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FALL 2015

UNDERSEA WARFARE

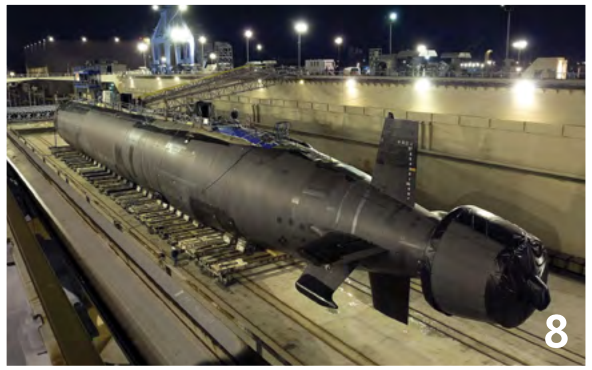
U. S. SUBMARINES… BECAUSE STEALTH MATTERS

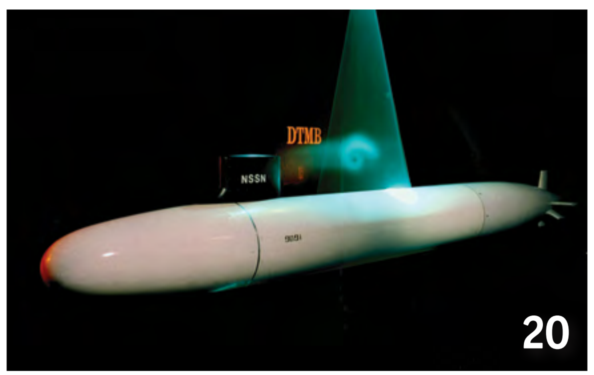
CARDEROCK:

Unparalleled Submarine Development Facilities and Support

INSIDE

Issue No. 59 Fall 2015





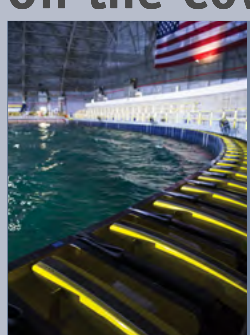
UNDERSEA WARFARE

THE OFFICIAL MAGAZINE OF THE U.S. SUBMARINE FORCE

CARDEROCK:

Unparalleled Submarine Development Facilities and Support

On the Cover



Close-up view of some of the 216 individually operated wavemaking paddles in the Maneuvering and Seakeeping basin at Naval Surface Warfare Center, Carderock Division.

Photo by U.S. Navy/Ryan Hanyok

Departments

UNDERSEA WARFARE is online at: www.public.navy.mil/subfor/underseawarfaremagazine

FORCE COMMANDER'S CORNER

Vice Adm. Joseph E. Tofalo, USN
Commander, Submarine Forces

Undersea Warriors,

Greetings from Norfolk! There has been a lot of activity since our last edition of *UNDERSEA WARFARE* Magazine, and I am pleased to be starting this edition with my first Force Commander's Corner. It is an honor to have been given this responsibility, and I look forward to the challenges and rewards of serving as your Force Commander.

Soon, Rear Adm. Roegge, Rear Adm. (sel) Richard, and myself will be releasing a joint *Commander's Intent for the United States Submarine Force and Supporting Organizations*. This *Commander's Intent* is meant to provide the Submarine Force with background and principles to help each and every member of the Force and supporting organizations to understand our priorities and future direction and their role in achieving them.

This *Commander's Intent* will update and supersede (as appropriate) all previous Force design and guidance documents. That said, you will find that the fundamental direction from those previous documents is preserved. This consistency and continuity should make it clear that we as a Force remain on the right track—our foundation is solid, our traditions reinforce the right attributes, and we have much to be proud of. This is less of a course change and more of some small rudder to keep us in the middle of the channel as we face changes in set and drift.

"Consistent with our history as a maritime nation, the responsibility to prevent challengers from using the sea to threaten these regions will fall predominantly on the United States Navy."

The situation we face presents us with challenges in at least three world regions, each of which places substantially different operational demands on the Force. Consistent with our history as a maritime nation, the responsibility to prevent challengers from using the sea to threaten these regions will fall predominantly on the United States Navy. As anti-access/area denial systems proliferate, the share of the Navy's responsibility that falls on U.S. submarine and undersea forces will only grow.

To address this situation, our primary lines-of-effort remain: Provide Ready Forces, Employ the Force effectively, and Develop Future Capabilities, with all three of these built upon the Foundation of our Strength—our undersea warriors, confident experts of the highest character, and their families. For those of you on the waterfront and in staffs that directly support, the majority of what you do is generate readiness.

In short we must continue to own the undersea domain. Undersea forces operate far forward and are persistent and covert. Our non-provocative influence can deter and de-escalate potential conflicts by providing cross-domain intelligence, real-time warning to U.S. leadership, and rapid transition from peacetime if required. We enable access for the entire joint force, operating inside adversary defenses, capitalizing on our stealth, and exercising surprise at the time and place of our choosing. I am deeply committed to this vision, and I am deeply committed to the tireless pursuit of undersea superiority.

Thank you for all you do—keep charging!

J. E. Tofalo

DIVISION DIRECTOR'S CORNER

Rear Adm. Charles A. Richard, USN
Director, Undersea Warfare Division

Undersea Warfare Team,

In August, I relieved Vice Adm. Tofalo as the Director of Undersea Warfare, and I'm thrilled to be here and be part of the OPNAV N97 team! This is truly a great time to be in the Navy, and to be in the Submarine Force.

The demand for undersea capability continues to grow rapidly as adversary anti-access/area denial (A2/AD) systems that can challenge the ability of our maritime air and surface forces to operate freely continue to proliferate. Next-generation nuclear submarines are being fielded by our potential competitors, and extremely quiet diesel submarines continue to proliferate globally, increasing the burden on our ASW forces and capabilities. We will be challenged to meet these demands as our undersea force structure shrinks over the next 15 years, but I am confident that we remain well positioned to respond to those challenges.

"Next-generation nuclear submarines are being fielded by our potential competitors, and extremely quiet diesel submarines continue to proliferate globally, increasing the burden on our ASW forces and capabilities."

As we look to the future, the type of influence that out platforms are capable of exerting will become increasingly important. To transform from a force that is platform-centric to one that is domain-centric will require enabling technologies such as new energy systems for sustained operations, networks for sharing information (not just data) with other domain nodes, fully integrated weapons like future torpedoes and missiles, building a system of systems to cover more area, more targets, more missions, more quickly, and the complete integration of manned/unmanned capabilities.

Our priorities, as established by Vice Adm. Tofalo, have not changed—because they are sound. Maintaining a survivable strategic deterrence remains our top focus. We must deliver Ohio Replacement on time, on budget, and with the right capabilities. Equally as important, we must maintain our *Ohio*-class operational availability to fully realize its unprecedented 42-year service life. We must also continue to build *Virginia*-class submarines. Currently, we are building two per year and working to find solutions for the years we are building Ohio Replacement, and we need every SSN we can get. Virginia Payload Module and Acoustic Superiority are off to a great start, and we're working very hard on getting the heavyweight torpedo line restarted, as well as improving weapon capabilities. A tremendous amount of hard work has been done on these priorities and must continue even as we look at other innovative ways to enhance our asymmetric advantage.

If you haven't seen the SECRET "Conflict of 2025" video (www.fleetforces.navy.smil.mil/csl), I recommend you take 10 minutes and watch it. It is part of why I think this is such an exciting time to be a Submariner. We are working hard to make that vision real, and most of you will get to operate those new capabilities in defense of our nation, as well as help define and build them. Every one of use has a key role to play, and I'm proud to be serving with you to make it happen. Keep charging!

C. A. Richard

UNDERSEA WARFARE
The Official Magazine of the U.S. Submarine Force

Charter

UNDERSEA WARFARE is the professional magazine of the undersea warfare community. Its purpose is to educate its readers on undersea warfare missions and programs, with a particular focus on U.S. submarines. This journal will also draw upon the Submarine Force's rich historical legacy to instill a sense of pride and professionalism among community members and to enhance reader awareness of the increasing relevance of undersea warfare for our nation's defense.

The opinions and assertions herein are the personal views of the authors and do not necessarily reflect the official views of the U.S. Government, the Department of Defense, or the Department of the Navy.

Contributions and Feedback Welcome

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CHINFO Merit Award Winner

Silver Inkwell Award Winner

LETTERS TO THE EDITOR

In keeping with *UNDERSEA WARFARE* Magazine's charter as the Official Magazine of the U.S. Submarine Force, we welcome letters to the editor, questions relating to articles that have appeared in previous issues, and insights and "lessons learned" from the fleet.

UNDERSEA WARFARE Magazine reserves the right to edit submissions for length, clarity, and accuracy. All submissions become the property of *UNDERSEA WARFARE* Magazine and may be published in all media.

Please include pertinent contact information with submissions.

Send submissions to:
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2000 Navy Pentagon
Washington, DC 20350-2000 *or*
underseawarfare@hotmail.com

FROM THE EDITOR

The article titled "What Really Happened to the Hunley and its Crew," published in the Summer Issue of *Undersea Warfare* Magazine, contained several errors. These errors have been corrected and an updated article can be view on our website at http://www.public.navy.mil/subfor/underseawarfaremagazine/Pages/default.aspx.

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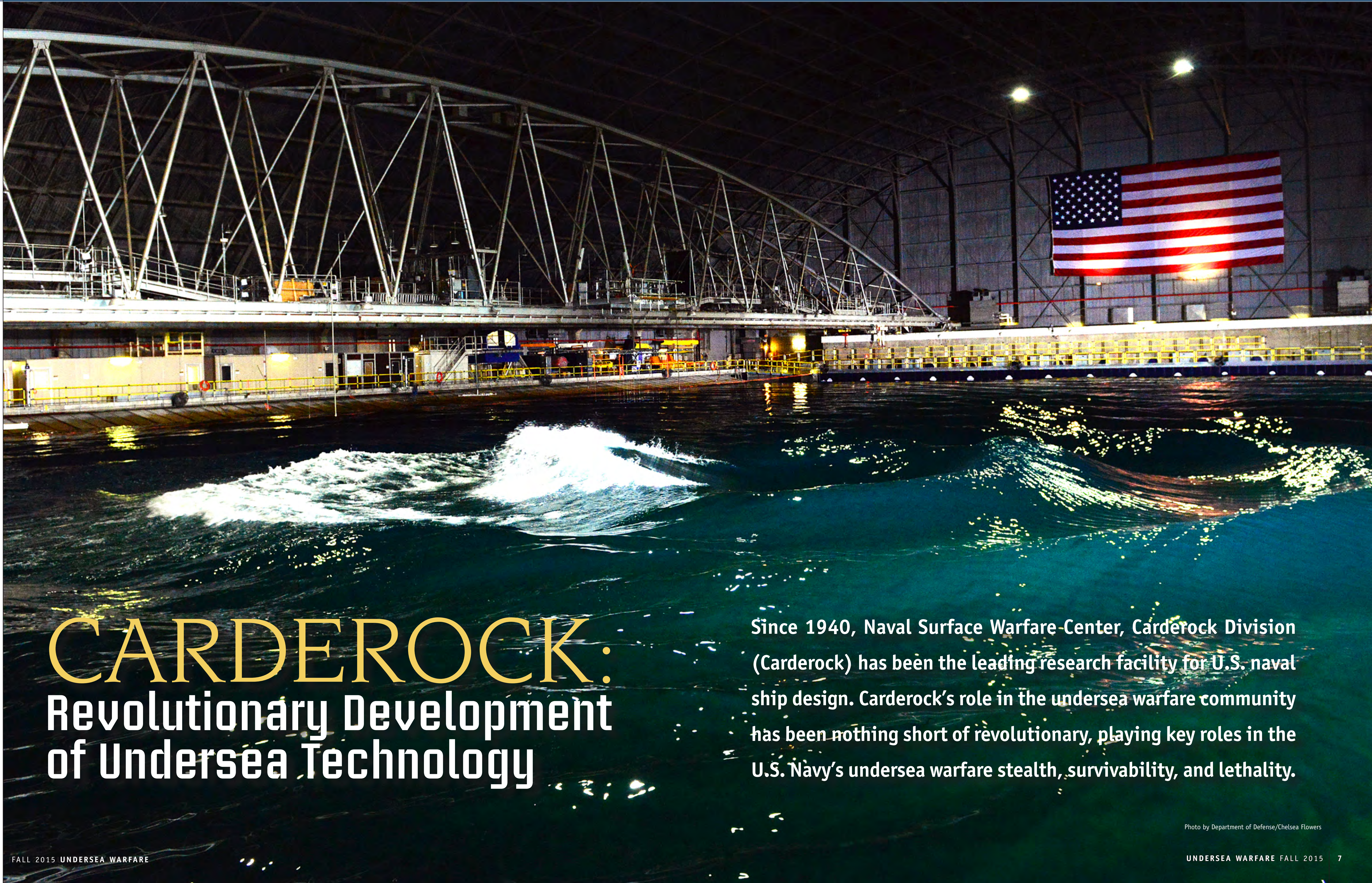
PHOTO CONTEST

Check out the winners of this year's Photo Contest located on the inside back cover.

by Naval Surface Warfare Center, Carderock Division



CARDEROCK: Revolutionary Development of Undersea Technology

Since 1940, Naval Surface Warfare Center, Carderock Division (Carderock) has been the leading research facility for U.S. naval ship design. Carderock's role in the undersea warfare community has been nothing short of revolutionary, playing key roles in the U.S. Navy's undersea warfare stealth, survivability, and lethality.

Photo by Department of Defense/Chelsea Flowers

Carderock's rich tradition of naval innovation began in 1898 when U.S. Navy Capt. David W. Taylor created the first "Experimental Model Basin" at the Washington Navy Yard on the Anacostia River. His brilliant idea quickly outgrew the Washington Navy Yard, and a move to nearby West Bethesda, Md., on the banks of the Potomac River took place just before the U.S. entered World War II.

Paralleling Taylor's genius was Rear Adm. George W. Melville, chief of the Bureau of Engineering in the 1890s, who fought for an engineering experiment station to build the machines to power the 20th century naval forces. Building on his vision, naval researchers designed and tested engines and fuels that drove the ships of World Wars I and II at the Engineering Experiment Station (EES) at Annapolis, Md. The Annapolis and Carderock institutions merged in 1967 into what is now the Naval Surface Warfare Center, Carderock Division.

Despite being a "surface warfare center," Carderock has a long history of contributions to the advancement of undersea warfare for the Navy, which wasn't well defined until after World War II when the U.S. entered an arms race with the then-Soviet Union. The need for advanced technologies and a mastery of innovation in supporting undersea warfare would prove to be a common theme in the motivation, success, and legacy of Carderock's contributions to undersea warfare.

At the heart of the post-World War II undersea arms race was the quest to find a way to power undersea ships so they could remain submerged and undetected. As a result, the U.S. Navy developed the Greater Underwater Propulsive Power Program, or GUPPY, for its submarines, based on the German Type XXI U-boat, to enhance submerged operational speed, endurance, and maneuverability. The program saw more than 50 submarines retrofitted during its duration, with submersible ship speeds reaching 18-20 knots. Carderock documented a wide variation in submarine engineering data throughout the GUPPY experiments but, due to the wide variation in data, could not create a standard handbook. Therefore, Carderock developed a process for designing and testing new submarine control features and pioneered new towing tank apparatuses, analysis techniques, simulation capabilities, and modeling techniques for predictive performance trials that would become standard engineering practices in all future naval engineering developments for submerged and surface vessels.

Around 1949, the Navy created Submarine Development Group Two (SUBDEVGRU 2), a team of Sailors, scientists, and engineers assembled to examine submarine tactics, equipment, and procedures. Submarine officers facilitated an atmosphere of professional cooperation among Sailors and civilian researchers. GUPPY and snorkel-research submarine Sailors began feeding information concerning the development of their special engineering features to research groups at Carderock and Annapolis. At the same time, SUBDEVGRU 2 headed up the primary investigation with augments of civilian scientists and engineers, including some from Carderock.

One scientist of note was Carderock physicist Marvin Lasky, who worked in the hydromechanics laboratory. His new work focused on sound detection and analysis and would prove to be a pivotal direction for future U.S. naval undersea engineering design. Lasky's well-tuned engineering ear focused on numerous noise problems with the GUPPY program after learning about roaring diesels, clanking valves on the snorkel pipe, the pipe's wake, cavitation, and numerous other self-defeating noise issues. Some noises were so severe as to render GUPPY conversion sonar ineffective. The research showed the Navy that, while the GUPPY conversions were able to produce faster submarines, they were far too noisy to be effective hunter-killers. This effort would be one of the most significant contributions to the Navy's undersea warfare community, led by a collaborative effort between the Navy's Underwater Sound Laboratory, New London, Conn. (and organizationally combined into what is now Naval Undersea Warfare Center (NUWC) Newport) and the David Taylor Model Basin, Carderock.

While Lasky's crew assumed overall responsibility for the sound silencing testing program, a team in Annapolis, led by electrical engineer Larry Argiro, focused on structure-borne, airborne, and over-the-side tests concentrating on machinery and their foundations. Both men shared their research and took leadership roles as the science of undersea sound silencing emerged. In 1963, their cooperation and the advancement of sound silencing science led to the Navy homogenizing its research efforts by merging the two groups. After the merge, Annapolis still concentrated its research on machinery noise while Lasky's crew worked on hydrodynamically generated noise, sonar self-noise, and radiated noise during submarine operation. Carderock work included sound test research in the Bahamas and remote work at Lake Pend Oreille, Idaho, studying towed arrays, acoustic and radar countermeasures, and small buoyant vehicle testing.

The combined work at Carderock and Annapolis led to modern-day sound silencing programs and significant acoustic stealth capabilities for the fleet.

The Navy acted on the findings of SUBDEVGRU 2 by recommending the development of a high-speed research submarine. The focus point of the submarine's design would be speed and maneuverability. Engineers were told not to worry about the design's surface performance. Carderock designed the prototypes, and their tests led to the selection of a hydrodynamic design known as "Body of Revolution Hull Test Series 58" or "teardrop hull," which eventually became USS *Albacore* (AGSS 569), considered by Carderock personnel at the time as their single greatest contribution of the institution over its century of innovation and invention. *Albacore* had a significant impact to the future of undersea warfare and served as the model of future submarine hull designs moving into the 1960s.

In 1954 the CNO stopped all work associated with alternative closed-loop engine solutions for submarines and focused its resources on the nuclear solution for propulsion. The adoption of the nuclear power plant as the sole source of propulsion for U.S. submarines led to multiple engineering opportunities for Carderock across multiple systems and disciplines. Carderock's early contributions to nuclear power included reactor design computations, and later acoustic and hydrodynamic improvements to enhance the hulls to improve stealth.

Development of nuclear reactor power plants utilized Carderock computational work in the design of the plants themselves. With the success of nuclear power as a sustainable source of power for submarines, there was then a need for auxiliary machines dedicated to life support by producing oxygen and removing the carbon dioxide the Sailors created so the submarine could remain submerged and undetected. These new needs led to the development of the submarine electrolytic oxygen generator (EOG), CO2 "scrubber," and CO-H2 "burner."

In the following sections, we'll look at how Carderock also influences the submarine construction process and operational capabilities by improving pressure hull design, shock testing different components of a submarine, measuring structure loads for under-ice operations, and testing maneuvering and handling qualities in different simulated sea conditions.

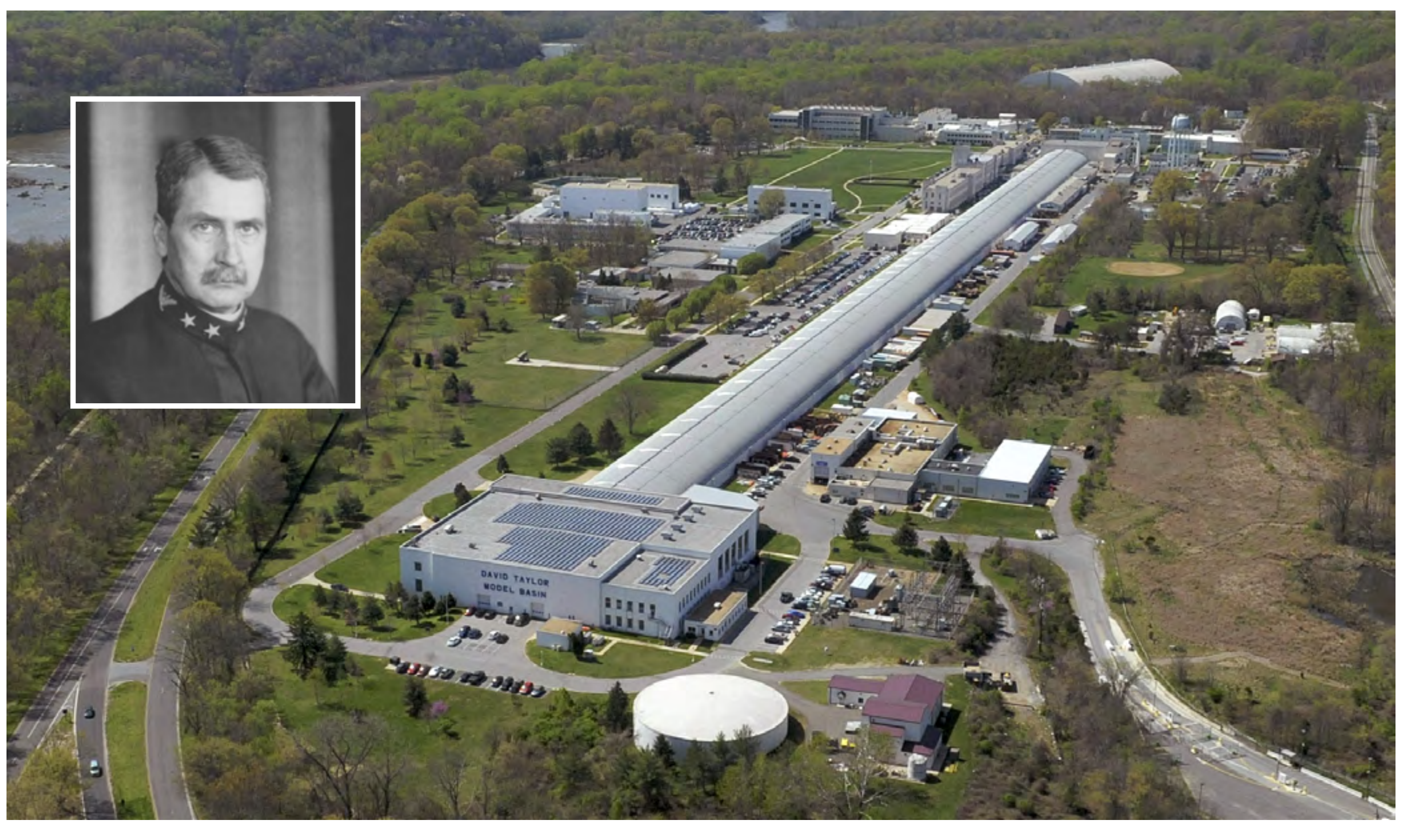


Photo by U.S. Navy

(Inset photo above) Rear Adm. David Watson Taylor, USN (March 4, 1864 - July 28, 1940) was a naval architect and engineer of the United States Navy. He served during World War I as Chief Constructor of the Navy, and Chief of the Bureau of Construction and Repair. Taylor is best known as the man who constructed the first experimental towing tank ever built in the United States.

The aerial photo above shows NSWC Carderock, the U.S. Navy's state-of-the-art research, engineering, modeling and test center for ships and ship systems. It is the largest, most comprehensive establishment of its kind in the world, serving a dual role in support of both our U.S. naval forces and the maritime industry.

Photo by U.S. Navy

USS *Albacore* (AGSS-569) was a significant development in the design of submarines because of its hydrodynamic design developed at Carderock. With the advent of nuclear propulsion, sustained underwater operations allowed submarines to be built in a manner which embraced underwater hydrodynamics without having to perform well on the surface of the water.

Submarine Fleet in Construction

Structural Mechanics

Carderock is the Navy's primary research, development, test and evaluation organization for submarines, submersibles, and undersea structures. For nearly 80 years it has provided the Navy and maritime industry with technical expertise for pressure hull structures. This includes conducting analytical stress and structural stability predictions, recommending improved design procedures, and conducting hydrostatic model tests. To complicate matters, the structural response can be different for different types of materials. Changes in technology have been beneficial to the submarine design community, but the goals remain the same as in the early days—provide a safe, reliable, and structurally efficient design.

Physical scale-model testing and at-sea testing have contributed to an understanding of the collapse phenomenon for materials and configurations that have been studied. Model testing has evolved whereby today's research models are characterized extensively for material and geometric imperfections. Models can be fabricated to include specified levels of geometric imperfections and specified weld strength. At-sea testing provides direct measurement of the structural response to evaluate full-scale details not amenable to inclusion in model tests or analytical models and to assist in defining areas that should be inspected. Current structural configurations employ high-strength materials and under-matched welding.

(Above) Final preparations are being made for the *North Carolina* (SSN 777) getting wet for the first time by filling her dry dock. Photo courtesy of Huntington Ingalls Industries via Bill Gonyo.

A few of the major structural elements that have been developed through research and at-sea testing include end closures, toriconical transitions to replace cone cylinder junctures, reduced-weight sandwich bulkheads, lightweight deep frames, and integration of missile tubes into the pressure hull structure. The community continues to optimize designs and improve structural efficiency to provide weight margin over the lifecycle of the vessel and allow for new weapons systems and increased payloads. However, it is important to remember the complexity of the design with regard to the various potential failure modes of a submarine pressure hull. The adage "the devil is in the details" fits quite well in describing the collapse phenomenon. Undersea structure designs will continue to improve as we continue to apply new science and engineering knowledge to our shipbuilding experience.

The Explosive Test Pond at the Naval Surface Warfare Center, Carderock Division is the only place the U.S. Navy performs to-scale underwater weapons testing with the ability to see and fully control all aspects of the tests to provide maximum analysis.

Virginia Payload Module Hull Structural Design and Testing

Beginning in the mid-2020s, the Navy will retire its existing fleet of four guided missile submarines, each capable of carrying 154 Tomahawk missiles. To help mitigate this loss of undersea strike capacity, the Navy is developing the Virginia Payload Module (VPM). The new module consists of four large-diameter tubes each capable of carrying seven Tomahawks. The current plan is to build VPMs as part of the Block V *Virginia*-class construction contract beginning in 2019. Carderock will develop two models in order to develop the final VPM design. The first model Carderock will build will be a complex scaled pressure hull model called a "criteria model." The criteria model helps Carderock's engineers study VPM's characteristics and establishes the criteria and guidelines necessary to be addressed in the design to ensure that the VPM will meet all its mission capability requirements.

Once data obtained from the criteria model are incorporated in the full-scale design, a second model, or "confirmation model," will be built. This second model will help Carderock confirm that the design is appropriate and its characteristics are understood. The confirmation model will verify and validate the final design features of the VPM and will certify and confirm the hull before initiating the construction of the Block V *Virginia*-class submarines.

Carderock, in a collaborative effort with General Dynamics Electric Boat, uses the important data and information provided by Carderock's modeling efforts for the final design of the VPM. Carderock contributes to the advancement and innovation of the Navy's submarine pressure hulls by conducting research and development through analytical and numeric methods and by leveraging tools for analysis and assessment on the data obtained from the empirical pressure hull model testing.

Deep Submergence

Full-scale, fully instrumented deep submergence structural evaluations are conducted on first-of-class submarines and on submarines that have undergone major structural modifications. Carderock works with the technical warrant holders for submarine structures to ensure structural adequacy and crew safety on U.S. submarines. Using approved design procedures validated by history and model test results provides confidence that the pressure hull is adequate for safe operations within a prescribed operating envelope. However, the deep dive structural evaluation provides in situ data that, when compared to analytics and model test results, confirms structural adequacy and provides additional insight for structural details that cannot be represented analytically or experimentally.

Although deep dives are not as numerous as in the past, they remain an important tool in submarine design. Recent deep dive structural evaluations have contributed to the removal of deep frame 38 for USS *San Juan* (SSN 751) and later *Los Angeles*-class boats, and incorporation of lock-out chambers for SSGNs. Recent first-of-class deep dive structural evaluations include USS *Seawolf* (SSN 21) and USS *Virginia* (SSN 774).

In terms of sizes and pressure range, the Deep Submergence Test Facility contains the most capable set of pressure tanks in the world for model testing. This facility is the only acceptable facility to test submarine confirmation and design criteria models, which are required for submarine design and certification.

The deep submergence pressure tanks provide the Navy and the maritime industry with the capability to test structures, components, and systems in an environment that simulates the ocean depths. As the only facility to test all of the Navy's current submarine confirmation models, the facility is a critical asset for any future submarine design.

Shock Qualification

Carderock's Survivability and Weapons Effects Division provides technical expertise in the field of submarine equipment shock hardening. They support Naval Sea Systems Command (NAVSEA) efforts to verify that equipment aboard *Virginia*-class submarines has met the shock requirements defined in the shipbuilding speci-

Sailors aboard the *Virginia*-class attack submarine USS *New Mexico* (SSN 779) tie mooring lines after the submarine surfaces through the arctic ice during Ice Exercise (ICEX) 2014.

fication. These efforts include executing shock tests of major systems on large shock test vehicles at the Underwater Explosion Test Facility, Aberdeen Proving Ground in Maryland, in collaboration with Army Test Center, Electric Boat Division, and NUWC Newport. They also support Ohio Replacement Program technology development efforts involving shock and other dynamic testing. The division's Dynamic Measurement and Test Branch maintains an extensive collection of time history data, high-speed videos, photographic documentation, and shock test reports from more than 50 years of shock testing that provide a valuable resource to component designers, analysts, and reviewers for ensuring a shock-hardened design.

Under Ice

Submarines surfacing through first-year sea ice in the Arctic region are limited by the forces required to penetrate the ice and the subsequent damage these forces may produce on the sails and their housed systems. In addition, after broaching the surface of the ice and settling into place, the hull and systems attached on the top of the hull are subjected to significant loads. The Arctic Structures Program within Carderock has produced guidance and an analytical methodology addressing Arctic surfacing limitations. Originally for USS *San Juan* (SSN 751), it has also been applied to other *Los Angeles*-class submarines as well as *Seawolf*-class, and *Virginia*–class submarines.

During Arctic operations, for the information to be of use to submarine operators, the limitations need to be presented in terms of surfacing parameters (i.e., ice thickness, trim angle, and impact velocity). An extensive empirical database has been developed. This database has been statistically analyzed to produce equations that predict the relationship between surfacing parameters and the resulting loads from both ice impact and penetration.

Any class of submarine may be expected to operate under the ice in wartime and, though it was not specifically designed for Arctic operations, the new *Virginia* class was evaluated for its Arctic surfacing limitations using the methodology previously developed. Damage predictions were made associated with surfacing parameters. These predictions provide information upon which decisions may be made for potential *Virginia*-class Arctic operations. This guidance for the *Virginia* class, similar to that produced for the *Los Angeles* class and *Seawolf* class, increases the Arctic capability of the fleet in general and specifically enhances the operational safety of the *Virginia* class.

Dolly Varden is a submarine model at Naval Surface Warfare Center Carderock Division's Acoustic Research Detachment in Bayview, Idaho.

Design and evaluation of vulnerable structures to Arctic forces has also been accomplished with the empirical database, as well as basic knowledge of ice failure loads and the manner in which a specific structure will be subjected to these loads.

Free-running Submarine Hydrodynamic Models

Model scale testing and experimentation is used to support the entire lifecycle of a submarine—from concept design studies to build and deliver—and various capability and performance changes over its lifetime. Carderock conducts two primary types of model experimentation: captive model experiments and free-running model (FRM) experiments.

Captive model experiments focus on the hydrodynamic forces and moments on the hull, appendages, and propulsor. FRM experiments look at the motions of the submarine during turning maneuvers, recovery from control surface casualty maneuvers, overshoots, and other maneuvers.

The FRM is an autonomous, battery-powered, free-running scaled submarine model that can be configured as a model of any of the submarine classes in the fleet. Because it is free running, it can move in all six degrees of freedom and provide an unsteady maneuvering capability. The FRM can perform a wide range of maneuvers and is currently the best predictor of full-scale submarine maneuvering performance at Carderock. The body is built from fiberglass supported by aluminum sections. The hull, appendages, and propulsor of the model are accurately built using the dimensions and specifications provided by the sponsor. Carderock maintains a fleet of these vehicles, allowing concurrent operations with more than one vehicle. They are constructed in three sections, including a central instrumentation can. The forward and aft sections operate flooded while the central instrumentation container is watertight. The models are completely autonomous and capable of independent operations. Onboard comput-

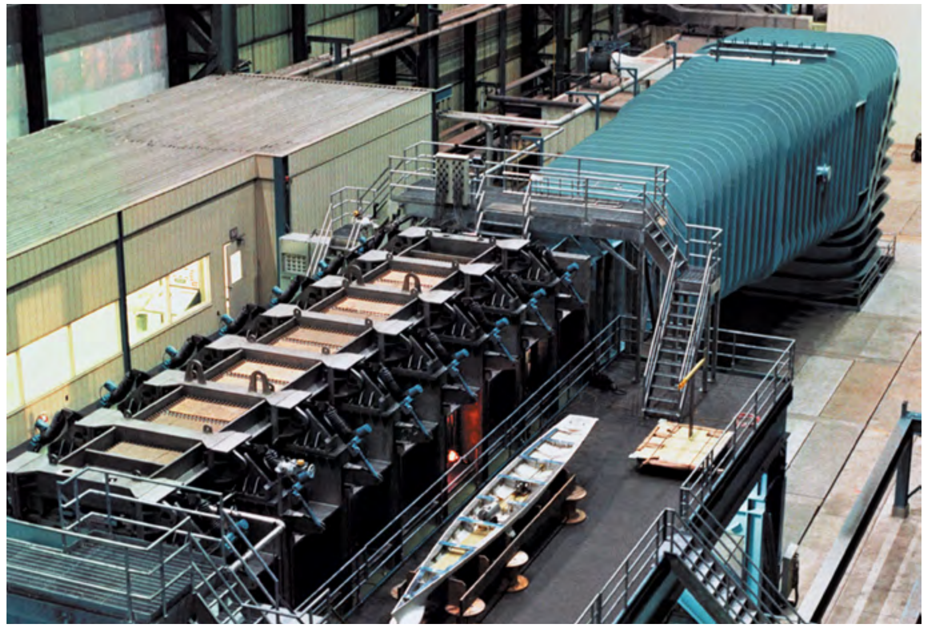
LSV 2 Cutthroat, the world's largest unmanned autonomous submarine, has been operating at the Acoustic Research Detachment in Bayview, Idaho, since its delivery in 2001. Cutthroat offers a cost effective and scalable research and development platform which enables advanced research and development in the areas of submarine hydroacoustics, hydrodynamics, and radiated noise reduction.

Acoustic Research Detachment

Little did the Department of the Navy realize when it began construction of North Idaho's Farragut Naval Training Center in 1942 that a small part of the base would one day become the Navy's premier acoustic test facility. The 22-acre Acoustic Research Detachment (ARD), a detachment of Carderock, is located on the shores of Lake Pend Oreille on what once was a World War II Training Center. Lake Pend Oreille, Idaho's largest, deepest (1,150 feet), and quietest body of water, provides an ideal environment for underwater acoustic testing. The ARD operates and supports unique large-scale submarine models, test areas on the lake, and land-based test facilities designed to support research, development, test and evaluation of submarine stealth technology.

ARD's state-of-the-art facilities support a wide variety of research and technology programs ranging from submarine propulsor development to the calibration of full-scale acoustic transducers. The dedicated civilian personnel who support the ARD mission form a highly capable and versatile workforce. This winning combination of committed workforce, ideal test conditions, and a controlled environment has saved the Navy millions of dollars over the years by avoiding the costs and complications associated with full-scale testing in the open ocean.

The data acquired at ARD over the past few decades have been critical to Navy submarine propulsor design, sonar dome development, construction cost reduction, and the development of acoustic signature reduction technologies. The Large Scale Vehicle-2, a large-scale autonomous model currently undergoing modifications in support of the Ohio Replacement Program, is used extensively to support propulsor research and development. Large-scale buoyant vehicle models support the evaluation of submarine hydro acoustic technologies. The Intermediate Scale Measurement System provides a unique static acoustic test capability unsurpassed by any other facility and is used to evaluate target strength and radiated noise measurements. The Advanced Electric Ship demonstrator, or SEAJET, provides a quiet surface hull for evaluation of surface ship signatures. ARD has been vital in supporting the design and stealth performance of submarines for the past several decades. Currently engaged in extensive support for the Ohio Replacement Program, ARD is well positioned to support the Submarine Fleet of the future.



The Very Large Test Apparatus submarine model will be tested at the Large Cavitation Channel (LCC) in Carderock's Memphis, Tennessee, detachment. The LCC is the most advanced and largest pressure-controlled recirculating water tunnel of its kind in the world. It provides a unique laboratory environment for advanced hydrodynamic and hydro acoustic testing. Photo by U.S. Navy

ers handle all of the data acquisition and model control tasks, and selected data can be uplinked to shore in real time. The FRMs are operated in one of two locations, the 360-foot-long by 240-foot-wide by 20-foot-deep Maneuvering and Seakeeping basin at Carderock or a Carderock-maintained test facility at the nearby Triadelphia reservoir. However, as the models are fully autonomous, they are capable of operating within other Carderock on-site and off-site test facilities.

The Very Large Test Apparatus Submarine Model

The Very Large Test Apparatus (VLTA) is a new scale-model testing capability being jointly developed by the Pennsylvania State University Applied Research Laboratory (ARL) and Carderock in support of submarine design efforts. It will be tested in Carderock's Memphis detachment Large Cavitation Channel and at ARL's Garfield Thomas Water Tunnel in State College, Pennsylvania.

The VLTA has new technologies and unique capabilities. It is larger than previous water tunnel tests. The larger scale allows for more relevant testing, enables significantly more instrumentation, and allows for more exact characterization of designs. The resulting VLTA model is more than 35 feet long and weighs more than 10 tons.

The development of the VLTA is a critical part of current design efforts and will be critical to future development programs. The new technologies that are being incorporated allow for improved modeling tools and enable characterization of important physics that weren't previously captured.

Photo by U.S. Navy

A robotic gas metal arc welder fabricates a weld in the robotic welding laboratory development system at Naval Surface Warfare Center, Carderock Division, in West Bethesda, Md. Carderock Division and their industry partners are developing highly specialized robotic welding systems to fabricate critical structures. The use of robotic automation improves worker safety, increases first-time quality, and reduces labor costs compared to traditional manual welding.

Advanced Signatures

Today, U.S. undersea forces hold a critical role in providing the ability of our Navy to provide deterrence and combat power at both the theater and strategic levels. A key element in the Submarine Force's ability to deter and strike at the time and place of our choosing is the inherent stealth that the force enjoys.

Historically, Carderock has been charged with the acoustic and non-acoustic signature health of the Navy's submarines. Using its array of acoustic and electromagnetic ranges, Carderock ensures the stealth and survivability of U.S. submarines throughout their operational lives and that these platforms remain as stealthy at the end of their service lives as the day they enter the fleet. This lifecycle management is not enough, however. The proliferation of advanced sensor technologies across the maritime domain seeks to challenge the inherent stealth of U.S. submarines. Carderock's advanced signatures programs continue to vigorously analyze both acoustic and non-acoustic undersea threats and, when necessary, assist in the development of systems and tactics to counter them.

The major efforts in these disciplines focus on understanding the fundamental physics that governs the detection of submarines at sea and on the advanced and emerging technologies that might be used

A physicist assigned to the Underwater Electromagnetic Signatures and Technology Division at the NSWC, Carderock Division, works on one of the over 300 triaxial magnetic field sensors permanently installed in the Magnetic Fields Laboratory.

to exploit these phenomena to create new vulnerabilities for the Submarine Force. Carderock continues to assess and develop expertise in a range of disciplines in the areas of acoustics, hydrodynamics, electromagnetics, and topside signatures as they relate to the operational performance of our Submarine Force. While most of this work remains classified, the result is a body of work that continues to maintain the safety, stealth, and survivability of the force.

Electromagnetic Signatures

Carderock Signatures Department is responsible for the design of underwater electromagnetic signature mitigation systems for the Ohio Replacement. These signature requirements will be achieved with the design and implementation of an advanced de-gaussing system and with magnetic treatment. The magnetic signature of the platform is composed of permanent and induced magnetism, where induced magnetism is caused when ferrous naval vessels pass through the Earth's magnetic field.

One of the primary tools used to combat electromagnetic signatures is the Magnetic Fields Laboratory at Carderock, a large-scale facility that provides advanced magnetic signature control systems to the Navy. The laboratory designs and evaluates candidate systems through the test of precision physical scale models constructed during the preliminary design phase of new ship classes.

The laboratory traces its history of scale model research to the 1940s, consistently producing models that accurately predict full-scale magnetic signature and signature control system designs optimized for performance and cost. The Magnetic Fields Laboratory is a unique research facility due to its large size, magnetic cleanliness, precision measurement capability, and ability to replicate all full-scale Navy magnetic signature control facility functions in scale. It is equipped with a large magnetic field control system enabling the simulation of ship operation on any heading at any geomagnetic location on earth. Scale models of up to 15 feet long and 1,000 pounds can be evaluated within a completely uniform magnetic field, and items of up to 44 tons can be tested.

Even in the earliest planning stages of new classes of submarines, Carderock's capabilities are brought to bear. In the following sections, we'll examine Carderock's involvement in the development of the Ohio Replacement and as part of a team tasked with conceptualizing what will become the successor to the *Virginia* class and evaluating new technologies to be used in production. We'll also cover Carderock's role in the development of training simulators and future undersea technologies such as ocean-deployed remote recharging and communications stations for submarines and unmanned undersea vehicles.

Acoustic Measurement Facilities

The Submarine Acoustic Signature Maintenance Program (SASMP) under the direction of NAVSEA Strategic and Attack Submarines (PMS 392), is tasked with providing the capability and facilities to measure and analyze the acoustic signatures of all in-fleet and new-construction submarines. This includes providing the testing and analysis capabilities used to support new submarine designs and research and development testing for submarine stealth improvements. This is accomplished by providing and maintaining facilities for radiated noise measurements selected for their ideal acoustic conditions. One facility, the Southeast Alaska Acoustic Measurement Facility (SEAFAC), is in a fjord near Ketchikan, Alaska, and serves the Pacific Fleet. The other major facility is referred to as the South TOTO Acoustic Measurement Facility (STAFAC), located in a deep basin of water called the Tongue of the Ocean (TOTO) in the Bahamas, which serves the Atlantic Fleet.

Photo by U.S. Navy

Both of these facilities are remotely located to take advantage of the extremely quiet acoustic background conditions required for accurate measurements. SEAFAC, located on an island next to the fjord, includes three major buildings, a pier, and extensive underwater cabling and measurement sensors. Additionally, SEAFAC is equipped with a static site where submarines can be tested in the absence of propulsion or flow noise. These facilities are operated and maintained by Carderock's Signatures Department in support of SASMP. STAFAC is also remotely located. The underwater infrastructure includes bottom-mounted sensors for tracking, a shallow water junction box for power and signal conditioning, as well as the high-gain arrays.

In addition to radiated noise facilities at SEAFAC and STAFAC, each submarine is instrumented during each test with carry-on systems to make onboard measurements and identify the sources of the signatures. A single installation for a *Virginia*-class trial may occupy a significant portion of the torpedo room, including up to 1,000 sensors and all associated cabling and processing equipment. Sophisticated ranging and tracking systems are also installed that work in conjunction with each facility to provide efficient, repeatable, and safe test conduct. All of this equipment is installed and removed for each test.

All data are processed real time at SEAFAC and STAFAC using hundreds of computers running on high-speed fiber networks. Once a test is completed, data are backed up and restored at analysis facilities for the Pacific and Atlantic fleets in Bangor Wash., and West Bethesda, Md. All analysis equipment, software, and massive storage capability is maintained by the Signatures Department of Carderock.

Supporting the Submarine Fleet in Operation

Approximately 40 percent of Carderock's work is for the undersea community, the majority of which is sponsored and directed by Team Submarine. In recent years, the Ohio Replacement and Virginia program offices have accounted for approximately half of Carderock's undersea work. The two programs rely heavily on the expertise that resides at Carderock, bringing in more than 50 employees with specialized and unique skill sets to supplement their Navy Yard staff. The programs also task Carderock for technical products and services that cover every facet of a major acquisition office: research and development, design, construction, modernization, logistics, and testing and evaluation. Carderock also supports many other submarine programs within Team Submarine, including in-service strategic and attack submarines, training systems, surveillance systems, escape and rescue, acoustic systems, undersea technology, international programs, and others.

(Above) Located in Behm Canal near Ketchikan, Alaska, SEAFAC provides an ideal ship acoustic measurement site characterized by low ambient noise and minimal noise interference. SEAFAC supports submarine operations over a full range of speeds and depths required for underway tests during acoustic trials. SEAFAC is also capable of supporting submarine target strength measurements.

Outside of Team Submarine, there are other undersea customers of Carderock Division that include Navy fleet and type commanders, shipyards, the Strategic Systems Program (SSP) office, the Navy Nuclear Propulsion Directorate (SEA 08), and others.

Out-of-Autoclave Bow Dome

The bulbous front end of U.S. submarines has been fabricated from high-quality fiberglass for many decades. These bow domes are typically free-flooded and house an array of sensors needed for navigation. The fiberglass, having impedance close to seawater, facilitates the transmission of the sensors' signals. To date, all fiberglass bow domes have been fabricated in an autoclave, a large pressure vessel capable of applying heat and pressure. In essence, the autoclave "cooks" the fiberglass material laminate while under pressure, the heat causing the material to cure while pressure compresses the laminate and forces out unwanted air.

Current bow domes under construction are for the *Virginia* class. The autoclave used for fabricating these domes is just large enough for the mold and dome itself. Carderock engineers recognized a need for an alternative to the geometric constraints of this standard autoclave method to build large-diameter fiberglass bow domes, so they teamed with their industry partners to develop and complete full-scale demonstrations for an alternative approach, labeled the "out-of-autoclave" (OOA) process. This new process facilitates the use of high-quality fiberglass materials for all future submarine platforms, including Ohio Replacement, independent of size.

Acoustic Trials

Acoustic signature measurements provide the Navy with knowledge of the detectability of their submarines and the information necessary to maintain mission readiness, develop enhanced capabilities to meet emerging threats, and evolve the quieting technology to help design tomorrow's fleet. For decades, Carderock has been the Navy's chief ship signature acquisition and measurement authority. Starting in the late 1950s, a variety of ships (*Monob* (YAG-61), *Deer Island* (YAG-62), and USNS *Hayes* (T-AG-95)) and land-based facilities (Carr Inlet Acoustic Range) successfully collected ship radiated-noise signatures. The application of ship silencing technology and the development of the *Seawolf* and *Virginia* classes of submarines were so successful that new measurement facilities and arrays needed to be developed and deployed to quantify our increasingly quieter submarine acoustic signatures. Today the South Tongue of the Ocean Acoustic Measurement Facility (STAFAC) and the Southeast Alaska Acoustic Measurement Facility (SEAFAC) are the Navy's state-of-the-art acoustic measurement facilities used to monitor the acoustic signature of the U.S. Submarine Fleet.

To maintain stealth and acoustic superiority, continual assessments of a submarine's acoustic signature is critical. NAVSEA sponsors signature measurement programs at Carderock. These programs characterize the acoustic posture of the submarine in a variety of operating conditions and, depending on the type of trial, an assortment of technical products are developed for the fleet and the technical community. For in-service submarines with a well understood acoustical history, a concise reporting of acoustic deficiencies and corrective actions are developed in support of the ship's maintenance period, as well as a ship susceptibility assessment used for ship operation.

For new-acquisition submarines, in addition to products to support the ship operator, a more in-depth report is developed that documents the ship signature as well as the systems and locations aboard the submarine that generate the noises. These results are then fed back to NAVSEA and the shipbuilder to prioritize and begin developing the necessary programs to mitigate any deficiencies. Working with the respective program offices and technical community, Carderock acquires data during acoustic trials needed to further the design of future submarine platforms. Acquiring data on in-service Navy ships allows Carderock to better bridge the gap between the research and development community and the ship construction community and provide the Navy with cost-effective acoustic silencing technology.

Electromagnetic Trials

Underwater Electromagnetic (UEM) systems' calibration trials on new-construction *Virginia*-class submarines are sponsored by the *Virginia*-class Program Office Warfare

The Submarine Rescue Diving and Recompression System's (SRDRS) Rescue Capable System (RCS), shown here in an exercise from 2011, is the U.S. Navy's deep-submergence submarine rescue asset. The Naval Surface Warfare Center, Carderock Division, together with Portsmouth Naval Shipyard, played a key role in a time-sensitive recertification of the Pressurized Rescue Module, the pressure hull structural component of the SRDRS, in 2013. The team provided analytical evaluation and hydrostatic testing in Carderock's Deep Submergence Test Facility in support of the recertification. Carderock expedited the testing necessary for the recertification, providing NAVSEA with the critical data 10 days ahead of schedule.

Engineers assigned to the Underwater Electromagnetic Signatures and Technology Division take measurements on the model track of the Magnetic Fields Laboratory. Photo by U.S. Navy

Requirements Division (PMS 450W). Carderock's Underwater EM Signatures and Technology Division has the technical responsibility for conducting these trials. Coordination among the fleet, the Magnetic Treatment Facility (MTF), and Carderock is required. Therefore, planning for a trial starts months ahead of the actual event with organizational coordination.

The first event of the trial is the arrival of the team at the MTF to install the onboard equipment that has been approved via the temporary alteration process. The technicians and engineers hand-carry the equipment to the boat for embarkation and installation. If the boat is not at the MTF, then the onboard personnel may ride the boat to the MTF, which is a large "drive-in" coil system with integral sea floor sensors (magnetometers) for measuring magnetic field. The MTF personnel will conduct any UEM tests called out in the test plan and then treat the boat to minimize the magnetic signature. After the treatment is completed, several days are allowed for relaxation and stabilization of the magnetic signature, followed by final calibration.

Submarine Maneuvering and Control Trials

The Submarine Maneuvering and Control Division, working on behalf of the Submarine Training Systems Office (NAVSEA 07TR), is responsible for the ship control operator trainers that provide shore-based training for all classes of U.S. submarines. Installed at each submarine base, the trainers replicate the environment of the ship control station and reside in a cab that moves in the pitch and roll directions. These trainers simulate the experience of steering, diving, ballast control, and casualty control for training. The scenarios may range from submerged maneuvering to surfacing and submerging to vertical ascent and descents. Ship control operator trainers are used by the submarine fleet to develop operator skills of the individual members of the ship control party by providing basic and advanced training in normal and casualty control procedures, and also provide a team training environment before deployment or while the ship is in port.

The trainers employ a variety of systems that serve five distinct functions: hydrodynamic modeling, tank modeling, realistic operation, ship motion, and instructor stations. The hydrodynamic models used in the trainers are the most extensive and accurate submarine simulations available. These model simulations used within each trainer are a direct product of the submarine maneuvering characterization process. The models provide the trainer with simulation capability of the submarine in a three-dimensional ocean environment. The operational environment may also be varied as it impacts the simulated motion through a variety of effects, including current, waves, and sound velocity profiles. Also relevant to the submarine profile in the trainer is accurate tank modeling. Tank systems, such as the main ballast system, trim tanks, depth control tanks, and the hovering and missile compensation tanks are modeled as applicable to the submarine class with their operation and effect on the submarine fully simulated.

Performance and special trials are conducted by the Submarine Maneuvering and Control Division on the first ship of each new class built for the Navy and on ships of existing classes when significant modifications have occurred to the hull, propulsor, or other hydrodynamic affecting appendages. Performance trials and special trials include a series of extensive sea trials designed to obtain definitive "truth" data concerning the hydrodynamic maneuvering and control characteristics of the ship. Trials planning, agenda preparation, test procedures, instrumentation calibration and installation, trial sites, data collection, and analysis and reporting are critical components in the process of executing these trials. The trials test and quantify the operational characteristics of the hull and the performance of the propulsion and control systems of the ship. The data are valuable to the ship for its mission and operation, and for the validation of the Navy's simulation and model scale prediction tools. Without this "truth" full-scale data, the ability to continually improve the prediction tools is diminished.

Performance trials, such as standardization trials and maneuvering trials, are performed to accurately assess the ship's design and operational performance. Standardization trials focus on the ship's speed and powering characteristics, while tactical maneuvering trials, such as tactical turns and accelerations/decelerations, provide data to characterize the overall maneuvering performance and capabilities of the ship. These trial results, coupled with model testing and simulation tools, support the development of critical fleet operational guidance such as the Submerged Operating Envelope and Ship Systems Manuals, the data of both directly impacting the ship and its ability to execute its mission in a safe and secure manner.

As part of the trials, the division provides NAVSEA and Carderock with certified and approved hydrodynamic trials directors to direct and execute the trials. The trials directors are responsible for the coordination of the trials with the ship, fleet support activities, the type commanders and Carderock trials personnel, the development of the trials agenda, and technical briefings to the relevant communities of interest. The trials team typically consists of four to eight additional personnel including Carderock hydrodynamicists, data acquisition and analysis specialists, and NAVSEA representatives from the Naval Systems Engineering Directorate (SEA 05) and the sponsoring program offices. If required, additional support from specific ship systems subject matter experts, such as ship control, will accompany the team during the trials.

Special trials are conducted with the objective of characterizing individual components of the ship in much greater detail, such as to investigate and characterize the overall effectiveness of the rudder. For this type of trial, the results are not only required for characterizing the full-scale ship and how the rudder affects performance, but the data will provide insight for future ship design decisions as well as the simulation tool development.

In 2004, digital maneuvering control systems were installed on *Virginia*-class submarines, to date the most heavily automated of any submarine class. At that time, the unprecedented "fly by wire" ship control systems were a big departure from existing control systems and had to be incorporated into the ship certification process following the SUBSAFE certification model. After a great collaborative effort among Carderock, NAVSEA, industry, and other government agencies, the first system was successfully certified to go to sea.

More than 10 years later, the division involves itself with maintaining the systems to the same rigorous standard to which they were first certified for use aboard submarines. The Submarine Maneuvering and Control Division is responsible for the work, dividing their efforts between software development activities and in-service engineering. The division supports both of these areas for the ship control systems on the *Ohio*, *Seawolf*, and *Virginia* classes and supports the initial ship control system design, development, and concept of operations for the Ohio Replacement Program. Division personnel are responsible for developing the computer software-based algorithms that are used in concert with the onboard hardware to control the rudder, stern planes, bow planes, and seawater flow control valves within the ship control systems. Teams of in-service engineering personnel install the completed tactical software upgrade that includes the control algorithms.

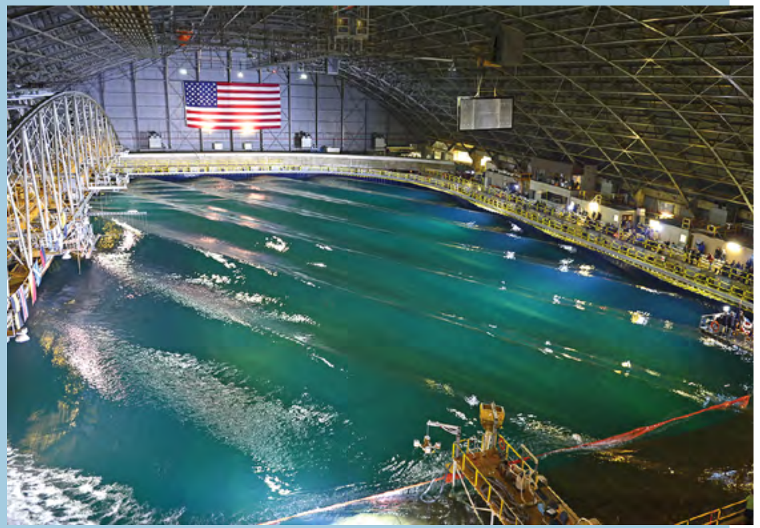
The certification of the algorithms is required via simulation at a land-based facility, followed by at-sea trials to fully validate the functionality of the algorithm. Simulation facilities exist at Carderock's Maneuvering and Seakeeping basin; at Lockheed Martin facilities in Syracuse, N.Y.; and Electric Boat in Groton, Conn. All three facilities use NAVSEA-accredited hydrodynamic maneuvering and control simulations, developed in accordance with the submarine hydrodynamic characterization process, as the basis for the certification process. The simulation is used in the tactical test bed to provide a closed-loop system to test the performance of the algorithms before installation on the submarine. After testing is completed, the software is integrated with the rest of the tactical ship control system software at Lockheed Martin or Electric Boat and tested on a tactical representation of the ship control hardware and supporting systems. Final certified tactical ship control system software is delivered and installed on the submarine and, based on the level of algorithm changes and/or submarine hydrodynamic changes, at-sea testing is performed before the ship is certified for unrestricted use of the automatic ship control system.

Maneuvering and Seakeeping Basin

Wavemakers at Carderock have been used to test both surface and subsurface vessels since the inception of wavemaking facilities. Submarines have the benefit of being able to avoid surface waves for most operational scenarios. However, for those cases where the sub must operate on the surface, seakeeping tests can be performed just as they typically are for the surface fleet. In the past, submarines have been tested in a fixed mode below carriages and as free-floating or forward-propelled models towed at or near the surface. The wavemakers have been used on these vessels to analyze survival modes at the surface and the effects of waves and wave slap on surfaced submarines.

All of the original wavemakers at Carderock were of the pneumatic type, introduced between 1950 and 1960. The benefit of the pneumatic wavemaker is that it has no moving parts below the water's surface. The wavemakers were very good at producing regular waves and could also be used for irregular waves. The fact that the waves were being made by a compressible media (air), however, resulted in a very irregular performance across the wavemaker frequency range.

Over the past decade, Carderock went through the process of designing and installing a new wavemaker for the Maneuvering and Seakeeping (MASK) basin. The new wavemaker is a displacement type consisting of 216 individual paddles. The MASK basin is shown in the photo while producing large regular waves during commissioning. The wavemaker is capable of producing regular and irregular waves, short and long crested seaways, bi-directional wave spectra, and other special coalescing events. The new wavemaker is better able to produce the expected types of waves in a realistic wave environment. Additionally, the control and performance of this displacement-type wavemaker allows for easier control and more exact production during a water experiment. It is anticipated that the improved control of wave production will lead to improved wave load determination on surfaced and near-surface subsea vessels and reduced testing costs. Photo by U.S. Navy/Ryan Hanyok



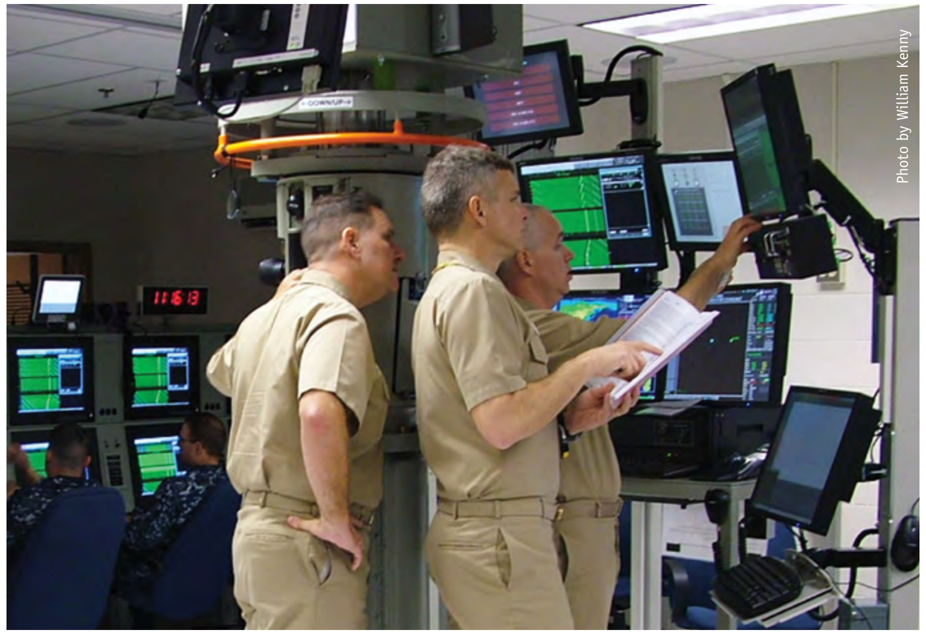


Photo by William Kenny

Officers at Naval Submarine School in Groton, Conn. monitoring a display in the Submarine Multi-mission Team Trainer.

Submarine Multi-mission Team Trainer

Carderock's Signatures Department provides advanced modeling and simulations of a submarine's acoustic properties. Signature modeling and simulation systems use the acoustic signature data that have been measured from submarine trials and measurement systems and then simulates how the sound is generated and propagated through the ocean environment to be received by another sensor. By properly modeling the source, the environment, and the receiver, a submarine's sonar system can then be fully stimulated with the energy propagating through the water and arriving at each sensor, just as it would when operating at sea. The All World Environment Simulation (AWESIM), developed by Carderock, provides this high-fidelity acoustic real-time simulation capability, which is then employed in support of testing the new sonar system build as it is under development and for training submarine crews to allow them to exercise their sonar along with the entire combat system in shore-based training facilities to perfect their skills with pre-deployment mission rehearsal training.

In support of the Submarine Training Systems office (NAVSEA 07TR), Carderock's Signatures Department, with the support of industry partners, leads the design and development of the Submarine Multi-Mission Team Trainer (SMMTT) in coordination with NUWC Newport. The SMMTT system uses the AWESIM acoustic simulation capability combined with the BYG-1 combat system and weapons simulation capability developed by NUWC Newport; high-frequency active simulation from Applied Research Lab, University of Texas; radar simulations from the Naval Aviation Warfare Center, Training System Division; and electronic warfare simulation to provide a fully integrated submarine combat system team training capability. Carderock also develops the high fidelity visual and infrared periscope simulation, which stimulates the imaging subsystems within SMMTT and has also been implemented for submarine navigation training with the Submarine Bridge Trainer. AWESIM is also used in the Surface anti-submarine warfare (ASW) Synthetic Trainer to improve sonar training aboard destroyers and cruisers and has been implemented in shore-based trainers developed for Integrated Undersea Surveillance Systems.

Li-Ion Batteries

The Advanced Power and Energy Branch at Carderock supports development and demonstration of specialized power systems and materials (electrochemical and mechanical), addressing their design and development to analyze and evaluate them for Navy use. Where lithium, lithium-ion, or other highly energy-dense power sources are used, a specialized and targeted safety assessment is conducted to provide risk quantification and reduction to program offices. Energy-dense power sources such as lithium batteries offer the greatest amount of energy by volume but come with potential for uncontrolled release of energy and toxic materials. Environments like aircraft canopies, ship holds, and submarines have common attributes: limited air space, limited fire suppression, and limited evacuation opportunities.

Carderock provides technical agent support to the NAVSEA 05Z Marine Engineering organization and other Navy System Commands, conducting analysis of carry-on/carry-off and embedded battery and power source hazards for payloads, replenishment, and ship-based systems. Through use of in-depth characterization of chemistry, power source design, failure modes, casualty effects, and platform impact analysis, Carderock evaluates the platform and personnel hazards posed by an energy source that may range in size from a wristwatch coin cell to several 40-foot ISO containers with a range of energy from tenths of watt-hours to thousands of kilowatt-hours.

U.S. Navy photo by John F. Williams

The Remus 600 is an example of the potential submarine payload relying on lithium-ion batteries for its energy source.

Submarine platforms have stringent requirements for atmospheric quality and control, and any release of material from a battery through its payload housing would degrade the breathable air. Manned submersibles pose an additional challenge for reliability and performance redundancy to assure safety of the personnel while underway.

Undersea power and propulsion poses numerous challenges to operate efficiently, purposefully, and safely when carried and launched from Navy platforms. Unmanned systems such as autonomous undersea vehicles (AUVs) may be carried by air, surface, or subsurface platforms and must be safe for personnel, the platforms, and the platform-unique environments to the system.

Recent successes include the deployment of lithium-battery-powered mine neutralization systems from helicopters and surface platforms, mine countermeasure systems, and numerous developmental AUV systems for operational sea trials. Other AUVs under evaluation include the Knifefish AUV, to be deployed from the Littoral Combat Ship, and various sea-gliders for extended-duration bathymetry needs. Future systems are expected to include advanced air-deployable sonobuoys and unmanned underwater vehicles (UUVs), the large displacement UUV, the manned dry combatant submersible, and integrated high-power systems aboard submersible platforms as Carderock continues to introduce and demonstrate new capabilities (e.g., undersea wireless energy transfer technology for remote charging) to warfighters in alignment with the Chief of Naval Operation's Speed-to-Fleet initiative.

Mobile Anti-Submarine Training Target

Carderock oversaw industry partners' construction of the Mobile Anti-Submarine Training Target (MASTT), which is a large-scale underwater autonomous vehicle built to support training for ASW platforms. It was built as a rapid prototype demonstration model with the requirement to support a training need for the Navy. The MASTT was constructed to be transportable to support the Navy's training needs wherever they may be required. MASTT operations are currently managed by the NUWC Keyport Detachment, San Diego, and is operated at its California naval ranges.

In response to a rapid Navy requirement, with a minimal budget, the MASTT was built to a few top-level performance requirements such as speed, depth, range, and mobile handling characteristics. The objective was to enable industry to use commercial off-the-shelf technology in supporting a rapid and inexpensive deployment to the Navy. The outcome was an impressive industry-Navy team effort in the design concepts pursued, commercial off-the-shelf technology used, and time of delivery.

MASTT builder's trials were planned and directed by Carderock and industry engineers and were conducted at the Carderock-ARD on Lake Pend Oreille, Bayview, Idaho. Given that the MASTT had yet to see water, the trials were conducted in a phased approach. Interim Test Readiness Reviews were conducted to ensure that all objectives were met and MASTT was ready to support further tests. During the MASTT builder's trials, MASTT demonstrated the functional strengths and capabilities that would support test requirements of the fleet. In addition, operational improvements were recommended to enable MASTT to better support future fleet testing at its permanent home in San Diego. The training value of MASTT will be assessed and positively validated in a series of integrated fleet demonstrations with air, surface, and submarine search platforms in fall 2015.

Photo by U.S. Navy

Mobile Anti-Submarine Training Target, a large-scale underwater autonomous vehicle, undergoes hydrostatic testing at Naval Surface Warfare Center Carderock Division, Acoustic Research Detachment's yellow barge on Lake Pend Oreille in Bayview, Idaho. The static yellow barge is fixed over 600 feet of water and provides a heavy lift capability to support testing and calibration of various Navy systems, sensors and transducers.

Supporting the Future Submarine Force

(Above) The wind tunnel at the Naval Surface Warfare Center, Carderock Division is one of many tools undersea warfare design and engineering professionals at Carderock use to minimize the detectability of hydrodynamic signatures of submarines. U.S. Navy photo by Peter Congedo

Submarine Concept Team

By 2044, the U.S. attack submarine fleet will be based on the complex integration of technology that is more than half a century old. Even with routine technology refresh, technology insertion opportunities, and major class improvements, it would be short sighted not to be preparing for the next "clean sheet of paper" attack submarine design. U.S. submarine designs historically take approximately 20 years from concept formulation to initial operating capability, and then each submarine serves for more than 30 years. The current Navy shipbuilding plan includes the start of construction of a new class of attack submarine in 2034. Focused concept studies would need to be completed about 10 years prior, and any significant technological advances would have to be at a reasonably high technology readiness level to be feasible for inclusion in the new class.

In 2014, Program Executive Office Submarines commissioned a small team to develop a plan for foundational studies leading to the next attack submarine. The Submarine Concept Team, led jointly by Carderock, NAVSEA 05, and NUWC Newport, was stood up as a result of that study. The intent is to lead the preparation for the next class attack submarine design to begin no later than the 2024 timeframe. This is being done through the development of future submarine designers, advanced design tools, and a series of advanced submarine concept studies.

Submarine Cost Estimating

Carderock's Cost Effectiveness Branch plays an integral role developing cost estimates through all phases of concept design, acquisition, operations, and support. This branch is a key member of NAVSEA Headquarters Cost Engineering and Industrial Analysis Division (SEA 05C). To support the early concept development phases, Carderock's cost analysts leverage a variety of cost estimating tools, including multiple regression-based cost models, to develop rough order of magnitude (ROM) cost estimates for designing, constructing, operating, supporting, and disposing of a class of submarines through its expected service life. These cost estimates support trade-off studies and cost-conscious decision making throughout the design development and selection process. The focus during the concept phase is to identify the key cost drivers and work closely with the submarine designers as a wide range of concepts, technologies, configurations, and capabilities are explored. Having ROM cost estimates early and throughout the design process is critical to informing the design process and developing a submarine concept that will meet the Navy's requirements and will fit within budget constraints.

The Cost Effectiveness Branch is dedicated to expanding and improving early-stage submarine cost estimating tools and processes. The branch also works with Carderock's Future Ship and Submarine Concepts Branch to integrate cost algorithms into concept design tools with the goal of developing a robust capability to assess thousands of design concepts with a technique called Design Space Exploration. The branch is also an active participant of the Submarine Concept Team.

The Cost Effectiveness Branch's overall effort and number of analysts supporting a program increases as the most promising submarine concepts progress into a formal analysis of alternatives and eventually to an acquisition program. The level of detail of the cost estimates increases dramatically as the submarine design matures and the acquisition strategy is developed. Throughout the acquisition process, Carderock's cost analysts are integrated with the NAVSEA Headquarters' Cost Engineering and Industrial Analysis Division and work with other organizations to develop a comprehensive, defensible program lifecycle cost estimate (PLCCE) that covers all costs associated with the program. The PLCCE and the service cost position are critical elements for a program as it progresses through the acquisition milestones and gate reviews and ultimately through proposal evaluation and award of the construction contract.

Forward Deployed Energy and Communications Outposts

The use of unmanned underwater systems has increasingly become a priority as the Navy increases its influence in the undersea domain in forward operating areas. These systems, including UUVs, can allow presence in threatening environments, often acting act as a force multiplier, deployed from the manned assets that carry them. However, these vehicles are limited by their onboard energy and data storage capacities. Current energy replenishment, data offload, and mission re-tasking of these vehicles is labor intensive and requires human intervention, consequently reducing operational time on station and thus decreasing mission effectiveness.

Forward Deployed Energy and Communications Outposts (FDECO) is an Office of Naval Research (ONR) Innovative Naval Prototype (INP) project, which starts in Fiscal Year 2016 and seeks to provide these services to assets deployed autonomously in forward operating areas. FDECO will prototype an open, scalable, and coordinated undersea energy, data, and communications infrastructure for undersea vehicles and sensors—think unmanned gas stations and cell phone towers under the ocean. FDECO will leverage modular system architecture so that multiple types of vehicles and assets can use it. In collaboration with industry, FDECO is executed across two system commands and three Navy laboratories. Carderock is the government energy lead for the project and is focusing the energy technologies into functional subsystems that, when combined, will meet the end desires of the warfighter. These subsystems include energy source and storage (like the types of stored gasoline in the gas station), management and power conversion (like how the gasoline gets to the right pump on time, in the right amount, and safely), and transfer and distribution (like the nozzle that physically puts the gasoline into a person's car). A key focus area will be non-penetrating (wireless) energy transfer to reduce the need for tight mechanical alignment tolerances with underwater vehicle docking technologies. This is akin to an electric car being wirelessly charged after pulling into the driveway.

While Carderock is focusing efforts on energy systems, NUWC Newport is the government lead for underwater docking and vehicle interoperability, and Space and Naval Warfare Systems Center Pacific (SPAWAR SSC Pacific) leads the underwater communications, command and control, and networks effort. Together, these three Navy labs pool their expertise to guide the project. FDECO is currently scheduled to finish in four years after completing two in-water demonstrations, leveraging a series of limited-objective experiments and technology integration events in key thrust areas to prove out advanced technologies.

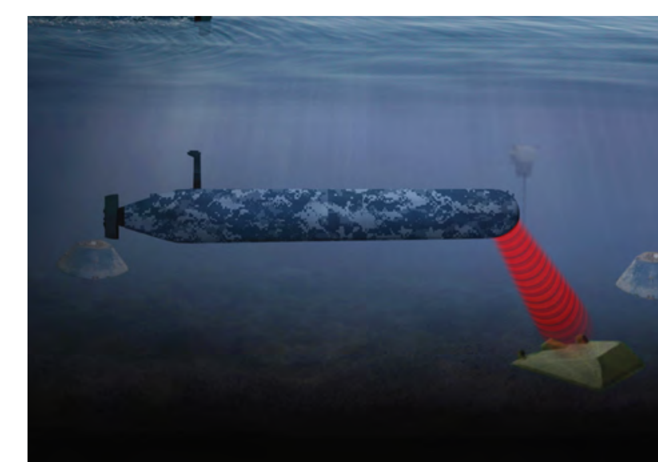
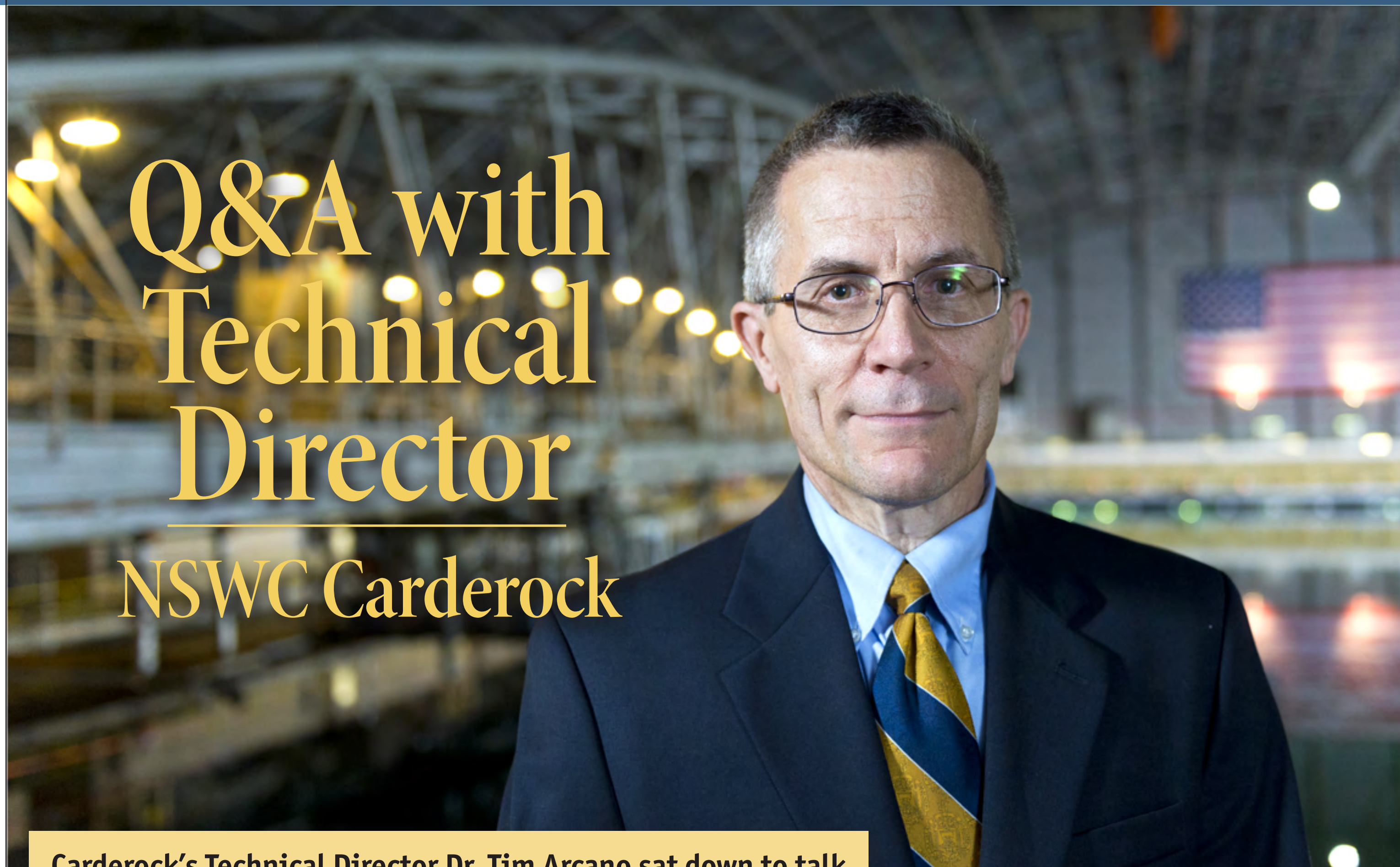


Photo courtesy of Bluefin

Unmanned undersea vehicles will extend the reach and effectiveness of submarines.



Q&A with Technical Director

NSWC Carderock

by Naval Surface Warfare Center, Carderock Division

Carderock's Technical Director Dr. Tim Arcano sat down to talk about Carderock's current efforts to support the undersea warfare community, and future directions for research and development.

How does Carderock Division support the undersea warfare component of the Navy's mission?

We all know that today's Navy is being asked to do more with less, so it's critical that we deliver versatile technologies that enable the Submariner to succeed with the overlapping and competing challenges that they are tasked with. We also know that the platforms we design today will still be in the fleet in 30, 40, and even 50 years. We need to innovatively design ships and submarines now to be flexible and adaptable for future technologies and even threats that might not yet even exist.

Commander Submarine Forces Vice Adm. Joseph Tofalo champions an undersea operation where we have the capability to reach farther and disrupt adversaries' operations while maintaining and protecting the best platforms and underwater vehicles. We are aligned with this strategic vision, working to fulfill the requirements and create new technologies that give the warfighter an advantage. The teams of scientists, engineers, and technicians at Carderock are staying ahead of the game. We draw on our past knowledge and the enormous amount of information we develop to help create the ships of tomorrow and anticipate future challenges. Also, as we foster a culture of innovation, I think we serve the current and future fleets well by looking at things differently—innovatively employing advanced technologies—while maintaining the technical judiciousness we are well known for.

I am proud of our workforce working hard each and every day to fulfill our mission: to ensure that the fleet of today and tomorrow is ready where it matters and when it matters.

What are some of the game-changing technologies that Carderock Division is working on for undersea warfare?

Let me highlight a couple of examples. We work on Unmanned Underwater Vehicles in collaboration with our counterparts at Naval Undersea Warfare Center (Newport Division and Keyport Division). Endurance, improving energy power density systems and safety, onboard power management systems, in situ recharging, and integration are key focus areas. We are striving to reduce cost drivers of vehicles and subsystems through commonality and modularity and by employing additive manufacturing techniques.

The Navy's future power and energy needs are broad and diverse. Carderock is one of the warfare centers poised to help develop and transition these technologies from university labs to industry partners. Wireless energy transfer, similar to that being driven by the electric vehicle market, is quickly becoming a critical component to having distributed underwater power and energy distribution networks. Another focus is improving safe, energy-dense lithium-ion batteries and capacitors, which will enable longer mission endurance and accommodate high-pulse power demands such as maneuvering, data transmission, and unique sensors. These power and energy advances are being pursued as part of a larger consortium; we periodically hold summits with stakeholders from across the undersea warfare enterprise, especially other warfare centers.

Another cutting-edge technology we are focusing on is additive manufacturing (AM), also known as 3D printing. AM has the capability to provide rapid response for improved capabilities by being able to directly print 3D objects without the constraints of traditional manufacturing. The Model Fabrication Facility in West Bethesda, Md., has produced functional parts for prototyping for more than 12 years. The parts are used in a variety of seakeeping and wind tunnel experiments to allow engineers and researchers to rapidly and accurately collect data. We are also actively engaged in research and development of new materials and AM processes to support broader implementation. For the Deputy CNO for Fleet Readiness and Logistics (OPNAV N4), Carderock plays a key role in the Naval Additive Manufacturing Technology Interchange in collaboration with other Naval System commands and the NAVSEA Warfare Centers to identify barriers to implementation, technology development areas, and steps to accelerate implementation.

As a working capital fund installation, Carderock's work mostly comes from outside sponsors and reflects the direct requirements of the fleet. What are you doing to shape your workforce to match known and future customer requirements?

Our goal is always to attract the absolute best and brightest to work at Carderock and support the mission. This effort begins with the investment in our future that we make through educational partnerships with local schools, STEM outreach and internships. Once students are here, it is our job to develop and retain them. I believe mentoring relationships are one of the best things we do here at Carderock, making sure our junior employees have access to senior leaders and subject matter experts. It encourages knowledge transfer both horizontally and vertically and keeps our engineers engaged. Predicting what customer needs will be and what the Navy will need next allows us to make subtle, dynamic changes in our staffing to ensure we are always ready to take on the work supporting the current and future fleets.

I understand that Carderock Division is working closely with OPNAV, PEO Submarines, NAVSEA, and industry in preparing the future workforce for the design of the next-generation fast attack submarine. Would you elaborate on this?

The U.S. Navy shipbuilding plan currently projects the authorization of the next-generation attack submarine in 2034. While this might seem a long way off, a 2034 authorization implies that an Analysis of Alternatives would need to be conducted 10 years earlier in 2024. This means that we have nine valuable years to prepare.

During this time, we need to develop the government submarine design workforce to ensure that we maintain the capability to be "smart buyers" in the future. We need to mature design tools and identify promising technologies now that will take years to develop so that they are feasible to include in a new submarine program.

We also need to design and evaluate the submarine in a different manner than we have in the past, as part of a larger "system of systems" where the submarine is just one node in the undersea warfare system in concert with off-board sensors and unmanned underwater vehicles.

And finally, we need to stay focused on cost. Affordability must be considered upfront to provide viable concepts for the future.

Carderock forms just one aspect of the multi-faceted Warfare Center enterprise. You've already mentioned some collaboration efforts. What else are you doing to collaborate with your sister warfare centers?

One project that highlights the collaborative spirit of the Warfare Centers is the work we're contributing to on the underwater wireless energy transfer systems that charge unmanned underwater vehicles. Carderock designed the wireless power transfer system, working with teams from Naval Undersea Warfare Center-Newport Division and Space and Naval Warfare Systems Center Pacific. Initial tests were conducted at Carderock, and in August the pieces physically came together for the first time at NUWC in Narragansett Bay, R.I.

We also engage with the greater technology community to ensure that our engineers are honed on the sharpest technology that industry has to offer. For National Engineers Week 2014, we welcomed Michael Jones from Google to host a variety of conversations on innovation. And earlier this year, when we cohosted a warfare center Energy Storage Summit here at Carderock along with NSWC Crane Division, Tesla Motors' Director of Powertrain Business Development Mateo Jaramillo keynoted the event, driving a discussion on the future of energy storage, a topic that has very real implications for the warfighter.

We're always looking for ways to collaborate across the Navy enterprise to advance new undersea technologies to the fleet, and we look forward to continuing these efforts with our military and industry partners as mission requirements continue to evolve.

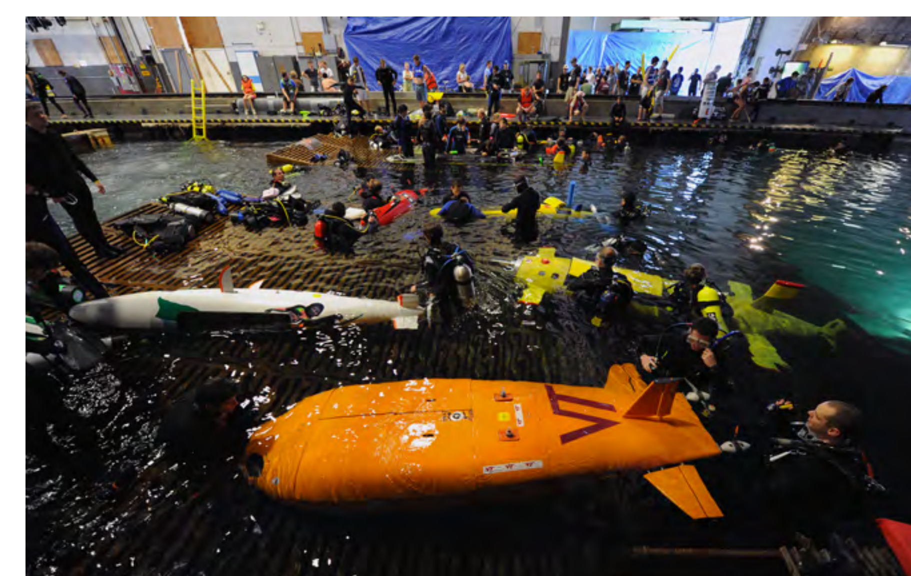


Photo by John F. Williams

Competitors prepare their submarines during the 13th International Human-Powered Submarine Race (ISR) being held in the David Taylor Model Basin at Carderock.

Why You Need to Join Naval Submarine League

The Naval Submarine League is a non-profit membership organization, founded in 1982 and committed to supporting, protecting and advancing the submarine force through awareness, public relations, and building a community of submarine advocates and enthusiasts.

The primary mission of the League is to promote awareness of the importance of submarines to U. S. national security.

Benefits of Being a Naval Submarine League Member

- Lifelong professional association to promote the importance of the Submarine Force
- Website where items of interest to the membership are available
- Multiple opportunities to hear from leadership and to share ideas
- Bi-Weekly updates on issues of interest to the membership
- Quarterly Professional Publication — *The Submarine Review*
- Local Chapters to support active duty and schedule social events to network with other submarine advocates and hear speakers of interest
- Annual Symposium, Submarine Technology Symposium and History Seminar
- Members-Only Naval Submarine League Group Forum on LinkedIn

Supporting the U.S. Submarine Force

The Naval Submarine League supports various Submarine Force activities, events and awards throughout the year:

- Awards presented throughout the year including: Fleet awards in multiple categories, Photo Contest awards, *Submarine Review* article awards
- Submarine Sailor of the Year Events
- Annual Three-Day Classified "Submarine Technology Symposium"

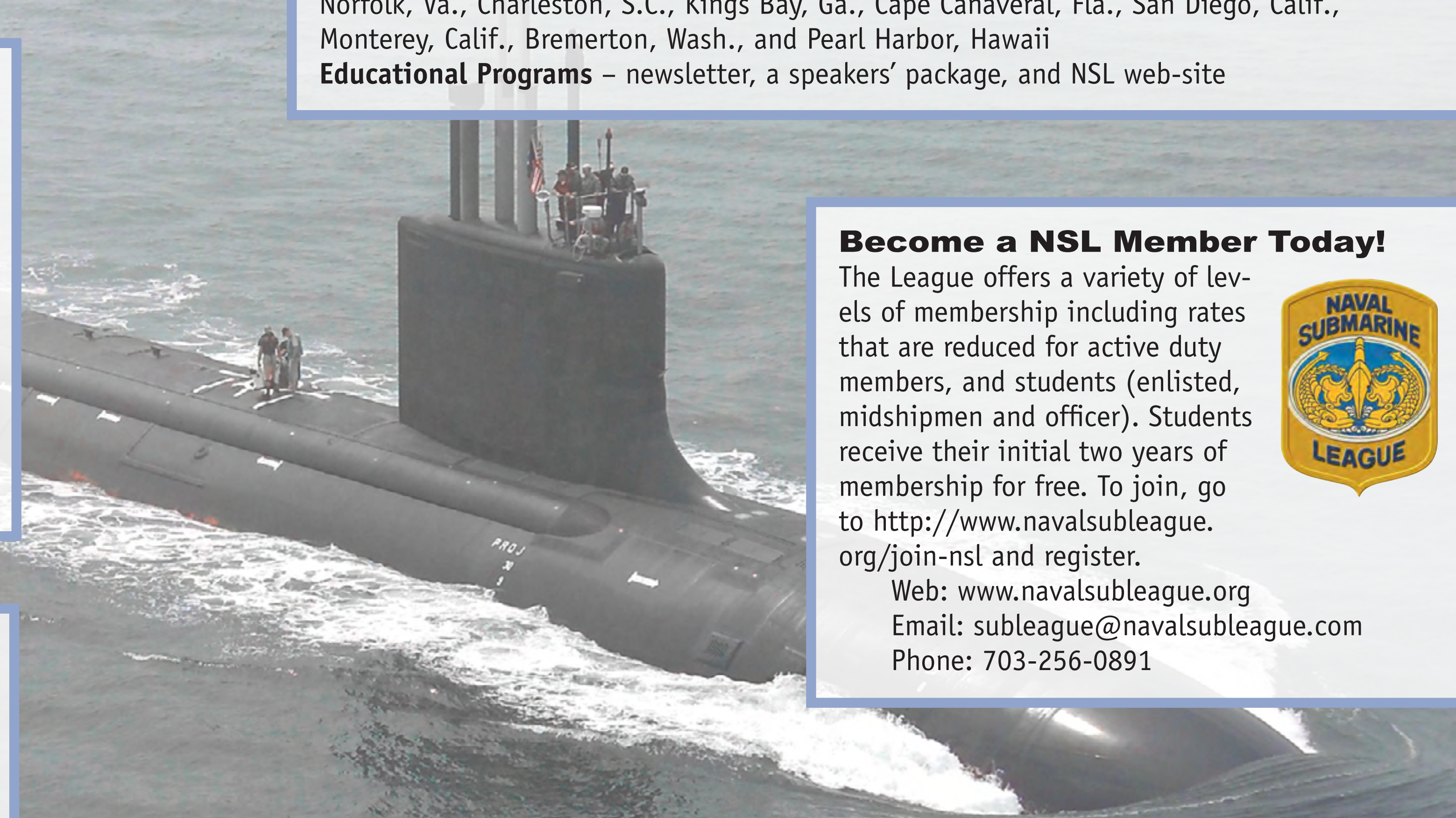
Navy Submarine League Events

Symposia/Meetings

- NSL Annual Symposium – held in Fall of each year
- NSL/APL Submarine Technology Symposium — a classified forum on technology developments
- Corporate Member Recognition Days — an opportunity for industry leaders to meet with submarine leadership
- Annual History Seminar — held in mid-April around the Submarine Force Birthday.

Chapter Events – professional and social gatherings (Groton, Conn., Washington, D.C., Norfolk, Va., Charleston, S.C., Kings Bay, Ga., Cape Canaveral, Fla., San Diego, Calif., Monterey, Calif., Bremerton, Wash., and Pearl Harbor, Hawaii

Educational Programs – newsletter, a speakers' package, and NSL web-site

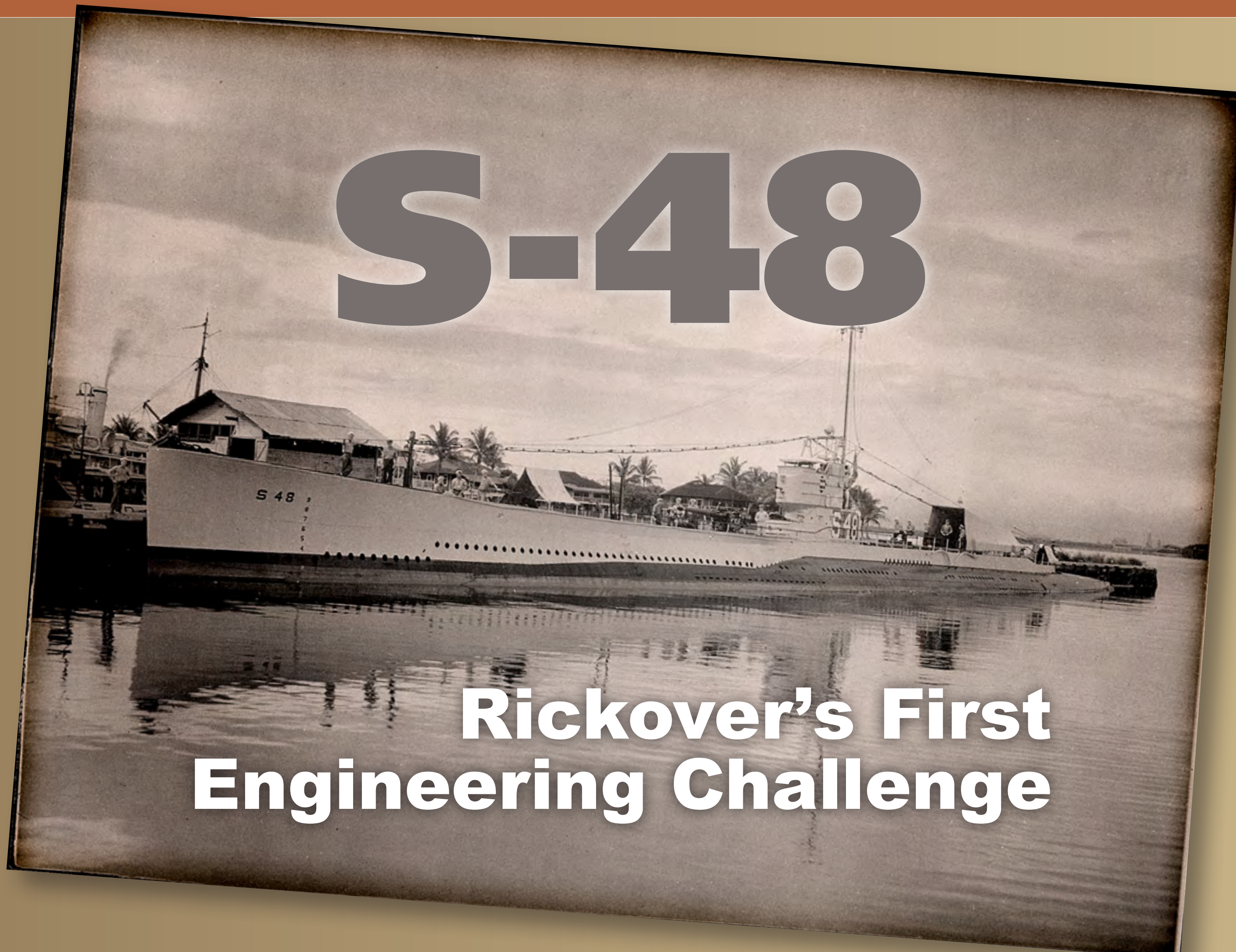


Become a NSL Member Today!

The League offers a variety of levels of membership including rates that are reduced for active duty members, and students (enlisted, midshipmen and officer). Students receive their initial two years of membership for free. To join, go to http://www.navalsubleague.org/join-nsl and register.

Web: www.navalsubleague.org
Email: subleague@navalsubleague.com
Phone: 703-256-0891

FOR ALL SUBMARINERS AND SUBMARINE ADVOCATES—PAST, PRESENT, AND FUTURE by Daniel J. Demers



S-48

Rickover's First Engineering Challenge

In December of 1932, Hyman G. Rickover, executive officer of *S-48*, wrote his wife, Ruth, "I hope that never again in my naval service will I ever be subject to conditions such as these." After graduating from submarine school in June 1930, the 30-year-old lieutenant was assigned to the submarine USS *S-48* (SS 159). His assignment lasted three years. Decades later he credited the *S-48*'s "faulty, sooty, dangerous and repellent engineering" with inspiring his obsession for high engineering standards. Rear Adm. William D. Irvin, who served with Rickover as an ensign aboard the sub, recalled that "anything that could go wrong on the *S-48* did go wrong."

When he was assigned to the *S-48*, it was the only remaining S-class submarine from the four-boat Group IV consisting of *S-48* to *S-51*. S-49 and S-50 experienced battery explosions and *S-51* sank due to a collision with a passenger ship. By the time Rickover reported aboard the *S-48*, her two surviving sister ships, themselves mechanical and electrical nightmares, had been decommissioned. The *S-48* had experienced its own serious mechanical and electrical problems long before Rickover reported for duty.

S-48's hard-luck history

The vessel's hard luck started 10 months after launching, when the yet-to-be-commissioned sub conducted her first test dive in New York Sound off of Penfield Reef on December 7, 1921. According to press reports, the 240-foot boat "was hardly under water before the shouted reports came from the aft part of the vessel: 'Engine room flooding! Motor room flooding!'" Emergency procedures kicked in. The men in the aft compartments stumbled forward and the forward compartment doors were shut. "A moment later the stern softly bumped on the bottom. The electric lights went out." Flashlights in hand, the sub's Commander, Lt. Francis Smith, ordered the ballast tanks blown, but "the weight of the water in the stern compartments was too much…her nose tilting up a little but that was all." Two hundred pounds of pig lead ballast bars were jettisoned through an air lock and four dummy torpedoes were shot out, on which the crew had painted "HELP" and "SUBMARINE SUNK HERE" along with numerous milk bottles "in which messages were enclosed giving notice of the plight of the vessel."

Slowly the bow began to rise like an inverse pendulum, but the stern stuck to the bottom. The upward tilt shifted the stern water. "Port batteries flooding!" yelled a crewman. The New York Evening News described the dramatic moment: "Breathing stopped. A flooded battery means chlorine [gas]." Cmdr. Smith and three crewmen immediately began bailing "to get seawater below the level of the [battery containers]…their hands were burned and every moment or two a whiff [of chlorine gas] drifted across their faces," making them cough and choke. No sooner had they gotten the water off the port side batteries that the starboard batteries started flooding. At the same time, the boat's bow continued to tilt upward as more material weight was jettisoned. At 30 degrees, the ships executive officers were certain the bow was above the surface "more than sixty feet from the bottom."

One member of the crew, while being pushed from behind, wriggled and worked his way out of the sub through a torpedo tube, which was about four feet higher than the ocean surface. A rope was passed up the tube, and the remaining crew of 50 were pulled out one by one. Hot coffee and blankets were also hauled up as the men huddled in the freezing weather. One Sailor's wet underclothing "was frozen into a solid casing about his shoulders and legs."

Some of the men went back down into the sub through the torpedo tube and "hauled out mattresses [which]…one by one were burned at the tip of the upstanding bow…the men sitting around their flaming signal…[warming themselves from] a stiff wind…[and] rough waters." They were finally rescued at 10:30 PM by a passing tug. The ordeal had lasted 14 hours, 10 of which were spent exposed to the frigid elements. Three men were briefly hospitalized for minor chlorine gas inhalation. Most of the men were employees of the Lake Torpedo Boat Co. of Bridgeport, Conn.

Initial reports by the Associated Press claimed that the sub had been hit by a tug boat, but it was later learned that somebody left open one of the airtight "manholes." Divers were able to secure the hatch and refloat the vessel.

By the following August (1922), the *S-48* began its second series of tests on Long Island Sound, diving to a depth of 100 feet and firing torpedoes and "other such trials." She was accepted and commissioned by the U.S. Navy in October of 1922. Over the next three years, she was in and out of New London, Conn. for repairs. She ran aground twice in 1926 during a violent storm once taking on water, which again caused chlorine gas to form. She was then returned to New London for the fifth time. Due to a lack of repair funds, the submarine was decommissioned. Funds became available in 1927 and repairs commenced, which included a hull extension of 25½ feet. In December 1928, she was recommissioned. Within seven months, she was back at New London undergoing repairs before resuming operations in June 1929. It was a year later that Rickover joined the crew.

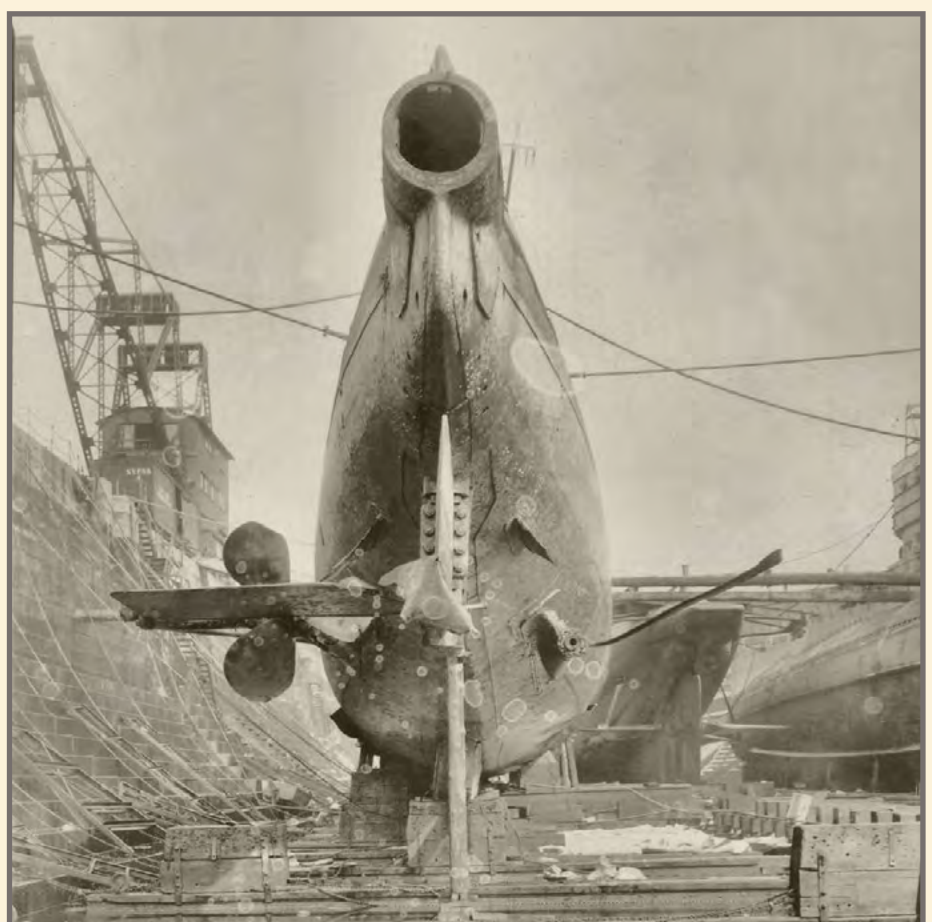
Rickover joins S-48's crew

In his biography, "Rickover: The Struggle for Excellence," Francis Duncan reports on a myriad of mechanical and electrical problems confronted by the young engineering officer on his first cruise aboard the *S-48*. He relates that the pneumatic control valves used to submerge the ship never "synchronized [properly and thus when diving] she [always] lurched to one side or the other…to as much as twelve degrees." Rickover wrote about his first cruise in July of 1930. Less than an hour into the cruise, a malfunctioning electrical controller forced the sub to stop. Once fixed, the gyro compass repeater then "went haywire…[making it] impossible to steer a correct course," he reported. About an hour later, an exhaust valve stem cracked, forcing another stop. It was repaired and "then three…cylinder jackets of the port engine developed leaks… [Rickover, fearing the Captain] would become disgusted [with his performance] took the chance and ran with the leaky cylinder jackets…" If that wasn't enough, several hours later "the electrician reported…something wrong with one of the main motors." Crawling into the bilges to check out a "jangling in the bow,"

he discovered the anchor chain was loose, “the control panel for the anchor windlass had become grounded.”

Two months later, smoke belched from a ventilator fan; a main battery had caught fire. According to Thomas Rockwell in his book, “The Rickover Effect,” the skipper, fearing an explosion, “ordered all men on deck, prepared to jump overboard if the expected hydrogen explosion occurred.” Believing the problem was his responsibility, Rickover volunteered to re-enter the sub and fix the problem. Rickover wrote, “the smoke was coming from the battery compartment…when it was opened black smoke billowed forth… Wearing a gas mask and trailing a lifeline [Rickover ventured through the hatch].” Finding no fire, he rigged a ventilating system and lime was placed in the compartment to absorb carbon dioxide. A later examination revealed that the fire had started by sparking battery connections. Three hours later, a short circuit in the “charred battery connections” started yet another fire, which he unsuccessfully attempted to put out with a carbon tetrachloride fire extinguisher. In desperation, he successfully sprinkled lime on the flames. It worked. The cause of the second fire was old and deteriorating insulation. Rockwell also relates that Rickover was confronted with propulsion motors that “were a continual source of trouble.” Showing his hands-on approach to problem solving, “he redesigned and rebuilt them [after which] they caused no further trouble.”

In July 1931, Rickover was promoted to Executive Officer. In November, the *S-48* had another mishap. She started a dive for a practice torpedo run and immediately “she took a twelve-degree list and a sharp downward angle. At seventy feet…she was out of control…blowing the tanks…brought her up… [A later] investigation showed a vent valve had failed to open.” In February of 1932, after several diving mishaps, a group of officers “nervous and tired, had drawn up a message…for all to sign, stating the ship was unsafe and could not complete her assignment.” According to Duncan, “Rickover argued them out of it…it would be bad for the reputations of all concerned and [told them] that he could work out a new diving procedure.” His diving protocol meant diving took longer, but it worked.



Making his mark on the Navy

Denied a coveted submarine command of his own, Rickover went on to become an Inspector of Naval Materiel, served on a battleship, and later commanded a minesweeper. In 1939 he was transferred to engineering duty (he had received his Master’s Degree in Electrical Engineering in 1929). A year later, he was promoted to command the electrical section of the Bureau of Ships and, at the end of WWII, commanded the Okinawa Naval Repair Base. A year later (1946) he was assigned to the Oak Ridge atomic energy facility, which led to his becoming chief of the joint Navy-Atomic Energy Commission Nuclear Propulsion Program, where he oversaw the engineering and construction of the Navy’s nuclear submarine fleet.

Adm. Hyman Rickover retired in 1982 having served 63 years—longer than any other man in naval history. The nuclear submarine fleet he helped develop resulted from exacting standards he credited to those three eventful years he lived aboard the “faulty, sooty, dangerous and repellent[ly]” engineered *S-48*. Adm. George W. Emery (Retired) once worked on Rickover’s staff. In a recent Naval History article he observed that Rickover made “a point to be personally on board during each nuclear-powered ship’s initial sea trials.” He missed two sea trials due to illnesses. According to Emery, it was Rickover’s “presence [that] set his demanding stamp of approval on both the material readiness of the ship’s nuclear-propulsion plant and state of training of her crew.” He held himself personally responsible for each submarine built and launched under his watch. Emery also reveals a personal part of Rickover’s attitude. A reporter asked him about his “powerful focus on quality standards,” to which he responded, “I love my son. I want everything that I do to be so safe that I would be happy to have my son operating it. That’s my fundamental rule.”

Adm. Rickover personified the American dream. Born into poverty in Russian Poland, his family fled to America to escape rampant anti-Semitism when Rickover was 6 years old. He entered the work force at the age of 9 to help support his family. At 14 he worked full time delivering telegrams while attending high school. In 1918 he was accepted at Annapolis. There he was known for his disciplined study. “[A]t night, when his three roommates slept, he sat in the shower stall, having rigged a blanket to hide the light, and prepared for the morrow’s class.” By the end of his career, he had been wined and dined by presidents, congressmen, senators, diplomats, and industry leaders. He was awarded two Congressional Gold Medals and the Presidential Medal of Freedom. The young Polish-Jewish immigrant proved that hard work and diligence in America makes anything possible.

Despite her frequent mechanical and electrical mishaps, sinkings, and groundings, the Lake Torpedo Boat Co. built *S-48* was finally deactivated in 1935 and berthed at League Island, N.Y. At the beginning of WWII, she was reactivated and used for training at New London. “Overhaul and repair periods [during the war] were frequent,” history records. The hard luck *S-48* was decommissioned in 1945 and scrapped the following year after 25 years of service, three of which inspired one of the Navy’s most respected and honored seamen.

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SailorsFirst

Secretary Ray Mabus triples maternity leave

Secretary of the Navy Ray Mabus announced that effective immediately, women who serve in the Navy and Marine Corps will have 18 weeks of maternity leave available to use during the first year of her child's life.

"In the Navy and the Marine Corps, we are continually looking for ways to recruit and retain the best people," Mabus said. "We have incredibly talented women who want to serve, and they also want to be mothers and have the time to fulfill that important role the right way. We can do that for them. Meaningful maternity leave when it matters most is one of the best ways that we can support the women who serve our county. This flexibility is an investment in our people and our Services, and a safeguard against losing skilled service members."

Department of Defense Instruction 1327.06, Leave and Liberty Procedures for the Department, charges Secretaries of the Military Departments with publishing departmental guidance in accordance with the DoD instruction. Under the section that delegates to the Secretary the ability to designate the level of control for convalescent leave that exceeds 30 days, Secretary Mabus has directed that commanding officers grant additional convalescent leave up to 84 days beyond the currently authorized 42 days of convalescent leave following the birth of a child.

For families, increased time following the birth of her child has tangible benefits for the physical and psychological health of both mother and child. For the Navy and Marine Corps, there is the likelihood that women will return to and stay in their careers, yielding higher readiness and retention for the services.

"When the women in our Navy and Marine Corps answer the call to serve, they are making the difficult choice to be away from their children—sometimes for prolonged periods of time—so that they can do the demanding jobs that we ask them to do." Mabus said. "With increased maternity leave, we can demonstrate the commitment of the Navy and Marine Corps to the women who are committed to serve."

The policy, effective immediately, will also apply retroactively to any woman who has been authorized convalescent leave following the birth of a child since Jan. 1, 2015. Commanding officers are required to grant a woman up to a total of 18 weeks, using a combination of maternity leave and convalescent leave beyond 30 days. A mother does not need to take all of her leave at once; however, she is only entitled to the use of this type of leave within one year of her child's birth.

Navy Establishes New Honor Graduate Ribbon

Secretary of the Navy Ray Mabus announced the establishment of a Recruit Honor Graduate Ribbon for superior performance during the Navy's basic military training, held at Naval Station Great Lakes, Illinois.

The first Navy Honor Graduate Ribbons were awarded to recruits during their pass-in-review rehearsal. The recruits who receive the ribbon will be authorized to wear it during recruit graduation.

To reward recruits for their superb performance during basic military training, the Honor Graduate Ribbon will provide a physical recognition of the Sailor's outstanding achievements in academics, physical fitness, recruit leadership and commitment to the Navy core values of honor, courage and commitment.

No more than three percent of the graduates from each training group will be designated as Honor Graduates and no retroactive awards are authorized.

In order of precedence, the ribbon shall rank immediately after the Navy Ceremonial Duty Ribbon.

Sailors volunteer for "Farm Day"

Twenty-three Sailors who are assigned to Naval Submarine Base New London (SUBASE) volunteered last month, on September 5, to help out at "Farm Day." Farm Day is a benefit hosted by the Lutz Children's Museum. It is held each year at the Fish Family Farm in Bolton, Conn. Those Sailors who volunteered assisted with activities such as hay rides, a farmer's market, and barn chores. Other activities included live music, barn tours, games, and arts and crafts.

Arleigh Burke Fleet Trophy Presented to USS *Columbia*

Pacific Fleet Commander Adm. Gary Roughead presented the Arleigh Burke Fleet Trophy to USS *Columbia* (SSN 771) during an Aug. 15 ceremony. Adm. Roughead formally recognized the Pearl Harbor-based submarine for being the most improved operational unit in the Pacific Fleet, and he credited the submarine's crew for their hard work and dedication to continuous improvement.

After completing a shipyard maintenance availability early last year, *Columbia* completed its Fleet Response Plan requirements, normally an 18-month process, in just eight months. During that time, the submarine trained prospective commanding officers as part of the Submarine Command Course, shot numerous exercise weapons, and conducted sound trial operations at the Southeast Alaska Acoustic Measurement Facility.

Welcome Home!

Electrician's Mate 1st Class Nick Benton, assigned to the ballistic-missile submarine USS *Pennsylvania* (SSBN 735) (B), gives his wife and daughter the first hug during the ship's homecoming at Naval Base Kitsap - Bangor. *Pennsylvania* is one of eight ballistic-missile submarines stationed at the base.

Photo by Mass Communication Specialist 1st Class Kenneth G. Taka

Changes of Command

Chief of Naval Operations
Adm. John Richardson relieved
Adm. Jonathan Greenert

Naval Reactors (NAVSEA 08)
Adm. James Caldwell relieved
Adm. John Richardson

Commander, Submarine Forces
Vice Adm. Joseph Tofalo relieved
Vice Adm. Michael Connor

COMSUBPAC
Rear Adm. Fritz Roegge relieved
Rear Adm. Phil Sawyer

COMSUBGRU 10
Rear Adm. Randy Crites relieved
Rear Adm. Chas Richard

COMSUBRON 4
Capt. John McGunnigle relieved
Capt. Jim Waters

Director, Undersea Warfare (OPNAV N97)
Rear Adm. Chas Richard relieved
Vice Adm. Joseph Tofalo

Trident Training Facility
Capt. George Perez relieved
Capt. Rodney Hutton

Undersea Rescue Command
Cmdr. Mark Hazenberg relieved
Cmdr. Andrew Kimsey

USS *Alabama* (SSBN 731) (G)
Cmdr. Matthew Chapman relieved
Cmdr. Brody Frailey

USS *Albuquerque* (SSN 706)
Cmdr. Don Tenney relieved
Cmdr. Trent Hesslink

USS *Boise* (SSN 764)
Cmdr. Chris Osborn relieved
Cmdr. Scott Luers

USS *Georgia* (SSGN 729) (B)
Capt. David Adams relieved
Capt. William Breitfelder

USS *John Warner* (SSN 785)
Cmdr. Burt Canfield relieved
Cmdr. Dan Caldwell

USS *Maine* (SSBN 741) (B)
Cmdr. Bill Johnson relieved
Cmdr. Kelly Laing

Secretary of the Navy (SECNAV) Ray Mabus speaks with guests attending a dual ship-naming ceremony for the Navy's newest Littoral Combat Ship, the future USS *Billings* (LCS 15) and future *Virginia*-class attack submarine, USS *Montana* (SSN 794), at Metra Park Rimrock Auto Arena. Mabus thanked the people of Montana for their support and contributions to the Navy and discussed the special bond that exists between a state and its namesake vessel.

Photo by Chief Mass Communication Specialist Sam Shavers

USS *Michigan* (SSGN 727) (G)
Capt. Gustavo Gutierrez relieved
Capt. Benjamin Pearson

USS *Michigan* (SSGN 727) (B)
Capt. Joseph Turk relieved
Capt. Erik Burian

USS *North Dakota* (SSN 784)
Cmdr. Mike Hollenbach relieved
Capt. Doug Gordon

USS *Pasadena* (SSN 752)
Cmdr. Mark Cooper relieved
Cmdr. Kenneth Douglas

USS *Rhode Island* (SSBN 740) (B)
Cmdr. Nirav Patel relieved
Cmdr. Louis Springer

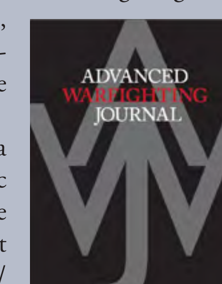
USS *Emory S. Land* (AS 39)
Capt. Mark Prokopius relieved
Capt. Robert Clark

USS *Frank Cable* (AS 40)
Capt. Andrew St. John relieved
Capt. Mark Benjamin

Inaugural issue of Advanced Warfighting Journal online

The Navy Warfare Development Command announces the launch of the Advanced Warfighting Journal. The AWJ is a classified, quarterly, theme-based, electronic periodical featuring warfighting development articles from subject matter experts from across the Navy.

The AWJ is intended to stimulate tactical warfighting conversations in ready rooms and wardrooms, inform readers about emerging capabilities, and connect them to Navy doctrine and tactics, techniques and procedures.



The inaugural AWJ focuses on a key CNO initiative: Electromagnetic Maneuver Warfare. AWJ is posted on the NWDC Navy Warfighting Development Portal (https://portal.nwdc.navy.smil.mil/awd/). Individuals can request access by going to the NWDC SIPR SharePoint Portal: https://portal.nwdc.navy.smil.mil/accounts/.

Navy integrated fires is the theme for the Fall 2015 AWJ, which will feature articles on efforts enabling our kill chain in the anti-access/area denial environment while disrupting adversary capabilities. Submissions are due Sept. 25, 2015 to NWDC_NRFK_AWJ@navy.smil.mil. Content is classified up to secret-noforn.

Contact Grant Sattler, NWDC N3 Outreach, for questions about submissions: alan.sattler@navy.mil; alan.sattler@navy.smil.mil; 757-341-4240.

Qualified for Command of Submarines

Lt. Cmdr. Chad Tella
USS *Cheyenne* (SSN 773)

Lt. Jonathan Cebik
USS *Nevada* (SSBN 733) (G)

Lt. Gregory Storer
USS *Hartford* (SSN 768)

Qualified in Submarines

Lt. Tyrell Arment
USS *Maryland* (SSBN 738) (B)

Lt. John Graves
USS *La Jolla* (SSN 701)

Lt. Colin Williams
USS *Tennessee* (SSBN 734) (B)

Lt. j.g. Jeremy Bohanan
USS *West Virginia* (SSBN 736) (B)

Lt. j.g. Adam Carlson
USS *Santa Fe* (SSN 763)

Lt. j.g. Christopher DeYoung
USS *Bremerton* (SSN 698)

Lt. j.g. Travis Hack
USS *Wyoming* (SSBN 742) (G)

Lt. j.g. Andrew Haines
USS *Bremerton* (SSN 698)

Lt. j.g. Paul Heft
USS *Rhode Island* (SSBN 740) (B)

Lt. j.g. Michael Hughes
USS *New Mexico* (SSN 779)

Lt. j.g. Nathaniel Pelletier
USS *New Mexico* (SSN 779)

Lt. j.g. Dylan Perry
USS *Toledo* (SSN 769)

Lt. j.g. Michael Plummer
USS *New Mexico* (SSN 779)

Lt. j.g. William Queen
USS *Mississippi* (SSN 782)

Lt. j.g. Joseph Richards
USS *Mississippi* (SSN 782)

Lt. j.g. Thomas Warner
USS *Rhode Island* (SSBN 740) (B)

Lt. j.g. Fleet White
USS *Olympia* (SSN 717)

Supply Corps Qualified in Submarines

Lt. Thomas Schwander
USS *Tennessee* (SSBN 734) (G)

Lt. Ryan Shipley
USS *Rhode Island* (SSBN 740) (B)

Lt. j.g. Dylan Perry
USS *Toledo* (SSN 769)

Qualified Nuclear Engineering Officer

Lt. David Chucoski
USS *Boise* (SSN 764)

Lt. Stephen Edwards
USS *Topeka* (SSN 754)

Lt. Nathan Heussenstamm
USS *Pasadena* (SSN 752)

Lt. Douglas Rohrback
USS *Kentucky* (SSBN 737) (B)

Lt. j.g. Joseph Buonaccorso
USS *Texas* (SSN 775)

Lt. j.g. Alexander Ford
USS *Newport News* (SSN 750)

Lt. j.g. Heath Hephill
USS *Georgia* (SSGN 729) (G)

Lt. j.g. Jeremy Hoffman
USS *Georgia* (SSGN 729) (G)

Lt. j.g. Neal Holmes
USS *Chicago* (SSN 721)

Lt. j.g. Erik Hunter
USS *Albuquerque* (SSN 706)

Lt. j.g. Katherine Irgens
USS *Georgia* (SSGN 729) (G)

Lt. j.g. William Jones
USS *Helena* (SSN 725)

Lt. j.g. Wylie Kulla
USS *Michigan* (SSGN 727) (G)

Lt. j.g. Conrad Kusel
USS *Florida* (SSGN 728) (G)

Lt. j.g. Kevin Lamott
USS *Key West* (SSN 722)

Lt. j.g. Jonathan Lozano
USS *Alaska* (SSBN 732) (G)

Lt. j.g. Jonathon Luetkenhoelter
USS *Jefferson City* (SSN 759)

Lt. j.g. Toby Marble
USS *Kentucky* (SSBN 737) (B)

Lt. j.g. Matthew McGury
USS *Henry M. Jackson* (SSBN 730) (G)

Lt. j.g. Joshua Meeder
USS *Columbia* (SSN 771)

Lt. j.g. Joseph Riffitts
USS *California* (SSN 781)

Photo by Mass Communication Specialist 2nd Class Johans Chavarro

Rear Adm. Phillip G. Sawyer, outgoing Commander, Submarine Force, U.S. Pacific Fleet (COMSUBPAC), walks through the side boys during the COMSUBPAC change of command ceremony at Joint Base Pearl Harbor-Hickam. The Pacific Submarine Force provides anti-submarine warfare, anti-surface ship warfare, precision land strike, intelligence, surveillance, reconnaissance and early warning and special warfare capabilities to U.S. Pacific Command and strategic deterrence capabilities to U.S. Strategic Command.

Lt. j.g. Oliver Rodewald
USS *Hartford* (SSN 768)

Lt. j.g. Jonathan Sass
USS *Pennsylvania* (SSBN 735) (G)

Lt. j.g. Brian Stanfield
USS *San Francisco* (SSN 711)

Lt. j.g. Ryan Veatch
USS *Florida* (SSGN 728) (G)

Lt. j.g. William Weatherspoon
USS *Florida* (SSGN 728) (G)

Lt. j.g. Louis Wu
USS *Olympia* (SSN 717)

"On a Mission to Defend Freedom" — USS *John Warner* is Commissioned

The *Virginia*-class attack submarine USS *John Warner* (SSN 785) was commissioned during a ceremony attended by more than 2,500 in its future homeport of Naval Station Norfolk, Aug. 1, 2015. Proudly displaying its motto "On a Mission to Defend Freedom," the ship is the 12th *Virginia*-class attack submarine to join the Navy's operating fleet.

The ship's namesake is John Warner, a five-term U.S. Senator from Virginia who also served as 61st Secretary of the Navy from 1972 to 1974. His wife Jeanne is the ship's sponsor. Warner is also the only Secretary of the Navy who served as both an enlisted man and an officer, in both the Navy and the Marine Corps. As a Sailor during World War II he served as an electronics technician third-class petty officer, and in the Korean War he was a captain with the Marine Corps 1st Marine Air Wing serving as a Ground Communications Officer.

John Warner is the second of eight Block III *Virginia*-class submarines to be built. The Block III submarines are built with new Virginia Payload Tubes designed to lower costs and increase missile-firing payload possibilities. The first 10 Block I and Block II *Virginia*-class submarines have 12 individual 21-inch diameter vertical launch tubes able to fire Tomahawk Land Attack Missiles

(TLAMS). The Block III submarines are built with two-larger 87-inch diameter tubes able to house six TLAMS each.

Construction on *John Warner* began April 29, 2009; the submarine's keel was authenticated during a ceremony on March 16, 2013; and the submarine was christened during a ceremony Sept. 6. The submarine is 377 feet long, has a 34-foot beam, and will be able to dive to depths greater than 800 feet and operate at speeds in excess of 25 knots submerged. It will operate for 33 years without ever refueling.

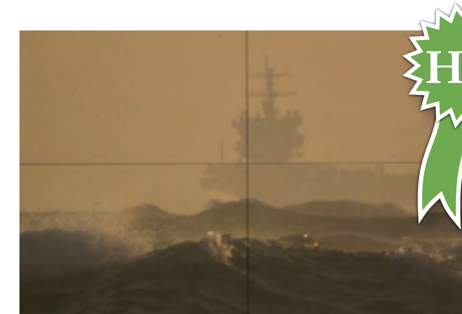
THE NAVAL SUBMARINE LEAGUE PRESENTS

17th Annual Photo Contest Winners

First Place: "Protecting Freedom," by ETC(SS) Michael A. Dlabaj

Second Place: "Pittsburgh Homecoming," by Mr. John Narewski
Naval Submarine Support Facility, New London

Third Place: "Minnesota SSN 783 is graced by the presence of multiple dolphins while on Bravo Sea Trials"
by Mr. John Whalen, Newport News Shipbuilding



Honorable Mention
"Legend in the Cross Hairs"
by Capt. Michael Bernacchi

Photo by Pete Hanson

USS *Growler* (SSG 577)
New York, N.Y

USS *Growler* was the second of the *Grayback*-class submarines laid down in February 1955 at the Portsmouth Naval Shipyard in Kittery, Maine. While under construction as a diesel-powered attack submarine, USS *Growler* was converted to carry four nuclear Regulus I guided missiles in a pair of cylindrical hangars set into the large, bulbous bow. These hangars opened aft through a set of doors by which the weapons could be moved onto a trainable launch ramp set into a well forward of the sail. The ramp was rotated athwartships for launching. She was launched in April 1958 and commissioned in August of that year with Lt. Cmdr. Charles Priest Jr. at the helm.

After sea trials and shakedown trials, *Growler* was ordered back to Portsmouth to receive her missiles. Returning to the Caribbean Sea, her crew trained in launching Regulus I and II guided missiles.

After the missile test firing, *Growler* returned to Portsmouth in April. She was then assigned to her duty port and proceeded to the Pacific Ocean via the Panama Canal, docking in Pearl Harbor on September 7th to serve as the flagship of Submarine Division 12.

At Pearl Harbor, *Growler* took part in a number of exercises and completed her post-shakedown tests for missile practice before the start of her patrols. Her first missile operations test in the Pacific took place in late October 1959 with two successful and accurate missile impacts.

On March 12, 1960, *Growler* departed on her first nuclear deterrent patrol carrying nuclear-armed Regulus II guided missiles. During the next three years, she performed nine strategic deterrent patrols.

Growler would depart from Hawaii with nuclear-armed Regulus sea-to-surface missiles, with patrols sometimes lasting more than two months and requiring her to remain submerged for days at a time. As the operating range of the Regulus I was about 500 nautical miles, her operating area had to be close to Soviet shores in case a launch was required.

Departing Pearl Harbor, *Growler* returned to Mare Island and was decommissioned on May 25, 1964 at the early age of six, having been awarded a Unit Citation by COMSUBPAC for her deterrence patrols. She was held in reserve for nearly 25 years until declared excess for the Navy's needs and was designated to be used as a target. Mr. Zachary Fisher, chairman and founder of the Intrepid Museum, undertook to save this unique and significant vessel for posterity. *Growler* was turned over to the Intrepid Museum in the fall of 1988 to become an exhibit and remains the sole survivor of the Navy's fleet of pioneering strategic missile diesel-powered submarines.

The Intrepid Sea, Air & Space Museum is dedicated to the exhibition and interpretation of history, science, and service as related to its home aboard the aircraft carrier Intrepid, a National Historic Landmark. In addition

www.intrepidmuseum.org/The-Intrepid-Experience/Exhibits/Growler.aspx