# NAVAL UNDERSEA WARFARE CENTER RESEARCH, DEVELOPMENT, TEST & EVALUATION

RIGHT FORCE, RIGHT READINESS, RIGHT COST for USW TECHNOLOGY, PRODUCTS, and SERVICES

NAVAL SEA SYSTEMS COMMAND

## A Word from NUWC Leadership...



The Naval Undersea Warfare Center (NUWC) has a proud heritage of providing superior undersea warfare (USW) products and services to the U.S. Navy. Our mission is enduring and our fundamental role of serving the Fleet is as vital today as it has ever been since our predecessor was created in 1869.

Our role as a Navy Warfare Center is to support the Chief of Naval Operations' (CNO) "A Cooperative Strategy for 21st Century Seapower" by bringing cost-effective solutions to the Fleet. In cooperation with our government, industry, and academic partners, we do this by developing conceptual ideas, seizing technological opportunities, and bringing these through product development, testing, sea-trial, acquisition, acceptance testing, Fleet introduction, and on-going support.

> We have a proud heritage of providing superior USW products and services to the U.S. Navy from concept research and development through Fleet introduction and life-cycle support

Our Warfare Center is flexible and agile, poised to address the challenges of our changing world. We have a highly trained and experienced workforce to provide readiness for today and the solutions the Navy will need for the future. To maintain our leadership role for the future, we continue to build a diverse workforce, enable innovation at all levels of the organization, and foster key strategic partnerships. We continue our work with our partners and international allies to meet the USW challenges of today and tomorrow and do this in the most cost-effective manner possible—to keep the U.S. Navy's USW capabilities the strongest in the world.

REAR ADMIRAL Patrick H. Brady, Commander, Naval Undersea Warfare Center Mr. Donald F. McCormack, Technical Director, Naval Undersea Warfare Center

### NUWC Mission & Vision

Operate the Navy's full-spectrum research, development, test and evaluation, engineering, and Fleet support center for submarines, autonomous underwater systems, and offensive and defensive weapon systems associated with USW and related areas of homeland security and national defense. Provide the Navy's core technical capability for the integration of weapons, combat and ship systems into submarines and undersea vehicles.

We are an integral part of the Naval Sea Systems Command (NAVSEA) and have been assigned a unique mission to provide technical leadership in concept formulation, research, development, fielding, modernization, and maintenance of systems that ensure our Navy's undersea superiority now and in the future. Mission success is realized when, through the development of cutting-edge technology and the utilization of our extensive knowledge base, advanced facilities, and technical authority, we deliver the best USW products and services to support the CNO's maritime strategy.

#### Full-spectrum dominance from the maritime domain—for submarine and USW systems satisfying today's needs and meeting tomorrow's challenges

We envision an undersea superiority that offers a wide array of tactical and operational options enabling the Navy to meet future challenges. This vision of USW ensures an innovative warfare-from-under-the-sea capability that will enhance the nation's seapower capabilities to influence actions and activities at sea and ashore. We will continue to confront these challenges head on, in close alignment with NAVSEA, Program Executive Offices (PEOs) and the warfighter, as we fulfill our responsibility as technical authority, provide "honest broker, trusted agent" support, translate warfighting requirements into technical terms, maintain and expand the military's USW technology base, and provide systems development and Fleet introduction. Working together with the Fleet, industry, and academia, we will provide innovative undersea security solutions for the nation while offering trusted advice as the technical partner of choice.



Experimental Unmanned Undersea Vehicle in 2003

### Why USW?





USW Domain

We are a maritime nation in an age of globalization. The safety and economic security of the United States rests upon the secure use of the oceans. USW, which is a key component of the CNO's "A Cooperative Strategy for 21st Century Seapower", makes vital contributions to our nation's warfighting readiness and ability to deter aggression, as well as to ensuring the security of sea lanes for global commerce, projecting power from under the sea, and meeting and defeating threats to our homeland from sea-based terrorism. USW seeks to allow friendly forces the full range of potential missions and to deny an opposing force the effective use of underwater systems and weapons.

#### More than 38 countries now operate over 360 diesel submarine platforms. Additionally, there is a proliferation of new weapon systems, asymmetric threats, and threats from worldwide terrorism—a strong USW capability enhances our ability to counter this emerging threat

There are many challenges to our ability to exercise sea control. Perhaps none are as significant as the growing number of nations operating both advanced diesel-electric and nuclearpropelled submarines—more than 38 countries now operate over 360 diesel submarine platforms. Additionally, the world has seen a proliferation of new weapon systems, growth of asymmetric threats, and increasing worldwide terrorism. USW helps the Navy meet these challenges by providing options for remaining hidden and operating in areas not available to traditional forces. USW enables extensive intelligence gathering, support of covert operations, and the ability to "track and trail" potentially unfriendly entities. Advances made in undersea communication, sensor, and unmanned undersea vehicle technologies promise an increasingly potent USW capability for both offensive and defensive actions.

Our nation's strategies now place overwhelming importance on sustaining a superior USW capability. The unique roles that undersea platforms and undersea distributed networked systems play are illustrated in the figure to the left. Our mission and vision clearly place NUWC at the forefront for ensuring that USW technologies and systems are able and ready when needed and that their development, test and evaluation are done in the most cost-effective manner.

### Role of a Warfare Center

The Warfare Center has a unique role within the NAVSEA competency alignment. Its ability to exercise the required Technical Authority role, its full-spectrum cradle-to-grave product responsibilities, its strong technical workforce and unique facilities provide corporate NAVSEA with a needed cost-effective capability to support today's Navy and provide for the Navy of the future.



Delivering Systems from Concept to Capability



#### A FULL-SPECTRUM Warfare Center

- Serving as the Navy's TRUSTED PARTNER in USW
- Delivering COST-EFFECTIVE capabilities
- Maintaining a STRONG Science and Technology (S&T) capability
- Performing the HONEST BROKER role
- Maintaining the Navy as a SMART BUYER
- Making INDUSTRY SUCCESSFUL
- Maintaining UNIQUE TECHNICAL CAPABILITIES and FACILITIES not found elsewhere
- Ensuring a COMPETITIVE ACQUISITION ENVIRONMENT is maintained
- Developing INNOVATIVE ACQUISITION CAPABILI-TIES with development of modeling tools and realistic testing of our products and systems

### **RIGHT FORCE Our Organization**



The Naval Undersea Warfare Center comprises NUWC Headquarters, two major Divisions, several Detachments and Remote Sites. Our Headquarters is located at Newport, RI, and our Divisions at Newport, RI and Keyport, WA. Our detachments and Remote Sites are spread across North America and the Pacific Basin, with locations at Andros Island, Bahamas; Lualualei, HI; Hawthorne, NV; San Diego, CA; Guam, and Nanoose, British Columbia.

#### We maintain a continuous worldwide presence in support of our mission

Our product-focused philosophy ensures the development and promotion of national expertise, sustains technical capabilities, and facilitates progress through cooperative efforts across all Divisions and Departments within the Warfare Centers. A close relationship is maintained with the Chief of Naval Research and numerous other Navy organizations supporting the full scope of NUWC responsibilities.



Breaking the Underwater Sound Barrier



MK 48 ADCAP Sink-Ex



Torpedo Launch from USV

**Reduction Technology** 



### **RIGHT FORCE Our People**



Our people are the national stewards for USW technology, with more than 4,000 employees representing 76,000 years of corporate knowledge. NUWC's leaders recognize and value the need to ensure that the right technical capabilities are developed and sustained and that the right people with the right skills are available for the future.

Our technical staff members are some of the most qualified in their fields, and through training and experience, they are uniquely suited to respond to the full range of Navy warfighter needs. NUWC's workforce is a national resource like no other and includes over 2,400 engineers and scientists who have earned 850 masters-level degrees and 142 doctorates. They are valued participants in national and international technology forums and routinely publish technical articles in professional journals.

We are uniquely qualified as the national steward of USW technology. We have developed and fielded many innovative products that significantly improve warfighting capabilities

As innovators, we have developed numerous products that significantly improve warfighting capabilities, as evidenced by the many patents awarded to our scientists and engineers. Over the past five years alone, NUWC personnel have been granted 330 patents covering a full range of USW technologies.

Our interaction with the Fleet commands, customers, and partners is strengthened through a global network that includes Field Team Members (FTMs) and Product Line Representatives (PLRs). These individuals are NUWC's forward presence, and they play an important role in the early identification and rapid response to critical Fleet needs by keeping us abreast of current and emerging requirements.



#### **Developing the Future Workforce:**

We actively promote programs to cultivate interest in the fields of science, engineering, and technology at all educational levels. We believe that by increasing awareness of NUWC and real-world science and engineering, we are developing future leaders and establishing the pipeline for our future talent. With diversity as a major component of our efforts, we hope to ensure that the next generation of scientists and engineers is well qualified, trained, and in place to support our mission when we face the difficult demands of the future. NUWC supports on-site programs, participates in several Educational Partnership Agreements (EPAs), and provides volunteers for off-site programs that expose a diverse group of young people to these important fields. Of note is our recent establishment of a Center of Excellence for Undersea Technology with the University of Rhode Island. As one of its major goals, the Center will develop the educational basis for solving the challenges posed by the undersea environment and foster the development of the next generation of undersea technology engineers and scientists poised to meet future challenges across the spectrum of undersea warfare.

#### NUWC's Workforce - A Major Asset



Bring a Child to Work Day



Comprehensive Employee Recognition Programs

Keyport Apprenticeship Program



Continuing Education Opportunities





### **RIGHT FORCE Our Products & Core Technical Capabilities**



Land-Based Testing for Fleet Superiority



Submarine Masts and Antennas We are a world leader in USW, providing the right products and capabilities to the Navy warfighter through innovative solutions, technological advances, and life-cycle stewardship.

NAVSEA has assigned each Warfare Center Division with specific responsibilities in the development and oversight of the core technical capabilities needed to fulfill today's requirements and address tomorrow's challenges (listed on the facing page). In support of the Warfare Centers full-spectrum life-cycle responsibilities, work in many technical capability categories is performed at both sites.

### We maintain the key set of skills and technical capabilities to do our job

We are NAVSEA's USW Technical Authority. Our USW Technical Warrant Holders are subject matter experts, responsible for establishing technical standards, entrusted and empowered to make authoritative decisions, and held accountable for the technical decisions made. In this role, they serve as "honest brokers" for our customers, providing analysis-driven, unbiased advice on USW capabilities and alternatives. They ensure safe and reliable operation and oversee the technical integrity of the Navy's engineering community.

Solar AUV

8



**Towed Array Fabrication** 

Submarine Launched Missiles



Undersea Weapons, Vehicles, and Countermeasures

#### **Division Keyport**

- Pacific USW Test and Evaluation Range and Test Facility Operations
- Independent USW Systems Test and Evaluation and Experimentation
- USW Weapons and Vehicles Range and Environmental Test Systems
- •Torpedo and Unmanned Undersea Vehicle Maintenance and Repair
- Obsolescence Management for USW Systems
- USW Systems Material Depot

**Unmanned Surface Vehicle** 

- Torpedo and Unmanned Undersea Vehicles In-Service Engineering (ISE) and Integrated Logistics Support (ILS)
- Submarine USW Systems ISE and ILS
- Carrier USW Systems
- Fleet Training and Training Management Systems



Shore-Based Radio Room



Tactical Tomahawk

#### **Division Newport**

- •USW Analysis
- •USW Sensor and Sonar Systems
- •USW Combat Systems
- •Torpedo Systems
- •Submarine Periscopes and USW Imaging Systems
- •USW Launcher Systems and Payload Integration
- •Torpedo and Sonar Defensive and Countermeasure Systems
- •USW Electronic Warfare, SIGINT, IO Sensors and Systems Integration
- •Submarine Tactical Missile Integration
- •Submarine Exterior Communication Systems
- •USW Communication Antenna Systems
- Undersea Range Technology and Application
- Atlantic Range Management
- •USW Distributed Netted Systems
- •USW Autonomous Vehicles
- •Undersea Surveillance Systems
- •USW Environmental Assessment Effects Analysis
- •USW Trainer Systems
- •USW Test and Training Operations
- •USW Systems Test and Evaluation



Periscopes



Vertical Launch System

## **RIGHT FORCE Products Platform Integration**

We have full-spectrum responsibilities for providing undersea combat systems capability for both submarines and surface ships. We also have a growing responsibility for engineering the entire USW battlespace through development of unmanned surface and undersea autonomous vehicles and the distributed networked systems that tie them together into a seamless warfighting capability. Our major areas of contribution for both submarine and surface ships are shown here.



### Areas of Expertise - Submarine

Surface Ship Sonar

Surface Ship USW Offensive and Defensive Systems, Including Torpedo Recognition and Alertment Anti-Submarine Warfare (ASW) Modules for Unmanned Surface Vehicles



### Areas of Expertise - Surface Ship USW

### **RIGHT READINESS Fleet Support**





We work hands-on with the Fleet to insure the maximum performance of their systems is achieved at all times

#### Hands-on Support:

At NUWC, we are serious about our national stewardship for USW technologies and unique facilities that support the life-cycle needs of the Navy. Our engineers play a major role supporting the Fleet during the introduction of new or upgraded capabilities, solving system integration problems and continually assisting the Fleet in its efforts to obtain maximum performance for its systems. Our personnel also ensure Fleet readiness with upgrade and repair services, obsolescence engineering (sustaining systems long out of production and helping industry restart production lines when their capabilities have diminished), system supportability, readiness assessment and monitoring, and material acceptance.





#### Maintenance, Upgrade, and Repair:

As a major component of our support to the Fleet, we maintain a full complement of modern upgrade, maintenance, and repair facilities, and the experience to handle electronic, electromechanical, propulsion, or guidance modifications for a broad spectrum of in-service systems such as torpedoes, mobile targets, periscopes, and towed array handling systems. These service facilities play a major roll in continued Fleet readiness by ensuring hardware availability both on a scheduled basis and by covering unexpected component casualties.



Periscopes





Torpedos





Towed Array Handling Systems



### **RIGHT READINESS Facilities and Ranges**





Anechoic Chamber

### Facilities:

We carry on the tradition that has ensured Fleet readiness in USW for over 130 years. We have the right skills and capabilities combined with the right test facilities and equipment required to maintain this readiness.

#### Our unique facilities enable the most cost-effective method of bringing technology and systems from conceptualization and demonstration to the Fleet

Our world-class facilities enable cutting-edge research, development, test, and evaluation (RDT&E), full-system life-cycle support for USW weapons and weapons systems; unique repair and maintenance equipment; rapid prototyping; resolution of obsolescence issues; and venues for evaluation, analysis, and experimentation in water, on land, and in synthetic environments. By providing precisely controlled, instrumented environments, integrated technical resources, and state-of-the-art modeling and simulation capabilities, these facilities enable the most cost-effective method of bringing systems and technologies from conceptualization to the Fleet; they are a critical component of maintaining Fleet readiness in USW. This collection of unique tools provides ongoing value to the Fleet, as well as to private industry, through partnership agreements for use of our one-of-a-kind facilities.

Wind Tunnel





Rapid Prototyping Seven Axis Numerical Control Machining Center



**Torpedo Industrial Complex** 

#### **Test and Training Ranges:**

We offer some of the finest undersea test ranges in the world, including the Atlantic Undersea Test and Evaluation Center (AUTEC) at Andros Island in the Bahamas; the Northwest Range Complex in Puget Sound, Washington, and British Columbia; the Littoral Undersea Test Facilities in Newport, Rhode Island and nearby areas.

### We operate full test & evaluation capabilities for all our major products

Our ranges enable testing, tracking, and analysis of sensors, hydrodynamic characteristics, radiated-noise measurement, and undersea weapon, vehicle, and USW system performance in a multitude of conditions, bottom types, slopes, and water depths. Operating in conjunction with land-based facilities, our ranges provide real-time data acquisition and analysis. We have also developed transportable underwater tracking ranges that can be deployed by the Fleet in the open ocean for exercises and training missions. These three-dimensional underwater ranges are quickly deployed and provide real-time tracking data with high accuracy.



Nanoose, Canada USW Range & Control Facility, British Columbia



Portable Ranges, Used Worldwide









Littoral Undersea Test Facilities

### **RIGHT COST Providing the Best Value to Our Customers**



We are on an aggressive journey of transformation, improving value to our customers by building a culture of continuous process improvement, streamlining the processes that bring our products from concept to the Fleet, and leveraging the alignment of the NAVSEA Warfare Centers to maximize efficiency of our business processes. Our workforce is empowered to identify and eliminate waste and find the most efficient methods to develop and deliver our products and services.

> With training and participation at all levels, we are building a culture of continuous process improvement to create the best value for our customers.

We have a number of robust processes in place to create an environment that facilitates efficient support of the Navy's needs today and tomorrow. We periodically perform rigorous self-assessments of many of our processes as part of the Command Inspection Program (CIP). We have established a Lean Program Office employing NAVSEA Lean, which is based upon the best practices of Lean, Six Sigma, and Theory of Constraints, to continuously improve processes, eliminate waste, and improve productivity, efficiency, and effectiveness. This culture of continuous improvement is ensconced in the entire organization from our senior executives to the newest recruit.

#### **Business Initiatives:**

NUWC is a Navy Working Capital Fund (NWCF) activity and as such, must operate like a business, minus a profit motive. We are funded only for the work we do so we must run efficiently to keep costs low and competitive. Our customers define their requirements, evaluate and approve likely proposals, and provide funding for specific projects and products, purchasing our expertise on a per-project basis. We consider labor, management, and capital investment in our pricing strategy, our work-year rates are set for the budget year. Our competitive stabilized rate protects our appropriated-fund customers from unforeseen cost changes and minimizes fluctuations in work levels, permitting a more effective use of resources.

### Education and discussion lead to constant improvement

Always striving for the highest quality products at the right cost, we have been recognized for our innovative business practices by the President's Quality Award Program, Department of Defense, Secretary of the Navy, Chief of Naval Operations, Naval Sea Systems Command, State of Washington, State of Rhode Island, and Executive Excellence Magazine, among others.





## **RIGHT FUTURE S&T Initiatives**

#### **Developing Technology for the Future:**

S&T is the seed for future USW innovation. It is vital to meeting our technology goals in the most cost-effective manner for the systems we design, deploy, and support. We continuously assess and evolve our USW technical leadership and capability to meet priority needs of future warfare. This requires determining the right technologies for the application, ensuring successful development, providing acquisition support, acceptance testing, in-service support, as well as developing the right partners to ensure success. Examples of technologies we are currently investigating are shown below. Our grand challenge initiative, Undersea Distributed Networked Systems (UDNS), is described on the facing page.



Jellyfish Sensors: Electro-active polymers for smart distributed sensor fields



**Single Crystal Hydrophones:** Optimization of single crystal materials for next generation of active/passive sensors



**Bio-Robotic Vehicles:** Explores neurosciencebased control technologies for undersea vehicles

Solid Oxide Fuel Cells:

Ideal stealthy energy source with significantly increased energy for extended UUV missions



With our partners in industry and academia, we are continually investigating new ideas to meet the needs of the future and avoid technology surprises



**Chaos-Based Telemetry:** Utilizing spread spectrum for improved doppler and range data telemetry



**Non-Toxic Anti-Fouling Strategies:** Utilizes conductive polymers, pulsed electric fields and non-chromate metals for sea going platforms

#### SEADEEP:

Two-way green laser comms and submarine/airborne transceivers





**Expendable Optical Comms Buoy:** Two-way UHF SATCOM using fiber optic tether from submarine 3" launcher

#### Technical Grand Challenge: Undersea Distributed Networked Systems

NUWC has undertaken a major initiative to develop the strategy, structure, and technology necessary to achieve a robust capability for the next generation of Undersea Distributed Networked Systems (UDNS). In the future, USW will be an even more important part of an integrated approach to controlling the maritime domain—providing total awareness and exploiting the battlespace from seabed to space. UDNS is a dispersed system of sensors, unmanned vehicles, platforms, weapons, command, control, and human systems, netted and working together to provide the clear view and situational understanding that allows total dominance of the undersea battlespace. We are actively collaborating with the Fleet ASW Command, senior Navy leadership, and other institutions to define requirements for UDNS. We are aligning our strategic plans, roadmaps, and S&T efforts as well as our existing USW efforts and improvements to achieve this vision of USW's contribution to U.S. Seapower in the 21st century.

We have already embarked on an effort to forge a healthy and robust UDNS capability at NUWC and have successfully completed an in-water demonstration of several key components on our Narragansett Bay test range. The complexity and importance of this capability requires that we draw on a broad spectrum of expertise, inside and outside of the organization. The UDNS initiative is being developed and implemented as a Navy-wide strategy that will facilitate horizontal integration and collaboration across NUWC Divisions and Departments as well as the development of external relationships with customers, Navy, government, industry, and academic experts. It will be a multi-year effort and the driving force behind efforts across the technical activities at NUWC. It is focused on the critical science and engineering technologies, trends, breakthroughs, and Warfare Center competencies that will enable operational UDNS for the Navy.



Conceptual Plan for Undersea Distributed Networked System

### A Rich Past to an Exciting Future: 1869 into the 21st Century

NUWC was established in 1992, consolidating expertise from the Naval Undersea Warfare Engineering Station (NUWES) in Keyport, Washington and the Naval Underwater Systems Center (NUSC) in Newport, Rhode Island. NUWC became the Navy's full-spectrum research, development, test and evaluation, engineering, and Fleet support center for submarines, surface ship USW, autonomous underwater systems, and offensive and defensive weapon systems associated with all aspects of USW. Comprising Headquarters and two major Divisions in Newport, RI and Keyport, WA, NUWC is built on a long tradition of innovation and excellence.

### Continuous service to the Fleet from 1869 into the 21st century

#### NUWC Division Keyport—Brief History

In 1914, the Pacific Coast Torpedo Station (PCTS) was established in Keyport, Washington, allowing improved efficiency of torpedo repair and ranging. The formation of PCTS eliminated the need to send torpedoes to Newport, Rhode Island. By 1930, the PCTS had become the United States Naval Torpedo Station (NTS) for the west coast with the nickname, "Torpedo Town USA."

In 1950, NTS was organizationally realigned to be the Naval Ordnance Depot (NOD). NOD operated for two years then was reverted to the original NTS organization.

In association with the Applied Physics Laboratory (APL) of the University of Washington, NTS was the developer of the first three-dimensional underwater tracking ranges in the world. In 1963, the joint U.S.-Canadian three-dimensional range was placed in operation in the Strait of Georgia and is still in operation today.

By 1978, recognizing new responsibilities taken on by NTS, such as support services for the Trident submarine, underwater mines, and underwater test ranges, NTS became the Naval Undersea Warfare Engineering Station (NUWES), which, as stated above, was merged into the NUWC organization in 1992.





#### NUWC Division Newport—Brief History

In September 1869, the U.S. Naval Torpedo Station (NTS) was officially activated as an R&D activity in Newport, Rhode Island, becoming the Navy's first experimental ordnance activity thus beginning more than a century and a quarter of USW expertise. During both the first and second World Wars and the time leading up to them, the expertise available at Newport was utilized to develop the extensive engineering and production capabilities needed to produce the torpedoes used so widely in these conflicts.

In 1951, the manufacture of torpedoes shifted to private industry and NTS was transitioned from its wartime focus back to its R&D roots, becoming the Naval Underwater Ordnance Station (NUOS) and locating to our current site at Coddington Cove. The activity's mission was expanded to include weapon launcher and fire control systems for submarines. In 1966 the activity was named the Naval Underwater Weapons Research and Engineering Station.

Division Newport's expertise in sonar systems can be traced to the Columbia University Division of War Research and Harvard Underwater Sound Laboratory, which were both established in 1941. During World War II, the Columbia Laboratory developed passive detection devices and Harvard produced active ASW sonar devices. In 1945, the Harvard Laboratory sonar functions were merged with the Columbia Laboratory in New London, CT, to establish the Naval Underwater Sound Laboratory. Work performed at these laboratories formed the foundation for understanding the nature and behavior of underwater sound. In the 1970s, the Naval Underwater Weapons Research and Engineering Station and the Naval Underwater Sound Laboratory were merged to create the Naval Underwater Systems Center (NUSC) in Newport, RI and New London, CT. NUSC continued the tradition of excellence in the areas of submarine warfare systems, submarine weapon systems, and surface ship sonar systems. For further information about the NAVAL UNDERSEA WARFARE CENTER contact

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