, Dave Tervonen, Meghan Nelson, Nick Tran, Drew Yourish, Jade Settoon, Melanie Dong, Karen LeJeune, and Tom Angle.

> **"WE KNEW THE NAVY WANTED TO MOVE TOWARD CLOUD COMPUTING AND MODERNIZED APPROACHES TO SOFTWARE DEVELOPMENT."**

About the author:
Steve Ghiringhelli is a public affairs specialist with Naval Information Warfare Center Atlantic corporate communications and public affairs.

CRANE ENABLES
AI
WITH
DIGITAL TOOLS

By Sarah K. Miller

NAVAL SURFACE WARFARE CENTER CRANE DIVISION CONTINUES TO IMPROVE ITS ARTIFICIAL INTELLIGENCE READY INFRASTRUCTURE, WHICH PROVIDES HARDWARE AND SERVICES FOR THOSE WORKING IN ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING.

Naval Surface Warfare Center (NSWC) Crane Division continues to implement a high-performance computing solution to enable artificial intelligence, machine learning, and deep learning for the Navy.

The enabling hardware is called the Artificial Intelligence Ready Infrastructure (AIRI). It was first integrated into NSWC Crane's research, development, test, and engineering network in 2018 and continues to adapt to evolving technology changes. AIRI features hardware and services made available on the established Navy High-Performance Computing Catalog, which allows

anyone within the Navy to replicate an AIRI to use on both open and secure networks. The AIRI hardware enables technical experts to leverage digital tools in artificial intelligence and machine and deep learning.

John Strange, a computer scientist at NSWC Crane, was on the team that first procured the AIRI technology and integrated in Crane's open environment. Various industry partners have confirmed that AIRI installation was the first within the Department of Defense. Strange said the AIRI solution available on the Navy High-Performance Computing Catalog can have a broad influence and be leveraged more throughout the Navy.

"AIRI is a hardware configuration that enables data architects and scientists with a tool that could be used to run critical training workloads at scale while significantly reducing compute times," said Strange. "Previously, employees working in these technology fields were custom building machines for this workload. This new solution impacts data scientists and engineers performing artificial intelligence, machine learning, and deep learning work by providing a standardized platform that can be used across the enterprise. Ultimately, there is potential to extend the use of AIRI beyond [these areas] as well."

High-performance computing is the practice of aggregating computing power in a way that delivers much higher functioning than one could get out of a typical single desktop computer or workstation in order to solve big problems in science and engineering. Computation is constrained by power and speed. As defined in the National Defense Strategy, there is a growing need to implement key technologies such as artificial intelligence to meet the needs of the Department of Defense and ensure warfighters are able to fight and win future wars.

Strange said the catalog isn't just a tool for the Navy civilian workforce.

"Generally, if a Sailor needs to rapidly procure [high-performance computing] services, train their people or unit to get smart on artificial intelligence and machine learning, or bring this capability to their classrooms, they can also access this through the catalog," said Strange. "The catalog includes hardware and software and allows you to get what you need to do jobs in data science, artificial intelligence, and machine learning."

After implementing the industry high-performance computing solution to the open environment, Strange said there was a growing need to provide the same technology to support unique defense secure computing environments. They leveraged Naval Innovative Science and Engineering funding at Crane to find a solution.

"This AIRI was installed and integrated into NSWC Crane Division's open research, development, test, and engineering network and made available to our data science community to leverage with their projects," said Strange. "While this implementation met the needs for those with existing workload, there was not a solution for more secure work."

In February 2020, Strange was asked to procure a lightweight version of the system to be placed on another research, development, test, and engineering network.

"We leveraged an existing contract to procure all of the required materials and services, as well as coordinate the integration of the new AIRI with NSWC Crane and our vendors," said Strange. "Now, anyone with a research, development, test, and engineering seat can access these hardware platforms."

After the solution was implemented on multiple open and secure environments, it was made available across

the Navy on the Navy High-Performance Computing Catalog, which is available through NASA's Solutions for Enterprise-Wide Procurement (SEWP) website.

Strange said the catalog has adapted to new hardware and software needs since it launched.

"Since 2020, the catalog has been updated to reflect the changes in hardware as part of the technical refreshes that naturally occur in this type of contract vehicle," said Strange. "Hardware changes over time, as well as software and services. The catalog evolves as things get outdated; that evolution is due to the technical refresh ability. The catalog adapts as well. For instance, our catalog started out with the Nvidia DGX-1 as the most coveted item available on the catalog. Since then, Nvidia stopped manufacturing and selling this model and began selling the Nvidia DGX A100."

Nathaniel Priddy, an information technology specialist at NSWC Crane, has worked on this initiative. He said the catalog works with preexisting containers.

"Containers are like a sandbox for an application or code base," said Priddy. "It doesn't depend on anything being installed locally on your machine to run. The systems you can procure from the catalog have the ability to run containers out of the box."

Teresa Crevier, a contracting officer and branch manager at NSWC Crane, said the contracting solution used with AIRI could be significant for the Navy.

"The contracting solution is flexible, usable, fast, and can be procured in a matter of days," said Crevier. "It gives autonomous capability to use and there is no ceiling. It's available for collaboration with other warfare centers. This has potential to be a big deal across the Navy."

Strange said there are many benefits to implementing this technology capability more broadly.
"The Navy High-Performance Computing Catalog was created so that others outside of Crane could take advantage of this hardware more easily," said Strange. "The HPC products and services are available on the Navy HPC Catalog which allows for rapid procurement, standardization of hardware, ease of procurement, and allows for technical refreshes over five to ten years. The solution also provides robust capability to Crane's key technology thrust areas, which impacts each mission area and a wide variety of customers across the DoD."

To learn more and to access the catalog, you make an account here: https://www.sewp.nasa.gov/

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TEAMING UP FOR ICEX AT THE TOP OF THE WORLD

By Susan Farley with additional reporting by Evan Crawley

PERSONNEL FROM THE NAVAL UNDERSEA WARFARE CENTER DIVISION NEWPORT SERVED A CENTRAL ROLE IN THIS YEAR'S ICE EXERCISE, AN INCREASINGLY IMPORTANT JOINT AND MULTINATIONAL EXERCISE IN ONE OF THE WORLD'S MOST STRATEGIC, AND UNFORGIVING, ENVIRONMENTS.

A recent three-week work assignment led a group of Naval Undersea Warfare Center Division Newport (NUWC Newport) employees to the top of the world on a grueling, productive, and rewarding adventure. In early March 2022, the teams began their journey to the Arctic Circle—more specifically, to Navy Ice Camp Queenfish as part of the Navy's biennial Ice Exercise (ICEX).

ICEX allows the Navy to assess its operational readiness, increase its experience in the region, advance understanding of the Arctic environment, and continue to develop relationships with other services, allies, and partner organizations. The Arctic Submarine Laboratory out of San Diego, California, coordinated the exercise, including the Navy's activities.

Part of that operational readiness is understanding the performance of torpedoes in the Arctic region. NUWC Newport engineers and scientists provided expertise in torpedo software, tracking and performance data, torpedo flushing, post-fire processing, undersea communications support, and environmental planning and compliance.

Warfare center engineers Charles Lury, Stephanie Zamorski, Richard Marini, and Jason Lemish, were on hand to provide troubleshooting and guidance to leadership in the command tent and aboard submarines while NUWC Newport's torpedo recovery team, which included Fred Buzzell, Erin DeLucca, Bryan Sullivan, Sean Riccio, and Nick Savage, recovered five exercise torpedoes from under the ice.

NUWC Newport's team was joined by other research and operational teams from the United Kingdom, Norway, Seal Team 2, and the Massachusetts Institute of Technology. The UK team, in particular, was there to observe NUWC Newport's torpedo recovery team as they worked through each recovery.

In preparation for ICEX 2022, the torpedo recovery team trained the underwater construction team from Virginia Beach, Virginia—which included Coast Guard divers—and the Mobile Diving and Salvage Unit from Pearl Harbor, Hawaii, on torpedo recovery procedures.

"It's a team effort to recover torpedoes fired during ICEX," Buzzell said. "It takes so much just to do the work that we wanted to make sure they were confident in the procedures."

Members of NUWC Newport's Engineering and Diving Support Unit have supported previous ICEX events, as part of the torpedo recovery team, but this was the first year that a NUWC Newport diver participated with other dive teams to complete an under-ice torpedo recovery. The process for recovering a torpedo in the Arctic is detailed and arduous, which is made more complex by extreme cold temperatures and windy conditions, said Savage, who took on that new role.


Sean Riccio and Bryan Sullivan in front of the submarine at ICEX 2022. Photo courtesy of Sean Riccio

"This experience brought my day job full circle and showed me the big picture," Savage said. "My day job often involves providing engineering dive support for submarines' towed array handler systems in port. One of the boats I repaired in recent months was the first one we saw break through the ice, thousands of miles away. Speaking with personnel from the ship and getting a report of no issues since was a cool feeling. It's a rare opportunity to see any boat out of port, but seeing that one was pretty special to me."

To prepare the team of ICEX newcomers, Buzzell made sure they knew what to expect from the exercise, environment, and living conditions. Most of all, he stressed the importance of safety.

"The Arctic is one of the most challenging environments on the planet," Buzzell said. "Every single part of the job is dangerous. For instance, we have to be very, very careful around the holes and make sure to clear the snow around the holes."
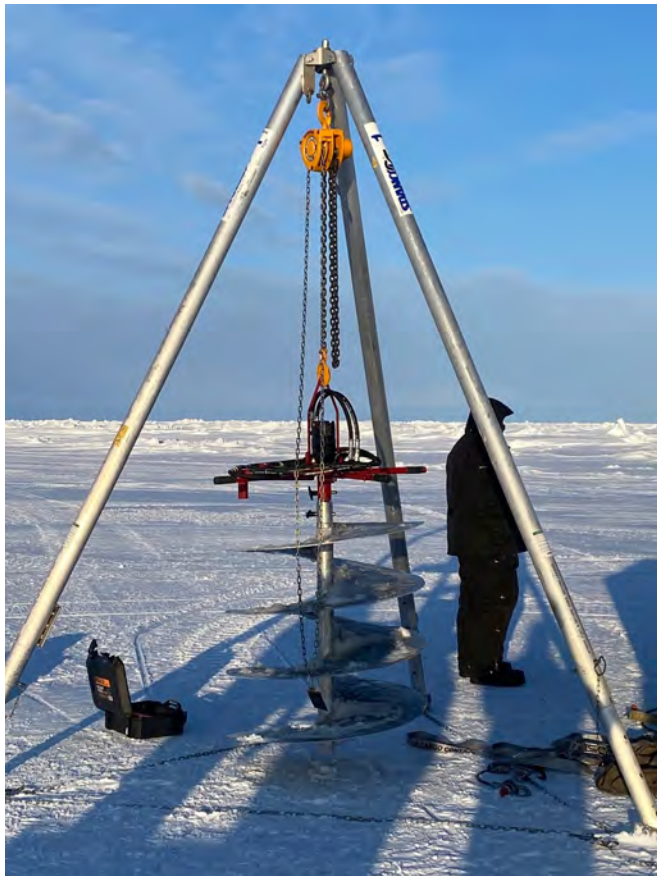
A specialized augur helped the teams retrieve five torpedoes through the ice during the exercise. NUWC Division Newport photo

This was Buzzell's third ICEX, and with each event he applies valuable lessons learned and new safety precautions. For example, specially designed sleds are used to move the torpedoes. By replacing a tripod with a gantry to set the torpedo on the sled, the team saved an hour—an important safety feature when every minute in extreme temperatures adds risk. The team spent nine days in the frozen environment—where the warmest day registered at minus 10 degrees Fahrenheit.

When a previous manual method for torpedo retrieval proved unwieldy and potentially hazardous, Buzzell conceived a new two-speed winch process using ballast weights. Working with the NUWC Newport's machine shop, his idea and sketch soon became a reality. ICEX 2022 was the first opportunity to employ this new device, which made quick work of the recovery while also making the process safer for the divers as well as those on the surface.

Buzzell researched the materials needed to withstand harsh Arctic conditions, determining that aluminum for the winch and strong, buoyant, and lightweight line for towing would work best. The idea is pure engineering and problem solving at work; Buzzell's design has since been submitted for a patent.

Time is a significant factor in all aspects of ICEX safety. Ice holes can freeze over in minutes, equipment can break, and both divers and their diving gear are at serious risk. To mitigate that risk, divers are the last to arrive on site and the first to leave.

"[The Arctic Submarine Laboratory] did a good job of planning and keeping the divers and dive gear warm," Savage said. "It can be catastrophic if the gear gets too cold and/or freezes. We had one day where external pressures caused the plan to change and for gear to sit on the ice a few minutes longer and some of the regulators froze. It was a time difference of about five to 10 minutes. We appreciate why [the laboratory] had those safety plans in place."

Another important step in the torpedo recovery process is removing the seawater from the torpedo's fuel tank, as seawater replaces fuel in the tank during the torpedo's run. The team must quickly remove eight gallons of slushy seawater within ten minutes of returning to camp to prevent damage to the rest of the torpedo's mechanism because of freezing. Practice and good communication allowed for the successful recovery of all five torpedoes and the draining of the fuel tanks throughout the event.

"Every action is meant for safety," Buzzell said. "It's a dangerous place. It might not look that way, but it is. Working in the Arctic is like nothing you've ever done."

"It's like flying to another planet," Sullivan added. "The conditions are so bizarre that you just deal with it the best you can. You use a lot of creativity and problem-solving."

Once the seawater was removed, the torpedoes were then shipped to Prudhoe Bay, Alaska—about 200 miles south of the Camp Queenfish ice floe for post-processing.

Despite the harsh conditions and long workdays, the team has many great memories of ICEX 2022.

"[The laboratory] and the Navy have gone through great lengths to make this event as safe as possible. Sure, there is more risk than a typical exercise, but to date there have been minimal—if any—injuries to Division Newport personnel over several ICEX events," said Lury. "This is

Flags at sunset at Ice Camp Queenfish. The exercise included personnel from the United States, the Royal Canadian Navy and Air Force, and the United Kingdom's Royal Navy. Photo courtesy of Sean Riccio

one of the highlights of my career and for a lot of the people I travel with it is for them."

"I will remember all the folks involved from various Navy commands all coming together to complete the mission safely and on schedule," Sullivan said. "We were only together for a very short time and had to become one team very quickly, which resulted in a successful exercise."

Savage echoed similar sentiments, noting how smoothly everything went with his team despite each of them having different day jobs.

"It was exciting, fun, and extremely memorable to work with such a great team," Savage said. "There was no sense of complacency and we were constantly looking at how we could work more efficiently not only during the operation, but for the next one as well."

As for the team leader, Buzzell will remember the way this new team was able to expertly execute the job.

"They worked very well together and made it seem that they had performed the evolutions many times before,"

Buzzell said. "I was impressed with each one of them."

That is not to say, though, that Buzzell would not do a few things differently next time.

"Next ICEX, I'll bring three neck warmers and one of those fur trapper hats. I'll also bring some lightweight insulated coveralls for camp use," Buzzell said. "There are still some process improvements that will be incorporated into the next event."

Ultimately, though, it was an experience that those involved will not soon forget.

"Every day was an awesome adventure and an experience that words cannot explain," Riccio said.

About the authors:

Susan Farley is a project manager and **Evan Crawley** is a technical writer, both with McLaughlin Research Corporation supporting the Naval Undersea Warfare Center Division Newport's public affairs office.

VERTICALLY INTEGRATED PROJECTS ACCELERATE THE PIPELINE

By Alan J. Michaels, William C. Headley, and Bryan D. Woosley

**VIRGINIA TECH AND THE NAVY ARE WORKING TOGETHER TO CREATE A NEW PIPELINE FOR THE DEFENSE WORK FORCE OF THE FUTURE.**

The Virginia Tech Hume Center for National Security and Technology is helping to cultivate the next generation of civilian leaders for the Navy, the Department of Defense, and the intelligence community to address critical science, technology, engineering, and math (STEM) gaps. A recent Office of Naval Research (ONR)-sponsored adaptation of the international vertically integrated projects (VIP) experiential learning model has created a foundational multidisciplinary research model that establishes thematic workforce development pipelines, feeding the front end of the nation's civilian STEM workforce.

As a concrete example of this VIP structure, Virginia Tech partnered with Naval Surface Warfare Center (NSWC) Crane Division through the Naval Engineering Education Consortium to create the Attacking Radio Frequency Machine Learning (Hack RFML) team, which has engaged more than 30 students, produced nearly a dozen student-led research papers, and contributed to a variety of applied research results approaching technology transition. Building on ONR and Crane's early adoption of the Hume Center's national security-focused VIP

model, additional contributions are being sponsored by the Office of the Undersecretary of Defense (Research & Engineering), the Office of the Director of National Intelligence, the Commonwealth Cyber Initiative, Raytheon Technologies, and CACI.

Vertically Integrated Projects

The VIP concept for experiential learning was initially developed at Purdue University, expanded and refined at Georgia Tech, and more recently graduated to an independent consortium consisting of 40 international member universities. Each university member has adapted VIP to fit their home institution, but common themes include the idea of faculty-driven, experiential learning-focused projects that are multidisciplinary, encourage team-based research, and built around long-term objectives that expand beyond individual semesters or deliverables. As such, students are encouraged to participate in the VIP efforts for multiple years, often starting in their freshman or sophomore years, and serve as mentors to incoming students as they grow into subteam leads. The Hume Center adaptation, sponsored by ONR,

ENGE 2634: *Intro to Restricted Research*

Hume Experiental Learning Infrastructure using VIP@VT Model
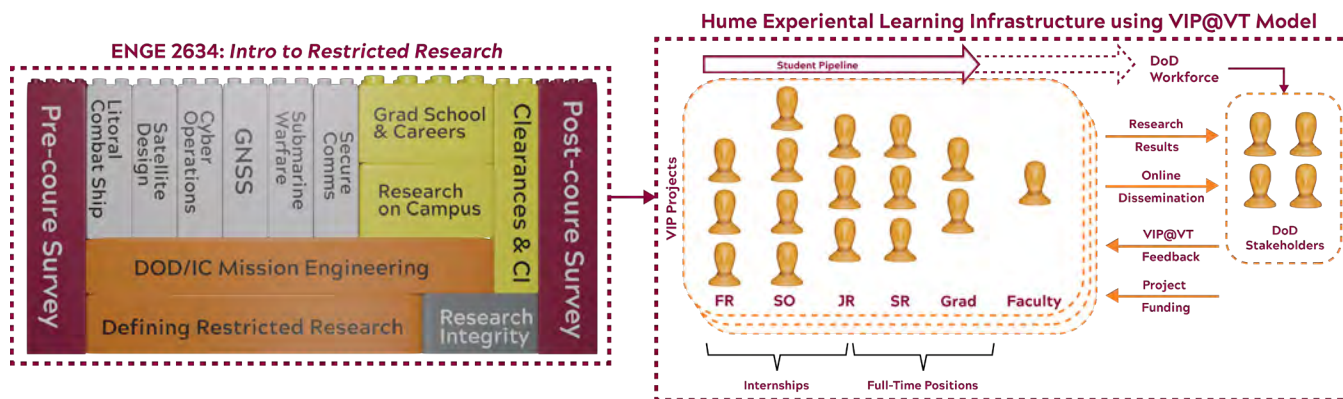
The pipeline-based experiential learning model, beginning with a sophomore-level, ITAR-controlled Introduction to Restricted Research course. Graphic by Chelsy Ables

places additional emphases on cultivating clearable US-citizen student pipelines, engaging students in real-world defense missions through hands-on, International Traffic in Arms Regulations (ITAR)-level research problems, and introducing undergraduates to restricted research through formal ITAR-level classroom experiences. Many of the defense labs have assisted with communicating these missions and career opportunities to students.

Intro to Restricted Research Course

As part of the VIP@VT program, we created a multidisciplinary ITAR-level curriculum for general engineering and sophomore students called "Intro to Restricted Research," recently approved as ENGE 2634. This class incorporates a common theme of requirements-based design while deconstructing missions and solutions such as the littoral combat ship, submarine warfare, special communications, satellite design and navigation, and the AH-64 Apache. There are guest speakers from national labs and faculty with on-campus opportunities for students to engage in restricted research, as well as an overview of the security clearance process. Post-course student surveys from the initial class showed 82 percent of responses indicate the experience made them somewhat/much more likely to pursue a career in the national security sector. Many of those students have joined experiential learning activities at the Hume Center, as well as shared their experiences with friends, contributing to increases in experiential learning participation. Based on these early results, the Office of the Undersecretary of Defense (Research & Engineering) has sponsored an expansion of the class, further facilitating Navy and defense engagement on campus.

Hack RFML

Our earliest adoption of the unique national security-focused VIP model was in an NSWC Crane-sponsored Naval Engineering Education Consortium project aimed at a cyber/electronic warfare evaluation of radio-frequency machine learning techniques. The project was broken into two subteams, the first seeking to test the resiliency of machine learning algorithms deployed on commercial-grade spacecraft, and the second evaluating

adversarial attacks (dataset poisoning, communications aware adversarial techniques, etc.), which may be viewed as tailored physical-layer cyber/electronic warfare payloads used to fool an adversary's machine learning system. To date, this research has engaged three graduate and nearly 30 undergraduate students; produced ten student-led conference/journal papers, three master's theses, and a military communications tutorial; and recognition of the team as most innovative team project at the 2019 VIP regional competitions. Equally important to these research outputs are the in-person engagements for NSWC Crane recruiters coming to campus, engaging with students as external evaluators, and on-site lab tours with the student team having an opportunity to visit and learn about life at Crane—witnessing operational systems such as the Ship's Signal Exploitation Equipment (SSEE) user terminal refurb and/or Trident II missiles in person.

Conclusions

This unique implementation of the VIP model, and the Navy-sponsored VIP@VT adaptations aimed at tailoring this pipeline structure to future defense workforce pipelines, have established an infrastructure at Virginia Tech that is promoting growth in a variety of clearable US-citizen STEM student pipelines. We see growing interest and engagement from the Navy labs, and anticipate near-term creation of additional VIP teams that will research electromagnetic materials and future undersea communications architectures. We hope to continue broadening the sizes and diversity of these thematic research teams to assist with filling critical skill gaps of tomorrow.

About the authors:

Alan Michaels and **William Headley** are professors in the Spectrum Dominance Division of Virginia Tech's National Security Institute.

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Marine Corps Lance Cpl. Tristen Crowell, a team leader with 3d Battalion, 3d Marines, holds security inside a secured building during military operations in urban terrain training on Marine Corps Training Area Bellows, Hawaii. The training was conducted to increase unit lethality and improve tactical decision making skills in offensive and defensive operations. This issue of Future Force explores the many ways science and technology are adding to the effort to achieve decision superiority.
Photo by Lance Cpl. Terry Stennett

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