



# NAVAL S&T STRATEGY

►► INNOVATIONS FOR THE FUTURE FORCE

W W W . O N R . N A V Y . M I L





# CNR Foreword



*Chief of Naval Research (CNR) Rear Adm. Mathias Winter, engages with participants at a professional event.*

**America** is a maritime nation with global responsibilities that require its naval forces to be respected around the world and decisively be where it matters, when it matters. More than ever, our Sailors and Marines depend upon technological advantages to help keep the peace, fight, win and come home safe—I am certain this strategy delivers that for them.

The Office of Naval Research was established by law in 1946 to ensure the technical superiority of our Navy and Marine Corps. Since then, science and technology (S&T) investments have yielded continuous payoffs and contributed to nearly every weapon system in the hands of Sailors and Marines today.

This work must continue; however, breakthroughs don't happen overnight. The Naval S&T Strategy guides ongoing research—about 1 percent of the Department of the Navy's (DoN) annual budget—that enables the efforts of our dedicated naval scientists and engineers in the Naval Research Enterprise. They are the driving force of innovation in DoN today, and of game-changing capabilities still to come.

Innovation can't be ordered, so at the heart of this strategy is a broad investment approach that leverages long-term, targeted basic and applied research, but also

gives talented people the flexibility needed to pursue new discoveries and promising ideas. Additionally, nine S&T Focus Areas (appendix A) provide specific objectives to support warfighting requirements, explore critical technology areas and promote fundamental knowledge expansion to collectively paint a picture of the future naval force that today's initiatives will help build.

Scientists and engineers at the Naval Research Laboratory (NRL), naval warfare centers, naval systems commands and across our partners in industry and academia benefit from this approach, and working together, they solve some of the most important challenges facing our naval forces and nation.

For example, basic research conducted in the 1960's at NRL on gallium nitride-based electronics is now the foundation of next-generation radars for our warfighting platforms. In 2014, a new prototype laser cannon was successfully deployed aboard the USS Ponce in the Persian Gulf, and rapid progress in the electromagnetic railgun, a revolutionary advancement in naval gun technology, will enable early testing on a ship at sea in 2016. Both lasers and railguns are high-powered precision electric weapons that will transform how we employ warships, support forces ashore and deliver power projection to meet modern security challenges more cost effectively.

In combination with other advances in autonomy, cyber technology, energy security, advanced training systems and missile defense, S&T innovations are delivering solutions for anti-access/area denial threats, distributed lethality operational concepts and future strategic deterrence needs—below, on and above the seas.

As the Chief of Naval Research, I am committed to the People, Organization and Mission across the Naval Research Enterprise that ensures our Sailors and Marines always play "away-games" and have the decisive technological, warfighting advantage, today and tomorrow. That is my promise of this strategy and the pledge of the naval S&T community.

MATHIAS W. WINTER  
Rear Admiral, U.S. Navy  
Chief of Naval Research



# Executive Approval




DEPARTMENT OF THE NAVY  
OFFICE OF NAVAL RESEARCH  
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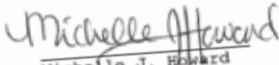
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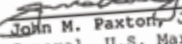
DECISION MEMORANDUM FOR ASSISTANT SECRETARY OF THE NAVY (RESEARCH,  
DEVELOPMENT AND ACQUISITION)  
VICE CHIEF OF NAVAL OPERATIONS  
ASSISTANT COMMANDANT OF THE MARINE CORPS

SUBJECT: DON S&T Corporate Board Approval of Naval S&T Strategy

The Corporate Board endorses and approves the Naval Science and Technology Strategy presented by the Chief of Naval Research in November 2014, and directs the Chief of Naval Research to implement the strategy.

  
Sean J. Stackley  
Assistant Secretary  
of the Navy  
Research, Development  
and Acquisition

  
Michelle J. Howard  
Admiral, U.S. Navy  
Vice Chief of Naval  
Operations

  
John M. Paxton, Jr.  
General, U.S. Marine Corps  
Assistant Commandant  
of the Marine Corps





***"The naval science and technology community is the pre-eminent source for good ideas and innovative concepts that provide the foundation of our Navy and Marine Corps' technological edge."*** — The Honorable Sean J. Stackley, Assistant Secretary of the Navy (Research, Development and Acquisition)



***"Partnered with the Navy, we will continue to pursue innovative concepts for maritime expeditionary operations..."*** — Gen. John Paxton, Jr., Assistant Commandant of the Marine Corps



***"There are great ideas out there-it's having the courage to go ask people about what they're doing that's different, and saying, 'I wonder how I could apply that to my organization?'"*** — Adm. Michelle Howard, Vice Chief of Naval Operations

# Executive Summary

For more than 90 years, the naval science and technology (S&T) community has been delivering technological advantages to Sailors and Marines. Game-changing capabilities are born from scientific research, and investments made today will ensure U.S. naval power and influence throughout the 21st Century.

The world is becoming increasingly interconnected by technology and globalization, the very sinews of which have always been found at sea. America is a maritime nation whose prominence is closely linked to its naval forces providing a broad range of capabilities. To meet Navy and Marine Corps technology needs, the Department of the Navy (DoN) maintains a broad portfolio of S&T initiatives to build the future force.

Accordingly, the naval S&T strategy is:

**To discover, develop and deliver decisive naval capabilities, near- to long-term, by investing in a balanced portfolio of breakthrough scientific research, innovative technology and talented people.**

Responsibility to execute this strategy is entrusted in public law to the Office of Naval Research (ONR). The chief of naval research (CNR) oversees the activities of ONR and three subordinate commands: the Naval Research Laboratory, ONR Global and office of special projects (PMR-51).

S&T is approximately 1 percent of DoN's budget. It is the "venture capital" of the Navy and Marine Corps, and high return on these investments is enabled by a unique strategic approach: ONR consolidates the management of basic and applied research funds and advanced technology development under one roof, making the naval S&T process efficient, flexible and responsive. Additionally, S&T investment priorities are reflected in the allocation of funds across four components of ONR's strategic portfolio:

- Quick Reaction S&T—responsive to immediate warfighter needs
- Technology Maturation—subsystems

and components for current and planned programs.

- Leap-Ahead Innovations—higher risk, high payoff disruptive technologies
- Discovery & Invention—fundamental science and long-term initiatives

Further alignment is achieved by mapping capability gaps to nine S&T focus areas listed below and defined in Appendix A:

- **Assure Access to Maritime Battlespace**
- **Autonomy and Unmanned Systems**
- **Electromagnetic Maneuver Warfare**
- **Expeditionary and Irregular Warfare**
- **Information Dominance - Cyber**
- **Platform Design and Survivability**
- **Power and Energy**
- **Power Projection and Integrated Defense**
- **Warfighter Performance**

This fourth version of the Naval S&T Strategy—which is updated biennially—identifies the strategic approach and reaffirms the principles of previous versions, while adjusting to current guidance from naval leaders. It further leverages advancements in a rapidly changing landscape of new technology and reaffirms commitment to basic research that underpins future innovations and affordable solutions.

This strategy enables naval leaders to harvest S&T investments made years ago to speed development of cutting-edge technologies like railguns, lasers, new radars and autonomous systems, to name a few.

Thousands of ONR-funded scientists, engineers and students across the country and around the world in the naval S&T community have contributed to nearly every technology in the hands of our deployed Sailors and Marines. This commitment will continue.

S&T investments made today in fundamental science and technology initiatives will ensure breakthroughs that yield affordable, decisive advantages for the Navy and Marine Corps to prevail when called upon.





*The Electromagnetic Railgun uses high-power electricity instead of chemical propellants to launch low-cost, guided projectiles greater than 100 miles at hypervelocity speeds. This proof-of-concept innovative naval prototype will be tested at sea in 2016 aboard a Joint High Speed Vessel (JHSV). The technology was made possible through investments in basic research to understand friction, wear and mechanics of interfaces subjected to extreme electromagnetic stress, high relative velocities and elevated temperatures. Research further solved the physical challenges and chemical processes that determine the life of the gun rails and enable higher rates of fire. Basic research has advanced Railgun technology from sci-fi to reality as the Navy considers designs for future all-electric ships.*

# The Naval S&T Strategy

## Naval S&T Origins

**From** their beginnings, the U.S. Navy and Marine Corps have leveraged innovation and technology to defend America's interests.

Whether it was ship design in the War of 1812; ironclads in the civil war; radar, carrier and amphibious operations in World War II; nuclear-powered submarines during the Cold War; or smart weapons and unmanned systems in modern conflict, naval technology has provided capabilities that ensure decisive advantages for our Sailors and Marines.

To ensure the superiority of U.S. naval forces after World War II, Congress established the Office of Naval Research (ONR) in 1946. ONR identifies science and technology solutions for the Department of the Navy (DoN) to address Navy and Marine Corps needs.

### Defined in law, ONR's mission is to:

"Plan, foster and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power and the preservation of national security"<sup>1</sup> and to "manage the Navy's basic, applied and advanced research to foster transition from science and technology to higher levels of research, development, test and evaluation."<sup>2</sup>

In short, ONR delivers technological advantages to the warfighter. Today's force is powered by naval research, and current investments will ensure the next generation of Sailors and Marines are equally dominant when called upon. S&T investments support essential mission capabilities to mitigate operational risks, meet emerging requirements and develop affordable, leap-ahead innovations for the future force.

### S&T Success:

**Critical Cold War technology:** The Sound Surveillance System (SOSUS) provided deep-water, long range submarine detection capability. Developed from underwater hydrophone technology at the Naval Research Laboratory as a new kind of passive sonar in the 1950s, SOSUS consisted of high gain, long fixed arrays placed in deep ocean basins. A key long-range early-warning asset for protecting the United States against ballistic missile submarines, SOSUS also provides vital cueing information for tactical, deep ocean anti-submarine warfare. Through the transition from the Cold War SOSUS was gradually condensed into a smaller number of monitoring stations, but the success of this system proved paramount in protecting our country from the Soviet submarine threat.

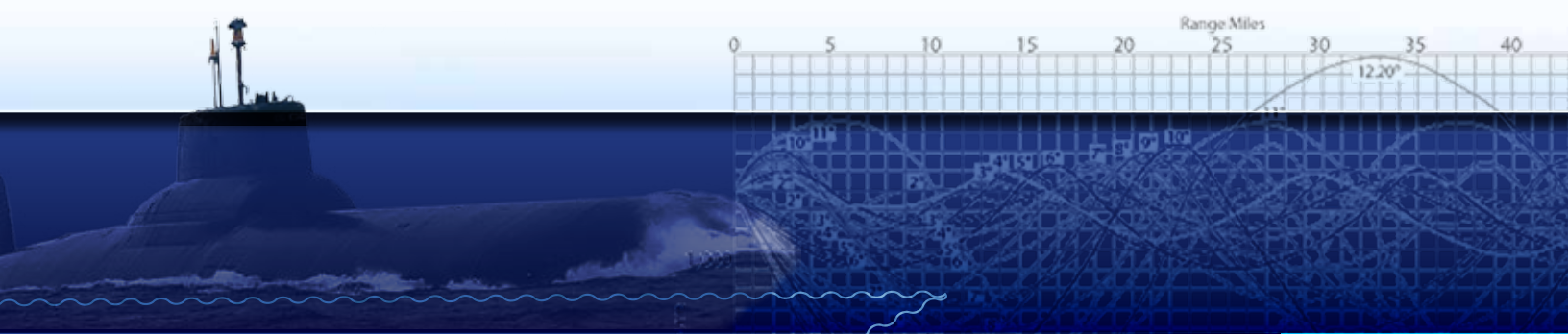
This strategy document describes how ONR sponsors scientific research that enables the operational concepts and decisive capabilities.

Developed in collaboration with stakeholders and approved by naval leadership **the strategy has three principal goals:**

- 1) Align S&T with naval mission and future capability needs
- 2) Balance and manage the S&T investment portfolio
- 3) Communicate the S&T vision and approach to senior decision makers, key stakeholders, partners, customers and performers.

By design, this strategy provides flexibility. ONR manages a portfolio of investments in near-, mid- and long-term scientific research and technology development. Breakthroughs don't happen overnight; therefore, a





strong basic research portfolio seeds future discoveries and is a critical component of this strategy.

Before new technologies can be developed, new knowledge must be created. S&T research requires working across scientific disciplines to solve complex challenges and develop new ideas.

While long-term research is underway, ONR also funds and administers quick-reaction S&T processes to mature component technology and develop innovative concepts that may be high risk but potentially high payoff. This range of options helps leadership stay ahead of a challenging and rapidly changing world, while making every dollar count as good stewards of the taxpayer's money.

Achieving this mission requires working with the best and brightest people from partner organizations both at home and abroad. Fostering the intellectual capital necessary for America's defense is fundamental to our national security. ONR acknowledges its responsibility in this strategy to ensure the future health of the naval S&T community by leading the efforts to encourage

interest in science, technology, engineering and mathematics (STEM) careers among our nation's students.

This Naval S&T Strategy enables responsiveness to warfighter needs while cultivating new ideas, a talented workforce and inspiring the next generation of premier naval scientists and engineers.

*The Large Displacement Unmanned Underwater Vehicle is being developed by ONR to operate long-term missions in both open ocean and coastal environments.*

<sup>1</sup>Public Law 588 of 1946

<sup>2</sup>Defense Authorization Act of 2011

# Technology Challenges in a New Era

**Today,** our Navy and Marine Corps are more essential than ever. Eighty percent of the world's population lives near the sea, 90 percent of all world trade travels by ocean and soon Arctic sea routes will open<sup>3</sup>. Some forecasts project a 50 percent increase in shipping volume by 2030<sup>4</sup>.

Globalization expands opportunities in trade but also enables technologies to rapidly transcend borders, placing more dangerous capabilities in the hands of our rivals or potential adversaries. New and emerging technology trends favor greater empowerment of individuals, small groups and ad hoc coalitions, making non-state actors and criminal networks more powerful<sup>5</sup>.

The global security environment will continue to be characterized by dramatic political, societal, ecological and technological changes. Technology will transform how we live and how the world connects; drive the global economy; and influence the balance of power as we know it, creating new security challenges for our nation and strategic imperatives for U.S. naval forces.

## Strategic imperatives include:

- A defense strategy that is shifting focus to the Asia-Pacific region—with more than half of the world's population and gross domestic product coming from Asian-Pacific nations, naval forces will play an increasing role in providing the security necessary to ensure prosperity for the U.S. and our Pacific allies.
- The interconnectedness of the world's economies—developed and emerging—combined with regional instability, population growth (from 7.1 billion today to 8 billion by 2030<sup>6</sup>), competition for resources (energy, water, food) and urbanization (especially in the littorals),

factor into the future security environment. The ability of sea-based forces to project power and support forces ashore will rise in importance.

- Increasing trade, geopolitical instabilities and the ongoing threat of unstable regimes, terrorism, piracy and natural disasters requiring rapid humanitarian relief demand a maritime force that is forward deployed and ready to quickly respond.
- Increased availability of sophisticated weapons and sensors will require use of the electromagnetic spectrum (e.g., radar, communication, cyber) and other advanced technologies to counter multifaceted threats including new anti-access, area denial challenges to naval operations in critical regions.






U.S. naval forces require a broad spectrum of core capabilities to assure access across the global maritime domain. Consequently, this S&T strategy invests in a balanced and broad portfolio of promising scientific research and innovative technology initiatives.

Incremental improvements to existing defense technology must continue to improve affordability and effectiveness, particularly in times of fiscal uncertainty. However, preventing technology surprise while creating surprise for potential adversaries is the enduring goal of defense S&T. Without an equal commitment to discover and exploit the value of new domestic and international innovations, America risks being blindsided by adversaries and overtaken by the pace of technology development.

Lasting strategic advantages in national security and economic competitiveness will only come from an ongoing commitment to open innovation, rapid prototyping and novel production methods to continuously shrink the technology development cycle and, hence, costs.

Naval S&T investments will uphold existing technological supremacy for the warfighter, while introducing new disruptive technologies. These research initiatives, led by highly motivated world-class experts, will provide affordable options for naval leaders.



*An X-47B Unmanned Combat Air System demonstrator conducts a touch-and-go and landing on the flight deck of the aircraft carrier USS George H.W. Bush (CVN 77).*

<sup>3</sup>Navy Climate Change Road Map, May 21, 2010; Vice Chief of Naval Operations

<sup>4</sup>IHS Jane's Navy International, Vol 119, Issue 1, Jan/Feb 2014

<sup>5</sup>Global Trends 2030, National Intelligence Council, Dec. 2012

<sup>6</sup>Global Trends 2030, National Intelligence Council, Dec. 2012

# Naval S&T Vision and Strategy

## The Naval S&T Strategy:

*To discover, develop and deliver decisive naval capabilities, near- to long-term, by investing in a balanced portfolio of breakthrough scientific research, innovative technology and talented people.*

The naval S&T community develops technological advantages to ensure that when called upon, our Sailors and Marines never find themselves in a fair fight; U.S. naval capability should be respected around the world and decisive when needed.

Technology also can be a cost-effective force multiplier. Over the years, naval S&T has contributed to dramatic increases in effectiveness of our forces on the seas and on the battlefield. As a result, the ability to project naval power and influence has remained high, while the number of weapons, platforms and the people required to complete the missions has steadily decreased.

This strategy aims at fulfilling a compelling S&T vision for the future Navy and Marine Corps, while retaining sufficient flexibility and freedom to meet emerging challenges.

## The Naval S&T Vision:

*Cutting-edge scientific research and technology provides decisive technological advantage and influence for our naval forces.*

The naval S&T community will:

- Exploit basic research to develop revolutionary new capabilities
- Mature and transition S&T advances to improve existing naval capabilities
- Respond quickly to current fleet and force critical needs
- Anticipate and counter potential technology surprise
- Hedge against uncertainty by providing affordable options to reduce risk.

This vision supports Department of Defense (DoD) guidance and the priorities of the secretary of the Navy (SECNAV), chief of naval operations and commandant of the Marine Corps. Maintaining the position of preeminent maritime power in the world requires an approach to S&T that is both responsive to current leadership direction and lays a solid foundation of research investments for the





future force. In fulfilling these duties, ONR executes the strategy below.

### **The Naval S&T Strategy:**

*To discover, develop and deliver decisive naval capabilities, near- to long-term, by investing in a balanced portfolio of breakthrough scientific research, innovative technology and talented people.*

The chief of naval research (CNR) oversees the activities of ONR and three subordinate commands in the execution of this strategy: the Naval Research Laboratory

(NRL) is the DoN's corporate laboratory, ONR Global, which has offices in strategic locations around the world, and the Office of Low Observable/Counter-Low Observable Policy, Technology, and Advanced Projects (PMR-51). In addition, ONR works with the Marine Corps Warfighting Laboratory (MCWL), naval warfare centers, as well as U.S. and international researchers from numerous universities, labs and businesses to help ensure our naval forces maintain their advantage (see Appendix B for more about the naval S&T organization).



### **Chief of Naval Research**

As an Echelon 1 commander, CNR reports to the SECNAV via the assistant secretary of the Navy for research, development and acquisition (ASN(RDA)). However, to ensure strategic alignment of the S&T investment portfolio, the vice chief of naval operations and the assistant commandant of the Marine Corps meet twice annually with ASN(RDA) and the under secretary of the Navy as the Naval Research, Development, Test and Evaluation (RDT&E) Corporate Board. This board receives program updates from the CNR to assess progress, hear recommendations and provide investment guidance on strategy execution.

The Afloat Forward Staging Base (Interim) USS Ponce (ASB(I) 15) conducts an operational demonstration of the Office of Naval Research (ONR)-sponsored Laser Weapon System (LaWS) while deployed to the Arabian Gulf.

## Executing the Strategy

**Long before the operational community recognizes a needed capability, scientists and engineers in the naval S&T community have spent countless hours conducting basic research on emergent concepts, methods and discoveries in the physical, engineering and life sciences.**

**Public** law assigns ONR responsibility for executing all naval S&T funding, which is typically around 1 percent of the DoN budget. The charge to do such vital work for our Sailors and Marines with a comparatively small budget is a challenge. To understand what ONR does and why it is important, it is useful to start with a brief discussion of what naval S&T is and to distinguish it from subsequent research and development (R&D).

Long before the operational community recognizes a needed capability, threat or potential advantage and years before the R&D/acquisition community can deliver a new weapon or sensor system to the fleet, scientists and engineers in the naval S&T community have spent countless hours conducting basic research on emergent concepts, methods and discoveries in the physical, engineering and life sciences.

Similar to venture capital, it is this farsighted, high-payoff S&T research that provides the basis for future advanced technologies to become acquisition programs of record.

The ASN(RD&A) is responsible for all naval S&T and subsequent R&D programs, which comprise the RDT&E budget, Chart 1. Funding for ONR S&T is historically about 12 percent of the appropriation, Chart 2.

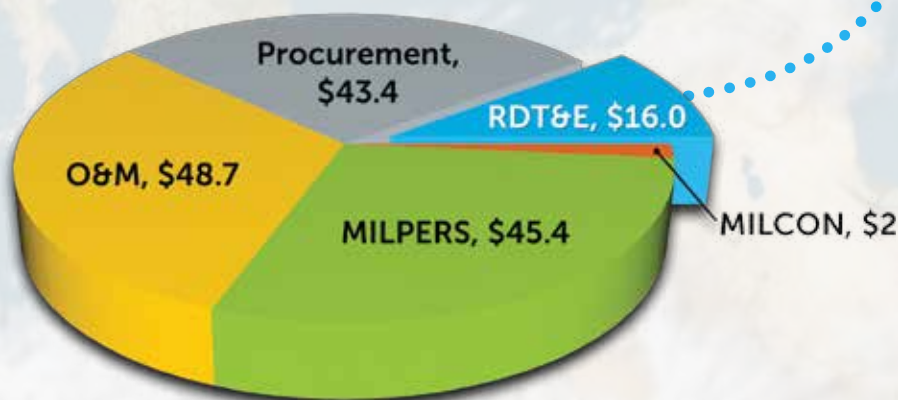
The naval S&T strategy is unique in that ONR is the only military service agency to house all three budget activities of S&T funding efficiently under one roof. As

a result, an ONR program officer can see a good idea through from concept to working prototype. Because ONR manages 6.1 basic research as well as 6.2 applied research and 6.3 advanced technology development funds, the naval S&T process is efficient, flexible and responsive.

This approach offers valuable strategic flexibility to adjust to the unpredictable nature of basic research to pursue unexpected or more promising results—and provides capability to surge rapid prototype development when responding to urgent operational needs.

Through S&T investments, ONR discovers, develops and delivers new technologies that become decisive naval capabilities (see Chart 3 on page 16).

*Chart 1: DoN Budget (\$B)*



*The RDT&E budget is further divided among seven budget categories (Budget Activities 6.1 thru 6.7)*



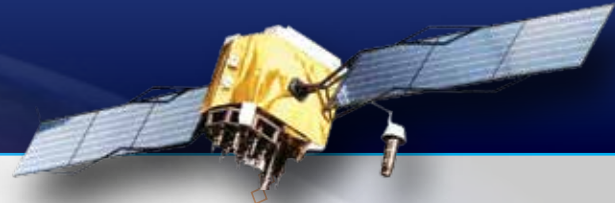


Chart 2: DoN RDT&E Budget (\$B)



Activities 6.1 thru 6.7 — Three funding lines (6.1, 6.2, and 6.3) are S&T, managed by ONR, which is about one percent of the entire DoN budget. The remaining four support R&D and acquisition.

(e.g., Global Positioning System (GPS), radar, autonomous systems, graphene, QuikClot and many more).

In fiscally austere times like today, there is great pressure to tie S&T more closely to R&D technology maturation or use it as a source for fixing identified funding shortfalls.

Resource sponsors question how they will make do with less in the face of pressing operational imperatives. Critical to the success of the Naval S&T Strategy is a commitment to basic research that underpins future discoveries and enables strategic options for naval leadership.

Successful technologies are transitioned to the acquisition community (e.g., systems commands and program executive offices) for additional maturation and procurement decisions.

In the late 1940s, ONR funded approximately 40 percent of the basic research—for the entire United States.

### Science in Action—A 20-Year Vision

While more than 70 percent of ONR's budget is in 6.2 and 6.3 funds, which go toward answering pressing warfighter needs, the 6.1 category of basic research represents the remaining approximately 30 percent of the naval S&T budget.

Basic research is the foundation of technology innovations and discoveries. These investments may take 20 years before they can be mapped to a naval need but have historically been the engine of ONR's track record of providing breakthrough solutions that shape the future force

### GPS Success:

ONR-funded basic research at the Naval Research Laboratory (NRL) led to the invention of the GPS, which has revolutionized the science of navigation. NRL's Navigation Technology Satellite III, launched in 1977, was the first satellite in the NAVSTAR GPS system. This first GPS, incorporated NRL's concept of time range, range-rate navigation and 12-hour orbit. The remarkable precision proved invaluable for precision weapon technology that was successfully employed during Operation Desert Storm in, targeting pinpoint strikes and positioning troops in featureless terrain. Apart from its primary military function, the satellite system now serves numerous civil and peacetime functions in the everyday lives of people around the world in cell phones, car navigation and air traffic control.

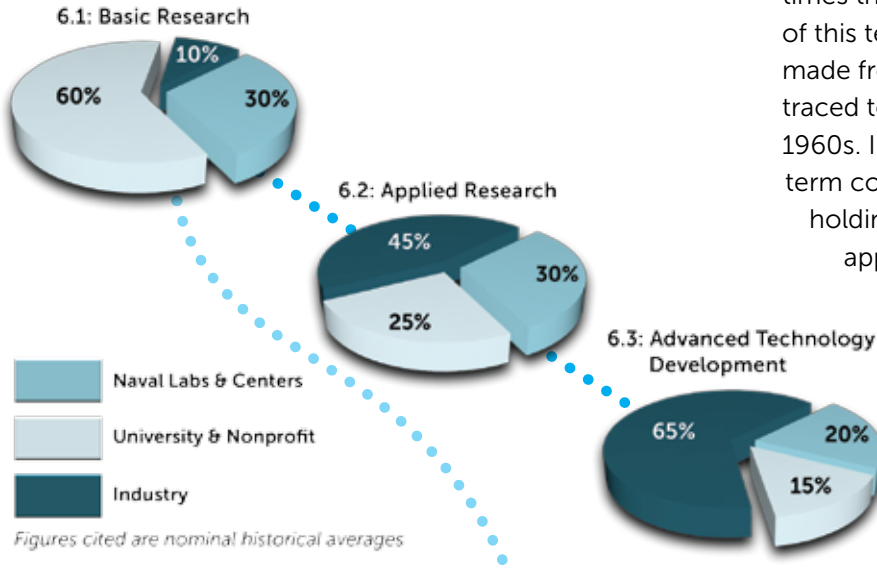
This provided the national security rationale for military basic research and gave American science its Golden Age<sup>7</sup>. Unlike the National Science Foundation (modeled after ONR in 1950), ONR has the ability to target its limited basic research funds, which gives DoN leverage to address its most vexing technology challenges.

The majority of funding for DoD research is

<sup>7</sup>Sapolski, "Science and the Navy: The History of the Office of Naval Research," Princeton University Press, 1990

# Executing the Strategy

**Chart 3: ONR S&T Budget**



**Per the Office of Management and Budget Circular A-11:**

**6.1 Basic Research** is defined as systematic study directed toward fuller knowledge or understanding of the fundamental aspects of phenomena and observable facts without specific applications towards processes or products in mind.

**6.2 Applied Research** is defined as systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.

**6.3 Advanced Technology Development** is defined as systematic application of knowledge or understanding, directed toward the production of useful materials, devices and systems or methods, including design, development and improvement of prototypes and new processes to meet specific requirements.

apportioned across DoN, Air Force and Army, DoD S&T agencies including Defense Advanced Research Projects Agency. Of that funding, DoN not only has the highest share of DoD 6.1 basic research, but it is typically more than 30 percent of ONR's annual budget. This reflects the naval investment strategy to leverage the value of fundamental science for breakthrough solutions and game-changing advantages.

For example, the Navy's next-generation of air/missile defense radar will enter service aboard Arleigh Burke-class destroyers this decade and will provide more than 30

times the radar capability of existing systems<sup>8</sup>. At the heart of this technology is a transformational semiconductor made from gallium nitride (GaN), whose origins can be traced to basic research sponsored by ONR since the 1960s. Increased reliability, smaller size, lower long-term costs and efficiency are all advantages of GaN, holding great promise for both Navy and commercial applications. Interspersed throughout this document are additional vignettes highlighting technologies that have emerged from basic research.

When the here and now present tough choices for DoN leadership, ONR's S&T portfolio and technology initiatives offer a hedge against a changing world and uncertainty. This approach has served the Navy and Marine Corps well, ensuring not only operational advantages, but a leadership role in advanced technology development in the United States and for the world.

The Naval S&T Strategy is aimed at emphasizing and expanding this advantage.

## Innovations & Partnerships

Recognized by Institute of Electrical and Electronics Engineers (IEEE), Navy scientists have the number 1 patent portfolio when it comes to newly patented discoveries and inventions for international government S&T agencies.

**ONR Worldwide Partnerships:**

- 3,340 principal investigators
- 3,000 graduate students
- 50 states, 50 countries
- 914 companies

## S&T Demand Signals—Inputs to the Strategy

The majority of ONR's S&T efforts respond to warfighter needs by providing near- to mid-term solutions. From urgent battlefield requirements, such as lifesaving medical technology, to improved performance of ships and aircraft and enhanced affordability for major acquisition programs, ONR coordinates and integrates inputs to optimize S&T investments—to include science advisors embedded in Navy and Marine Corps commands.

<sup>8</sup>Majumdar, "The Heart of the Navy's Next Destroyer," USNI, 30 Jul 2013



ONR receives technology “demand signals” from naval assessments of capability gaps and science and technology objectives (STOs). These STOs are developed and submitted by Navy and Marine Corps staffs to address needs within a warfighting functional area (aviation, surface, subsurface, expeditionary, etc. (see S&T Strategy Process, page 22)).

An essential part of this process is the **Future Naval Capabilities (FNC)** program. Managed by ONR, the FNC program is the primary mid-term S&T solution provider. It provides vetted solutions to naval technology requirements and capability needs. Over the course of a two- to four-year development cycle built upon research conducted over previous years, products are demonstrated and transitioned to the acquisition sponsor for integration into a program of record.

### Future Naval Capabilities

By design, at least a third of ONR’s S&T budget in 6.2 and 6.3 funds are dedicated to FNCs. Governance of the program is uniquely shared across naval stakeholders at the three-star level Technology Oversight Group (TOG). The TOG reports to the Naval RDT&E Corporate Board, which ensures that FNC decisions are prioritized and requirements-driven.



### Wireless Vital Signs Monitor

The ONR-developed Wireless Vital Signs Monitor is a small device that measures and records a patient’s electrocardiogram, pulse oximeter, heart rate and non-invasive systolic, diastolic and mean blood pressures. The information can be transmitted to a battlefield corpman’s laptop, electronic tablet or smartphone where it calculates even more patient information, such as trends, pulse pressure and complexity indices. It is strapped on to an injured Sailor’s or Marine’s arm or leg, for instance, and it captures all vital signs from the point of injury. It is capable of transmitting and downloading information to a hospital’s emergency department monitoring system.

Since its inception in 2002, in response to congressional direction to foster technology transition, the FNC program has grown in value and success. Transition rates of

S&T into programs of record have steadily improved, delivery times have decreased and coordination has strengthened between the fleet/force, S&T, acquisition and resource communities (see Appendix C for more about S&T governance).

Other mid-term processes go beyond demand signals and include an element of “technology push.” Rather than just responding to warfighter requirements, programs like SwampWorks conduct short exploratory studies and experimentation to examine medium-risk, disruptive technologies for their potential application to Navy and Marine Corps missions.

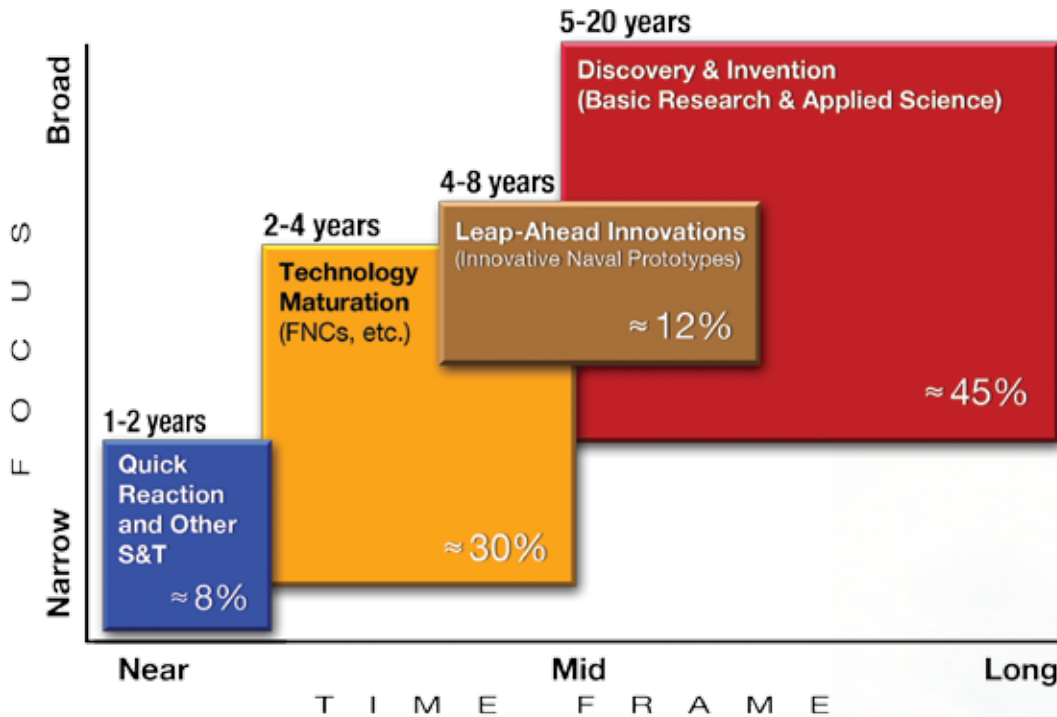
Larger in scope, scale and risk, **Innovative Naval Prototypes (INP)** anticipate needs by developing high-payoff emerging technologies with the

potential to revolutionize operational concepts. INPs push the imagination of our nation’s technical talent to deliver transformational warfighting capabilities. For their experimental nature or radical departure from established requirements, processes and concepts of operation, INPs must be approved by the RDT&E Corporate Board. Submarine-launched autonomous systems, electromagnetic railguns and high-power lasers are examples of INP initiatives that are maturing today.

Sometimes, innovation can’t get into the hands of the warfighter fast enough. To respond to near-term demand

# Executing the Strategy

## S&T Investment Portfolio



This figure shows the four components of the investment portfolio, which include all S&T funding and the supporting non-S&T funds that ONR manages. The percentages are determined by the RDT&E Corporate Board and considered programmatic floors for each component of the portfolio.

signals, ONR manages several quick-reaction S&T programs using 6.3 funds that, in some cases, directly connect the warfighter to the scientist.

First among these is the **TechSolutions** program. Ideas are submitted online from Sailors and Marines straight to ONR for evaluation. Typical projects take one to two years and deliver prototype technologies that are tested and evaluated working side-by-side with the warfighter.

Many TechSolutions products are transitioned to the acquisition community for further refinement, production and delivery to the Navy or Marine Corps. On average, 10–12 projects are active per year. While TechSolutions is only a small part of ONR’s budget, no other S&T program is more closely coupled to making an immediate improvement in the lives of the warfighter.

The demand for S&T solutions is very high. To make every dollar count, ONR works to prioritize investment

for the most important capabilities and deliver them in a judicious and cost-efficient manner.

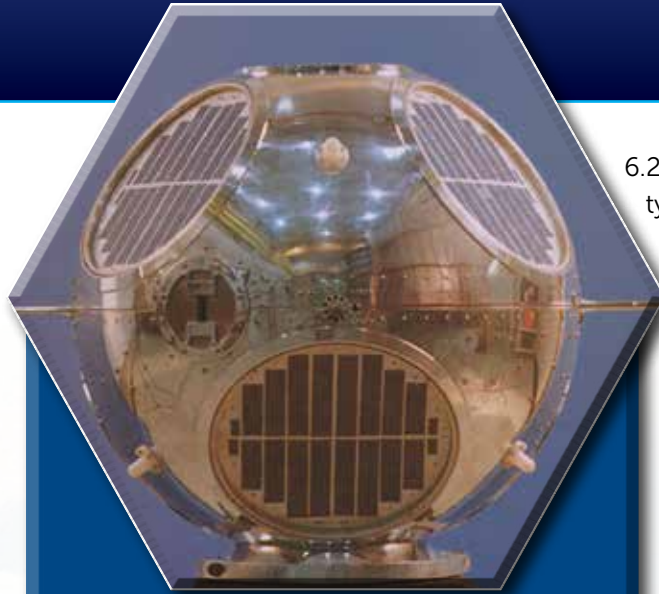
### Investment Portfolio

S&T Investments fall into four broad components that reflect both the *time frame* and *focus* (see above chart) related to long-term DoN strategic goals. Together, they comprise a balanced investment portfolio of promising scientific research and innovative technologies.

The following is a brief explanation of each category:

**Discovery and Invention (D&I):** Includes basic research 6.1 and early applied research 6.2. This is the seed corn that explores nascent technologies for future application. The NRL (see sidebar) conducts much of DoN’s basic research and receives 20 percent of their funding from ONR. The D&I portfolio by design has a broad focus with a long time span—from five to 20 years—needed to mature discoveries. Its programs





are selected based on potential naval relevance and technology opportunity (see Appendix D). In addition, five National Naval Responsibilities (NNR) are D&I research areas unique to the naval service and/or areas where the Navy has historically taken the lead (see Appendix E; for more about Research Areas see Appendix D). ONR structures the D&I programs to support teams of researchers investigating high-priority topics and opportunities that intersect more than one traditional technical discipline which serves to stimulate innovations, accelerate research progress and expedite transition of results into naval applications. Outstanding young scientists and engineers who are beginning their independent research careers, showing exceptional potential for leadership and demonstrating a commitment to community service and the advancement of STEM education are also an element of the D&I portfolio (see Appendix F).

**Leap-Ahead Innovations:**

Includes INPs and the majority of SwampWorks efforts. This technology portfolio defines the future of naval warfighting. INPs achieve a level of technology suitable for transition—in four to eight years. SwampWorks efforts are smaller in scope than INPs and are intended to produce results in one to three years. This component is where higher risk is typically accepted to produce a higher payoff. Leap-Ahead Innovation funding comes from both

**Naval Research Laboratory**

Thomas Edison argued that “the government should maintain a great research laboratory. ... In this could be developed ... all the technique of military and naval progression without any vast expense.” Secretary of the Navy Josephus Daniels invited Edison to serve as the head of a new body of civilian experts—the Naval Consulting Board—to advise the Navy on science and technology. The board’s most ambitious plan was the creation of a modern research facility for the Navy, which led to the establishment of the NRL in 1923. For more than nine decades, NRL has been central to advancing the technological edge of our Navy and Marine Corps. NRL research led to breakthroughs in radar, satellites (pictured above), Cold War technology and modern autonomous systems. Today, research at NRL encompasses electronics, electronic warfare, materials, information systems technology, space platforms cyber, marine environments, fuels, virtual reality, superconductivity, biomolecular science, engineering, autonomous systems and nanotechnology. See [www.nrl.navy.mil](http://www.nrl.navy.mil) for more.

6.2 and 6.3. Program managers are typically from ONR, while a deputy program manager from the acquisition community is often a good match to help facilitate the transition to the acquisition community. The CNR, in consultation with senior Navy and Marine Corps leadership, identifies candidate INPs that are forwarded to the RDT&E Corporate Board for approval.

**Technology Maturation:**

This portfolio delivers critical component technologies to naval acquisition programs. This includes FNCs, which mature in a two- to four-year time frame into products from the late stages of applied research (6.2) and advanced technology development (6.3). In addition to the FNC funding, this portion includes approximately two-thirds of the Marine Corps 6.3 funds, all of Joint Non-Lethal Weapons Directorate 6.3 funds, advanced manufacturing technologies (ManTech) and the majority of the low-observable, counter-low-observable (PMR-51) funds. ManTech helps programs achieve their respective affordability goals by transitioning new manufacturing technology to gain efficiencies and lower production costs.

**Quick Reaction:** this portfolio responds to urgent technology needs and solve problems for warfighters. This includes funds for TechSolutions, as well as Navy and Marine Corps experimentation, one-third of the Marine



## FNC Success Story

The Navy's fifth littoral combat ship (LCS), USS Milwaukee, will be the first to benefit from new high-power density waterjets aimed at staving off rudder and propeller damage experienced on high-speed ships. The new Axial-Flow Waterjet Mk-1, developed as an FNC, can move nearly half a million gallons of seawater per minute, providing more thrust per unit than current commercial waterjets. Four of the new waterjets will propel the LCS to speeds greater than 40 knots. The smaller, more efficient waterjets will help the LCS avoid excessive maintenance costs associated with cavitation—a phenomenon that occurs when changes in pressure create air bubbles on rotating machinery, such as marine propellers. Repeated occurrences can cause whole chunks of metal to wear away, leading to frequent repairs and replacements. The waterjets' new design is expected to also increase the lifespan between repairs.

Corps 6.3 funds, responses to Urgent Operational Needs Statements and high-priority demands from the fleet/force and a percentage of SwampWorks efforts. These are warfighter centric technology projects responsive to the immediate needs identified by the fleet, operating forces or naval leadership—within one to two years.

Each project is structured with definable metrics and includes appropriate systems command elements in an integrated product team concept. While neither a substitute for the acquisition process nor a replacement for the systems commands, TechSolutions aims to provide the fleet/force with prototype technologies that can

be rapidly and easily transitioned.

### Quick Reaction Success: HUD Glasses

With the overwhelming amount of data available to warfighters in the field, TechSolutions worked with the Marines to develop a solution using head-mounted augmented reality displays. Using a Heads Up Display (HUD) the glasses enable the warfighter to see relevant mission data and complete critical tasks simultaneously. Developers and performers leveraged the ODG X-6 Glasses technology to create a system that will work in remote environments and allow Marines to develop their own tactical applications in the field.

Response to (Joint) Urgent Universal Need State-ments (UNS/ JUONS)



and threat-based demands from senior fleet/force leadership are addressed by ONR within 24 months. Additionally, Chief of Naval Operations Speed to Fleet (CNO S2F) programs accelerate insertion of maturing technologies into the fleet to address critical Navy warfighting needs. It provides initial advanced capability, while allowing the acquisition process to address doctrine, organization, training, material, leadership and education, personnel and facilities issues in parallel. CNO S2F also hastens the transition of technology readiness level 6 capabilities from 6.3 to advanced component development and prototypes in 6.4, and enables user evaluations in a relevant operational environment.



# Executing the Strategy

ONR also manages some non-S&T resources that directly support the components of the investment portfolio (e.g., ONR headquarters support, Manufacturing Technology program, Technology Insertion Program for Savings, Technical Information Services, etc).

## Experimentation

In partnership with ONR, the Naval Warfare Development Command, Naval Postgraduate School, Naval War College and MCWL explore future warfighting concepts and evaluate the capability potential of emerging technologies. In support of this effort, Commander, U.S. Fleet Forces Command, in coordination with Commander, U.S. Pacific Fleet, leads the Fleet-led Experimentation (FLEX) program. Through war games, exercises, experiments and operational lessons learned, ideas are tested, analyzed and refined.

The intent of the FLEX program is to rapidly evaluate:

- **Innovative concepts**
- **Fleet Concepts of Operations**
- **New tactics, techniques and procedures**
- **Technologies and changes in doctrine, organization, training, materiel, leadership development, personnel, facilities and policy actions.**

The FLEX program focuses at the operational and tactical levels of warfare, across the full range of military operations, to enhance warfighting capabilities or to fill a capability gap. FLEX is distinct from, but may inform and be informed by, developmental or operational testing requirements associated with Programs of Record or early experimentation conducted within the naval S&T program.

Additionally, MCWL conducts concept-based experimentation in coordination with the operating forces in order to develop and evaluate tactics, techniques, procedures and technologies to meet future warfighting capability needs. These experiments often employ commercial and advanced products of S&T investments by ONR and DARPA as surrogates for future technical capabilities.

Experimentation contributes to the definition of requirements and in the establishment of technology priorities within the combat development process.



## INP Success Story

The Autonomous Aerial Cargo/Utility System (AACUS) program will enable unmanned helicopters to support Marine Corps forces on the front lines using cutting-edge technology developed by ONR. The system consists of a sensor and software package that will be integrated into rotary-wing aircraft to enable autonomous unmanned flight and detect and avoid obstacles in unfavorable weather conditions. The capability will be a welcome alternative to dangerous convoys, manned aircraft or air drops in all weather conditions, as experience in Afghanistan and Iraq showed, where Marines frequently found themselves under fire from adversaries or the target of roadside bombs and other improvised explosive devices. Simple to use, a Marine with minimal training can call up the supplies needed and order the flights using only a handheld tablet.

# Outputs and Outcomes

The foremost customer of this strategy is the naval warfighter. However, there are multiple stakeholders involved in the discovery, development and demonstration of new technologies. ONR coordinates thousands of partnerships with academia, industry and laboratories across the country, and around the world, to respond to (and anticipate) the needs of the Navy and Marine Corps.

Technology is the primary product, or output, of this S&T strategy. The decisive capabilities that these new technologies deliver to the fleet/force are the desired outcome.

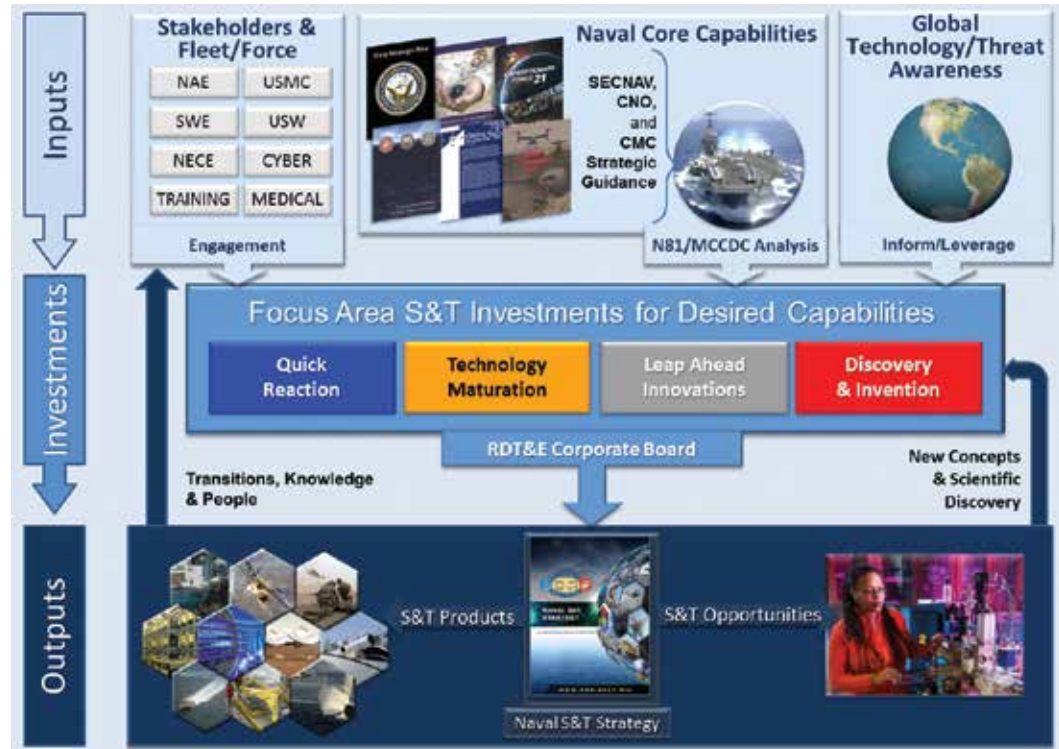
In the process of discovering, developing and delivering S&T, other outputs are produced: the knowledge to develop a new technology, as well as its supporting research community—the people. Together, these form the academic and industrial base of the naval S&T community.

## Outputs of the Strategy:

In this strategy, outputs are defined as what is produced. S&T investments provide products and opportunities for further discoveries. ONR enables the technical superiority of our naval forces by producing knowledge and technology transitions and developing the research community. These are briefly described below. Appendix C describes the governance associated with each of these S&T outputs.

- **Knowledge:** Scientific discovery generates new knowledge and technologies that expand capabilities and enable innovative concepts of

## Naval S&T Strategy Process



operations. Knowledge (gained from research, successes and failures) leads to new technology pathways and reduces technical risk in later stages of research and development. ONR program officers constantly evaluate cutting-edge S&T for potential breakthroughs in naval capabilities and maintain knowledge of worldwide developments in their disciplines.

- **Transitions:** ONR strives to provide viable paths for scientific discoveries and maturing technology to transition to DoN. ONR programs, business practices and partnerships work to transition and bridge the “valley of death” between S&T and formal acquisition programs managed by systems commands (e.g., NAVSEA, NAVAIR, SPAWAR, NAVSUP, MARCORSSYSCOM) that proliferate the resulting capabilities to the warfighter.



- **People:** More than 50 percent of the S&T workforce will be retirement eligible by 2020. DoN is focused on this challenge and is dedicated to the future health of the naval S&T community. ONR devotes the majority of its basic research (6.1) funds to university programs. In addition to grants to individual investigators, fellowship programs support faculty, graduate and undergraduate education of U.S. citizens who plan to work in Navy and Marine Corps laboratories. Special programs also support the education and professional development of minority students and faculty members. ONR leads DoN efforts to inspire U.S. students to pursue careers in STEM. The CNR is the Navy's STEM executive.

### Outcomes of the Strategy:

The above outputs (knowledge, transitions and people) are pursued to tie desired outcomes to naval capabilities. ONR coordinates S&T efforts based on nine approved focus areas, which are managed by ONR departments/ codes and led by a Senior Executive Service member, to facilitate cross-departmental cooperation.

The nine naval S&T focus areas are:

- **Assure Access to Maritime Battlespace**
- **Autonomy and Unmanned Systems**
- **Electromagnetic Maneuver Warfare**
- **Expeditionary and Irregular Warfare**
- **Information Dominance - Cyber**
- **Platform Design and Survivability**
- **Power and Energy**
- **Power Projection and Integrated Defense**
- **Warfighter Performance**

Think of each as a three-dimensional framework ONR leverages to coordinate multidisciplinary research, cut horizontally across the organizational structure and span multiple warfighting requirements.

S&T focus areas help align, balance and communicate the efforts between the warfighter, ONR and the S&T community. Each reflects a strategic imperative for the Navy and Marine Corps. Major changes to the focus areas include:

- Updates to account for changes in the strategic landscape that drive S&T investments, as well as advancements in research and new technologies
- Refinement of focus area objectives to account for accomplishments, changes in capability gap assessments and higher-level naval guidance
- Adjustments to the Information Dominance Focus Area to reflect emphasis on cyber, including shifting electromagnetic spectrum objectives to a new focus area: Electromagnetic Maneuver Warfare
- Realignment of total ownership cost to an underlying theme of affordability that is a persistent across all S&T focus areas.

Appendix A provides a synopsis of the strategic drivers, vision, description and high-level S&T objectives that each focus area will achieve.



*Dr. Rhonda Stroud, head of the nanoscale materials section at the Naval Research Laboratory explains her work to the Director of the White House Office of Science and Technology Policy Dr. John P. Holdren.*

## Conclusions

**ONR** has contributed to nearly every technology in the hands of Sailors and Marines deployed around the world today. Powered by naval research, the U.S. Navy and Marine Corps are ready to respond anytime, anywhere across the broad range of military operations—on land and below, on and above the seas.

S&T investments made decades ago will enable the Navy to deploy, on a ship bound for the Persian Gulf, the first solid-state laser that can deliver shipboard defense at \$1 per shot. Other technologies under development, such as the electromagnetic railgun, will offer new multi-mission capabilities for ships.

In the near future, autonomous systems will be used to reduce risk to Sailors and Marines and extend aircraft, ship, vehicle and submarine capabilities at a lower cost than manned systems.

Recent advances in hull coatings for ships will translate into roughly \$1 billion in lower fuel costs by reducing drag on vessels at sea, as well as lower maintenance costs needed to keep the ships free of marine growth and debris. New technology for Marine Corps tactical vehicles will also cut fuel usage by millions of gallons per year and provide greater operational range.





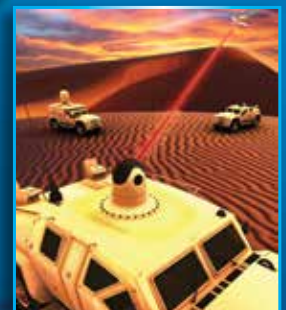


Additionally, advanced manufacturing techniques developed for programs like the F-35 Lightning II aircraft, Virginia-class submarine and Littoral Combat Ship bring significant cost savings: on the order of a billion dollars over the next five years. There are many examples where small investments up front lead to big savings over the lifetime of a system.

Numerous technologies developed for naval applications have resulted in significant civil and economic benefit. Naval researchers during the Cold War, for instance, developed GPS satellites, sonar and radar technologies that led to cell phones, fiber optics and lifesaving medical devices. As the defense

budget shrinks, naval leaders are challenged to respond with smart investments that result in affordable solutions and leap-ahead gains in capability per dollar. The Naval S&T Strategy delivers these options and develops partnerships across academia, industry and international agencies for future force.

Finally, behind all the high-tech systems in the Navy and Marine Corps are the extraordinary people in the naval S&T community. These scientists and engineers serve their country every day by contributing great ideas and innovative concepts to build the future force and give our Sailors and Marines their decisive edge.



# Appendix A

## Focus Areas

### Assure Access to the Maritime Battlespace

Autonomy & Unmanned Systems

Electromagnetic Maneuver Warfare

Expeditionary & Irregular Warfare

Information Dominance—Cyber

Platform Design & Survivability

Power & Energy

Power Projection & Integrated Defense

Warfighter Performance

warfare, mine warfare and Navy Special Warfare technologies and capabilities, including exploitation of every aspect of the changing environments in which they operate.

Critical to success are understanding and synthesis of ocean-atmosphere processes at high spatial and temporal resolution as they impact naval operations in the open ocean, Arctic and littorals. To achieve this, forces need real-time, environmentally adaptive sensors, processing, systems and strategies. Development and use of distributed and autonomous ocean systems are a vital response to this need. Innovative approaches (not requiring perfect knowledge) to modeling and simulations of complex environments, including interactions with systems, form a key part of this challenge.

**Strategic Drivers:** Proliferation of anti-access, area-denial capacity and capabilities among potential adversaries drives the need for technologies that assure access for naval forces. The complexity of the littoral battlespace and changing environmental conditions, such as the increased open water in the Arctic Ocean, demands advanced high-resolution environmental observation and prediction capabilities.

**Vision:** Assure access to the global ocean and littoral reaches and hold strategic, operational and tactical targets at risk. Sense and predict environmental properties in the world's oceans and littorals to support tactical and strategic planning and operations. Improve operational performance by adapting systems to the current and evolving environment.

**Description:** Naval forces must be able to attain global maritime, littoral, riverine and inland access to denied areas. They must maintain the ability to penetrate and operate in hazardous areas, where others cannot, to hold at-risk, anti-access targets and deny sanctuary to adversaries. To accomplish this and provide access for our forces, this focus area improves anti-submarine



U.S. Navy photo by Mass Communication Specialist Seaman Jerine Lee



# Assure Access to the Maritime Battlespace

## Objectives:

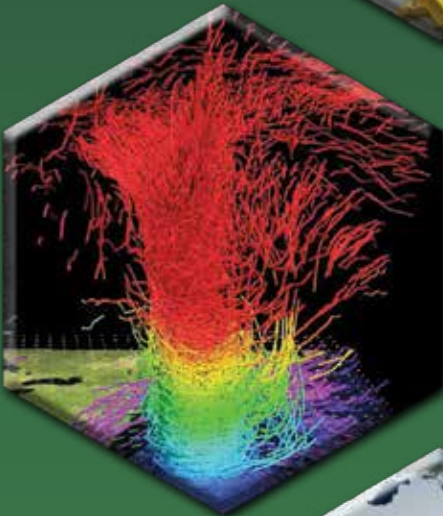
### Achieve and Maintain Undersea Dominance

- Detect, classify, locate and track threat submarines in shallow, deep and Arctic waters, exploiting automation and adaptation to the environment
- Off-board sensing, cooperative vehicle autonomy, increased endurance, autonomous classification, data exfiltration and networking in unmanned systems to expand reach and reduce threat exposure
- Develop next-generation data and target fusion to expand regional anti-submarine warfare, mine warfare and amphibious warfare operating picture to the theater level
- Rapidly detect and clear mines through the Beach Exit Zone; neutralize from a distance



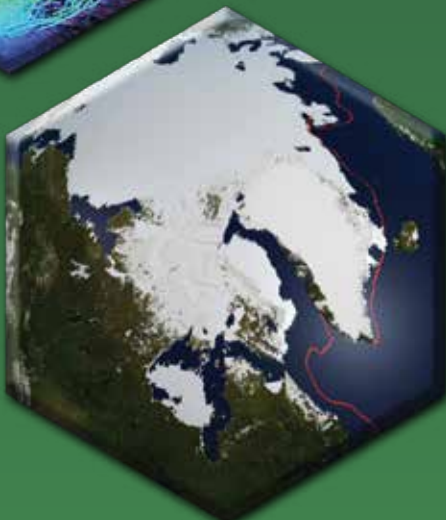
### Improve Mobile Autonomous Environmental Sensing

- Autonomous sensing of global maritime and littoral environments to Beach Exit Zone
- Environmental sensing that adapts the sensing strategy to changing conditions



### Match Environmental Predictive Capabilities to Tactical Planning Requirements

- Fully coupled (ocean-atmosphere-wave-ice) global, regional and local modeling and prediction for operational planning at tactical, strategic and climate scales
- Forecasts for refractivity, duct heights, fog, rain, clouds, visibility, trafficability and tropical cyclones at global, regional and tactical scales to increase mission go/success



### Maximize Systems Performance via Adaptation to the Environment

- Optimize sensing and reduce false alarms by adapting to an evolving physical environment
- Avoidance behaviors and overarching situational awareness to adapt to the tactical environment
- Adapt to changing conditions in the near space environment

# Appendix A

## Focus Areas

### Assure Access to the Maritime Battlespace

#### Autonomy & Unmanned Systems

#### Electromagnetic Maneuver Warfare

#### Expeditionary & Irregular Warfare

#### Information Dominance—Cyber

#### Platform Design & Survivability

#### Power & Energy

#### Power Projection & Integrated Defense

#### Warfighter Performance

decentralized control that is flexible in its level of autonomy with the ability to get the right level of information to the right echelon at the right time. This may include defeating asymmetric and emerging threats via persistent and stealthy distributed, large-area presence; stimulation of suspect entities; and disruption and deception of potential hostiles. Additionally, this may include providing a highly survivable, self-organizing, adaptive mission capability that cannot be easily defeated just by killing individual platforms and sensors, as well as affordable capabilities to do things that would be unaffordable or result in impractical manning otherwise. Where necessary autonomy design should allow for ease of launch and recovery as well as provide graceful degradation in the event of failure. Finally, autonomous systems will address a wide range of other functions in support of the warfighter, including logistics/cargo delivery/lightening the load for naval units; casualty evacuation and other medical applications; humanitarian/rescue operations; shipboard damage control/firefighting; deck operations of ship-based aircraft; and ocean/environmental sensing.

**Strategic Drivers:** Increased proliferation of inexpensive lethal threats targeting individual warfighters and high-value assets, combined with continued rapid advances in computing, power and energy, robotics, sensors and position guidance technologies, drives the requirement to augment expensive manned systems with less expensive, unmanned, fully autonomous systems that can operate in all domains.

**Vision:** Achieve an integrated hybrid force of manned and unmanned systems with the ability to sense, comprehend, predict, communicate, plan, make decisions and take collaborative action to achieve operational goals. The employment of these systems will reduce risk for Sailors and Marines and increase capability.

**Description:** Autonomy and unmanned systems will be used in all operating domains, performing multiple missions, and will be developed into numerous platforms. Central to achieving that vision is the development of a distributed system of heterogeneous unmanned systems relying on network-centric,





# Autonomy & Unmanned Systems

## Objectives:



### Human/Unmanned Systems Collaboration

- Developing natural modes of interaction
- Understanding intent and recognizing deception
- Dynamically changing levels of autonomy



### Scalable and Robust Distributed Collaboration

- Task allocation/assignment, planning, coordination and control for heterogeneous systems
- Airspace/waterspace/ground traffic management
- Predicting behaviors of large numbers of unmanned systems
- Validating and verifying complex, distributed autonomous systems
- Cooperative autonomy to enable multiplatform sensor fusion



### Perception and Intelligent Decision Making

- Autonomous adjudication between wide-area exploration and more focused exploitation
- Automated processing from sensor data to information to actionable understanding
- Learning context, adaptive recognition and scene understanding



### Novel Platforms and Integration

- Bio-inspired systems that rely on principles of perception, sensori-motor control, biomechanics and fluid dynamics found in nature but not yet in engineered systems
- Microrobotic systems that rely on nanotechnology, synthetic biology and microelectronic and photonic information processing to achieve capabilities at very small sizes
- Integrated system capabilities for long-duration missions



### Intelligence Enablers and Architectures

- Integrated architectures and intelligence for decentralized systems
- Reasoning and learning
- Scalable planning and re-planning

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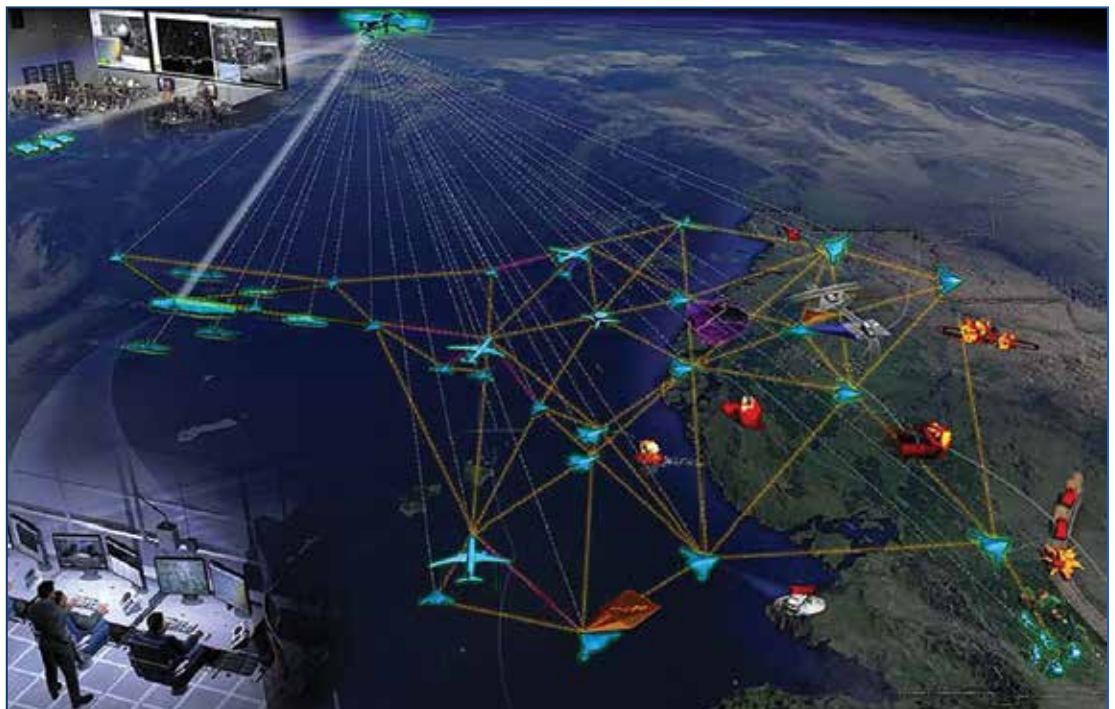
Warfighter Performance

communications; deny the adversary the ability to use the spectrum except as we allow it; and assure that our sensors and electronic attack systems operate across the full span of the electromagnetic spectrum.

**Description:** The electromagnetic spectrum is a key operational maneuver space enabled by continuous, real-time awareness of all spectrum activity. Spectrum dominance is a prime component, which includes efforts that focus on communications, surveillance, EW and electronics to understand and shape the battle space. Ultra-wide band systems, along with monitoring the spectrum, can make use of unused portions of the spectrum, which avoids the enormous manpower requirement to manually de-conflict in the current process. The ability to assure access to the full spectrum is essential for battle space awareness and threat surveillance/ weapon sensor engagement.

**Strategic Drivers:** Rapidly expanding commercial use of the electromagnetic spectrum and the traditional method of block allocation have caused congestion. This impedes the DoD and naval forces' use of the spectrum particularly in situations of limited availability in critical regions. Current naval systems were designed to operate in narrow, fixed bands in line with spectral policy.

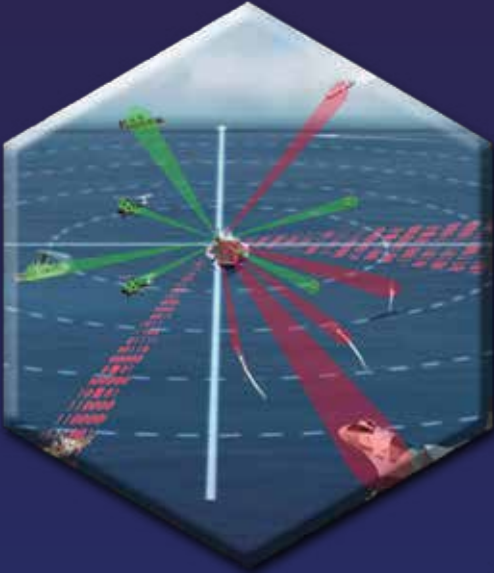
**Vision:** Enable the warfighter to have complete control of the electromagnetic spectrum to ensure that naval forces can utilize it as required for electronic warfare (EW), surveillance and





# Electromagnetic Maneuver Warfare

## Objectives:



### Spectrum Dominance

- Understanding the electromagnetic environment through sensing
- Assuring access to the full spectrum for battle space awareness, threat assessment and offensive and defensive operations
- Influencing/controlling the opponent's battle space picture



### Electronic Warfare

- Full-spectrum electronic sensing measures
- Integrated and coordinated electronic attack
- Resilient electronic protection



### Advanced Electronics, Sensing and Response Techniques

- Ultra-wide-band apertures and electronics
- Techniques for anti-jamming/spectral efficiency
- Machine learning for automated response
- Management and control algorithms for spectral management across battle force, systems and components

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area investment will deliver enhanced capabilities across all warfighting functions in order to enable littoral access and crisis response across the range of military operations. These investments will facilitate sea-based, decentralized operations by high-performing, highly lethal, network-enabled small units capable of aggregating and disaggregating to meet the operational requirements of the most austere and complex environments. Specific areas for increased capability development include mobility, communications, sustainment and training. Additionally, EIW investments will enable our forces to be as effective in Irregular Warfare as they are in traditional warfare. This will be accomplished by developing technologies that increase the warfighter's ability to maneuver within the human and informational dimensions of the future battlespace. Specifically, EIW technologies will improve the warfighter's ability to interact with target populations, identify threat activities, solve complex problems and adapt to ambiguous situations via kinetic and non-kinetic means—at a tempo that outpaces that of our adversaries.

**Strategic Drivers:** Emerging geopolitical and socioeconomic conditions have resulted in the rise of non-traditional threats, failed states and a decrease in assured host nation support. Naval forces will face potential adversaries armed with advanced and increasingly lethal warfighting capabilities. They will confront complex hybrid, asymmetric and irregular challenges across diverse, austere and distributed battlespaces, and will be called upon to be the nation's crisis response force.

**Vision:** Naval warfighters of the future will possess the full spectrum of expeditionary kinetic and non-kinetic capabilities required to operate across the entire range of military operations, decisively defeat traditional threats and effectively confront irregular challenges.

**Description:** The Expeditionary and Irregular Warfare (EIW) focus





# Expeditionary & Irregular Warfare

## Objectives:



### Battlespace Awareness:

- Sensors and sensor systems for observation and collection
- Operations/intelligence fusion
- Automated production and delivery of mission-relevant information to the tactical edge



### Irregular Warfare Operations:

- Social, cultural, behavioral domain understanding, modeling and analysis
- Tactical cyber operations with delimited effects
- Social media exploitation and management



### Expeditionary and Distributed Operations:

- Modular, scalable, and autonomous ground platforms and capabilities
- Fires as a networked commodity
- Reduction of the logistics burden across the Marine Air-Ground Task Force
- Tactical warfighter operations (mobility vs. survivability, decision making, training and tools, performance, fitness and resiliency)



### Irregular Threat Countermeasures:

- Counter asymmetric weapons and explosive hazards afloat and ashore
- Biometric identification and surveillance
- Tactical site exploitation and forensics
- Signatures management across the electromagnetic spectrum

# Appendix A

## Focus Areas

Assure Access to the Maritime Battlespace

Autonomy & Unmanned Systems

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Expeditionary & Irregular Warfare

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sary, target or network by assuring that autonomous, continuous analyses of intelligence, persistent surveillance and open information sources have, at all times, optimized the possible courses of action based on commander's intent.

**Description:** Information dominance requires systems and paradigms that are interoperable, provide decision-making superiority through assembly of the data, understanding the battlespace and support for decision-making. It enables operations across coalitions, joint forces and diverse mission areas that are physically large, exhibit complex dynamics, and contain many objects, events and activities. Integral to achieving information dominance are flexible communications and network architectures.

Future systems must provide capabilities for achieving and maintaining communications and networks in highly dynamic, dispersed and disadvantaged (denied, disrupted, intermittent and limited bandwidth) environments. The computational architecture will provide capabilities to manipulate and interpret data to support C2, CS and intelligence, surveillance and reconnaissance systems while enabling a more resilient information infrastructure through hardening the hosts, data sharing and data integrity of networks. Full Spectrum Cyber provides the ability to utilize and manipulate the adversary's data and networks for our purposes. Additionally, it protects our networks and data (e.g. personnel, operational and logistics). Data science is a combination of how data is

**Strategic Drivers:** Potential adversaries are investing in advanced technologies that will challenge our advantages in the critical information domain. Nation states and non-state actors seek to degrade our command and control capabilities, networks and computer systems. Cyber threats continue to grow and rapidly proliferate. Globalization and the exponential growth in computing and wireless communications capabilities have transformed the information environment from an enabling medium to a core warfighting capability for both our naval forces and those of our adversaries. Data volume, voracity and velocity necessitate improved management and analysis techniques.

**Vision:** Enable the warfighter to take immediate, appropriate action at any time against any desired adver-

represented, organized, processed, shared and interpreted under relevant context and with necessary assurance.





# Information Dominance–Cyber



## Objectives:

### Decision-Making Superiority

- Rapid accurate decision-making for C2/CS/ISR in Big Data environments
- Machine reasoning and intelligence
- Distributed mission-focused autonomy for control of large sensor information networks
- Data error management
- Data science involving the use of analytics and reducing information down to its critical element



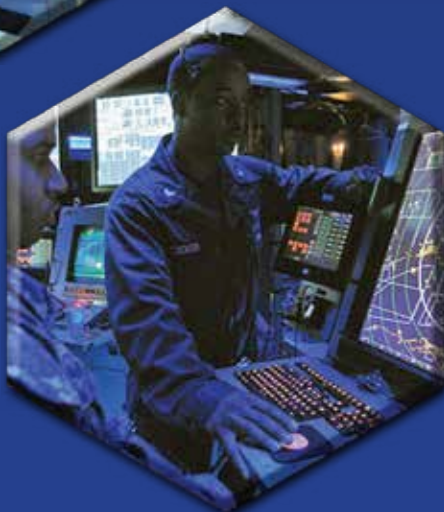
### Full Spectrum Cyber Operations

- Computer network attack
- Computer network defense
- Computer network exploitation



### Communications and Networks

- Dynamic, scalable tactical communication networks
- High-performance, low-cost communication solutions
- SATCOM denial mitigation
- Precision time and navigation



### Computational and Information Construct

- Open source, open architecture and service-oriented architecture/Tactical cloud
- C2/CS/ISR integration and data interoperability
- Autonomous control architectures
- Alternative computational architectures

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Warfighter Performance

**Strategic Drivers:** Increased number, range, precision and lethality of adversary weapons, coupled with a growing mandate within the DoD to field affordable, modular, survivable and upgradeable platforms that support increasingly diverse, sustained operations, directly influence this focus area.

**Vision:** Provide naval platforms that are agile, fuel-efficient, flexible and capable of operating cost-effectively in varied environments. Enable manned and unmanned naval platforms and forces to seamlessly operate in hostile environments while avoiding, defeating and surviving attacks.

**Description:** This focus area is motivated by the interest to develop and deliver platform concepts, systems and component technologies that improve the performance of military platforms (air, ground and sea) to meet operational requirements under all environmental conditions. There are five concentration areas: mobility, survivability, payload optimization, sustainability and life cycle management.

Both platform mobility and survivability require a better understanding of hydromechanics, aerodynamics, electro-mechanics, electromagnetics, materials and

material science, structural mechanics and dynamics, intelligent control and the computational mechanics necessary to improve the design capability for advanced high-performance platforms. The development of validated design tools capable of rapidly and accurately analyzing and evaluating novel air, ground and sea/coastal/riverine platforms with advanced system performance characteristics is a high priority. There is significant effort to understand and minimize susceptibility, and enhance survivability and recoverability technologies while returning or increasing mobility and enhancing mission capability. New platforms will achieve this by incorporating a balance of stealth, hardening and damage tolerance that may include automated recovery systems. Furthermore, computational tools that model the platform's interaction with its environment (physical, electromagnetic, etc.) are essential to the development of other protection systems such as electronic warfare and hardkill systems.

Payload optimization is centered on technologies and design that ensure the broadest excursions in power, weight and stability over the envisioned lifetime of the platform. Central to the capabilities of these platforms is a desire to reduce sustainment requirements and/or make it easier to sustain during operations. Efforts are centered on platform interfaces as well as platform efficiency to reduce sustainment needs. Payload commonality is critical in future designs. To ensure the greatest lifetime of these platforms, this focus area addresses interface standards and modularity to provide flexibility and ease of maintenance and upgrades during service life.





# Platform Design & Survivability

## Objectives:



### Mobility

- Advanced platform design focused on efficiency, agility and affordability
- Autonomous and unmanned vehicle mobility
- Explore future ship-to-shore connector technologies



### Susceptibility/Survivability

- Advanced vehicle structures and materials
- Rigorous platform performance models
- Low observable (LO) and counter-LO technologies
- Softkill techniques
- Automated response and recovery technologies



### Optimized Payload Capabilities

- Modeling and simulation tools
- Modular/affordable platforms
- Advanced structural, mechanical and electrical support infrastructure



### Affordable Fleet/Force Modernization

- Modular systems
- Interfaces and standards to support payload commonality
- New materials and methods to increase reliability and reduce maintenance costs
- Technology advancement during shipyard midlife overhaul and new construction



### At-Sea Sustainment

- Payload and weapons movement
- Underway replenishment
- Interface systems and approaches
- Integrated asset visibility and management

# Appendix A

## Focus Areas

Assure Access to the Maritime Battlespace

Autonomy & Unmanned Systems

Electromagnetic Maneuver Warfare

Expeditionary & Irregular Warfare

Information Dominance—Cyber

Platform Design & Survivability

**Power & Energy**

Power Projection & Integrated Defense

Warfighter Performance

**Strategic Drivers:** The increasing global demand for energy, heavy reliance on fossil fuels, environmental issues and rising costs emphasize the need for energy security and self-sufficiency. There is a critical need for greater energy efficiency, reduced consumption and increased use of alternative energy sources. New naval platforms, payloads and support systems have increased capabilities and automation, but as a result have increased power needs. New approaches are needed for efficient power electronics, power conditioning and storage. Reduction of our expeditionary energy footprint and personal power demands are also critical drivers.

**Vision:** Increase naval forces' freedom of action through energy security and efficient power systems. Increase combat capability through high energy and pulsed power systems. Provide the desired power where and when needed at the manned and unmanned platform, system and personal levels.

**Description:** Power and energy are essential considerations for every Navy and Marine Corps tactical system and platform, every operation and deployment, and at the shore-based infrastructure. The naval force views energy in terms of security and capability, as well as in terms of cost, conservation and environmental impact.

Aggressive goals are described in documents such as the "Department of the Navy's Energy Program for Security and Independence" and the "Marine Corps Expeditionary Energy Strategy and Implementation Plan." The goal of science and

technology (S&T) investment is to develop scientific understanding and new approaches and capabilities that transition power and energy from laboratories to the military end-users.

ONR carries out the Navy power and energy research mission toward specific Navy and Marine Corps objectives in coordination with the research efforts of other Department of Defense services, and in partnership with other federal agencies including the Department of Energy (fuel cells, batteries, etc.) and the Department of Agriculture (biofuels).

Recent conflicts have highlighted the financial and human costs of the power and energy logistics tail of our forward operating bases. Marine Corps plans to reduce this logistics tail are supported by S&T efforts to develop energy efficient systems and platforms. Examples include: highly portable solar cells and concentrated solar systems; fuel cells; low-energy approaches to desalination and water purification; improved rechargeable batteries; and efficient distribution systems (e.g., micro-grids). The tradeoffs in terms of cost, performance and portability often lead to unique requirements and solutions.

Navy platforms are challenged with increasing electric power requirements and the necessity to transform into a more electric fleet to meet future challenges—including the adoption of advanced electric weapons. Next generation weapons systems such as phased-array radars and directed energy weapons operate on continuous and pulsed high power that cannot be met with current generation energy storage and distribution systems. ONR has invested in technologies to increase system energy and power densities, and in new power system architectures with the capability to instantaneously direct power to where it is needed across the propulsion and weapons systems.

Unique naval power and energy requirements drive S&T investment. Examples include: considerations for operation in the sea salt environment; Navy unmanned underwater vehicles using fuel and oxidizer combinations that support air-independent propulsion; compact, high capacity power systems; and associated thermal management and safety concerns.



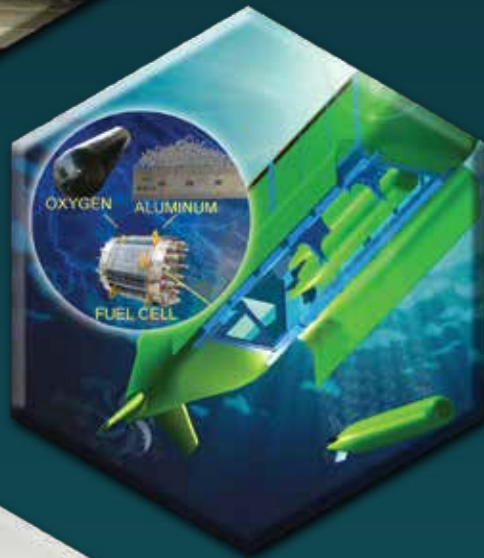


# Power & Energy

## Objectives:

### Efficient Power and Energy Systems

- Increased efficiency and power density on platforms and reduced weight for personal power through advanced materials, devices and architectures
- Efficient power conversion, switching, distribution, control and thermal management
- Efficient power generation equipment including engines, generators, motors and actuators



- Electrochemical, thermal, dielectric and kinetic energy storage
- Energy harvesting
- Power for distributed sensors



### Energy Security

- Alternative and renewable energy sources for naval operations
- Issues associated with the logistics and compatibility of future alternative fuels
- Resilient power networks and systems for platforms and shore-based infrastructure



### High Energy and Pulsed Power

- Energy storage, switching and control systems
- Pulsed power architectures
- Thermal management

# Appendix A

## Focus Areas

Assure Access to the Maritime Battlespace

Autonomy & Unmanned Systems

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Power & Energy

Power Projection & Integrated Defense

Warfighter Performance

**Strategic Drivers:** Future adversaries will seek to neutralize U.S. conventional advantages by capitalizing on asymmetric capabilities that incorporate mobility, range, speed and deception. Naval platforms will be on the front line of our national integrated defensive capabilities to defeat these emerging threats that are proliferating. At the same time, the fleet/force must be able to effectively strike targets with survivable, scalable and cost-effective weapons that have sufficient range, speed and accuracy to complete a variety of missions while reducing risk to our warfighters without creating unnecessary collateral damage or loss of life.

**Vision:** Strengthen and enhance naval power-projection capabilities and integrated layered defense by improving manned and unmanned platforms, payloads and weapons. This enables U.S. and our partner nations' forces to complete missions at extended ranges within hostile environments by avoiding, defeating and surviving attacks. Demonstrate improvements and new capabilities in standoff indirect precision fires for time-critical targets through the use of transformational technology such as electromagnetically launched kinetic projectiles, hypersonic missile propulsion, scalable weapons effects and

directed energy weapons. Explore technologies and cooperative engagement scenarios that drive favorable cost-exchange ratios for naval operations. Exploit the emerging concept of distributed lethality of the force.

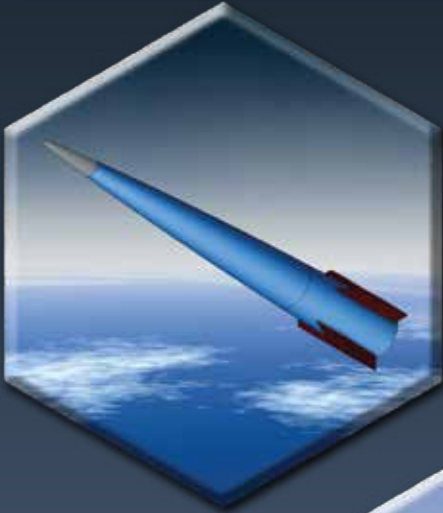
**Description:** The development and delivery of scalable, affordable and decisive effects on target are critical to U.S. military objectives. These efforts include targeting, decision support and precision strike by air, surface and undersea platforms. This focus area strives for enhancements and innovation in naval time-sensitive strike capabilities to improve the ability of naval forces to engage the enemy at extended ranges across the maritime domain in the littorals, inland and on the high seas. Engagements will span the spectrum of desired scalable effects (e.g. deter, disable, damage, defeat, destroy). Power projection emphasizes these capabilities at a speed, rate and distance that neutralize any adversary's ability to conduct effective operations. The ability to strike is negated without the ability to defend platforms against attack spanning the range from small arms and hand-held weapons, swimmers and small boats to ballistic and cruise missiles and undersea threats. Integrated defense will include detection, identification and soft- and hard-kill defeat. Technologies will address an integrated layered defense approach, which extends the naval engagement influence beyond the threat-effect range with near real-time response and neutralization. Future multi-mission weapons systems will provide both offensive and defensive capabilities. Asymmetry works both ways; there is efficiency in defeating a million-dollar missile with directed energy for the price of a gallon of fuel.





# Power Projection & Integrated Defense

## Objectives:



### Future Naval Fires

- Sustained and high-volume, precision direct and indirect fires to extended ranges
- Deeper and more cost-effective conventional magazines
- Directed energy potential for enhanced and sustained engagements



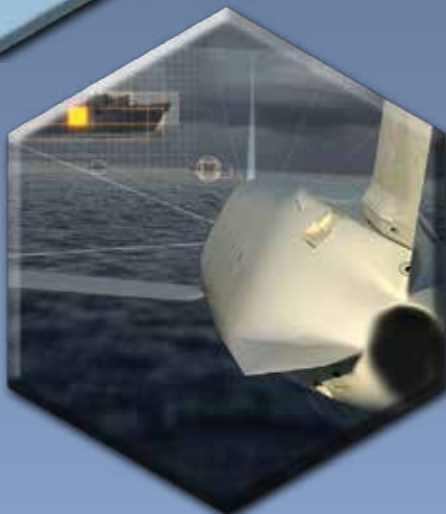
### Integrated Layered Defense Across the Entire Detect-to-Engage Continuum

- Detection, classification, identification, and tracking of potential threats
- Hard/soft kill and lethal/non-lethal scalable countermeasure options
- Cooperative engagement, reliable 360-degree threat targeting and tracking
- Data fusion, decision-making and battle management aids



### Time-Critical Precision Strike

- Insensitive munitions-compliant, high-performance, scalable-effects weapons
- High-speed, extended-range engagement and assessment of time-critical targets
- Hardened/moving target (air, surface or underwater) strike capabilities
- Weapon GPS denial compensation, counter countermeasures and enhanced maneuverability for precision engagement



### Extended Threat Neutralization Capabilities

- Near real-time engagement through electronic warfare, directed energy and hypervelocity weapons
- Extended standoff beyond the threat damage range
- Counter-LO and asymmetric threats such as small boats and unmanned systems
- Collaborative weapons effects technologies

# Appendix A

## Focus Areas

Assure Access to the Maritime Battlespace

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Power Projection & Integrated Defense

**Warfighter Performance**

human-systems integration. Model-based simulation technologies using live, virtual and constructive elements support scalable multi-mission, multi-platform and multi-echelon distributed training, experimentation and mission planning. Training and analytical tools address the irregular warfare challenges posed by nontraditional social, political, economic, ethnic and religious factors. Biologically inspired systems that provide novel sensors, materials, energy sources and autonomous systems promote operational readiness and sustained, effective and efficient operations. Other investments increase the survivability and recovery of injured forces. Combat and shipboard injury mitigation will be enhanced for challenging environments such as remote sea operations, sea basing, distributed operations afloat and ashore. Models of injury prediction and personal protective equipment will allow more effective designs to increase survivability and mobility. Health and fitness optimization approaches improve warfighter resilience to physical and psychological stressors. These investments will reduce costs over the life cycle of the warfighter while enhancing readiness.

**Strategic Drivers:** Increasing personnel costs, force reductions, complex manning requirements and challenging operating environments drive an increased focus on warfighter performance, effectiveness, efficiency and protection.

**Vision:** Enhance warfighter performance through improvements in personnel selection, assignment, training and decision support. Design training and operational systems that enable effective human-machine interaction and mission readiness across individual, team, platform and integrated fleet levels. Prepare warfighters to deploy anywhere and anytime using configurable systems that adjust and adapt to their needs across the full range of military operations. Maintain warfighter health and recovery from injuries at point of injury, during casualty evacuation and in isolated and austere operational environments afloat and ashore.

**Description:** The Warfighter Performance Focus Area facilitates the readiness of naval forces at the individual, team and fleet level to meet the operational requirements in uncertain environments ranging from the most austere to highly complex. Specific areas for increasing readiness include efficient manpower selection and assignment, training, education and





# Warfighter Performance

## Objectives:

### Manpower, Personnel, Training and Education



- Advanced approaches to personnel recruitment, selection, assignment, retention and professional development
- Enhance fundamental information-processing abilities in naval recruits utilizing world-class innovative training technologies
- Accelerate and enhance training time and impact while reducing costs
- Develop tools and techniques to achieve ubiquitous, engaging, scenario-based training and automated performance-based readiness assessment
- Enable training tailored to the individual and team anywhere, anytime through simulation-based technologies for multi-mission, multi-platform training



### Bio-engineered Systems

- Develop and demonstrate biologically inspired intelligent sensors and autonomous systems
- Design computational cognitive models for intelligent systems and synthetic forces for operational experimentation, mission planning, real-time decision support and training systems
- Exploit understanding of neurocognitive processes to enhance combat system design and adaptive digital tutoring systems



### Warfighter Health and Survivability

- Improve the continuum of casualty care from the point of injury, en route, and shipboard to definitive care at treatment facilities
- Reduce incidence of noise-induced hearing loss and explore mitigation and remediation
- Influence the development of advanced materials and improve design for lightweight body armor and equipment
- Characterize and mitigate health and performance risks in undersea operations
- Enhance warfighter resilience to physical and psychological stressors

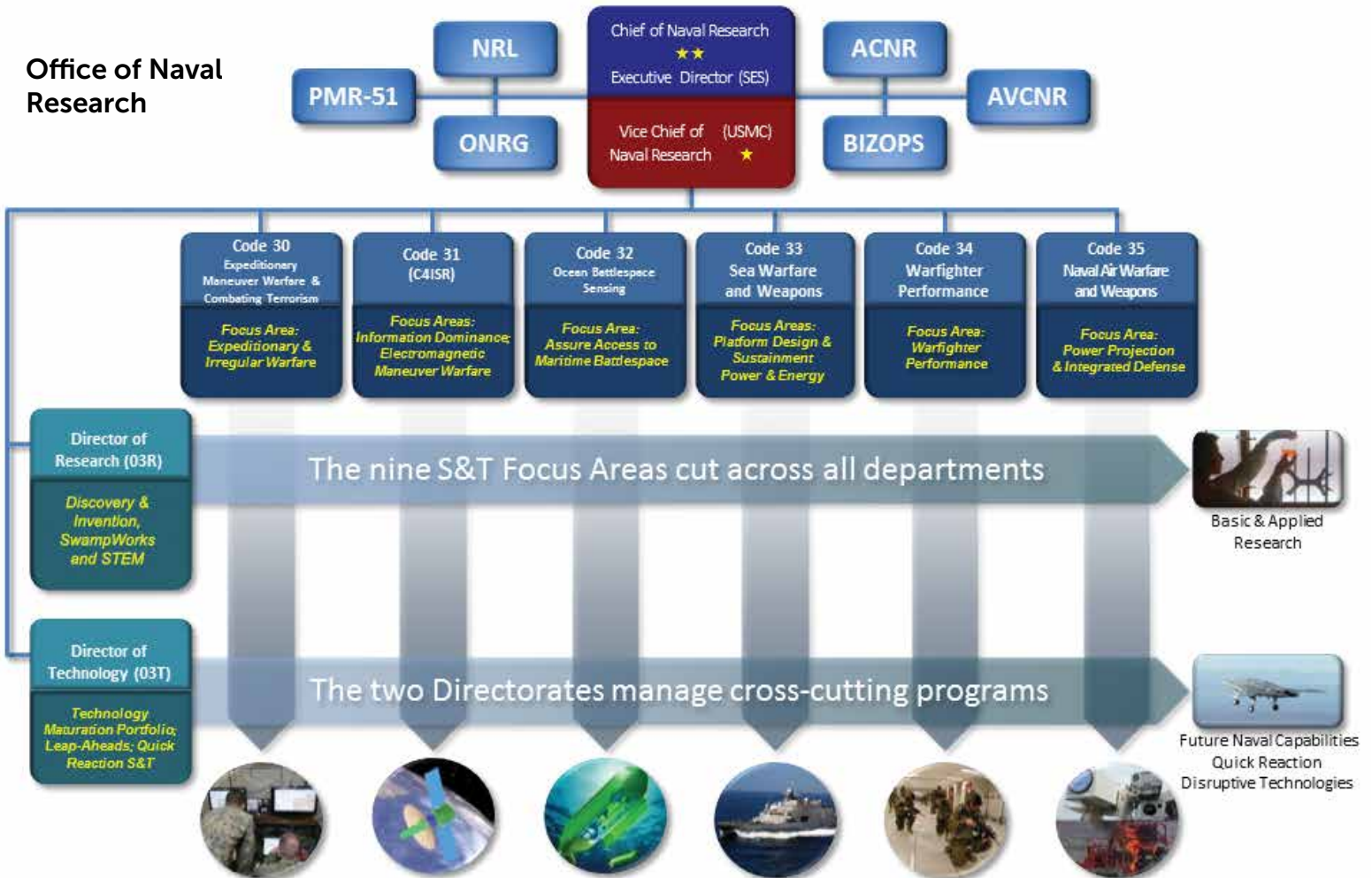


### Human Systems Design and Decision Support:

- Reduce training and workload requirements through human-centric system design
- Create design engineering tools and standards incorporating human capacities into system performance
- Incorporate the human element into design and control of autonomous and robotic systems
- Develop effective, user-friendly decision support systems for kinetic and non-kinetic operations

# Appendix B Organizational Structure

## Office of Naval Research



To better understand how the Department of the Navy executes this science and technology (S&T) strategy, it is helpful to know more about how the major S&T commands, under the purview of the chief of naval research (CNR), are organized and work together:

- Office of Naval Research (ONR)
- Naval Research Laboratory (NRL)
- Office of Naval Research Global
- Marine Corps Warfighting Laboratory (MCWL)
- Office of Low Observable/Counter-Low Observable Policy, Technology, and Advanced Projects (PMR-51)

The CNR is responsible for all naval S&T funding and therefore oversees operations in ONR, as well as NRL, ONR Global and PMR-51. The vice CNR manages multiple Marine Corps responsibilities, including director, Futures Directorate; commanding general, MCWL; and executive agent for Marine Corps S&T.

ONR is a matrix organization with six S&T departments, two directorates and business operations (BIZOPS), which

manages contracts, grants, human resources, budgeting and legal matters. The above organizational chart illustrates these relationships.

### Naval Research Laboratory:

A major portion of the basic research that ONR manages is conducted at NRL. As the corporate research laboratory of the Navy and Marine Corps, NRL conducts a broad program of scientific research and advanced technology development. NRL has served the Navy and Marine Corps and the nation for more than 90 years. ONR provides a base funding to NRL for 20 percent of its research every year.

The broad-based scientific research that NRL provides serves as the foundation to develop solutions and deliver new technologies. A few examples of NRL rapid response efforts include pathogen detection techniques, lightweight body armor, contaminant transport modeling, countermeasures to emerging threats and communications interoperability.



NRL is also the lead naval laboratory for research in space systems, firefighting, tactical electronic warfare, microelectronic devices, autonomy and artificial intelligence.

NRL's Institute for Nanoscience conducts highly innovative, interdisciplinary research at the intersections of the fields of materials, electronics and biology in the nanometer size domain to provide the Navy and DoD with scientific leadership in this complex, emerging area and to identify opportunities for advances in future defense technology.

For more information about NRL visit: [www.nrl.navy.mil](http://www.nrl.navy.mil).

### ONR Global:

As the level of research and development activity continues to accelerate outside of the United States and access to information and knowledge becomes more rapidly and widely available, it is increasingly critical that U.S. naval S&T maintain close connections with the global research and development community.

ONR Global searches the world for promising scientific research and advanced technologies and then helps apply them to address current and future naval capabilities. Through strategic engagement around the world, ONR Global leverages international S&T advances, develops S&T-based partnerships, maintains global technology awareness, and facilitates transition of technology to the warfighter.



*This timelapse photo shows the NRL-developed eXperimental Fuel Cell Unmanned Aerial System (XFC UAS) being deployed. The XFC is a submarine-launched, fully autonomous electric UAS for low-cost ISR missions.*

To best accomplish its mission, ONR Global maintains a forward presence in the international S&T community and at Navy, Marine Corps, and joint commands (see map on page 46). Three complementary programs form the core of ONR Global's outreach:

- **The International Science Program:** accesses the world's top research laboratories and technical experts (in over 50 countries annually) to discover novel science and research approaches that offer a potential of solving naval challenges. ONR Global provides seed funding to international researchers to explore new avenues of promising naval-relevant S&T and to foster collaboration with naval S&T scientists. Seed funding is available in three types:
  - Visiting Scientist Program: supports short-term travel for foreign scientists to the U.S. in order to socialize innovative S&T ideas or findings with the Naval Research Enterprise
  - Collaborative Science Program: financially supports international workshops
  - Naval International Cooperative Opportunities in S&T Program (NICOP): provides direct research support to foreign scientists to help address naval S&T challenges.
- **The International Naval S&T Cooperation Program:** oversees and coordinates S&T exchanges with foreign defense organizations to maintain strong bonds and establish mutually beneficial S&T projects with military partners
- **The Science Advisor Program:** embeds technical staff in Navy, Marine Corps, and Joint commands in order to best understand the operational needs of warfighters and to assist in transitioning technology to the Fleet and Forces.

Examples include:

- Tsunami detection from the Ionosphere – a NICOP with French investigators demonstrated that scintillation in the ionosphere caused by major earthquakes can be connected through modeling methods to produce techniques for early detection of tsunamis
- Plasma sprayed  $\text{Al}_2\text{O}_3$  coatings – a NICOP with Indian investigators successfully reinforced  $\text{Al}_2\text{O}_3$  coatings at the nano-meter and micro-meter levels, which now enable a new approach for economical and longer-lasting emission control for automobile and gas turbine engines

# Appendix B

## Organizational Structure

- Mobile Flight Deck Cleaning Recovery and Recycling System – this technical solution was rushed to the USS BATAAN and BONHOMME RICHARD when their flight decks were fouled by very small metallic balls during resurfacing.

Ultimately, ONR Global connects U.S. RDT&E organizations with the warfighter and with the global scientific community to ensure that the U.S. Navy and Marine Corps quickly leverage and benefit from the broadest range of S&T research and innovative concepts available.

For more information about ONR Global and its strategy visit: [www.onr.navy.mil/global](http://www.onr.navy.mil/global).

### Marine Corps Warfighting Laboratory:

The Futures Directorate is a newly established organization within the Marine Corps Combat

Development Command with a mission to identify plausible future security environments, develop and explore warfighting concepts and concepts of operations. Within the Futures Directorate, MCWL explores and analyzes service concepts using an integrated combination of research, modeling and simulation, wargaming, experimentation, S&T discovery and integration, and analysis.

The S&T Division within MCWL works with various S&T organizations to develop the vision, policies and strategies needed to exploit scientific research and technological development in support of combat development and experimentation. S&T thrust areas include Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance; Marine Air-Ground Task Force Fires; Autonomy/Robotics; Expeditionary Logistics and Medicine; Maneuver; Force Protection; and Cyber/Electronic Warfare.



### ONR Global Around the World



For more information about ONR Global and its strategy visit: [www.onr.navy.mil/global](http://www.onr.navy.mil/global)



# Governance and Processes

The four S&T investment portfolios and nine S&T focus areas represent the overall approach to execute this naval S&T strategy. Turning vision into products that deliver decisive capability for our Navy and Marine Corps requires coordinated efforts from many different S&T stakeholders across the naval S&T community. This section provides a snapshot of the governance processes that ONR uses to manage the four portfolios and S&T focus areas.

### Management of Focus Areas:

- Each of the nine S&T Focus Areas is assigned the responsibility of a Senior Executive Service leader at ONR, who is given broad authority to work across departmental lines.
- The focus area leader is responsible for fostering research in the objectives and generating progression of products from basic research through transition.
- Each focus area is reviewed biennially with the update of this strategy document. Objectives are evaluated for progress, as well as coverage across the S&T portfolio. Programs and projects that are not executing or that are found to be out of scope are at risk of being terminated and their resources re-allocated.

The supporting processes for bringing the S&T vision and strategy to reality are the key to successful implementation. There are many management processes in place to determine which S&T investments are worth pursuing and also key business processes ensure fiscal responsiveness and efficiency. Following are a few descriptions worth highlighting to help illustrate how the planning cycle works.

More than 80 percent of ONR-sponsored S&T is awarded to external performers in academia, industry and the naval research community. To ensure quality and relevance of programs peer reviews are conducted throughout the annual cycle (see sidebar). In addition, efficient and effective business processes are vital to achieving our S&T objectives. Business intelligence

software and the enterprise resource planning financial system helps ensure funds are efficiently and effectively allocated.

Each year in December, ONR conducts an investment balance review (IBR). This review is conducted by the CNR in his dual role as the director, innovation, test and evaluation, and technology requirements officer.

The IBR funding decisions are documented and new internal fiscal guidance is balanced with the Navy's programming and budgeting information system funding controls. This new fiscal guidance is updated and distributed within ONR (and NRL, ONR Global) to support shared understanding of funding changes. The results are used in support of ONR's budget formulation and execution processes.

The following chart is provided to illustrate a typical annual cycle of key S&T events, processes and reviews.

### ONR Peer Reviews:


The peer review panel consists of a minimum of three members with the required expertise. Members may be external to ONR, from academia, industry or another government agency. The panel evaluates eligible projects in the following areas:

- Significance and originality
- Scientific merit and accomplishment
- Risk and potential impact
- Principal investigator

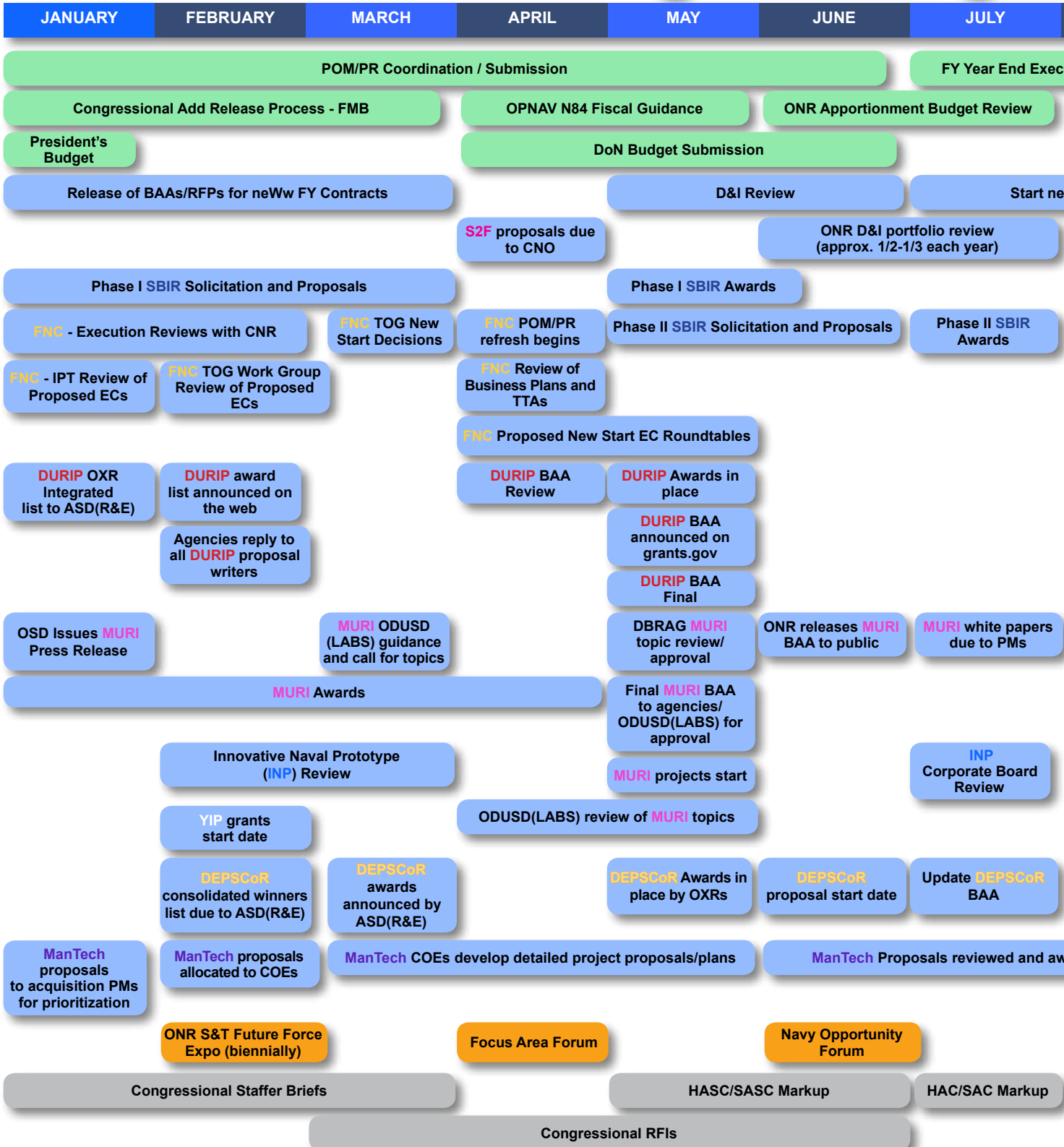
Results are reviewed by the program officer, division director, department head and director of research and adjustments made to the projects as needed. The department head presents the results of the peer review to the executive director, vice CNR, and the CNR.

# Appendix C

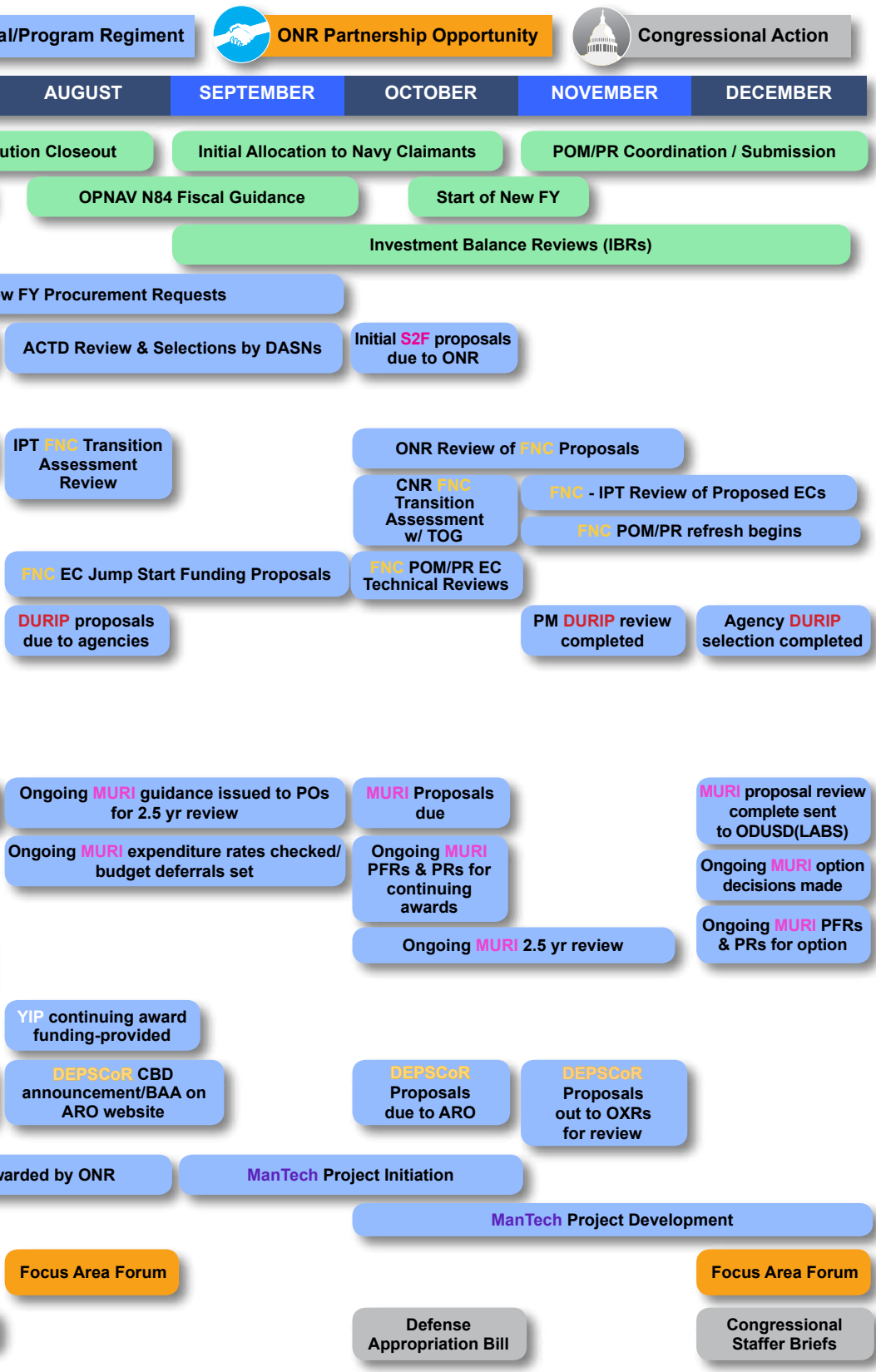
## Key Events, Processes & Reviews that Affect DON S&T

 Financial/Budget Regiment

 Technical







# AT A GLANCE

## WHAT IS ONR?

The Office of Naval Research (ONR) provides technological advantage to the Navy and Marine Corps through investments in science and technology (S&T) research.

## HOW DOES ONR WORK?

Continuous investment by ONR in new and innovative technology enables Department of the Navy to build and maintain the world's most capable naval forces. The process is long term, yet highly responsive to near-term naval needs. In fact, ONR's balanced S&T portfolio is allocated to meet the broad spectrum of warfighter requirements:

- ◆ 8% Quick reaction
- ◆ 30% Technology maturation
- ◆ 12% Leap-ahead innovations
- ◆ 45% Discovery and invention (basic and applied science)

## WHAT DOES ONR ACHIEVE?

ONR brings technology to aircraft, ships, ground vehicles and satellites and develops the S&T that gives Sailors and Marines the advantage they need to maintain the upper hand and stay safe.

## Naval S&T Research Areas

Naval S&T Focus Area	Objective Categories	S&T Research Areas
Expeditionary and Irregular Warfare	<ul style="list-style-type: none"> <li>• Battlespace Awareness</li> <li>• Irregular Warfare Operations</li> <li>• Expeditionary and Distributed Operations</li> <li>• Irregular Threat Countermeasures</li> </ul>	<ul style="list-style-type: none"> <li>• Data Visualization and Training</li> <li>• Efficient Processing</li> <li>• Tactical Networking</li> <li>• Over the Horizon Communications</li> <li>• Small Unit Communications Technologies</li> <li>• Cross-Domain Network Operations</li> <li>• Human Social, Cultural, and Behavioral Sciences</li> <li>• Pattern Recognition</li> <li>• Spectrum Protocol Content Awareness and Influence</li> <li>• Precision Target Identification and Location</li> <li>• Small Unit Air Defense</li> <li>• Networked Fires</li> <li>• Small Unit Water Purification</li> <li>• Small Unit Power</li> <li>• Fuel Efficiency</li> <li>• Vehicle Power Generation</li> <li>• Autonomous platforms and payloads</li> <li>• Psychometrics</li> <li>• Instructional Design and Technology</li> <li>• Machine Learning</li> <li>• Immersive Sciences</li> <li>• Explosive Hazard Defeat</li> <li>• Counter RPGs and ATGMs</li> <li>• Counter Tactical Surveillance and Targeting</li> <li>• Biometrics</li> <li>• Forensics</li> <li>• Personal Survivability</li> <li>• Vehicle and Personnel Signature Management</li> <li>• Vehicle Survivability</li> </ul>
Platform Design and Survivability	<ul style="list-style-type: none"> <li>• Mobility</li> <li>• Susceptibility/survivability</li> <li>• Optimized Payload Capabilities</li> <li>• At-Sea Sustainment</li> <li>• Affordable Fleet/Force Modernization</li> </ul>	<ul style="list-style-type: none"> <li>• Platform Design focused on efficiency, agility, and affordability</li> <li>• Autonomous and Unmanned Vehicle Mobility</li> <li>• Vehicle Structures and Materials</li> <li>• Platform Performance Models</li> <li>• Low Observable (LO) and Counter LO Technologies</li> <li>• Softkill Techniques</li> <li>• Automated Response and Recovery Technologies</li> <li>• Modeling and Simulation Tools</li> <li>• Modular/Affordable Platforms</li> <li>• Structural, Mechanical, and Electrical Support Infrastructure</li> <li>• Payload and Weapons Movement</li> <li>• Underway Replenishment</li> <li>• Interfaces and Standards</li> <li>• Sea Platforms</li> <li>• Air Propulsion</li> <li>• Air/Ground Vehicles</li> <li>• Functional Materials</li> <li>• Structural Materials</li> <li>• Manufacturing Science</li> </ul>



Naval S&T Focus Area	Objective Categories	S&T Research Areas
Assure Access to Maritime Battlespace	<ul style="list-style-type: none"> <li>• Achieve and Maintain Undersea Dominance</li> <li>• Improve Mobile Autonomous Environmental Sensing</li> <li>• Match Environmental Predictive Capabilities to Tactical Planning Requirements</li> <li>• Maximize Systems Performance via Adaptation to the Environment</li> </ul>	<ul style="list-style-type: none"> <li>• Anti-Submarine Warfare Surveillance</li> <li>• ASW Performance Assessment</li> <li>• Bio-sensors, Bio-processes, and Bio-inspired Systems</li> <li>• Electronic Warfare Attack</li> <li>• Functional Materials</li> <li>• Intelligent and Autonomous Systems</li> <li>• ISRT-ESM</li> <li>• Large Vessel Stopping</li> <li>• Littoral Geosciences, Optics and Biology</li> <li>• Marine Mammals</li> <li>• Marine Meteorology</li> <li>• Mine Neutralization</li> <li>• Nanometer Scale Electronic Devices and Sensors</li> <li>• Navigation &amp; Precision-Timekeeping</li> <li>• Networked Sensors</li> <li>• Non-Lethal Weapons</li> <li>• Ocean Acoustics</li> <li>• Physical Oceanography</li> <li>• Solid State Electronics</li> <li>• Space Environmental Effects</li> <li>• Spacecraft Technology</li> <li>• Unmanned Air Vehicles</li> <li>• Unmanned Sea Vehicle Technologies</li> <li>• Naval Power Systems</li> <li>• Sea Platforms</li> <li>• Affordability/Reduced Platform Lifecycle Cost</li> <li>• Air/Ground Vehicles</li> <li>• Information Assurance and Anti-tamper</li> <li>• Intelligent and Autonomous Systems</li> </ul>
Autonomy and Unmanned Systems	<ul style="list-style-type: none"> <li>• Human/Unmanned Systems Collaboration</li> <li>• Perception and Intelligent Decision Making</li> <li>• Scalable and Robust Distributed Collaboration</li> <li>• Intelligence Enablers and Architectures</li> <li>• Novel Platforms and Integration</li> </ul>	<ul style="list-style-type: none"> <li>• Intelligent and Autonomous Systems</li> <li>• Unmanned Air Vehicles</li> <li>• Unmanned Sea Vehicle Technology</li> <li>• Unmanned Ground Vehicles</li> <li>• Human Robotic Interaction/Human Factors</li> <li>• Machine Reasoning, Learning, and Intelligence</li> <li>• Scene/Image Understanding</li> <li>• Biorobotics, Cognitive Science, and Neuroscience</li> </ul>
Information Dominance - Cyber	<ul style="list-style-type: none"> <li>• Communications and Networks</li> <li>• Computational and Information Construct</li> <li>• Full Spectrum Cyber Operations</li> <li>• Decision Making Superiority</li> </ul>	<ul style="list-style-type: none"> <li>• ASW Surveillance</li> <li>• Computational Decision Making</li> <li>• Bio-sensors, Bio-processes, and Bio-inspired Systems</li> <li>• Communications and Networks</li> <li>• Applied &amp; Computational Analysis</li> <li>• Human Factors Organizational Design and Decision</li> <li>• Complex Software Systems &amp; Information Assurance</li> <li>• Cyber Security &amp; Information Operations S&amp;T</li> <li>• Intelligent &amp; Autonomous Systems</li> <li>• Spacecraft Technology</li> <li>• Optimization</li> <li>• Data Science</li> <li>• Command &amp; Control and Combat Systems</li> <li>• Quantum Information Sciences</li> </ul>

# Appendix D

## Naval S&T Research Areas

Naval S&T Focus Area	Objective Categories	S&T Research Areas
Electromagnetic Maneuver Warfare	<ul style="list-style-type: none"> <li>• Spectrum Dominance</li> <li>• Advanced Electronics, sensing and response techniques</li> </ul>	<ul style="list-style-type: none"> <li>• Electronics Materials and Devices</li> <li>• Electronic Warfare</li> <li>• Multifunction Systems</li> <li>• Nano Electronics</li> <li>• Precision Time and Navigation</li> <li>• Quantum Measurement Architecture Devices</li> <li>• Radar &amp; Electro-optical/IR Sensing</li> <li>• Surface/Aerospace Surveillance</li> </ul>
Power and Energy	<ul style="list-style-type: none"> <li>• Energy Security</li> <li>• Efficient Power and Energy Systems</li> <li>• High Energy and Pulsed Power</li> </ul>	<ul style="list-style-type: none"> <li>• Advanced Naval Power Systems</li> <li>• Air Platform Power</li> <li>• Bio-derived Materials and Systems</li> <li>• Functional Materials</li> <li>• Personal Power</li> <li>• Power Electronics</li> <li>• Power for Future Electric Weapons and Radars</li> <li>• Materials, Computation, and Prediction</li> <li>• Manufacturing Science</li> </ul>
Power Projection and Integrated Defense	<ul style="list-style-type: none"> <li>• Future Naval Fires</li> <li>• Integrated Layered Defense Across the Entire Detect-to-Engage Continuum</li> <li>• Extended Threat Neutralization Capabilities</li> <li>• Time-Critical Precision Strike</li> </ul>	<ul style="list-style-type: none"> <li>• Advanced Energetics</li> <li>• Air Platform Survivability</li> <li>• Directed Energy</li> <li>• Electromagnetic Guns</li> <li>• EW Attack</li> <li>• Expeditionary Firepower Torpedo Defense</li> <li>• Expeditionary Force Protection</li> <li>• Functional Materials</li> <li>• High Speed Weapons Technologies</li> <li>• ISRT-ESM</li> <li>• Mining</li> <li>• Non-Lethal Weapons</li> <li>• Precision Strike</li> <li>• Sea Platform Survivability</li> <li>• Solid-State Electronics</li> <li>• Affordability/Reduced Platform Life-Cycle Cost</li> <li>• Air/Ground Vehicles</li> <li>• Intelligent and Autonomous Systems</li> <li>• Manufacturing Science</li> <li>• Structural Materials</li> <li>• Materials, Computation and Prediction</li> <li>• Platform Affordability</li> <li>• Undersea Weaponry</li> </ul>
Warfighter Performance	<ul style="list-style-type: none"> <li>• Manpower, Personnel, Training and Education</li> <li>• Human-system Design and Decision Support</li> <li>• Bio-engineered Systems</li> <li>• Warfighter Health and Survivability</li> </ul>	<ul style="list-style-type: none"> <li>• Human factors, Organizational Design and Decision Research</li> <li>• Manpower and Personnel</li> <li>• Training, Education and Human Performance</li> <li>• Undersea Medicine</li> <li>• Bio-sensors, Bio-processes and Bio-inspired Systems</li> <li>• Casualty Care and management</li> <li>• Casualty Prevention</li> </ul>



# Appendix E

## National Naval Responsibilities

The maritime environment is complex. Seventy percent of the world is covered by ocean, which gives the U.S. a vested interest in leading research areas critical to the sea services. These areas are called National Naval Responsibilities (NNR), and the health, strength and growth of our knowledge in these fields depends upon Department of the Navy funding and ONR's leadership to cultivate research. There are five NNR's, which are explained more fully below:

### 1. Ocean Acoustics

- Focuses investments in shallow water acoustics, high-frequency acoustics and long-range/low-frequency propagation
- Supports improved shallow-water anti-submarine warfare, wide-area surveillance, enhanced ballistic missile submarines security and rapid environmental assessment

### 2. Undersea Weapons

- Focuses on multidisciplinary systems design, guidance and control, undersea warheads, counterweapons and countermeasures and super-cavitating weapons
- Supports improved guidance and control capabilities for the littoral environment, improved weapon effectiveness and increased weapons load-out on naval platforms

### 3. Naval Engineering

- Conducts major field experiments that integrate various technologies into innovative ship concepts
- Supports improved ship design tools and better analytics for platform affordability assessments

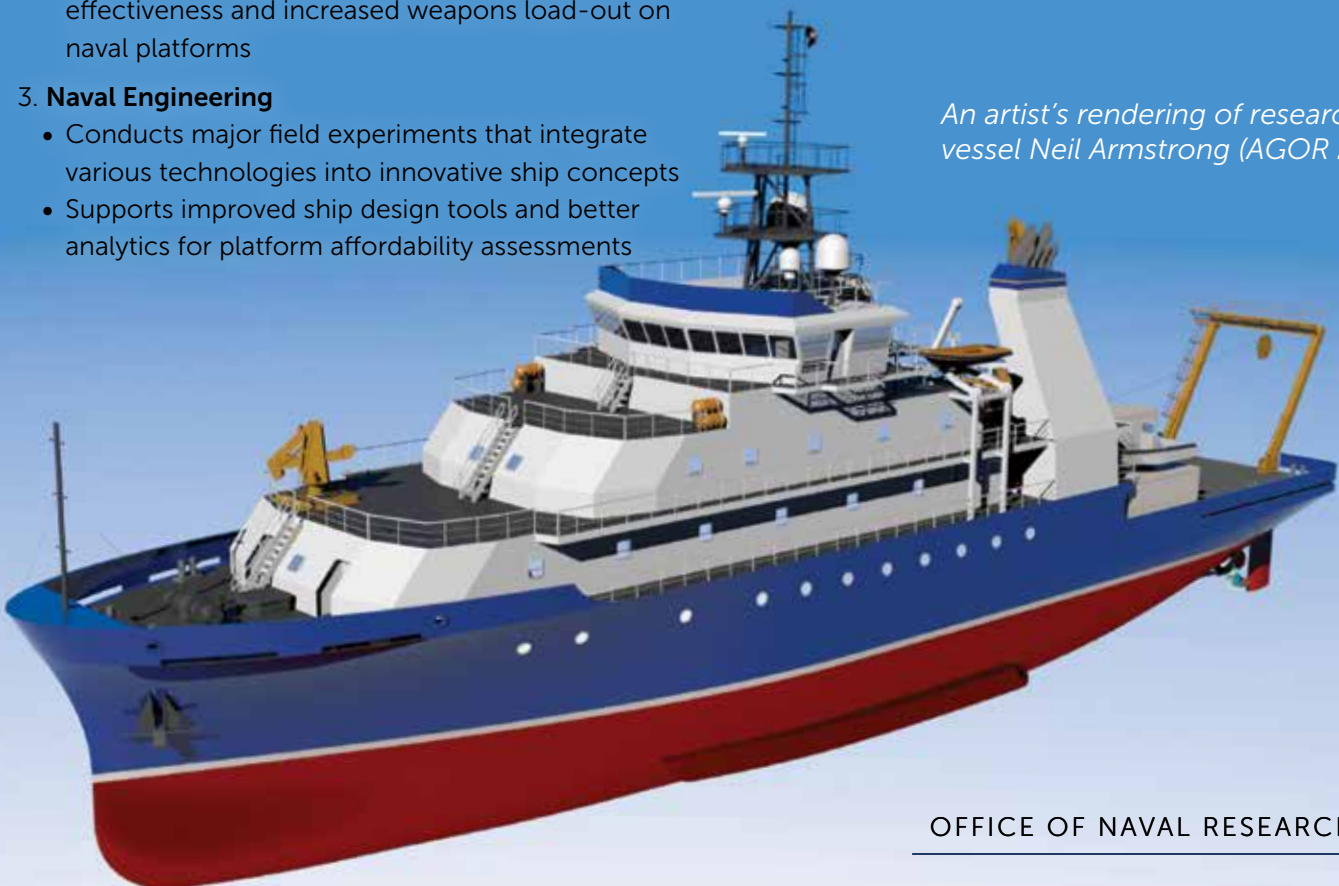
### 4. Undersea Medicine

- Encompasses non-recompressive treatment for decompression sickness (DCS), arterial gas embolism, accelerated decompression and mechanisms for militating against the effects of DCS
- Supports extended warfighter reach; greater freedom of action in the water column, thermal extremes and contaminated water; and optimized submariner and diver performance

### 5. Sea-Based Aviation

- Focuses on necessary S&T disciplines and representative facilities to meet next-generation sea-based aircraft technical challenges in the following disciplines: aircraft structures; propulsion; propulsion integration; ship interface and operations; avionics and electronics; air refueling; aerodynamics; and guidance, navigation, control/autopilot/autonomy; and design tools
- Acknowledges sea-based aviation as a critical area requiring a distinctive S&T base to enhance naval aviation's role and effectiveness in power projection.

*An artist's rendering of research vessel Neil Armstrong (AGOR 27)*



# STEM & Workforce Development



## Science, Technology, Engineering, and Mathematics (STEM):

The basic building block for the future workforce is a robust, strategic commitment to STEM education and talent development. The U.S. is the world's technology leader, and the Department of the Navy (DoN) currently enjoys an extraordinary level of technological superiority across the full spectrum of its missions. Maintaining this technological edge requires a culture of innovation and the capacity to draw upon the ideas and approaches of a diverse and skilled science and engineering (S&E) workforce.

**Development and Sustainment:** The researcher base program and S&E workforce programs support the S&T community as a whole. The S&E workforce programs educate and encourage the academic and professional development of scientists and engineers in fields relevant to disciplinary research and establish partnerships among academia, industry and naval laboratories. ONR works to increase minority institution and small business participation through education programs, grants, contracts and cooperative agreements with Historically Black Colleges and Universities/Minority Institutions.

ONR's Small Business Innovation Research/Small Business Technology Transfer programs reach out to tap the innovation provided by small businesses. Combining people with different attributes, backgrounds and skills will foster the creativity needed to address new and developing threats. The S&T community must ensure that it maintains a culture that stimulates an open exchange of ideas across the workforce.

Mindful of the increasing use of networked collaboration, teamwork and risk-benefit analysis, we must focus internal

training programs on collaboration and management skills broader than specific technical expertise. We must expand the conceptual model of lifelong learning and increase the use of adult learning techniques to maintain and improve skills over the course of entire careers.

**Science and Engineering Workforce:** The quality of naval research depends upon nurturing and sustaining a well-educated, highly experienced and motivated workforce. These professionals must respond to immediate and strategic military technology requirements and maintain a high degree of excellence in the face of many demographic and resource challenges. Congress has recognized the importance of the continued development of the S&E workforce in all of the defense laboratories.

In Section 219 of the National Defense Authorization Act for Fiscal Year 2009 (Public Law 110-417), Congress directed the establishment of a Department of Defense-wide program to enhance the S&E capability of the defense laboratories. It authorized the director of a defense laboratory to utilize up to 3 percent of all funds available to fund in-house workforce efforts. The DoN has established the Naval Innovative Science and Engineering (NISE) program to implement congressional and DoD direction.

The In-house Laboratory Independent Research, Independent Applied Research and NISE programs provide the necessary resources to foster high-quality innovative basic and applied research, mature and promote technology transition and improve the workforce through advanced degrees and training. These programs seek to improve the naval research and development capacity and allow naval scientists and engineers to better manage and oversee their industrial and academic partners as they seek solutions that deliver game-changing advantages to DoD and the nation.

In order to attract and retain highly qualified individuals, DoN must continue to promote a work environment commensurate with the cutting-edge scientific research being conducted by providing modern laboratory equipment and facilities. Investments in people, training/educational opportunities and facilities are critical to the long-term workforce development.



## Acronyms

<b>ASD(R&amp;E)</b>	Assistant Secretary of Defense for Research and Engineering	<b>MCWL</b>	Marine Corps Warfighting Laboratory
<b>ASN(RD&amp;A)</b>	Assistant Secretary of the Navy for Research, Development and Acquisition	<b>MILCON</b>	Military Construction
<b>ARO</b>	Army Research Office	<b>MILPERS</b>	Military Personnel
<b>ASW</b>	Anti-Submarine Warfare	<b>MURI</b>	Multidisciplinary University Research Initiative
<b>BA</b>	Budget Activity	<b>NAVAIR</b>	Naval Air Systems Command
<b>BAA</b>	Broad Agency Announcement	<b>NAVSEA</b>	Naval Sea Systems Command
<b>C2</b>	Command and Control	<b>NAVSUP</b>	Naval Supply Systems Command
<b>CBD</b>	Commerce Business Daily	<b>NRL</b>	Naval Research Laboratory
<b>CNO</b>	Chief of Naval Operations	<b>ODUSD(LABS)</b>	Office of the Deputy Under Secretary of Defense (Laboratories)
<b>CNR</b>	Chief of Naval Research	<b>O&amp;M</b>	Operations and Maintenance
<b>COE</b>	Center of Excellence	<b>ONR</b>	Office of Naval Research
<b>CS</b>	Combat Systems	<b>OXR</b>	Offices of Air Force, Army, and Navy Research
<b>D&amp;I</b>	Discovery and Innovation	<b>PFR</b>	Program Financial Review
<b>DEPSCoR</b>	Department of Defense Experimental Program to Stimulate Competitive Research	<b>PM</b>	Program Manager
<b>DoD</b>	Department of Defense	<b>PMR-51</b>	Office of Low Observable/Counter-Low Observable Policy, Technology, and Advanced Projects
<b>DoN</b>	Department of Navy	<b>POM</b>	Program Objective Memorandum
<b>DURIP</b>	Defense University Research Instrumentation Program	<b>PR</b>	Purchase Request
<b>EC</b>	Enabling Capability	<b>R&amp;D</b>	Research and Development
<b>EIW</b>	Expeditionary Irregular Warfare	<b>RDT&amp;E</b>	Research, Development, Test and
<b>EW</b>	Electronic Warfare	<b>ROPO</b>	Research Opportunities For Program Officers
<b>FLEX</b>	Fleet-led Experimentation	<b>SAC</b>	Senate Appropriations Committee
<b>FMB</b>	Financial Management Branch	<b>SASC</b>	Senate Armed Services Committee
<b>FNC</b>	Future Naval Capabilities	<b>S&amp;T</b>	Science and Technology
<b>FY</b>	Fiscal Year	<b>S2F</b>	Speed to Fleet
<b>GPS</b>	Global Positioning System	<b>SBIR</b>	Small Business Innovation Research
<b>HAC</b>	House Appropriations Committee	<b>SOSUS</b>	Sound Surveillance System
<b>HASC</b>	House Armed Services Committee	<b>SPAWAR</b>	Space and Naval Warfare Systems Command
<b>INP</b>	Innovative Naval Prototypes	<b>STEM</b>	Science, Technology, Engineering and Mathematics
<b>IPT</b>	Integrated Product Team	<b>TTA</b>	Technology Transition Agreement
<b>IR</b>	Infrared	<b>TOG</b>	Technology Oversight Group
<b>JCTD</b>	Joint Concept Technology Demonstration	<b>YIP</b>	Young Investigator Program
<b>ISR</b>	Intelligence, Surveillance and Reconnaissance		
<b>LCS</b>	Littoral Combat Ship		
<b>LO</b>	Low Observable		
<b>ManTech</b>	Manufacturing Technology		
<b>MARCORSYSCOM</b>	Marine Corps Systems Command		

The Naval S&T Strategy is:

*"To DISCOVER, DEVELOP and DELIVER decisive naval capabilities, near- to long-term, by investing in a balanced portfolio of breakthrough scientific research, innovative technology and talented people."*



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