UNDERSEA WARFARE TECHNOLOGIES
Advancing Undersea Capabilities

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Undersea Warriors,

Greetings from Norfolk! Last issue we spoke about the Asia-Pacific, its dynamic environment, and the highly professional submarine forces that partner with us there. This issue covers the work of other crucial Submarine Force partners: the highly capable research and development organizations ensuring that we own the best systems and platforms. Much of this issue specifically discusses expanding the reach of those platforms with a new generation of autonomous undersea vehicles.

The time for these systems is clearly now. The Navy’s Design for Maintaining Maritime Superiority points out how the increasing rate of technological creation and implementation drives the rapidly accelerating changes we face in the maritime environment. Our adversaries are aware of, and adapting to, these changes. We need to get faster in our operations, learning, processes, acquisitions, and innovation to outpace them.

Reading through this issue will give you a couple of examples of how we’re doing just that; from the use of virtual and mixed reality for the purpose of production and training to advancements in Unmanned Undersea Vehicles (UUVs) and cognitive thinking Autonomous Undersea Vehicles (AUVs). Our record of success is growing as demonstrated by the shortened delivery schedule and reduced cost of the Virginia-class, which was designed in a virtual environment. The use of virtual technology has enabled the inexpensive delivery of immersive environments for the purpose of training, while augmented reality delivers amplifying details to allow for more effective and efficient real-time decision making. Taking it a step further, we’re looking to equip AUVs with “intelligent autonomy” to carry out an independent decision-making process based on decades of corporate knowledge and then execute based on those decisions.

One thing hasn’t changed though. It doesn’t matter if the machine is manned or unmanned; any submarine sitting at the pier is capable of doing just one thing by itself; rusting. It is the people who design, test, build, operate, and maintain the machines who determine how effective they will be in combat. Make no mistake; combat is our business. I could not agree more with Rear Adm. Roegge’s statement in this issue that, “the quality of our Submariners is the best it has ever been.” The intelligence and resiliency of our Submariners and supporting partners allow us to make our force stronger. There’s an old saying: “if you’re not getting better, then you’re getting worse.” No matter where you are in the force, I challenge you to continuously improve the processes where you are today to produce a leaner, more flexible, more efficient and lethal force.

That is how we all get better.
That is how we will win.
Thank you for all you do. Keep charging!

J.E. Tofalo
FORCE COMMANDER’S CORNER
Vice Adm. Joseph E. Tofalo, USN
Commander, Submarine Forces

“I could not agree more with Rear Adm. Roegge’s statement in this issue that, “the quality of our Submariners is the best it has ever been.”

Undersea Warfare Technologies

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U.S. Submarine Commissionings and Decommissionings

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U.S. Navy Divers display the American Flag out a dry deck shelter mounted on an SSN while conducting UUV testing operations.

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In this issue you will have the opportunity to read about new technologies we’re pursuing, including our family of unmanned vehicles, mixed reality solutions, cognitive computing, and fundamental shifts in our build philosophy. This complex plan establishes the basis for quickly leveraging evolving improvements and revolutionary technologies, establishing the clearinghouse for inputs from the fleet, industry, and builders. A clear example of how this will be used is our intention to “up-arm” our SSNs by leveraging existing weapons to improve our lethality in multiple domains. Stay tuned.

In this issue you will have the opportunity to read about new technologies we’re pursuing, including our family of unmanned vehicles, mixed reality solutions, cognitive computing, and fundamental shifts in our build philosophy. Also in this issue, RADM Fritz Roegge shares his insights as Commander, Submarine Force Pacific, a very active part of the world. Keep up the great work out there; we’re behind you 100 percent. You are part of the domain team that is expected to own the seas before and during any conflict, no matter the adversary, no matter the location. Wear that pin proudly. Like so many before us, the nation depends on our ability to conduct its business forward, with certainty.

W. R. Merz
In your mind, what is your role as Commander, Submarine Forces Pacific (COMSUBPAC)?

As a type commander, my staff is responsible to man, train, and equip Pacific Fleet submarines for their missions. Those missions are the same as the ones that Commander, Submarine Force, U.S. Atlantic Fleet (COMSUBLANT) submarines perform, but of course we tailor our efforts for the unique operating areas of the Pacific, whether in deep-water broad-ocean areas or in shallow-water high-contact-density environments.

COMSUBLANT and COMSUBPAC differ from other Navy type commands because of our operational command responsibilities that are in addition to our man/train/equip functions. Here in the Pacific, I command Task Force 34, responsible for Theater Undersea Warfare (TUSW) in the Eastern Pacific under Commander Third Fleet, and I also command Task Force 134, responsible for the strategic deterrent mission under Commander, U.S. Strategic Command.

COMSUBPAC is also the one type commander with Navy-wide man, train, and equip responsibilities for some unique undersea missions. These include our submarine escape and rescue capabilities under Submarine Squadron 11 in San Diego, Calif.; the fixed arrays and the Surveillance Towed Array Sensor System (SURTASS) ships of our Integrated Undersea Surveillance Systems (IUSS) under Commander, Undersea Systems in Dam Neck, Va.; the research and development programs such as Unmanned Underwater Vehicles under Submarine Development Squadron 5 in Bangor, Wash.; and our two submarine tenders now home-ported in Guam.

In order to achieve this, I provide guidance and set priorities, such as we did last year when we published our “Commander’s Intent for the Submarine Force and Supporting Organizations.”

This is sort of a “textbook” definition of my role, but I think a simpler way to describe it is that my job is to provide what our submarine crews need in order to be successful at the challenging missions we assign them and to help Sailors accomplish their own personal and professional goals.

The combination of this important work, our superb Submariners, and the fact that I wake up each morning in Hawaii, means that I clearly have the best job in the Navy!

What challenges do you see today in the Pacific Theater?

Our challenges are pretty clear from every newspaper’s headlines and from watching the news banners scrolling across your favorite cable news program. Competition among nations often plays out first in competition on the high seas, and so there are many Indo-Asia-Pacific nations adding to their naval capabilities and, more specifically, their submarine capabilities.

Russia is operating at levels we haven’t seen since the Cold War, and they’ve modernized their force with new platforms like the Severodvinsk SSGN and the Dolgorukiy SSBN and with new capabilities like the Kaliber weapons system. China is expanding its capabilities and also the areas of their operations. They’ve deployed surface action groups around the world and even into the Bering Sea, and their submarine operations are similarly expanding in their reach. This year both North Korea...
and India launched ballistic missiles from submarine platforms, and around this region there are now more than 20 nations operating submarines or pursuing that capability.

With RIMPAC 2016 concluding, what lessons did we learn from the exercise? We confirmed what we already knew: no matter what flag they fly, naval forces and their Sailors and Marines have much more in common than they have as differences. The most important commonality was the talent and professionalism of each nation’s mariners and their focus on improving our ability to work together. This was no small task, as RIMPAC 2016 had 26 nations participating and brought 45 surface ships and five submarines to Pearl Harbor. As both the RIMPAC TUSW Commander and also as the submarine operating authority (SUBOPAUGHT), we invested heavily in ensuring exercise safety, and I was pleased that we had no untoward events. The personal relationships that develop through such multi-lateral operations build trust, and we have long understood the need for trust to be an operational enabler, it must be built. You cannot surge Trust.

What role do our international partners play in the Pacific Theater in the Undersea Domain?

COMSUBPAC submarines benefit from the great partners, friends, and allies we share in the Pacific. Our boats and their crews benefit from port visits and logistics stops in traditional locations like Japan, Korea, the Philippines, Singapore, and Australia. This year we’ve also had submarines and tenders in Malaysia, Palawan, and Vietnam. This access is essential for us to maintain our boats at high readiness throughout their lengthy and demanding deployments. In return, we’ve had visits to U.S. homeports from a number of our partners and friends in Japan, Korea, Malaysia, Australia, and Chile; and many more nations send Submariners to attend courses and use the trainers at our training centers in Pearl Harbor and in Guam. This not only gives our subs the opportunity to train against advanced and highly proficient diesel subs, but it improves our interoperability; and this is paying off now in increasing multi-national cooperation—and success—in TUSW.

What is your favorite memory or sea story from your junior officer or department head tour?

All my fondest memories are associated with great shipmates doing success—in TUSW. This is paying off now in increasing multi-national cooperation—and highly proficient diesel subs, but it improves our interoperability; and now our submarines were the only forces able to immediately begin war patrols. They carried the battle across the Pacific and into Imperial Japanese home waters while our fleet was repaired. And although submarines made up only 2 percent of our entire Navy, they sunk 30% of all Japanese warships and 55% of all Japanese merchant ships sunk.

But today’s Submariners are another greatest generation, and what we do every day is adding to the proud history of our Submarine Force. Undersea superiority is just as important to our national security today as it has been throughout our past, and we’re making significant investments in modernizing our submarines, in adding capabilities like UAVs and UUVs, and in our people through initiatives such as those in Sailor 2025 in order to ensure we maintain that superiority. As potential adversaries develop capabilities designed to thwart the United States, the risk to aircraft and ships grows daily, but the Submarine Force retains the unique ability to go undetected anywhere in the world and to hold at risk the things that potential adversaries hold most dear. So should the future hold another Pacific competitor to challenge the United States, then in that future it will once again be the Pacific Submarine Force that will lead the way. That makes this an incredibly exciting time to be a Submarine, and an incredibly important time for our Submarine Force to maintain its superiority. Our Navy and our nation should expect no less.

How has the role of a Pacific SSN changed since you were a junior officer?

Our submarines have so much more capability now, and the quality of our Submariner is the best it has ever been. But our SSNs still rely upon the same core characteristics of stealth, mobility, endurance, and firepower. Our Navy and our nation still rely upon us to use those attributes to demonstrate warfighting processes that will deter aggression; we must be able to operate undetected anywhere in the world, and be able to hold at risk the things that potential adversaries hold most dear. To that extent, our role hasn’t changed at all.

What is the greatest lesson you learned as a junior officer?

To be myself. I originally thought there was some textbook approach to being a division officer or a watch officer that had to be followed. Over the years I’ve learned that there are many different ways to be a successful leader, and trying to act against your own nature in an effort to emulate someone else’s approach is usually as unsuccessful as it is unnatural.

Where do you see the Pacific Submarine Force going in the future?

I think our future is informed by our past. On December 7th in Pearl Harbor we remembered the successes and the sacrifices of our World War II Submariners. After that attack, Chief of Naval Operations Admiral Harold Stark gave the order to “EXECUTE AGAINST JAPAN UNRESTRICTED AIR AND SUBMARINE WARFARE,” and our submarines were the only forces able to immediately begin war patrols. They carried the battle across the Pacific and into Imperial Japanese home waters while our fleet was repaired. And although submarines made up only 2 percent of our entire Navy, they sank 30% of all Japanese warships and 55% of all Japanese merchant ships sunk.

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Much of what makes the U.S. Navy so effective at defending U.S. interests at home and around the world is a result of its longstanding relationships in the private sector. Industry and academia continue to contribute to the Navy’s unmatched strengths by conducting research and development in cutting-edge technologies. They work hand-in-hand with us to apply those advancements and breakthroughs to naval applications, making what was once the domain of futuristic science fiction a reality for our Sailors today.

In this issue we provide a glimpse of such futuristic technology and the processes by which it gets put to use by America’s Navy. The following four articles examine how industry and academia leverage their technological expertise on behalf of your Navy so that we can meet our goals and objectives in protecting Americans and our allies and friends overseas. Following are two articles from academia partners, followed by two more from partners in industry.

The first article comes from Johns Hopkins Applied Research Laboratory (JH APL), delves into the realm of augmented reality and virtual reality, both facets of what is called mixed reality. These technologies have made significant progress lately, and JH APL is bringing them to bear on Naval training applications. Training Sailors by using these technologies was cost prohibitive a decade or so ago, but the commercialization and growing popularity of the hardware and applications is driving costs down and making training in potentially high-risk or complicated activities accessible and safe, not to mention effective.

The second article comes from from Penn State University’s Applied Research Laboratory. The authors describe how intelligent autonomy can be applied to Navy UUVs using the existing submarine command structure and crew knowledge base to give it intelligent autonomy. This will give the MANTA decision-making abilities similar to those of a live watch stander crew.

The third article comes from an industry partner, Riptide Autonomous Solutions, which has developed a small but capable unmanned undersea vehicle (UUV), that can be fielded in large numbers at low cost. The small UUV, along with other sized vehicles, has the potential to address the rapid global advancement of submarine technology by future potentially adversarial governments. It will do this by providing an adaptable UUV platform that can be deployed in large numbers, extending sensor ranges and acting as force multipliers. This platform is promising enough that Navy labs have begun to take deliveries of the small UUV for Navy-specific experimentation and testing.

The fourth article is from an industry giant that got its start by selling the Navy its first submarine, the USS Holland (SS1) in 1900. General Dynamics Corp.’s Electric Boat Division gives us a look at how independent research and development processes are used to create previously impossible technologies and capabilities, one only the province of imagination and wishful thinking, not only possible but a reality. From digitizing display and flow and force characteristics of propeller backwash to better study and understand its effects and improve propeller design to developing and integrating the Virginia-class Block III Large Aperture Bow array to save space and money and improve the array’s capabilities, Electric Boat’s independent research and development processes have helped to make these and other significant advancements possible.

It’s often difficult to see clearly what’s in our technological future, particularly in the area of submarines, for which secrecy and stealth are vital to mission success. Without divulging too much, we’ve pulled back the curtain a bit in this issue to give you just a peek at some of the things that the Navy, in cooperation with our academic and industry partners, are bringing to our very near-term future.
Mixed Reality for Submarine Applications

Recent technology advances in high-resolution displays, motion sensing, and compact computing/micro-processing have changed the way people interact with computing. Immersive environments can now be delivered inexpensively to anyone who owns a smartphone. A small additional cost of a head-mounted display can take that immersive presentation to the next level. This immersive computing technology is referred to as Mixed Reality (MR).

Mixed Reality covers the spectrum of technologies that have been maturing rapidly over the last decade. The continuum of MR spans from the physical (real) world to the fully virtual and includes Augmented Reality (AR) and Virtual Reality (VR). MR adds computer-generated objects/environments to varying degrees to enhance a user’s knowledge or understanding and enable interactive behaviors within the MR environment. DoD has long been investing in technologies that enable the range of MR experiences. Initial investment resulted in lab-based prototypes that supported expensive training and held the promise of future operational use. However, this R&D investment is on the verge of bearing real operational fruit with the commercialization of the technology. MR technologies are currently being tackled and may soon be overcome with programs like Intel’s initiative, Project Alloy. While technology continues to advance, the understanding of its impact on people and effects of use for extended periods of time are not fully tested.

One of the biggest challenges to getting the technology deployed is the burden of developing quality 3D content. Another immersive technology, Augmented Reality (AR), maintains the physical world and blends new information into the user’s field of view. One of the first commercial applications of AR technology was the yellow first-down line in televised football games. AR affords much more mobility than a full immersive VR and does not always require head-mounted displays. Many AR applications run on mobile devices like smart phones and tablets. AR provides information quickly and exploits or discriminates objects in the real world. This ability makes AR an excellent fit for navigation applications. AR also allows a level of limited tactile feedback as it can work with real-world objects. Additionally, AR worlds generally don’t require the visual fidelity of VR to recreate the environment and thus need less graphical processing to be effective.

Similar to VR, AR is not without its own limitations and drawbacks. Many AR devices are less capable graphically, resulting in lower fidelity and lower-quality 3D imaging. The AR mobile devices are also more limited in power and battery life. AR devices sometimes have difficulty synchronizing the real world with blended objects. AR devices rely on multi-sensory input to display correctly (e.g., wireless motion, graphics, range, and light distortions). AR applications are prone to over saturation or information overload and as a result can distract the user from core objectives, and a user-centered design approach is key to successful implementation. As with VR, the impact on the user is not yet fully researched and tested. As with VR, the biggest hurdle with AR is the ability to develop and map quality content.

The enhancements to the physical world and simulation of real-world effects lend MR to things that are seldom practiced in the real world, things that are complicated and hard to understand, novel experiences that are difficult to practice (AR for maintenance), and things that require suspension of belief to be effective (VR for fire drills). MR has shown to be effective, however, in improving human performance through immersive training, realistic mission rehearsal, and enhanced information presentation.

“Mixed Reality covers the spectrum of technologies that have been maturing rapidly over the last decade. The continuum of MR spans from the physical (real) world to the fully virtual and includes Augmented Reality and Virtual Reality.”
Many years of MR research and development has shown great promise in improving mission performance. Research has demonstrated the effectiveness of AR and VR to various applications that are directly related to submarine operations. Education studies have found that learning time decreases with virtual simulations and that AR is an effective educational medium. These studies found that AR allowed mechanics to locate tasks more quickly, in some instances, with less overall head movement than when using current maintenance aid systems or an enhanced version of the system currently used by U.S. Marine Corps mechanics.

Applying MR capabilities to future submarine fleet applications has the potential to improve operator effectiveness, situational awareness, training, and mission rehearsals.

Operator effectiveness
AR enables overlaying information on a user’s environment based on access. This can enhance team collaboration and communication by enabling teams with different levels of security to be co-located and reduce the information flow bottlenecks. Additionally, as seen in maintenance applications, AR allows for overlay of task steps that are complicated, rare done, and difficult to recall. VR allows for immersive collaborative environments for individuals who are not co-located. A shared environment extends the Common Operating Picture concept and would allow for collaborative interaction of the environment; when one individual interacts with an entity in the environment, the other collaborative participants would also experience the change.

Situational Awareness (SA)
Extensive design and development has been conducted for displaying submarine and submersible SA displays for post-mission analysis as well as real-time tactical decision aids. Although some 3D technologies are beginning to be used, most of these displays are still 2D. As fleet submariners are required to conduct more operations in concert with other manned and unmanned systems, the opportunity to use VR and AR in multi-source intelligence and other SA tools will improve operational effectiveness. VR and AR have the potential to improve SA across the operational functions in a submarine and other platforms. One example of using AR in operations for enhanced SA is the Navy’s Divers Augmented Vision Display (DAVD) research program. DAVD is a high-resolution, see-through, head-up display embedded directly inside a diving helmet. This NSWC Panama City-developed prototype can provide divers with real-time visual display of sonar, text messages, diagrams, photographs, and video. The VR technology development is much further along than the research to explore new ways of showing SA data using these devices. The cost effectiveness of emerging hardware allows for more research into the best ways to leverage AR and VR technologies to support SA in submarine operations.

Training and Mission Rehearsal
Research in learning demonstrates that ideal mediums of learning are based on the learning objective. For example, you might want to have supplemental information hover over a physical system component; AR is well suited for this application. The training requirement may instead be to practice a given physical task in a specified level of proficiency; this type of training is suited to VR where that physical task can be simulated in an immersive environment full of risk where actual mistakes don’t result in real danger. A current Navy example of this is the Virtual Environment for Submarine Shiphandling Trainer (VESUB). VESUB is a VR-based computer system using virtual environment and head-mounted display technology. The trainer provides the Officer of the Deck (OOD) trainee individual instruction in the knowledge and skills necessary to successfully and safely pilot and maneuver a surfaced submarine through restricted waterways avoiding collisions and groundings.

AR and VR technologies are possible and useful for training and mission rehearsal; the issue is determining where to apply them. The commoditization of these technologies offers an opportunity for the Navy to match the right training environment (SA, VR, AR) based on training objectives. This facilitates development and deployment of effective training environments that leverage the best of all technologies. These technologies are mature and, when coupled with physics-based modeling and simulation capability, have proven to be a very effective way of delivering training for a modest investment. MR-based training is software-intensive to allow for rollout of the training quickly. An incremental/agile strategy of focusing on the most critical (or deficient) learning objectives has worked well for these systems. This approach has also been synergistic with existing but more expensive training assets (e.g., hardware trainers / reality platforms) as VR is cost effective for reaching a large audience and preparing students for the most effective training possible in expensive or unique training assets.

VR technologies have the potential to improve the suspension of disbelief required for providing engaging training products. Several VR trainers already exist; however, additional research in determining how these technologies could be best applied to training in the naval special operations community is needed. VR training is much more feasible given the significant reduction in hardware cost. For example, it is known that experiential learning improves acquisition of skills; these environments enable low-risk experiences that may be applicable to operations. VR would provide an opportunity to rapidly and inexpensively research, develop, and test training technologies that can be deployed across the service, allowing for skill retention and career progression. Sailors could take tests in a low-risk, distributed learning environment providing experiences applicable to high-risk operational activities. This would enable a research initiative with the aim of transitioning to operational training.

The Navy and submarine community recognize that MR has great potential to impact operator effectiveness and mission readiness. The Office of Naval Research, in collaboration with Space and Naval Warfare Systems Center (SPAWAR) in San Diego, has created an augmented reality exploitation program known as BARRETT (Battlespace Augmented Reality Exploitation Technology) Lab to showcase cutting-edge technology for the warfarefighter, researchers, government, industry, and academia. This Navy research partnership expanded recently with Rear Adm. Frederick “Fritz” J. Roegge, the commander of Submarine Force, U.S. Pacific Fleet (COMSUBPAC), officially opening the COMSUBPAC Innovation Lab (iLab) on November 7, 2016. In addition to SPAWAR, the iLab partners with the Naval Sea Systems Command (NAVSEA) New Training Technologies Program Office. This facility allows for Submariners to rapidly prototype with commercial visualization technologies.

MR capabilities are at a technological point where significant impact to operations can be made. Near-term and longer-term research to understand the operational effectiveness and how human performance changes as a function of technology is still needed to achieve full potential.

References
The Coming Revolution in Cognitive Autonomous Underwater Vehicles

With the advent and successes of the MQ-1 Predator, RQ-4 Global Hawk, MQ-9 Reaper, and other Unmanned Aerial Vehicles (UAVs), expectations for vehicles with extended reach capabilities have been growing within the warfighter community for Autonomous Underwater Vehicles (AUVs). The Predator’s significant impact in the Middle East operational theatres beginning with Afghanistan and Pakistan is largely due to the ability to achieve safe standoff for the warfighters. It provided reliable operation while executing relevant precision strike missions. The chief of naval operations in a congressional report in February of 2016 stated:

“Autonomous Undersea Vehicles are a key component of the Navy’s effort to improve and expand undersea superiority. These unmanned vehicles will be able to operate independently from or in cooperation with manned vehicles…”

While AUVs can perform waypoint operations, avoid basic obstacles, keep from grounding, and activate payloads, their autonomous decision-making is limited and often non-existent. To be operationally relevant for most missions, AUVs must be able to perform multi-dimensional decision-making in an environment that simultaneously considers all factors including weather, sea state, water column characteristics, fishing areas, merchant lanes, geopolitical boundaries (tertiary waters and economic exclusion zones), shipping lanes, threat active and passive detection, countermeasures, degraded self-health, information assurance, GPS denial, mission timeline constraints, water space boundaries, and energy management.

These real-world challenges are routinely resolved by submarine crews, who have 100 years of corporate experience in dealing with the manifold unpredictable realities of the ocean environment and underwater operations. The coming generation of AUV systems will need to leverage this expertise and knowledge and embedded it in intelligent autonomy that will enable platforms to perform relevant missions. These systems will require intelligent multi-dimensional decision-making abilities akin to the human watch team on a submarine.

Simultaneous with the increasing mission need for intelligent AUVs is the rapid acceleration of Artificial Intelligence (AI) technologies, spearheaded by industry and technology leaders within government laboratories and academia. An anecdotal example of this is the race by auto makers to produce autonomously operating vehicles. This has resulted in significant industry investment as they anticipate the market potential. Similarly, Apple (Siri), Microsoft (Cortana), Google (Google Now), Facebook (Fasttext), and many others are working toward semantic understanding for improving human interaction with their systems.

Because of the convergence of increasing AUV mission needs and rapidly advancing AI technologies, the Navy community is on the verge of creating AUVs with greatly increased operational capability and usefulness. Deep belief networks, genetic algorithms, learning systems, cognitive architectures, and other AI techniques will provide critical capabilities in leading this advance.

A promising next-generation autonomy system has been developed through funding by the Office of Naval Research (ONR) SwampWorks to develop a framework in which cognitive technologies and crew knowledge and expertise from Subject Matter Experts (SMEs) can be naturally combined. As a starting point, the team determined that incremental improvement in existing fielded autonomy technologies, many of which date back to the 1980s and 1990s, would be insufficient to handle the decision complexity and ambiguity of real environments that future missions require.

A clean sheet approach was taken to incorporate cognitive decision-making and the capability to enable learning mechanisms as an intrinsic part of the architecture from the ground up. The team created the “Multi-agent Architecture for Natural and Trusted Autonomy” (MANTA) system, which directly incorporated the submarine watch stander crew as its model for autonomy as depicted in Figure 1.

Using the submarine watch team as a model for autonomy provided significant benefits.

- Functional decomposition and modularity of the system is natural in that each member of the watch stander team is well defined and coherent, which is fundamental to software architecture.
- Knowledge of the crew and its expertise naturally fit into the appropriate correlated agent.
- Interactions between watch team members (software agents) is well defined in the submarine “Interior Communications Manual” (ICM), and these natural language literacies form the basis for the messaging interfaces and agent interaction.
- Delegated authority provides back-up and oversight as the Commanding Officer (CO) delegates to the Officer of the Deck (OOD) and on down. High-level monitoring and correcting occur when needed.
- This adds to resiliency and safe operation when incorporated within autonomy.
- Levels of constraints are inherent in the team hierarchy, providing layered operating margins for mission execution. For example, water space is allocated from fleet to the submarine. Within that allocated water space the CO directs the navigator to define the ships operating envelope (where in the ocean the submarine will operate) to provide safe transit and operating constraints, and within that the OOD works to stay near the Path of Intended Motion.

Figure 1. MANTA incorporates a software agent for the primary roles of the Submarine Watch Team.
Using this same approach in software provides layered safety and makes it robust with regard to the dynamic environment.

- Collaborative operations between manned and unmanned systems is natural in that the vehicle is tasked with mission objectives, timelines, and priorities within its capabilities just as a human or another manned system. This means that no specialized interface is required between manned and unmanned systems.

- Trust in autonomy (an often overlooked but critical attribute for autonomy acceptance) is attained as tasking and interactions are all natural language. Explanation of decisions is provided by each agent as it would be in the watch team providing transparency.

- The approach is open-ended (not brittle) as an intelligent advisory agent. For example, an evolved capable navigator could even augment the submarine crew over time and be used for training. A crucial feature in MANTA’s approach is the ability to apply the correct technology to the agents within the system and to enable incorporation of future technologies without breaking the model. Figure 2 shows that each agent is composed of a cognitive layer, a computational layer, and an interactive layer. The cognitive (thinking/deciding) layer, a piece missing in operational AUVs today, enables multi-dimensional decision making to take place using cognitive technologies that are well suited to simultaneously handle the variety of considerations mentioned earlier, accomplishing the mission within environmental, threat, time, and capability constraints.

- Architecture layers can be replaced as new technologies evolve. For example, MANTA started using Robot Operating System (ROS) for the intercommunications layers. Mid-stream in development ROS was replaced with ZeroMQ, an alternative messaging method. This was accomplished without impacting the computation and cognitive layers. Soar is currently used for the cognitive layer, but the laying allows replacing with a different cognitive engine such as Adaptive Control of Thought-Rational (ACT-R). An individual agent may also use a different cognitive engine than the rest of the agents. In addition to the intra-agent modularity, the inter-agent modularity in MANTA allows any agent to be replaced so long as the new agent conforms to the agent intercommunications.

- To incorporate cognitive technology with the SME knowledge base, a cross-disciplinary team composed of computer scientists (engineering and AI), cognitive psychologists, active duty Submariners, and mathematicians was used to develop the prototype system that was regularly tested throughout the summer of 2017 on a small IVER-3 AUV.

- The resulting autonomy architecture breaks the paradigm currently used in today’s AUV systems and is indicative of the coming revolution in intelligent autonomy.

- While the cognitive layer is new with regard to fielded systems, leveraging the vast submarine operational SME knowledge base provides a jumpstart toward advancing development of knowledge-based systems that can be effectively used in smarter, fully autonomous AUVs. The rapid pace of innovation of cognitive systems and the capability to inject advancements into an architectural framework will continue to foster the dynamic and unconstrained environments typical of the modern battlespace. Moreover, using a submarine tactical center as the fundamental design model for the AUV is a game changer. It enables a natural inclusion of cognitive decision-making functions at all levels (every software “role”) and enables the evolution of more robust AUV systems.

- Funding Source via Naval Sea Systems Command (Omnius contract) N00024-12-D-2404

- Lt. Mark Rothgeb and Dr. John Sustersic Applied Research Laboratory at the Pennsylvania State University

- Figure 2. The layered approach in each agent allows naturally appropriated technologies to be applied in each layer.

- Retired AUV Specialist Dan Lawrence hand launching a Micro UUV

- UVs have a history dating back to 1957 with the Special Purpose Underwater Research Vehicle (SPURV) developed by the University of Washington’s Applied Physics Laboratory. Academia and special government programs drove the early decades of research, but advancements were slow. Throughout the 1960s, 1970s, and 1980s, more rapid growth came for the Remotely Operated Undersea Vehicle (ROV) market. It is commonly said that the ROV’s single largest advantage is that it has a tether, which provides for the ability to remotely power the vehicle as well as provide operator-in-the-loop communications and control via real-time access to the vehicle’s sensor suite. It has also been said that the ROV’s single largest disadvantage is its tether, as it limits the range of the vehicle to the tether length and the tether and tethery handling equipment can weigh 10 to 20 times more than the vehicle, making deployment and logistics a challenge.

- In the late 1980s and early 1990s, advancements were made by several academic and scientific research organizations in the design of lower-cost, autonomous vehicles that leveraged available technologies in commercial computer processing coupled with lower-power ROV sensors. Several large U.S. defense contractors such as Boeing, Lockheed Martin, and Northrop Grumman led major program development efforts for the Navy during the planned Large Displacement Unmanned Undersea Vehicle (LDUU) and developing an accelerated demonstration plan for an even bigger Extra Large Displacement UUV (XLDDUUV), one new technology start-up sees opportunity at the opposite end of the spectrum. Rapid Autonomous Solutions has introduced a new product dubbed a micro-unmanned Undersea Vehicle (UUV) and it has started to make deliveries of this new class of UUV into the Navy development labs and to commercial and academic clients.
this period. With declining defense budgets in the early 2000s, smaller UUV startups established their footing on smaller procurements for U.S. and international defense, scientific, and commercial clients. Since the 2010 timeframe, the market has grown steadily as the U.S. Navy released three large ($50M to $100M) multi-year programs for Autonomous Undersea Vehicles (AUVs) and oceanographic gliders, commercial oil and gas expanded to deeper fields off South America, Africa, and Asia, and environmental monitoring requirements grew. Recent market studies suggest the current UUV market globally is about $2B, and that it is set to double by 2020. As the U.S. Navy lays out its strategy and future force structure, which is supported by numerous studies and war games, it views the stealth, survivability, and warfighting dominance of its undersea warfighting capability. Submarines need UUVs to extend the sensor range of the submarine and act as force multipliers.

To date, military use of UUVs has largely been driven by Explosive Ordnance Disposal (EOD) requirements. They are used to perform the dull, dirty, or dangerous tasks that take the Sailor out of the minefield. They are launched from, recovered by, and often maintained on surface support craft that charpente these vehicles by maintaining reasonably close stand-off ranges for missions that typically last from 8 to 24 hours. As the Submarine Force looks to operationally employ UUVs going forward, these same EOD mission durations and concepts of operations are not aligned to the submarine mission requirement. The submarine has vastly superior sensing capabilities and situational awareness compared to the UUV, not to mention decision making capability. Submarines need UUVs to go beyond their sensor coverage range and operate for some period of time (depending on the mission) without requiring the submarine to constantly provide care and direction. This allows the submarine to focus on higher priority missions versus shepherding one or more deployed UUVs. Unless the vehicle can operate on its own for a period of days to weeks, it offers limited operational utility to the submarine. This is what has driven the U.S. Navy to look to larger, more capable and cozier UUV platforms that can store enough energy to operate for these longer periods. As with all military systems, though, as price increases, quantities decrease, and there is a quality in quantity.

As a new market entrant, Riptide set out to develop a small, capable UUV platform that could be fielded affordably in high quantities. To accomplish this, it aligned to a standard A-sized sonobuoy form factor (4.88” diameter) and targeted a vehicle price on par with expendable, single-use systems like sonobuys and Expendable Mobile ASW Training Targets (EMATTs). It sought to drive cost down while increasing flexibility through modularity in both hardware and software. As demonstrated by its initial pre-production deliveries, Riptide was able to produce a 300m-rated UUV via highly flexible 3D printing fabrication techniques. The vehicles built to date have both free-flooded or dry payload volumes. They have been configured with single and dual frequency sonars, 360 degree cameras, and acoustic modems with more configurations in production. The standard vehicle is approximately 40 inches long and weighs about 22 lbs. It is powered by 144 alkaline AA batteries for their reasonably good energy density (on par with rechargeable lithium), worldwide availability, and unrestricted safety and shipping regulations (unlike lithium).

With the high emphasis Riptide put into the hydrodynamic and electrical efficiency of the vehicle, this enables most payloads to run to 24 for 48 hours, depending on payload power and vehicle speed. How does that achieve the days-to-weeks requirement for the Submarine Force? For this new class of UUV, Riptide has established an exclusive partnership with Open Water Power. Open Water is in development of an aluminum seawater energy system that provides a significantly higher energy density than all known lithium battery chemistries, both rechargeable and non-rechargeable, as well as all known fuel cells. Under initial Navy certification testing, it was also found to be highly safe given that the aluminum alloy is readily machinable with no added safety precautions. Open Water has demonstrated multiple cell stacks operating at greater than 10X the energy density of rechargeable lithium. Riptide will commission initial trials of the Open Water energy system by May of 2017. Initial design concepts predict that the micro-UUV will be able to store approximately 5 kW of energy, which will provide the vehicle with a range of about 1,500 nautical miles at 2.8 knots.

In 2011, then Chief of Naval Operations Adm. Gary Roughead issued a challenge to the UUV industry to deliver a 1,000 nautical mile UUV. Many developed conceptual solutions, but the cost to deliver was prohibitive. Riptide, enabled by Open Water Power, is very close to delivering that capability in a highly affordable vehicle that weighs less than 25 lbs.

But what can it do? Ultimately, the vehicle, enabled by the power system, is the primary reason to procure an UUV. The mission dictates the appropriate sensor. Reasonably high powered active sensors like sonars could be fielded for a few days to a week depending on their required power levels. Lower-power oceanographic sensors such as those used on gliders, hydrophones or magnetometers are ideal for longer-duration missions lasting up to a month. With an 8 to 10 knot speed capability, short-duration rapid expendable neutralization missions are also an option. In the past 18 months since starting out, Riptide has seen keen interest from various sensor providers for new, lower-cost, smaller variants of their standard sensor products. As quantities increase, greater savings are also realized, but it is important to note that secondary benefits exist as more systems are fielded, such as improved reliability and improved performance.

So, where is it going? In the U.S. Navy as well as in the global market, the demands for unmanned undersea systems are increasing. As with most operational needs, no platform is ideal for every scenario. Each platform offers advantages and disadvantages that need to be factored into their selection. With cost tending to be a major consideration, it is foreseen that there will be several XLDUUVs, potentially tens of LDUUVs, hundreds of Medium Displacement UUVs (MDUUVs), and possibly thousands of micro-UUVs. Each will offer its own unique set of capabilities for the future fleet.

Jeffrey W. Smith is the President of Riptide Autonomous Systems. He has spent his 23-year plus career supporting the U.S. Navy and the Submarine Force.
Driving R&D Success in a Complex Engineering Environment

Measuring success in innovation is hard. Pairing this difficult task with innovating in an undersea domain that is a dynamic system-of-systems environment, which includes submarines, which are their own complex engineering challenge, creates a thought-provoking job for any program manager. At Electric Boat, the complexity of the product and inherent uncertainty of exploring new technologies and methods requires constant vigilance on the innovation front. One component of the innovation engine at Electric Boat is Independent Research and Development (IR&D), a cornerstone of the company’s R&D efforts for decades.

IR&D is a source of potential solutions for the technology challenges faced by the Department of Defense (DoD). IR&D enables fixed, indirect expenses, and companies have the independence to decide which technologies to pursue as long as they have potential interest to the DoD. IR&D does not include work that is part of a federal contract, so any technical data rights remain with the company. Selecting IR&D projects is the sole responsibility of the company conducting the IR&D work. To increase the chances for transition, however, it is important for companies to keep their DoD customers aware of promising technologies and integration efforts.

At Electric Boat, the IR&D portfolio is set up to integrate new capabilities into the way the product operates through designing the best platform and the way the product is built. Building an IR&D portfolio starts with developing an internal Request for Proposal (RFP) that takes into consideration the goals from the company’s strategic plan, technology development needs from Electric Boat’s concept development group and from lessons learned from our larger submarine development programs, and customer needs and perspectives from the Navy’s strategic science and technology documents. The RFP is then released to the entire company for project ideas that not only are aimed at delivering value to the company and the customer but take affordability and the end user into mind. This article will showcase three different submarine-related IR&D successes at Electric Boat.

**Propeller Crashback Simulation**

In 2007, computational fluid dynamics engineers at Electric Boat achieved a milestone in the simulation of propeller crashback. Propeller crashback is the sudden reversal of rotation by marine propellers, usually performed under emergency conditions. This maneuver creates large-scale unsteady flow structures when the propeller operates in the reverse direction, generating large side loads that result in high peak blade stresses and impact the maneuvering performance of the vehicle. Using computational methods to predict these types of forces was limited in the past due to the substantial computational resources required for accurate crashback flow simulations. The engineers were able to capitalize on the supercomputing power at the Naval Oceanographic Office Major Shared Resource Center (NAVOSMRC) in conjunction with Electric Boat’s IR&D-funded computational fluid dynamics (CFD) solver. This was a milestone because the side forces generated during crashback were not well understood at the time and have significant implications in propeller design and marine vehicle maneuvering. The methodology was not only a breakthrough for propeller analysis but can also be applied to pumps, complex internal fluid flows, and control surface design. The engineers were able to use this method to assess the main feed pump on USS Virginia (SSN 774) and also the design of the Ohio Replacement control surfaces. At large angles of attack, control surfaces can have large separated flow structures, much like the structures examined in the crashback study. The methodology developed for the crashback scenario applies to this type of problem and ensures that simulations are as close as possible to real-world conditions. It is essential to ensure that design margins can be safely eliminated from designs in order to still produce and deliver an affordable, safe product.

**Large Aperture Bow Array**

A second successful example, which highlights a technology that was integrated into the platform, is the development and integration of the Large Aperture Bow (LAB) array on Virginia-class Block III. The LAB array change accounted for $11 million of the $200 million cost savings goal for the Virginia-class design. This bow redesign was not only the number one technology-based cost saver leading to a $2 billion Virginia-class, but it also opened up the front end to enable the insertion of large flexible payload tubes. The array concept was initiated under IR&D in 2003 and 2004.

Engineers at Electric Boat worked through various concepts to eliminate different space-consuming features from legacy bow arrays to create an array that returned more allocable volume to the submarine but also to develop a more capable array. Using their initial IR&D work as a springboard for discussions with the Navy, the concept was so compelling it was rapidly transitioned to contract R&D in 2005. The contracted R&D funding allowed further development of the concept and in-water testing of the concept. Hundreds of SUBSAFE penetrations were eliminated as part of the design, and life-of-the-hull transducers were integrated into the design. This technology was first delivered on USS North Dakota (SSN 784) in 2014.

**Fly-by-wire Ship Control Stations**

In a third example, IR&D funding was used at Electric Boat to initiate innovation that was then carried down through different submarine programs. This effort started with IR&D in the 1980s when Electric Boat was investing in advanced fly-by-wire ship control stations. Over the course of 10 years, Electric Boat invested approximately $3 million on research and technology integration for future ship-control stations. This work under IR&D was the initial steps for the first Virginia-class fly-by-wire ship control station. The work done for the Virginia-class was leveraged for the Ohio Replacement ship control stations.

The fly-by-wire transition enabled integrated fault detection and isolation during operation. To keep innovation moving for future ship control stations, Electric Boat is currently funding efforts to integrate next-generation automation into ship control and also take advantage of advances in human systems integration to create a more user-friendly environment for future Submariners.

To turn vision into reality, Electric Boat is partnering with industry and academia to ensure that future ship control stations benefit from the best, most affordable technology solutions. It is important to not be complacent with the successes that have already come to fruition. At Electric Boat, we are aiming to understand all of the customers’ needs today and tomorrow to align our IR&D portfolio investments to provide the best product. The Navy strategic documents that are available through the Defense Innovation Marketplace, including the Navy Science and Technology Strategic Plan and Undersea Warfare Science and Technology objectives, provide invaluable insight during portfolio development. Two annual crowdourcing events with our entire workforce and also our summer interns keep the innovative ideas flowing to feed the IR&D program. Going forward, capitalizing on the talent and passion of our young workforce paired with mentorship from our top-tier experienced engineers will help de-risk the R&D of advanced technologies. There are many more examples of success in IR&D at Electric Boat and numerous examples of success in failure. IR&D is not the place to “play it safe” but to shake out and verify new ideas for the future. Success is achieved through partnerships with technology providers, academia, and the labs, and these partnerships play a crucial part in developing more

References

In August 2016, the Naval Undersea Warfare Center (NUWC) Division Newport hosted the second Annual Naval Technology Exercise (ANTX) at its Narragansett Bay Test Facility in Newport, RI. With the theme of “Cross Domain Communications and Command and Control,” more than 30 participants demonstrated complementary technologies that showed the benefits of managing and controlling operations across the air, sea, and sub-sea domains.

ANTX provided an opportunity for warfare centers, industry, and academia to demonstrate in-water technologies and collaboratively help them evolve before their introduction to the fleet. One of the many goals of the event was to accelerate the technology development cycle from concept to in-water testing through rapid prototyping and fleet insertion.

Known for its intellectual capital in the undersea warfare domain, NUWC Newport is an important hub for undersea activity. It is a key conduit across the development spectrum—from science and technology to fleet support. ANTX is the venue that helps NUWC Newport connect its research and development (R&D) partners to the needs of the acquisition and warfighting community.

Dr. John Burrow, Deputy Assistant Secretary of the Navy for Research, Development, Testing and Evaluation, kicked off the event and in his keynote address said, “Rapid prototype experimentation and demonstration will change the way we do business.” Dr. Burrow also highlighted the presence of senior Navy leadership to drive the evaluation of products for the warfighter as an important aspect of ANTX. He noted the importance of improving the current acquisition process of getting technology to the fleet.

“The acquisition process must be fast in order to have the operational advantage and technological superiority. This would give the Navy the capability to marry mature technology with existing needs,” said Burrow. “From an acquisition perspective, the Navy wants affordable solutions from a competitive environment. Industry participation must not be dominated by one party.”

Success stories

The promise of ANTX to provide a venue to demonstrate new technologies and new concepts was indeed realized. Following the 2016 event, both participants and attendees saw a variety of benefits.

Doug Prince, Lockheed Martin business development, unmanned underwater vehicles, said, “This is the first time that three autonomous vehicles in three different domains [air, surface, and underwater] have worked together to execute a mission. This was a significant milestone.”

Another large player, Northrop Grumman, demonstrated cross-domain collaboration of unmanned underwater vehicles (UUVs), unmanned surface vehicles (USVs), and unmanned aerial vehicles (UAVs) to conduct an anti-submarine warfare (AWW) mission with autonomous detection, track, classification, and engagement. Northrop Grumman also successfully adapted commercial-off-the-shelf unmanned maritime systems to accomplish an ASW mission in a challenging shallow-water environment.

A smaller company, Digital Design and Imaging Service (DDIS), demonstrated a tethered surveillance aerostat balloon equipped with an ultra-high-resolution, nine-eye camera cluster. Through ANTX introductions, DDIS was able to find Navy programs and commercial partners to refine their maritime aerostat capabilities to support over-the-horizon communication relays to surfacing unmanned submarines.

Engineer David MacCulloch from L-3 displayed his underwater energy harvesting technology at ANTX in an effort to share his work with a targeted audience.

“This was one of the most relevant shows we’ve been to,” said MacCulloch. “We have been able to talk to decision-makers as well as engineers who have been asking probing questions.”

After touring the displays and connecting...
with warfare center and industry personnel, Capt. William Guarini, Program Executive Office Littoral Combat Ship (PEO LCS), said, “ANTX provided an impressive forum for industry, warfare centers, and university participants to display and demonstrate leading-edge technologies relevant to autonomous systems. As a program manager, I was able to discuss and better understand broad R&D efforts with significant future potential throughout our Navy.”

**Biggest takeaways from 2016**

- Hosting an unclassified event allowed non-traditional participants—firms not typically involved in defense products—to demonstrate their technologies’ potential for meeting a defined Navy need. ANTX cast its net to a wider audience in an effort to bring innovation to the fleet faster.
- Collaboration was forged in an unclassified setting, with interested parties seeking each other out both before the selection to participate in the solicitation response process and while crafting their solution. After being selected for ANTX, participants were able to develop their technology solutions with other interested partners.
- Various stages of technology development were exercised—from hardware that was already in the acquisition process (MK18 Mod 2 Increment 2 UUV system, or magneto-inductive communications with a UUV).
- The low-risk, inclusive, collaborative event allowed participants to take risks and stretch goals to exercise their technologies. Pushing new technologies and new concepts to their limits, or even to failure, is a learning experience for our participants to share across the R&D community supporting the CNO’s goals in high-velocity learning.
- With all the successes of the ANTX 2016 event, it is worth reminding ourselves of all the hard work and resources necessary to pull off an event like this. The participants should be commended for commitment to demonstrating technical excellence. Hence, it becomes ever more important to build on a strong foundation for future events, and also to continue to build and strengthen relationships across the R&D community.

**Fostering collaboration**

Industry partners continue to seek greater engagement in the acquisition process. For industry to work closely with the Navy, the current state is to bid on a proposal or form a partnership through a Cooperative Research and Development Agreement. Due to limited resources, these methods may exclude some potential partners. ANTX solves this by providing an open forum to get in front of stakeholders and demonstrate technology. This collaboration will lead to better products that meet the warfighters’ needs sooner.

Traditional engagement includes meetings, which can often be a one-way communication. At ANTX, engineers and scientists can gather to develop better insights that are shared—both sides benefit and evolve. The in-person experience helps developers of technology better understand the need to morph their products and socialize their technologies and increased collaboration among technology centers.

**Culture change**

In addition to the partnerships, the essential professional networking, and the vast workforce development opportunities provided by ANTX, an underlying message of the event is culture change. Persuading decision-makers within the warfare center enterprise, industry, and academia to view technology development as a multi-entity sandbox is the shift in culture needed for the rapid advancement of capabilities. The ability to collaborate and innovate must be made easier for people in all communities and at all levels.

Participating in events such as ANTX and experiencing positive results—both tangible and intangible—can facilitate a change in behavior by all involved on both sides of the acquisition process to collaborate and innovation are happening not just at ANTX but all the time. The desired future state is that collaboration and innovation is the norm across the technological landscape.

**Naval research and development establishment and defense industry**

Following the success of ANTX 2016, the Marine Corps will conduct a similar exercise in April 2017 at Camp Pendleton. ANTX 2017, August 14-18, will connect NUWC Newport to Naval Surface Warfare Center Panama City and NUWC Keyport.

The ultimate goal from a warfare center perspective is for industry—including businesses both large and small—to partner with the Navy’s technical departments and test their technologies in the Navy’s unique labs and ranges. Improving the Navy’s undersea test and evaluation infrastructure and adding new capabilities are priorities that will yield two significant benefits. First, it accelerates the development and test cycle so that we are learning faster and more quickly fielding relevant products for the warfighters. Second, as it is expensive to test undersea technology, maintaining easily accessible test infrastructure lowers the barrier to entry, particularly for small businesses, into the undersea domain.

Government and industry should be leveraging their efforts. By sharing what they are doing, they can share costs and evolve faster. ANTX provides its participants with greater insights to the capabilities that the warfighter needs as well as breakthrough capabilities they did not know were possible.

The end result is that industry prosper and the warfighters get what they need… sooner!

I would like to thank the following organizations for their participation in ANTX 2016:

- Northrop Grumman; University of Maryland Center for Environmental Science Horn Point Laboratory; Ultra Electronics; Kongsberg; Northrop Grumman; University of California Santa Barbara; Penn State Applied Research Laboratory; Lockheed Martin; Ocean Aero; MKEL, Inc.; Ultra; Riptide Autonomous Solutions; Bluefin Robotics; General Dynamics Mission Systems; Digital Design and Imaging Service; University of Rhode Island; DBV Technology; PNS 502; SPARRK Systems Center Pacific; etc.; A2 Electrics; Mison; Hole Oceanographic Institution; Kongsberg; NSWC Panama City; and Polartec.
iLab Opening Boosts Submarine Innovation

Rear Adm. Frederick “Fritz” J. Roegge, Commander, Submarine Force, U.S. Pacific Fleet (CSP), joined industry partners to cut the ribbon officially opening the CSP Innovation Lab (iLab) on Nov. 7, 2016.

The CSP iLab is an unclassified space created to allow Submariners to prototype virtual reality (VR) and augmented reality (AR) technologies to generate ideas for low-cost solutions to fleet training and operational challenges. Squadron commodores and unit commanding officers are highly encouraged to send their Submariners to the CSP iLab to:

- **See** cutting-edge VR/AR technologies
- **Share** ideas for using VR/AR aboard submarines
- **Shape** the future of submarine training, operations, and maintenance

The iLab’s mission is to exploit and leverage commercial sector research and tools from the computer gaming industry and cellular phone markets to explore the latest technologies.

“This emerging maker-space is where Submariners can prototype low-cost solutions to training and operational problems using cutting-edge virtual reality and augmented reality tools,” said Roegge. “To achieve high-velocity learning, we must expand the use of learning-centered technologies and put them in the hands of our greatest asset: our Sailors. Our Sailors are the ones closest to the problems and therefore the ones best positioned to come up with innovative ideas for their solutions.”

The CSP iLab supports the Commander Pacific Fleet (CPF) Bridge initiative, the Chief of Naval Operations’ “High Velocity Learning,” and the Secretary of the Navy’s “Innovation Bridge initiative, the Chief of Naval Operations’ “High

The iLab needs Submariners of all ranks and career fields to observe the technologies and generate ideas for their use. Ideas both bold and modest, will be captured via log books or email. An iLab Idea Board will review the proposals for further development. The goal of the iLab is to rapidly transition cutting-edge technology ideas, generated by the Submariner, to the waterfront.

“The iLab is a breakthrough initiative to present transformative tools to the Submarine Force and gather input to rapidly improve shipboard learning technologies,” said Capt. Erik Buiten, COMSUBPAC director for training, doctrine, and tactical development.

**Current iLab Capabilities**

**OceanLens.** OceanLens is like Google Earth for the undersea environment, viewed via an Oculus Rift Virtual Reality headset. It includes a 3D immersive environment for visualizing undersea topography (bathymetric data). Some ideas for use include drive-through or swim-through swath visualization with bathymetric features, assigned swath workspace to ships, adjacent swath workspace assigned to other submarines, and stay out/warning areas. Higher resolution bathymetric data could be used for planning and rehearsal of near or on-shore missions.

**Eagle 360 Piloting Brief.** The Eagle 360 capability uses a 3D immersive environment for visualizing undersea topography (bathymetric data). Some ideas for use include drive-through or swim-through swath visualization with bathymetric features, assigned swath workspace to ships, adjacent swath workspace assigned to other submarines, and stay out/warning areas. Higher resolution bathymetric data could be used for planning and rehearsal of near or on-shore missions.

**360 Video Capture/Replay.** Sailors can leverage 360-degree video for immersive capture of submarine training and maintenance events. They can easily record “what right looks like” and then share best practices with other Sailors. Recent technologies available in the iLab allow rapid transfer of 360-degree video to a commercial smartphone or headset using a simple app. No special stitching is needed before Sailors can review the event as if they were there. Recently, a Sailor used the iLab’s Samsung Gear360 video camera to capture short events and then made them available for viewing on a smartphone or headset in about five minutes.

Ideas can always be submitted to CSPLab@navy.mil or CSPLab@navy.mil. There will be quarterly iLab Idea Boards conducted at CSP beginning in December. The top ideas that emerge will be prioritized by CSP leadership and pushed forward. For more news from the Pacific Submarine Force, visit www.csp.navy.mil.

photo by Petty Officer 2nd Class Michael H. Lee

**HoloLens 3D Immersive Walk-Through.** Using the Microsoft HoloLens Augmented Reality headset, Submarines can virtually experience how to move within and through a holographic model floating in the iLab. Holograms can include any object from the real world, ranging from running engines, commercial aircraft, or military submarines. These holograms allow the Sailor to experience being there without physically being there. Some uses include training for new crewmembers at submarine school to shorten the time to become familiar with the layout of their new submarine, training firefighters who may not have regular access to all compartments in a submarine, and visualizing maintenance issues such as interference removal for planning. The submarine’s officer of the deck could use the HoloLens and OceanLens together to “see through” the hull of the submarine for more intuitive situational awareness of the increasingly complex undersea environment, including contacts, bottom topography, wave propagation, contacts, and unmanned systems. The HoloLens has Skype capability so the Sailor can see through the eyes of the Sailors and coaches them through maintenance, operations, or inspections in real time. For example, several Sailors put together a physical valve/galvanized pipe assembly in the iLab by getting coaching from a remote expert via Skype on HoloLens. Hands-free on-demand support can both improve the response time to Sailors who need assistance and lighten the burden on technical representatives by reducing airline flights, cost, time, and fatigue from traveling.

**zSpace 3D Maintenance.** zSpace allows Sailors to interact with a 3D display using stereoscopic glasses and a special pen. Sailors can easily practice virtual maintenance activities on any modeled equipment. The glasses have head tracking, which allows Sailors to view equipment from all sides. They can virtually disassemble and reassemble equipment, shift to an exploded view of all subcomponents, and make equipment housing transparent so that they can really view interior parts. All available in the iLab is an iPad-based demonstration of a 3D-printed Woodward Governor diesel control. The interactive training visualizes the operations, maintenance procedures, and instructional videos required to install, remove, and start-up a diesel generator using a Woodward Governor.
US Navy Ratings

The Navy announced the establishment of four new ratings for active duty Sailors, yeoman submarine (YNs), logistics specialist submarine (LSS), culinary specialist submarine (CSS) and fire controlman Aegis (FCA) in NAVADMIN 021/17.

This realignment was made to improve management of ship life inside and personnel inventory for both the Surface and Submarine ratings.

The new ratings will be effective:
- Sept. 2, 2017, for E-6
- Oct. 17, 2017, for E-7 through E-9
- Nov. 28, 2017, for E-1 through E-5

Sailors serving as Aegis fire controlman and yeomen, logistics specialist, culinary specialist submarine Sailors will be converted to their applicable service rating by enlisted community managers with no action needed from the member.

More information can be found at www.npc.navy.mil.

New App for Blended Retirement Choices

A new mobile application designed to enhance financial literacy for Sailors is now available that will help provide the latest info on the Blended Retirement System (BRS) that goes into effect in 2018.

Targeted primarily for active duty and reserve service members, the app also serves as a valuable tool for families.

Users will be able to explore issues like managing their credit, building a spending plan, home buying, moving, as well as how to navigate survivor benefits, insurance and the Thrift Savings Plan (TSP) among many other topics.

Outside of the standard financial topics, there is a BRS resources tab that includes infographics, frequently asked questions, as well as training links that will be refreshed as new courses and training materials become available. Once finished, the retirement calculator for BRS will be included as part of the app as well.

Service members eligible to opt into BRS will have until the end of 2018 to decide if they want to switch to the new plan.

Everyone serving today can stay under the current system, while those with fewer than 12 years of service as of the end of 2017 will have an opportunity to opt into the new retirement system.

New Sailors will automatically be enrolled into the new system as of the start of 2018.

The Navy Financial Literacy mobile application is available for both Apple and Android devices and can be found at www.navyfinliteracy.com.

Welcome Home!

Petty Officer 1st Class Jonathan Atkins is greeted with a kiss by his wife Jennifer during a homecoming celebration for Los Angeles-class attack submarine USS Oklahoma City (SSN 723), Oklahoma City, one of four forward-deployed submarines homeported in Apra Harbor, Guam, returned to Guam after an eight-month maintenance period known as “Booing.”

Photo by Petty Officer 2nd Class Krista Jenkins

SUBASE New London Opens Navy’s First NOFFS Zone

A ribbon cutting ceremony was held for the Navy’s first Navy Operational Fitness and Fueling System (NOFFS) Zone at Morton Hall Gymnasium on Naval Submarine Base New London (SUBASE), Jan 12 which features an indoor turf area, battle ropes, fire flipping, weight lifting, box jumping, and other movement based activities.

Originally designed for Sailors to continually be physically active while not having access to a fitness facility or equipment, NOFFS has been undergoing a rebranding since 2014, and aims to instruct Sailors how to physically train effectively and safely, and make health and nutrition choices in both shore and operational environments.

“NOFFS mimics the same type of motions done on the waterfront like pulling, pushing, and lifting,” said Capt. Paul Whitecarrver, commanding officer of SUBASE. “We want to prevent injuries in the future, and it’s pretty awesome for SUBASE New London to open the first NOFFS Zone.”

The original NOFFS Operational program released in 2009 provided Sailors with resistance bands that could easily be taken out to sea, or at home, requiring minimal space.

“Many people associate NOFFS with a bag of rubber bands, but we wanted to give people another look at what NOFFS really is, an entire system including the facility, nutrition and cell phone application where you can still have the virtual trainer if an MWR Fitness trainer isn’t available in person,” said Tunde Ridley, Morale, Welfare and Recreation (MWR) section head of Navy Fitness. “The program focuses on resiliency and eliminating musculoskeletal injuries, and provides a program where Sailors or anyone who wants to use it didn’t have to think about it. We eliminate the guesswork.”

Ridley also said there are four different NOFFS series available, Operational, Strength, Endurance and Sandbag that combined with the web-phone application, Sailors can easily be trained to train with from home, deployed, or in a fitness facility.

MWR trainers at Morton Hall will be hosting classes seven times a week, and the NOFFS Zone is available for individual and command use. For more information, please call MWR at (860) 694-2298.

Additional pilot NOFFS Zones opening in the future include Naval Base Kitsap-Bangor, Naval Base Ventura County, Naval Station Norfolk, and Naval Air Station Pensacola.

The NOFFS application is available for both Android and iOS, and can be found at www.navynfitness.org

USA DDG (SSN 700)

The star of “The Hunt for Red October” returned from its final overseas deployment last November and, after 33 years in the fleet, will be inactivated.

As one of 42 Los Angeles-class submarines remaining in the fleet, it was the first attack submarine to carry a dry-dock shelter, which housed a vehicle for launching and recovering special operations forces. Dallas was commissioned July 18, 1981 as the seventh member in a class of 61 submarines.

Dallas was initially attached to Submarine Development Squadron 12 in New London, Conn., and was used for research and development projects. She had a London Island, three Mediterranean, seven North Atlantic deployments, and circumnavigated the globe. She also participated in Operations Desert Shield/Storm in the 1990s.

The Navy postponed the decommissioning of O×tos to 2017 from her earlier scheduled retirement in 2015, that decided that saved $10m in pre-inactivation restricted availability (PRI) costs and enabled the Navy to focus on mission requirements and balance workload and workforce needs across the force.

USA DDG (SSN 711)

The contract to build USA San Francisco was awarded to Newport News Shipbuilding and Dry Dock Co. in 1975, and her keel was laid down in 1977. She was launched on October 27, 1979, and commissioned on April 24, 1981.

Following an initial shakedown cruise, San Francisco joined Submarine Force, U.S. Pacific Fleet and moved to her homeport at Pearl Harbor, San Francisco completed deployments in 1982, 1983, 1985, and 1986 with the U.S. Seventh Fleet and various independent operations in the Pacific in 1986 earning the Battle Efficiency “T” for Submarine Squadron Seven in 1985. She earned a Navy Unit Commendation, a second Battle Efficiency “T” for Submarine Squadron Seven, and her crew was awarded the Navy Expeditionary Medal for independent operations in 1988.

In 1994 the submarine was awarded the Commander Submarine Squadron Seven “T” for excellence in tactical operations and a Meritorious Unit Commendation for the 1994 Western Pacific deployment.

USA Colorado (PCU 788)

Colorado (PCU 788) is the 15th Virginia-class fast-attack submarine and the fifth Virginia-class Block III submarine. Virginia submarines are constructed in a joint partnership between General Dynamics Electric Boat and Huntington Ingalls Industries Newport News Shipbuilding. The boat began construction in March of 2012 and is tracking to a late 2017 commissioning. Colorado is currently completing her construction at the Electric Boat shipyard in Groton, Conn.

Boat’s sponsor: Elizabeth A. Mabus

Commanding Officer: Capt. Jason Schneider

Executive Officer: Lt. Cmdr. Stephen Cal

Chief of the Boat: ETCM (SS) Freddie Richer

USA Indiana (SSN 789)

Indiana (SSN 789) is the 15th Indiana-class fast-attack submarine and the sixth Virginia-class Block III submarine. The boat began construction in September of 2012 and will be christened on April 29, 2017 when the boat’s sponsor, Mrs. Diane Donald, breaks a bottle of champagne on the bow.

Boat’s sponsor: Diane Donald

Commanding Officer: Capt. Gretchen Zimbauer

Executive Officer: Lt. Cmdr. Matt Haladay

Chief of the Boat: Master Chief Kerling

USA Colorado (PCU 788)

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Boat’s sponsor: Anna A. Mabus

Commanding Officer: Cmdr. Ken Franklin

Executive Officer: Lt. Commander Stephen Cal

Chief of the Boat: ETCM (SS) Freddie Richer

USA Indiana (SSN 789)

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Boat’s sponsor: Diane Donald

Commanding Officer: Capt. Gretchen Zimbauer

Executive Officer: Lt. Cmdr. Matt Haladay

Chief of the Boat: Master Chief Kerling

Leaving the Fleet

US Navy Decommissioned USS Colorado

After 33 years of service, the Los Angeles-class submarine USS Colorado was decommissioned February 27 at Pearl Harbor Oahu.

The keel was laid by the Electric Boat Division of General Dynamics in 1979, and she was launched March 13, 1982. Albuquerque was commissioned on May 21, 1983, at Naval Base New London, and deployed 21 times to every corner of the globe, accumulating approximately 1.1 million nautical miles steamed, the equivalent of 52 global circumnavigations. She performed 1,075 dives, made port calls in 32 countries, and had 14 commanding officers. The boat earned three Navy Unit

Chief of the Boat: ETCM (SS) Stephen Burchette

USA DDG (SSN 700)

The star of “The Hunt for Red October” returned from its final overseas deployment last November and, after 33 years in the fleet, will be inactivated.

As one of 42 Los Angeles-class submarines remaining in the fleet, it was the first attack submarine to carry a dry-dock shelter, which housed a vehicle for launching and recovering special operations forces. Dallas was commissioned July 18, 1981 as the seventh member in a class of 61 submarines.

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"What is Sailor 2025? How is it going to affect me? What’s in it for me?"

Sailor 2025 is the Navy’s program to improve and modernize personnel management and training systems to effectively recruit, develop, manage, and retain the force of tomorrow. In a nutshell, it means giving Sailors more control and ownership over their careers! Sailor 2025 is built on three pillars:

- A modernized personnel system
- An enriched culture
- A career continuum of learning

The Navy has already started modernizing personnel policies to give Sailors ownership over their careers. Here are some ongoing initiatives that have been recently “revamped” and improved:

- Career Transition Program (CDP) – Some program eligibility barriers have been removed and participant quotas have been increased. CDP now allows Sailors to enjoy a sabbatical from the Navy for up to three years to pursue goals of their choosing.

- Fleet Scholar Education Program (FSEP) – Expanding, fully-funded, in-residence graduate degree opportunities at civilian institutions by 30 billets at the officers’ (URL and IWC officer) choice of institution.

Billiet Based Distribution (BBD) – Expanded choice and flexibility; enables the Navy to more efficiently assign personnel in support of warfighting readiness and more accurately match Sailors’ unique skillsets to specific billets.

Moritious Adwancement Program (MAP) – Provided more opportunities to Fleet Cds, CMCs, and the Chief’s Mess to better identify and meritiously advance talented, hard-working Sailors at sea and ashore.

Secretary of the Navy Tours with Industry (SNTW) – Provided opportunities for 30 top-performing Sailors at high-performing corporations to observe and learn the newest insights and best practices to bring back to the Fleet.

Navy Entitled Rating Modernization – This is a multi-year initiative to eliminate Navy rating titles. It will ensure enhanced career flexibility where combinations of rates with similar training and experience exist. It will ultimately provide greater training and credentialing opportunities and help Sailors become more marketable to civilian employers once they leave the Service.

Visit the following websites for more specific Sailor 2025 information and guidance: https://www.public.navy.mil/bupers-npc/career/talentmanagement/Pages/default.aspx

Changes of Command

USN Adm. (SSBN 732) (G)
Cdr. Eric Cole relieved Cdr. Craig Greinert

USN Adm. (SSN 755)
Cdr. Ray Wilson Jr relieved Cdr. Robert Landis

USN Adm. (SSBN 698)
Cdr. Travis Zettel relieved Cdr. Wes Bringham

USN Adm. (SSN 795)
Cdr. Adam Biemond relieved Capt. Travis Petzdahl

USN Adm. (SSBN 748)
Cdr. Brian Bloem relieved Capt. Jack Housholder

USN Adm. (SSBN 749) (G)
Cdr. Dougallon relieved Cdr. Michael Beal

USN Adm. (SSBN 750)
Cdr. Andru Ring relieved Cdr. Scott McCants

USN Adm. (SSBN 766)
Cdr. Paul Spiller relieved Capt. Roger Mayer

USN Adm. (SSBN 780)
Cdr. Ken Juenger relieved Capt. Joe Evenson

USN Adm. (SSBN 786)
Cdr. Ben Seidenberg relieved Cdr. Jesse Porter

USN Adm. (SSBN 795) (B)
Cdr. Eric Cole relieved Cdr. Craig Greinert

USN Adm. (SSBN 795) (G)
Cdr. Eric Cole relieved Cdr. Craig Greinert

USN Adm. (SSBN 800)
Cdr. Ken Juenger relieved Capt. Joe Evenson

USN Adm. (SSBN 805) (B)
Cdr. Eric Cole relieved Cdr. Craig Greinert

USN Adm. (SSBN 805) (G)
Cdr. Eric Cole relieved Cdr. Craig Greinert
Lt. j.g. Michael Bauck
USS Albuquerque (SSGN 727) (G)

Lt. j.g. Marcus Roberak
USS City of Corpus Christi (SSN 780)

Michael Rand
USS Joffreys City (SSN 759)

Joannah Rohren
USS Alder boils (SSN 758)

Lt. j.g. Costain Rehberg
USS Atlanta (SSBN 730) (B)

Lt. j.g. Ethan Kegler
USS Albuquerque (SSGN 726) (G)

Lt. j.g. Kara Smith
USS Nashville (SSN 728) (G)

Lt. j.g. Lyanna Vermeers
USS Groton (SSN 762) (G)

Lt. j.g. Joshua Williams
USS Colorado (SSN 774)

Lt. j.g. Michael Senk
USS San Diego (SSN 756)

Lt. j.g. Daniel Stendig
USS San Diego (SSN 756) (B)

Lt. j.g. Andrew Sommers
USS San Diego (SSN 756) (G)

Lt. j.g. Bradley Toebbe
USS Virginia (SSN 774)

Lt. j.g. Nathan Thiem
USS Louisiana (SSN 724)

Lt. j.g. Michael Rubino
USS Virginia (SSN 774)

Lt. j.g. Andrew Tesch
USS Colorado (SSN 728) (G)

Lt. j.g. Andrew Tjpole
USS Colorado (SSN 728) (G)

Lt. j.g. Michael Wynne
USS Oklahoma (SSN 777)

Lt. j.g. Kevin nunnen
USS McNary (SSN 746) (B)

Lt. j.g. Kevin Auke
USS Auke Bay (SSN 750) (G)

Lt. j.g. Jonathan Butts
USS Colorado (SSN 728) (G)

Lt. j.g. Andrew Long
USS Colorado (SSN 728) (G)

Lt. j.g. David Pruett
USS Colorado (SSN 728) (G)

Lt. j.g. Thomas Ritter
USS Colorado (SSN 728) (G)

Lt. j.g. Cameron Butts
USS Colorado (SSN 728) (G)

Lt. j.g. William Mitchell
USS Colorado (SSN 728) (G)

Lt. j.g. Andrew Voss
USS Colorado (SSN 728) (G)

Lt. j.g. Joseph Painley
USS City of Corpus Christi (SSN 780)

Lt. j.g. Andrew Som
USS Virginia (SSN 774)

Lt. j.g. Owen McGrath
USS Housatonic (SSN 735)
CONSUBPAC Winners of 2016 Battle “E” Efficiency Competition Awards:

**CONSUBURON 1**
USS Greenville (SSN 772)
Lt. Russell Friel
USS Hornet (SSN 701)
Lt. Timothy Gannatti (SSN 759)
Lt. Joshua Jones
USS Sharp (SSN 754)
Lt. Kevin Tutor
USS Philadelphia (SSN 704)
Lt. John Ford
USS Oklahoma (SSN 750)
Lt. James Holton
USS Oklahoma CI (SSN 705)
Lt. Joseph Hussey
USS Princeton Gulf (SSN 40)
Lt. Colonel Myers
USS Providence (SSN 759)
Lt. Christopher Talbot
USS Virginia (SSN 774)
Lt. Colonel Myers
USS Colorado (SSN 788)

**CONSUBURON 15**
USS Tuapse (SSN 794)
Lt. Col. D. Lammers (D)
Lt. Cdr. S. Tarr EI (E)
Lt. Cdr. R. McDonnell
EVON M. Schecter
Lt. Col. D. Lammers (D)
Lt. Cdr. S. Tarr EI (E)
Lt. Cdr. R. McDonnell
EVON M. Schecter

**CONSUBURON 17**
USS Alaska (SSBN 731) (B)
Lt. Cdr. P. Barnhardt
Lt. Cdr. D. Latta
FOM J. Leonard
USS Alaska (SSBN 731) (G)
Lt. Cdr. M. Chapman
Lt. Cdr. J. Quinn
FOM J. Racus
USS Ohio (SSBN 726) (B)
Capt. B. Berkhout (D)
Capt. D. Waldow (R)
DTC A. Simons
FOM S. Rice

**CONSUBURON 19**
USS Ohio (SSBN 726) (B)
Capt. B. Berkhout (D)
Capt. D. Waldow (R)
Lt. Cdr. A. Simons
FOM J. Racus

**Submarine Tender**
USS Prado (SSN 760)
Capt. A. St. John
Lt. Col. G. Callahan
OMDPM P. Swenson
Special Category
USS Arco (SSBN 5)
Lt. Cdr. Z. Harry
Lt. Cdr. J. Smith
OMDPM J. Jennings
Special Category
USS Rescue Command
Lt. Col. M. Hazenberg
Lt. Cdr. J. Babick
HMPN F. Lazarin

**Qualified Submarine Supply Officer**
Lt. j.g. Joseph Gabriel Chirinos
USS Colorado (SSN 788)
Lt. j.g. Nick Douglas
USS Pasadena (SSN 752)
Lt. j.g. Lucas Gallant
USS Colorado (SSN 771)
Lt. j.g. Jason Horne
USS Tiptoe (SSN 754)
Lt. j.g. Justin Higgins
USS Alex (SSN 775)
Lt. j.g. Amedeo Iapari
USS Seawolf (SSN 775)
Lt. j.g. Darryl Lindsey
USS Ashville (SSN 788)
Lt. j.g. Nick Norton
USS Spook (SSN 766)
Ens. Justin Kiel Sorensen
USS Colorado (SSN 772)
Lt. j.g. Samuel Theodore
USS Oklahoma CI (SSN 723)
Lt. j.g. Tammy Thompson
USS Mississippi (SSN 762)

**QM Officer**
Capt. A. St. John
USS Colorado (SSN 788)
Lt. j.g. John Ford
USS Philadelphia (SSN 705)
Lt. Colonel Myers
USS Providence (SSN 759)
Lt. Colonel Myers
USS Colorado (SSN 774)

**USS Colorado (SSN 788)**

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December 3, 2016 USS Colorado (SSN 788) was Christened by Ship’s Sponsor, Annie Mabus, in ceremonies at General Dynamics Electric Boat Shipyard in Groton, Connecticut.

As an honor the Battleship USS Colorado (BB 45), which was christened in 1923 with a bottle of “muddy Colorado River water”, December’s ceremony featured a sparkling wine produced by Colorado winery Balistreri Vineyards which rested in a bucket filled with ice made from Colorado River water.

Seven veterans of WWII service on Battleship Colorado were present and, as part of the ceremony, presented to the crew pens made of teak decking salvaged from the battleship when it was decommissioned in 1947.

After a blessing by Father Anthony Dinoto, the ceremony concluded with the breaking of the bottle of sparkling wine with the traditional words “In the name of the United States, I Christen thee Colorado. May God bless her and all who sail in her.”
When the Blueback was launched in 1959, she was the last diesel-electric submarine to be commissioned by the U.S. Navy. Of the three Barbel-class submarines, the Blueback is the only one still existing.

USS Blueback was launched in May 1959 with Lt. Cmdr. Robert Gautier in command. Ingalls Shipbuilding Corp. had never built a submarine before—in fact, no shipyard in the entire southern United States had built a submarine since the early attempts during the Civil War.

After being commissioned on October 15, 1959, the boat went through a short “fitting out” period of arming and crewing before heading out in 1960 to San Diego. There she performed acceptance trials and training runs before relocating to Pearl Harbor. In 1965, she was deployed to assist American operations in Vietnam where she served three tours of duty. Blueback spent the next decade patrolling the Pacific and running special assignments in the Far East. In return for her service, Blueback was awarded two battle stars for participating in high-profile engagements during Vietnam. Unfortunately, much of Blueback’s operational history is still classified. Never the less, her superior engineering allowed the crew to complete a wide variety of reconnaissance and covert operations.

During Blueback’s 30 years of service, she and her crew were proud to represent the Submarine Force and the United States in many noteworthy events, including significant international naval exercises. Domestically, for example, she represented the Submarine Force at SUBASWEX, and overseas she participated at RIMPAC’75, RIMPAC’77, and RIMPAC’84, sailed to Australia to participate in the anniversary of the Battle of the Coral Sea, and also visited Colombia, South America where she joined Task Force 138 for exercises at UNITAS XVIII.

During her service history, the USS Blueback was modified by the Navy to incorporate the latest technologies; however, these modifications did not negatively impact the boat’s character-defining features or significance. The most notable modification was the relocation of the dive planes from the vessel’s bow to the sail in 1964.

As a testament to the excellence of the Sailors who served on the Blueback, she earned a Meritorious Unit Commendation and three Battle “E” Efficiency awards.

The Blueback was decommissioned in 1990 and donated in 1994 to the Oregon Museum of Science and Industry (OMSI) in Portland. The museum staff has carefully restored the boat to its in-service appearance, altering only what was necessary to make the boat accessible to the public.