Naval S&T Strategic Plan

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From their beginnings, the U.S. Navy and Marine Corps have leveraged innovation and technology to defend U.S. interests. To ensure the superiority of U.S. Naval forces after World War II, congress established the Office of Naval Research (ONR) in 1946 to "plan, foster and encourage scientific research in recognition of its paramount importance to future Naval power and national security."

This is the third iteration of the Naval Science & Technology Strategic Plan, and it reflects the evolution of future requirements combined with the fiscal realities of today. We have tightened the number of S&T Focus Areas, adjusted our investment strategy and streamlined processes to leverage innovations that can meet emerging requirements and quickly transition new technologies.

Developed in collaboration with stakeholders and approved by the S&T Corporate Board, this plan has three principal goals: (1) align Naval S&T with Naval mission and future capability needs; (2) balance and manage the S&T portfolio; and (3) communicate the S&T vision and approach to senior decision-makers, key stakeholders, partners, customers, and performers. In approving this plan, the S&T Corporate Board emphasized the need for increased senior Navy and Marine Corps leadership engagement in the S&T process with the goal of providing greater clarity on the Fleet and Force demand signals and focusing future capability investments, critical in the anticipated fiscal environment.

By design, this strategy provides flexibility. Pursuit of future game-changing capabilities requires investments in high-risk, high-payoff S&T. Breakthroughs don't happen overnight; therefore, a strong Basic Research portfolio will remain a critical component of this strategy. Concurrently, ONR funds and administers quick-reaction S&T tools that respond to requests submitted directly from the warfighter to deliver working prototypes in 12 to 24 months. As good stewards of the taxpayer's dollar, this range of options helps make every dollar count.

Delivering on the promise of this plan requires us to work with the best and brightest people from partner organizations both at home and abroad. S&T research invests in people, but declining interest in science, technology, engineering and math (STEM) careers in America is a risk to the health of our domestic S&T community, our technological superiority and our economic strength. We acknowledge this concern and make provisions in this plan for increasing Naval STEM activities to support the development of the future Naval science and engineering workforce.

All we do is for the warfighter.

NEVIN P. CARR, JR.
Rear Admiral, U.S. Navy
Chief of Naval Research

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SEP 01 2011

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 at the 21 June 2011 Science and Technology Corporate Board meeting and directs the Chief of Naval Research to implement the strategy.

Sean J. Stackley Assistant Secretary of the Navy Research, Development and Acquisition	Jonathan W. Greenert Admiral, U.S. Navy Vice Chief of Naval Operations	Joseph F. Dunford General, U.S. Marine Corps Assistant Commandant of the Marine Corps

Table of Contents

Foreword i

Science & Technology Corporate Board Decision Memorandum iii

1. Introduction 1

2. Background 4
- Management Approach 7
- S&T Outputs 8
- S&T Enablers 8

3. Strategy Development 9
- Hedging Against Uncertainty 9
- Strategy Process 10
- Strategy Timeframe 11
- S&T Taxonomies 11

4. Naval S&T Focus Areas 12
- Assure Access to the Maritime Battlespace 13
- Autonomy and Unmanned Systems 15
- Expeditionary and Irregular Warfare 17
- Information Dominance 19
- Platform Design and Survivability 21
- Power and Energy 23
- Power Projection and Integrated Defense 25
- Total Ownership Cost 29
- Warfighter Performance 31

5. Implementation 33
- Discovery and Invention 33

Leap Ahead Innovations 35
Acquisition Enablers 36
Quick Reaction and Other S&T 37
Speed to Fleet 39
Naval Research Laboratory 40
Global Technology Awareness 41
ONR Global 42
Naval Research Enterprise 43
National Naval Responsibilities 44
Science and Engineering Workforce 46
Science, Technology, Engineering and Mathematics 46
Development and Sustainment 47
Interagency Coordination and Alliance 47
Measuring Success 48
Business Processes 48

6. Execution 49

7. Summary 51

Appendices:

A: References and Web Links 53
B: Naval S&T Research Areas 55
C: Acronyms 58

List of Figures:

Figure 1: S&T Corporate Board Composition 2
Figure 2: ONR Investment Portfolio 4
Figure 3: ONR Managed Funding 6
Figure 4: Naval S&T Strategy Process 10
Figure 5: ONR Global Presence 42
Figure 6: Metrics to Evaluate S&T Portfolio 48

1. Introduction

The Naval Science and Technology (S&T) Strategic Plan describes how the Office of Naval Research (ONR) sponsors scientific research efforts that will enable the future operational concepts of the Navy and the Marine Corps. Department of Defense (DoD) and Department of the Navy (DON) strategic documents provide the basic foundation for this plan. The priorities of the Secretary of the Navy (SECNAV), Chief of Naval Operations (CNO) and Commandant of the Marine Corps (CMC) are reflected in the shape of the investment portfolio and nine S&T Focus Areas outlined in the plan. This is a broad strategy that articulates a general direction for the future, while retaining sufficient flexibility and freedom of action to meet emerging challenges or alter course as directed by senior Naval leadership. The Navy and Marine Corps depend on S&T to discover, develop and demonstrate high-payoff, game-changing technologies to ensure the Fleet/Force retain a significant advantage over potential adversaries. This plan enables tomorrow's technologies for our warfighters across all domains.

As the DON's S&T provider, ONR identifies S&T solutions to address Navy and Marine Corps needs. Since its establishment in 1946, ONR continues to be the first place that senior Naval leadership turns to for addressing emerging technology issues and challenges. The ONR mission, defined in law, 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*"[1] 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.*"[2]

Naval S&T Vision: Sponsor scientific research and technology to:

- Pursue revolutionary, game-changing capabilities for Naval forces of the future,
- Mature and transition S&T advances to improve existing Naval capabilities,
- Respond quickly to current Fleet and Force critical needs, and
- Maintain broad technology investments to hedge against uncertainty and to anticipate and counter potential technology surprise.

ONR was established as an Echelon 1 command with the Chief of Naval Research (CNR) reporting to SECNAV. The Assistant Secretary of the Navy for Research, Development and Acquisition (ASN-RDA) exercises staff cognizance over ONR. The Naval S&T Corporate Board, composed of ASN-RDA, the Vice Chief of Naval Operations (VCNO), and the Assistant Commandant of the Marine Corps (ACMC) was established to provide additional guidance to the CNR, approve the overall shape of the investment portfolio, and approve specific Innovative Naval Prototypes (INPs). In 2003, the S&T Corporate Board established the Technology Oversight Group (TOG)[3] at the three-star level to provide senior, focused advice on technology matters impacting the future capabilities of the Navy and Marine Corps. The TOG provides an integration and assessment function across the Future Naval Capabilities (FNC) program. The primary functions of the TOG are to ensure FNC

[1] Public Law 588 of 1946
[2] Defense Authorization Act of 2001
[3] Joint Letter dtd May 2003: ASN RDA, VCNO and ACMC, TOG Charter for FNC

investments are aligned to warfighter needs, fully coordinated to address identified capability gaps and properly planned to eliminate duplication of effort and to facilitate transition. The TOG provides guidance for the oversight, management and execution of the FNCs. It is co-chaired by the Deputy Chief of Naval Operations for Integration of Capabilities and Resources (CNO N8) and the Commanding General, Marine Corps Combat Development Command (MCCDC). Figure 1 depicts the current composition of the S&T Corporate Board and the TOG. Asterisks indicate non-voting members.[4] Over the past decade the membership of the TOG and its business rules have evolved to support staff reorganizations and emerging issues. The TOG annually prioritizes FNC program S&T investments, directly ties these investments to Navy and Marine Corps requirements and improves S&T transitions through additional senior leadership visibility. The TOG provides a critical linkage of S&T and requirements and the transition of S&T technology efforts to acquisition. In its 3 May 2005 guidance, the Corporate Board directed that the CNR develop a Naval S&T strategy. This document is a refinement of the second Naval S&T Strategic Plan published in February 2009.

Figure 1. S&T Corporate Board Composition

ONR receives its S&T demand signals in part from the Navy and Marine Corps staffs, Fleet/Force, Enterprises (Community) and stakeholders. These primarily come in the form of Science and Technology Objectives (STOs) that are developed within a warfighting functional area and are generally not prioritized. In approving this plan, the S&T Corporate Board emphasized the need for increased senior Navy and Marine Corps leadership engagement in the S&T process with the goal of providing greater clarity on the Fleet and Force demand signals and focusing future capability investments, critical in the anticipated fiscal environment. This will be accomplished through periodic interaction with the CNO's Futures Group and Marine Requirements Oversight Council (MROC) to vet potential INP candidates and affirm S&T priorities. Additionally, periodic S&T updates will be provided via a CNO's Update Brief (CUB) and Marine Corps Operations / Intelligence Brief (Ops/Intel).

Global S&T trends, shifting geopolitical relationships, the future security environment, advanced warfighting capabilities of potential adversaries and the reality of constrained budgets are the strategic drivers that shape the nine S&T Focus Areas, as well as their visions and objectives. Inputs from Navy and Marine Corps staffs, ONR Global and program officers are included. Global S&T trends include dramatic

[4] Joint Letter dtd 7 Sep 2010: ASN RDA, VCNO and ACMC, DoN TOG Charter for FNC (update)

increases in global information access, increasing employment of cyber technology, rapid increases in computing power, expansion of wireless communications networks, development of unmanned/autonomous systems, robotics, directed energy capabilities, nanotechnology, advanced precision weapons, stealth and signature reduction, and breakthroughs in human protection, learning and performance, and biological and material sciences.

Globalization continues to enable technologies to rapidly transcend borders, increasing interdependence among nations, and placing a premium on access to the world's commons. However, shifting geopolitical relationships will create greater potential for economic competition and flash points. Population growth, urbanization (especially in the littorals), and competition for resources all factor into the future security environment. The prevailing view of the future is one of increasing instability and potential conflict. Nations will continue to improve their conventional warfighting capabilities with advanced weapons, and non-state actors will seek to acquire weapons of mass destruction and other advanced lethal military capabilities. The blurring of conventional warfare, irregular challenges, terrorism and criminality is an emerging reality. Our potential adversaries will seek to deny us access and freedom of maneuver and action. Sea-based forces that can project power or provide humanitarian and disaster relief will rise in importance. These issues must be addressed within the context of constrained budgets over the immediate future. In Section 4, each Focus Area addresses the specific strategic drivers that determined our S&T vision and objectives.

This strategy ensures that ONR's investments respond properly to Naval needs and support the realization of innovative Naval operational concepts. It focuses S&T efforts on the needs and capabilities articulated in Navy and Marine Corps guidance and input from the Naval Research Enterprise (NRE) stakeholders (including the Naval Enterprises [Community], the combatant commands, OPNAV, and HQMC). This strategy highlights the importance of making every research dollar count, supports the continued improvement of our technology transition rates to acquisition programs and facilitates the acceleration of technology insertions to the Fleet and Force. "Speed to Fleet" is critical to maintaining our Naval warfighters' technological advantage over enemies that can adapt quickly. The intent is to push capability forward to mature technology in the hands of the warfighter, while pursuing longer-term program of record insertion in parallel, rather than the traditional series model.

ONR continues to maintain a global approach to identifying technological advancements. ONR leverages academic institutions, industry (large and small) and other S&T organizations, including the Defense Advanced Research Projects Agency (DARPA), National Science Foundation (NSF), Department of Energy (DOE), National Aeronautical Space Administration (NASA) and others. In reaching out to our partners and customers, ONR readily embraces a culture of open innovation and crowd sourcing to ensure broad access to new ideas. This plan also increases focus on Science, Technology, Engineering and Mathematics (STEM) educational outreach efforts that are needed to support the development and sustainment of the future Naval science and engineering workforce.

The principal goals of this strategic plan are to:

- Ensure alignment of Naval S&T with Naval missions and future capability needs,
- Balance and manage the S&T portfolio, and
- Communicate the S&T vision and approach to senior decision-makers, key stakeholders, S&T partners, customers and performers.

The Naval S&T vision and the role of ONR are discussed in the following sections. Section 2 provides background on balancing the S&T investment portfolio, Section 3 describes the strategy development process and Section 4 describes the nine S&T Focus Areas that were distilled from the Naval capability needs. Section 5 outlines the current ONR approach to providing the S&T necessary to support these capabilities, describes the NRE and discusses the National Naval Responsibilities, STEM and business processes. Section 6 highlights high-impact future Navy and Marine Corps capabilities that will be enabled by successful implementation of this strategy. Section 7 provides a summary and link to the ONR website.

2. Background

To meet current and emerging warfighter needs and deliver future Force capabilities, ONR invests in mid- and long-term research while allowing for responsive, limited near -term technology insertions. Figure 2 shows the key components of our investment portfolio, which include all S&T funding and the supporting non-S&T funding that ONR manages. The percentages are programmatic goals for each component of the portfolio. During Program Objective Memorandum (POM) development the CNR applies the remaining 5 percent to reinforce these areas and to accelerate developments for high-priority programs. The makeup of the portfolio shown is based on POM-13 data. The percentage goals have changed to reflect both funding levels and Fleet and Force needs.

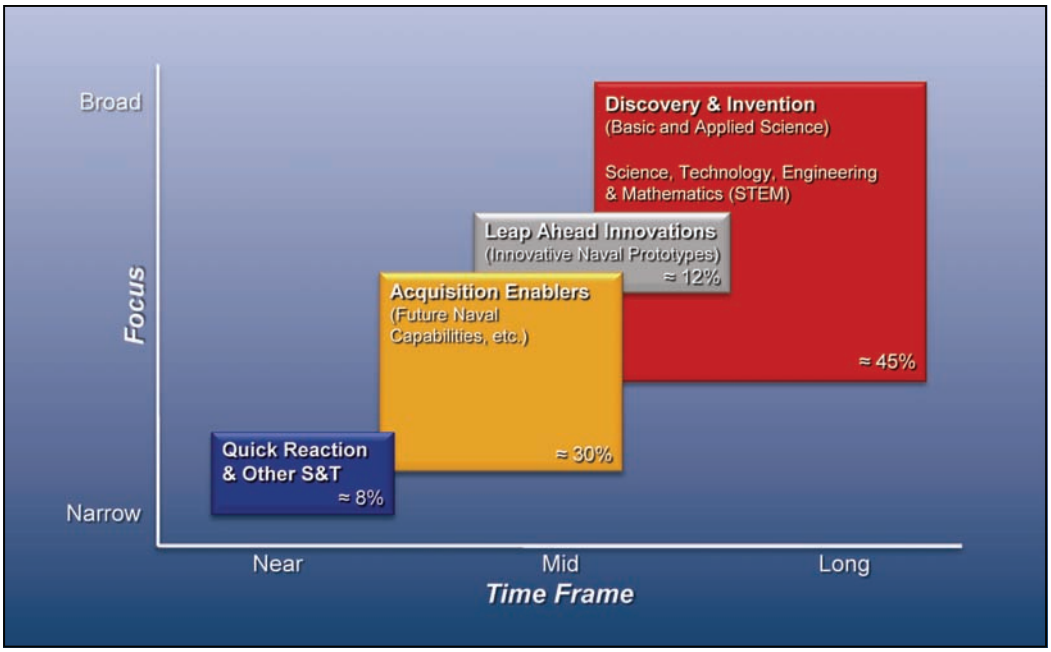


Figure 2. ONR Investment Portfolio

DoD's previous guidance to increase Basic Research at 2 percent real program growth over the past several years has resulted in the increased size of the Discovery and Invention (D&I) component. Likewise the projected draw-down of combat operations and reduction of Urgent Universal Needs Statements is reflected in the Quick Reaction (QR) component. The Leap Ahead component has been increased to support the advancement of game-changing disruptive technologies. S&T's role is not to avoid risk or failure, but to take scientifically feasible risk, and learn from failures when they do occur. ONR investigates new ideas to generate technology options, mitigate risk in acquisition, and lower the total ownership cost of military systems.

The balanced S&T portfolio illustrated in Figure 2 produces both knowledge and products that contribute to long-term DON strategic goals. The following is a brief explanation of each category:

- **Discovery and Invention** consists of Basic Research (Budget Activity (BA) 6.1) and early Applied Research (BA 6.2). This is the seed corn that explores "undiscovered technologies" for future application. The D&I portfolio by design has a broad focus with a long time span from 5-20 years needed to mature discoveries. Its programs are selected based on potential Naval relevance and technology opportunity. D&I investments are the essential foundation required for advanced technology and leverage other service, governmental, department, industry, international and general research community investments.

- **Leap Ahead Innovations** include Innovative Naval Prototypes (INP) and the majority of SwampWorks efforts. These are technology investments that are potentially game-changing or disruptive in nature. INPs achieve a level of technology suitable for transition in 4 to 8 years. SwampWorks efforts are smaller in scope than INPs and are intended to produce results in 1 to 3 years. This component is where we typically accept higher risk to produce a higher warfighter payoff. Leap Ahead funding comes from both Applied Research (BA 6.2) and Advanced Technology Development (BA 6.3).

- **Acquisition Enablers (AE)** include Future Naval Capabilities (FNC) – component technologies that deliver in a 3 to 5 years time horizon. The FNCs mature technology into requirements-driven, transition-oriented products in the late stages of Applied Research (BA 6.2) and Advanced Technology Development (BA 6.3). FNCs provide enabling capabilities to fill gaps in OPNAV and MCCDC requirements analyses identified in the Navy and Marine Corps strategies. In addition to the FNC funding, this component includes approximately two thirds of the Marine Corps BA 6.3 funds, all of Joint Non-Lethal Weapons Directorate (JNLWD) BA 6.3 funds, the Manufacturing Technology (ManTech) program and the majority of the Low Observable, Counter Low Observable funds. The non-FNC-related funding in this component is commonly referred to as "AE Other."

- **Quick Reaction** includes funds from ONR TechSolutions, Navy and Marine Corps Experimentation, one-third of the Marine Corps BA 6.3 funds, Rapid Technology Transition (RTT), Science Advisor program, responses to Urgent

Universal Needs Statements and high-priority demands from the Fleet and Force and a percentage of SwampWorks efforts. These are off-the-shelf technology projects responsive to the immediate needs identified by the Fleet, operating forces or Naval leadership with a 12 to 24 month time horizon.

In the investment portfolio, ONR Headquarters Support costs (Personnel and Other) and NRL facilities costs are proportionately spread across the four components.

ONR manages non-S&T resources (BAs 6.4 through 6.7) that directly support the components of the investment portfolio. These programs include: ONR Headquarters Support, ManTech, RTT, Technology Insertion Program for Savings (TIPS), Technical Information Services, Science Advisor Program and NRL facilities. Figure 3 shows the relative size of these efforts.

ONR also manages other non-S&T funds that are not included in either the investment portfolio depicted in Figure 2 or Figure 3. These include CNO-funded programs, Center for Naval Analysis, Operational Test & Evaluation Force (OPTEVFOR) Support and Small Business Innovation Research (SBIR). Funding for SBIR is based on a congressionally mandated percentage of the RDT&E appropriation. SBIR is not programmed as part of DON appropriated funds.

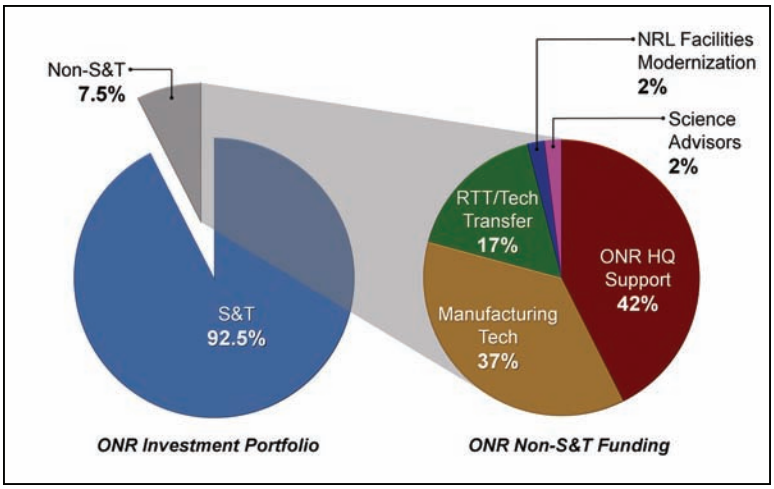


Figure 3. ONR Managed Funding

See Section 5 for a more detailed explanation of the investment portfolio and Appendix A for helpful related web links.

S&T supplies the pipeline of knowledge, concepts and prototypes that leads to products and builds a cadre of scientists, engineers and researchers focused on Naval issues and challenges. Without this pipeline, we would be at risk of losing our Naval forces' technological advantage. Many technologies ONR sponsored at University Affiliated Research Centers (UARC), Navy laboratories, academia and industry have yielded solutions to emerging problems and provided the fertile ground in which to grow our scientific community.

The value of ONR's broad focus in the D&I component of the investment portfolio is highlighted in the above vignette. It documents how investments in Basic Research led to a series of discoveries that proved to have a military application. The technology was advanced over time and has recently been demonstrated successfully in an operational environment. In addition to improving platform survivability against mines, a significant reduction in weight of the degaussing system was achieved. The key take away is that ONR's D&I efforts support all components of the investment portfolio. Interspersed throughout this document are additional vignettes highlighting technologies that have emerged from Basic Research.

High Temperature Superconductive (HTS) Degaussing

Twenty years of Basic Research into HTS technology has yielded improved minesweeping magnets and a 36-megawatt HTS motor, enabling more efficient and effective shipboard degaussing systems.

Naval mine strikes account for 77 percent of U.S. Navy ship casualties since 1950. Compared to legacy copper wire coils, HTS technology is significantly lighter, provides superior degaussing and more efficiently produces a magnetic flux "coil effect."

Weight and space savings provide Naval architects options. Following a successful at-sea test onboard USS HIGGINS *(DDG 76) in 2009, HTS degaussing is being incorporated in Littoral Combat Ship construction.*

Management Approach: Selecting research for future Naval Force capabilities must be balanced within the current constrained fiscal realities. This has presented a very challenging investment environment. ONR therefore manages the diverse Naval S&T portfolio to:

- Address enduring Naval needs and ensure every dollar contributes maximum impact,
- Maintain investments and intellectual capital in areas unique to the Navy and Marine Corps,
- Promote a culture of open innovation across the Naval Services,
- Encourage new researchers and stimulate competitive research with technically proficient program officers and efficient business processes,
- Seek partnerships with academia and industry that complement or enhance S&T outputs,
- Encourage informed risk-taking and learn from failure,
- Provide pathways for transitioning S&T outputs, including interactions between the S&T community and potential technology users in early stages,

- Identify and leverage global technological advances,
- Counter technological surprise, and
- Hedge against uncertainty.

S&T Outputs: S&T investments provide products for the Enterprises (Community) and opportunities for further discoveries. S&T enables the technical superiority of our Naval forces by producing knowledge, transitions and people. These are briefly described below. Section 5, "Measuring Success," contains the metrics associated with each of these S&T outputs.

- **Knowledge:** Scientific discovery generates knowledge and new technologies that expand capabilities and enable innovative concepts of operations. Knowledge (gained from both successes and failures) leads to new technology pathways and reduces technical risk in later stages of research and development. ONR Program Officers constantly evaluate the cutting-edge of 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 the DON via the Enterprises (Community), broader DoD, industry and, ultimately, to the warfighter. ONR programs and business practices work to transition and bridge the "valley of death" between S&T and acquisition programs.

- **People:** ONR is dedicated to developing the S&T workforce that the Naval Services need to maintain their technological superiority. More than half of ONR's Basic Research funding goes 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 laboratories. Special programs also support the education and professional development of minority students and faculty members. This revision of the Naval S&T Strategy places an increased emphasis on STEM education and outreach.

S&T Enablers: Two fundamental enablers for Naval S&T are global technology awareness and the science and engineering workforce and performer base. Global technology awareness is vital to mitigating technological surprise and exploiting international technology advancements. In our quest to identify the best performers and most promising technologies for the Navy and the Marine Corps, we strive to reach out and access intellectual capital worldwide. Central to our mission is ensuring the supremacy of Naval technology; therefore, we must maintain the requisite U.S. S&T capacity and expertise. Naval S&T fosters the education and professional development of the science and engineering workforce in support of the NRE. SECNAV assigned ONR as the lead for identifying all Naval STEM efforts within the NRE. These two enablers will be discussed further in Section 5.

3. Strategy Development

The events of the 21st century have dramatically transformed the strategic landscape and highlighted the importance, versatility, expeditionary nature and power projection capabilities of Naval forces. We have been at war for almost the entire decade with our forces engaged in struggles far from the homeland. Based on the current world situation, the predicted future is best characterized by uncertainty, realities of irregular and increasingly unrestricted warfare and the potential of conventional warfare against technologically sophisticated adversaries. *A Cooperative Strategy for the 21st Century Seapower* (CS-21) provides the foundation for the role that Naval forces will play in this challenging new era to protect our way of life and global interests. This overarching strategy, combined with additional detailed guidance from SECNAV, CNO and CMC, provide top-level guidance for the Naval S&T Strategic Plan.

ONR's S&T investments to address these security challenges will be made in an increasingly complex, uncertain and constrained fiscal environment. We must strive to leverage our S&T investments effectively with our partners. The rapid global flow of technology, information and ideas provides both opportunities and challenges. Advances in technology have traditionally given our Naval forces the decisive advantages that enable them to dominate the maritime battlespace. ONR's research must look globally and capitalize on the best and brightest ideas to preserve our technological superiority and prevent technological surprise. In his POM development memorandum, SECNAV identified specific areas of emphasis: "Investment in research and development to ensure the most promising, militarily-useful and affordable technologies are identified and made available for the future requirements of the Navy and Marine Corps."

The Naval S&T investment portfolio is balanced and prioritized. It supports the achievement of CS-21 strategic imperatives. It focuses on closing gaps in capability where significant risk is evident. Navy and Marine Corps investments support those essential mission capabilities where taking operational risk is unacceptable to our warfighters.

Hedging Against Uncertainty: S&T provides the DON the means to be agile in adapting to unforeseen risks and a strong foundation of cutting-edge warfighting capability. To support the Department's ability to access the right capability and capacity for the fight at hand and in the future, ONR manages a balanced investment portfolio, as previously described in Section 2 and explained more fully in Section 5.

ONR manages the Naval "hedge fund" for a changing world. S&T provides a cost-effective approach to providing a range of capabilities that can be pulled rapidly into acquisition as risks or opportunities emerge globally. In doing so, ONR maintains a strong connection not only with the Fleet/Force, but also with the global academic, industrial and government S&T communities. While retaining its long-term orientation, ONR's portfolio balance ensures the ability to quickly redirect resources as needed, sometimes slowing, sometimes accelerating or altering the development and fielding of a given technology as dictated by the evolving pace and nature of emerging threats and opportunities.

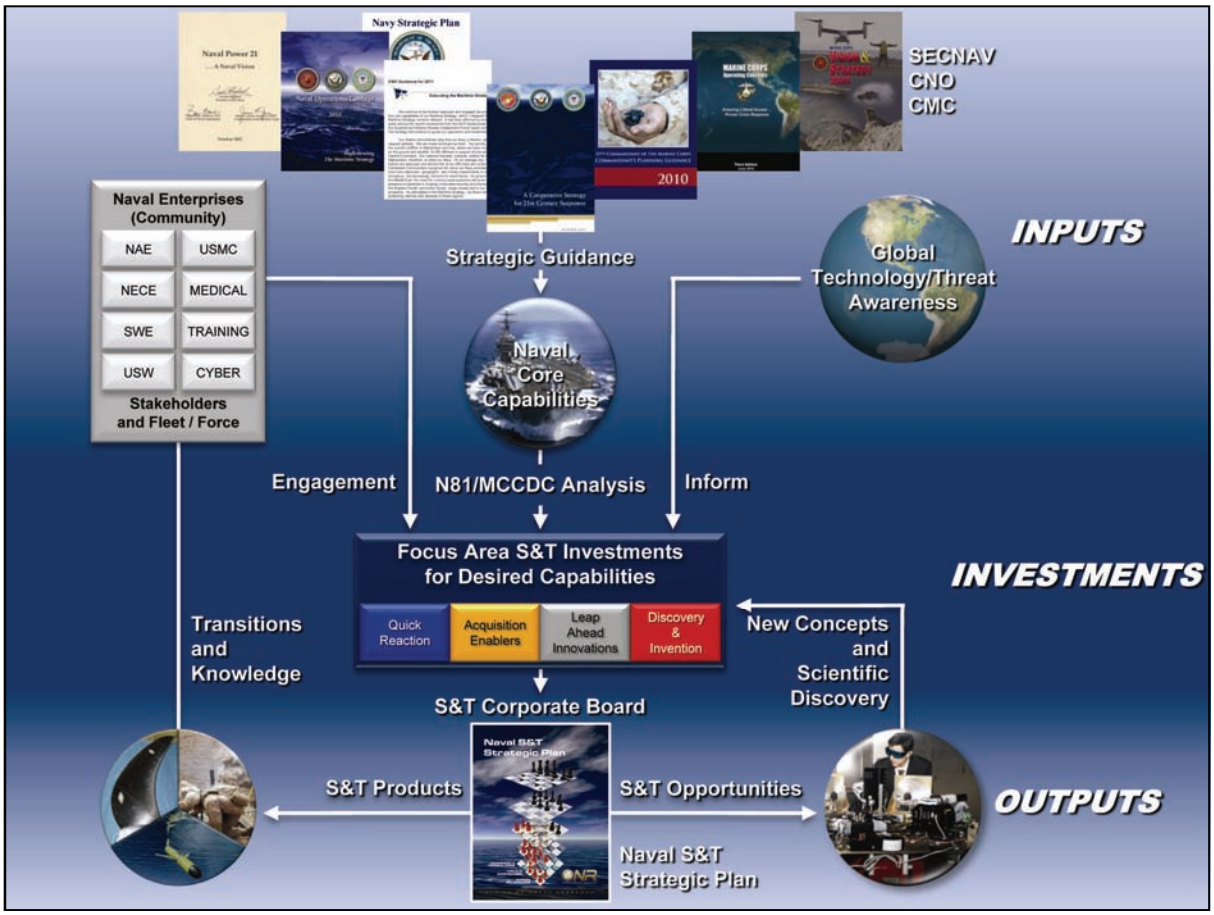


Figure 4. Naval S&T Strategy Process

Strategy Process: The Naval S&T Strategic Plan is developed based on a top-down approach. Key guidance documents underpin Navy and Marine Corps missions, Force capabilities and technology needs in the context of DoD goals. The strategic planning process is depicted in Figure 4. Naval core capabilities were distilled from the formal guidance documents. These core capabilities were analyzed in the approved contingency scenarios and gaps identified. The identified gaps, inputs from Naval Enterprises (Community), Stakeholders to include Fleet/Force, global technology inputs from industry and academia and threat awareness shaped the development of the Naval S&T Focus Areas. The inputs led to the development of the investments in appropriate components of the portfolio. The resultant outputs of these investments are S&T products for the Enterprises and S&T opportunities to be further explored in other components of the portfolio. Below is a more detailed discussion of the process.

- **Naval Core Capabilities:** Based on the objectives identified in the national and DoD strategic plans, *A Cooperative Strategy for 21st Century Seapower* defines core capabilities for our Naval Force. *Navy Strategic Plan FY-13* provides strategic imperatives for the Navy and *Marine Corps Vision and Strategy* identifies both core competencies and objectives. Finally, *Naval Power 21* provides Focus Areas for the Navy and Marine Corps team. In reviewing these documents, we have extracted the key guidance and priorities and will refer to this distillation in Figure 4 as Naval Core Capabilities. They are linked to mission needs and articulated security challenges. We also examined the

warfare capability analyses conducted by OPNAV N81 and MCCDC that support the definition of capability gaps. From the identified Naval Core Capabilities and the supporting analyses we developed our nine Naval S&T Focus Areas. The Focus Areas provide a vision for each area and the objectives and sub-objectives to attain that vision over time. The investment portfolio supports the resourcing of these S&T Focus Areas.

- **Naval Enterprise (Community) and Stakeholder Inputs:** ONR receives Naval Enterprise and Marine Corps capability needs and technology objectives directly from leadership. Specific S&T inputs include the Enterprise and Marine Corps strategic plans and their Science and Technology Objectives (STO). A list of references can be found in Appendix A.

- **Global Technology/Threat Awareness:** S&T must have a global scope to ensure access to the best available technologies and prevent technological surprises. The S&T that covers each Focus Area is defined and, where necessary, expanded to project future security threats based on technology feasibility. Where feasible, disruptive inputs within each capability area have been considered to identify research priorities for the S&T portfolio.

- **S&T Products:** Include both knowledge and the transition of technologies in the form of components or system prototypes to the Enterprises (Community) via the Systems Commands and in some case directly to the Fleet/Force.

- **S&T Opportunities:** Broad investments lead to new scientific discoveries and technology options applicable to Naval needs. Including S&T opportunities in the planning process feeds new knowledge back into the S&T portfolio and priority-setting process.

Strategy Timeframe: This plan will be revised at two-year intervals to keep current with user needs and technology opportunities. This allows ONR to provide current guidelines for S&T programs and focus communications between the researcher and user communities.

S&T Taxonomies: While implementation of the Strategic Plan centers on the S&T Focus Areas, which are based on Naval capability needs, there are also other approaches to describing the S&T investment portfolio. One used regularly to manage the portfolio and make investment decisions is referred to as the S&T Taxonomy of Research Areas. Its structure approaches the Naval S&T portfolio from a research perspective, in that it identifies specific fields of S&T investment.

Appendix B identifies the Research Areas associated with each Focus Area. Since Research Areas are technology-based whereas Focus Areas are capability-based, an investment in a particular Research Area, like Solid State Electronics, often supports several Focus Areas. The S&T Research Areas illustrate the total investment in a particular science or technology and indicate how a single investment can be leveraged to satisfy multiple Focus Area needs.

4. Naval S&T Focus Areas

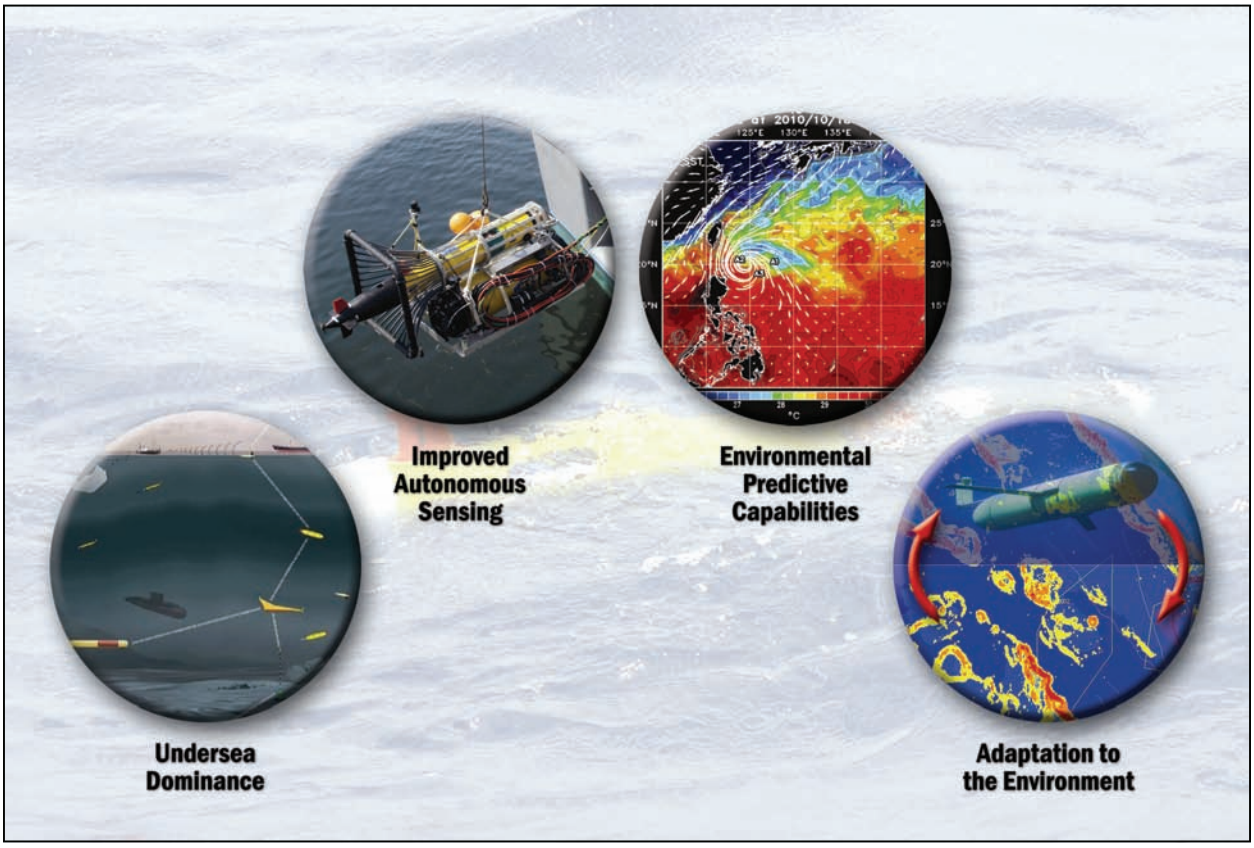
For each of the nine Focus Areas, the following sections provide a synopsis of the S&T strategic drivers, vision, description, high-level objectives and sub-objectives that were presented to and approved by the Naval S&T Corporate Board. These Focus Areas highlight how S&T advances Naval capabilities and guides our investments. The corresponding S&T Research Areas are listed in Appendix B. The Naval S&T Focus Areas map the needs of the warfighter to the world of S&T. They embody enduring themes and are:

- Developed from Naval needs,
- Sized for reasonable scale and magnitude, and
- Linked directly to warfighting functions.

Critical warfighting technologies to ensure a future Naval Force capable of meeting shifting and ever-changing requirements, from peer competitor maritime warfare to providing more routine operations around the globe.

The Office of Naval Research Infantry Immersion Trainer (IIT) utilizes a mixture of real and virtual technologies that are leading to advances in Marine Corps training and combat readiness.

Assure Access to the Maritime Battlespace



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 and tactical targets at risk. Sense and predict environmental properties in the global ocean 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, in order 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 warfare (ASW), mine warfare (MIW) and Navy Special Warfare (NSW) technologies and capabilities, including exploitation of every aspect of the changing environment 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 ocean 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.

Objectives:

Achieve and Maintain Undersea Dominance

- Rapid detection and clearing of mines through the Beach Exit Zone; neutralization from a distance
- Detect, classify, locate and track threat submarines in shallow and deep water, exploiting automation and adaptation to the environment
- Off-board sensing, cooperative vehicle autonomy, networking and autonomous classification in unmanned systems to expand reach and reduce threat exposure
- Next-generation data and target fusion to expand regional ASW, MIW and amphibious warfare operating picture to the theater level

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

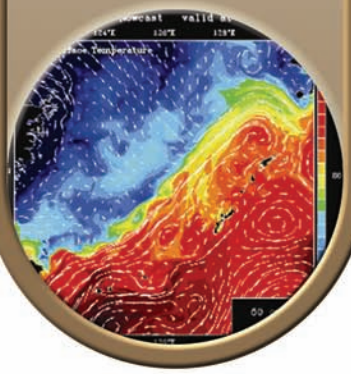
DISCOVERY and INVENTION
...where creativity thrives

Mobile Ocean Sensing Feeds Operational Forecasts

Around 1970, ocean scientists recognized stationary and ship-based sampling alone could not provide sufficient understanding of ocean time and space variability. Ocean engineering Basic Research created unmanned off-board platforms such as surface drifters, vertically-profiling drifting floats, propeller-driven unmanned underwater vehicles and buoyancy-driven ocean gliders.

Now deployed by the Naval Oceanographic Office, these platforms provide the Fleet situational awareness and feed enhanced ocean prediction models that forecast ocean currents, density structure and sound speed.

Operational modeling centers in Monterey, CA, and Stennis Space Center, MS, provide timely and accurate forecasts that feed system and sensor performance prediction algorithms in support of Naval operations.



Autonomy and Unmanned Systems

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 required 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 appropriate actions to achieve its 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, 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 providing affordable capabilities to do things that would be unaffordable or result in impractical manning otherwise.

Objectives:

Human/Unmanned Systems Collaboration

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

Perception and Intelligent Decision Making

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

Scalable and Robust Distributed Collaboration

- Task allocation/assignment, planning, coordination and control for heterogeneous systems
- Airspace/waterspace management
- Predicting behaviors of large numbers of unmanned systems
- Validation and verification of complex autonomous systems

Intelligence Enablers and Architectures

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

The Littoral Combat Ship USS Independence
(LCS 2) recovers an RQ-8A Fire Scout Unmanned Autonomous Helicopter.

(illustration by Bob Sternberg)

Expeditionary and Irregular Warfare

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 and irregular challenges across diverse, austere and distributed battlespaces.

Vision: Naval warfighters of the future will possess the full spectrum of expeditionary kinetic and non-kinetic capabilities required to defeat traditional threats decisively and confront irregular challenges effectively.

Description: The Expeditionary and Irregular Warfare (EIW) focus 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, communication, sustainment and training. Additionally, EIW investments will enable our forces to be as effective in Irregular Warfare (IW) 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 modern 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 — at a tempo that outpaces that of our adversaries.

Objectives:

Irregular Warfare Battlespace Awareness:

- Adaptive planning and direction of collection assets
- Sensors and sensor systems for observation and collection
- Data fusion and analysis for actionable intelligence generation
- Shared situational awareness and understanding

Influence Operations Enablers:

- Social, cultural, behavioral domain understanding, modeling and analysis
- Adaptive thinking, planning and wargaming
- Operational culture learning and language

Expeditionary and Distributed Operations:

- Sea-based and tailored tactical logistics
- Mobility and combat load reduction
- Lethality and survivability
- Tactical warfighter preparation (cognitive, physical performance and fatigue mitigation)
- Tactical command and control down to the small unit level

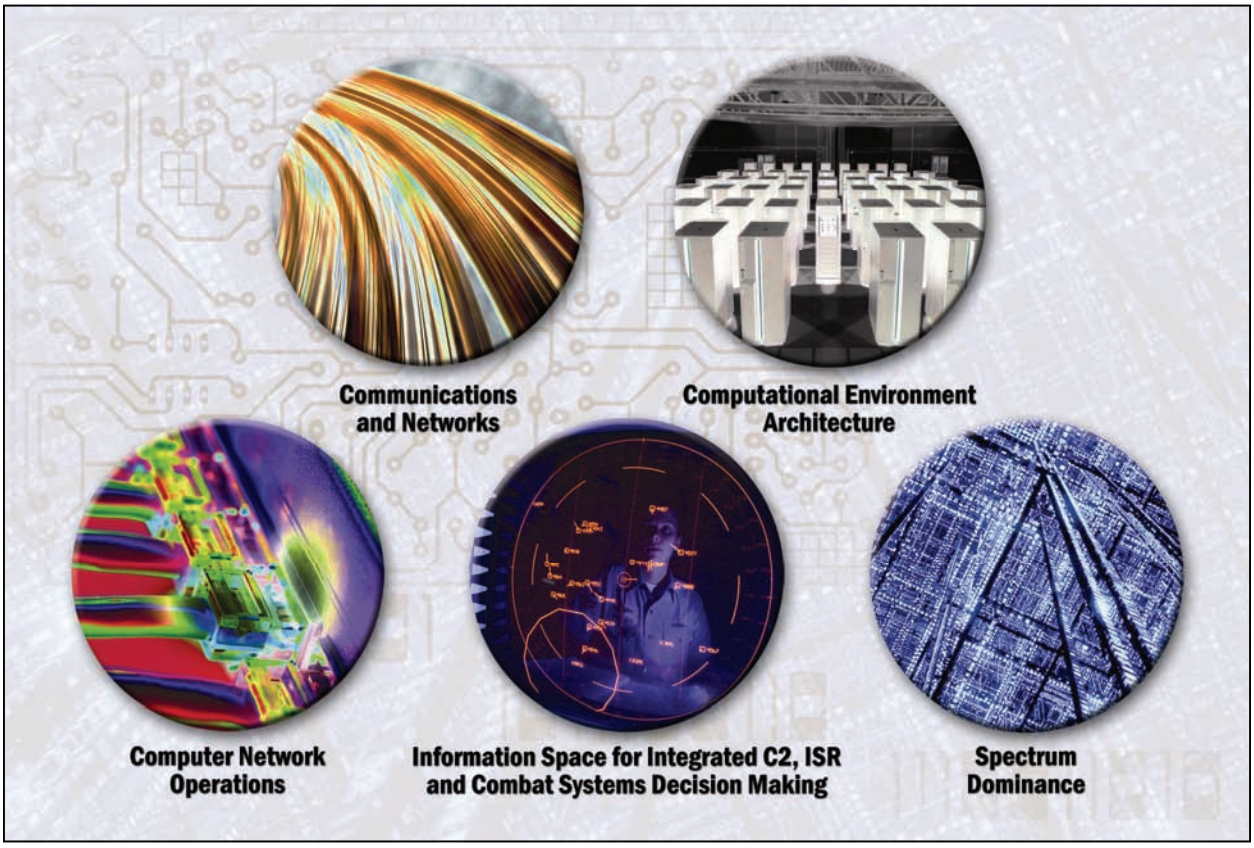
Irregular Threat Countermeasures:

- Counter asymmetric weapons and Counter Improvised Explosive Devices
- Biometric identification and surveillance
- Tactical site exploitation and forensics
- Human and irregular platform tagging, tracking and locating

The combat tactical vehicle technology demonstrator (CTV-TD) underwent automotive testing at the Nevada Automotive Test Center in Carson City. Built under contract for the Office of Naval Research, the CTV-TD is a test bed for the joint light tactical vehicle family. The CTV-TD offers several advantages and new technologies, including adjustable ride height, central tire inflation, an integral rollover protection system and improved survivability over the current Humvee.

(U.S. Navy photo by John F. Williams)

Information Dominance



Strategic Drivers: Potential adversaries are investing in advanced technologies that will challenge our advantages in the information domain. Nation states and non-state actors seek to degrade our command and control capabilities, networks and computer systems. 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 Naval Forces and our adversaries.

Vision: Enable the warfighter to take immediate, appropriate action at any time against any desired enemy, 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 such as the Information Space that assembles data, understands the battlespace and supports decision-making and operations across diverse mission areas that are physically large, exhibit dynamics and contain many objects, events and activities. Integral to achieving Information Dominance are flexible communications and networks architectures, as well as research and development that improve Naval operations within and exploitation of the extended space domain and that provide capabilities for achieving and maintaining our communications and networks in a highly dynamic, dispersed and disadvantaged (disruption, intermittent and limited bandwidth) environment. The

computational environmental architecture will provide capabilities to manipulate and interpret data to support C2, ISR and CS systems while enabling a more resilient information infrastructure through hardening the hosts, data sharing and data integrity of our networks. Spectrum Dominance is a key component, which includes efforts that focus on sensors, electronic warfare and electronics, and employing these sensors and capabilities to understand and shape the battlespace, as well as disrupting the threat's sensors from doing the same. Computer Network Operations provides the ability to utilize and manipulate the adversary's data for our purposes and is the complement of Spectrum Dominance.

Objectives:

Communications and Networks

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

Computational Environment Architecture

- Open source, open architecture and service-oriented architecture
- C2/CS integration
- Autonomous networked sensors control architecture
- Machine reasoning and intelligence architectures

Computer Network Operations

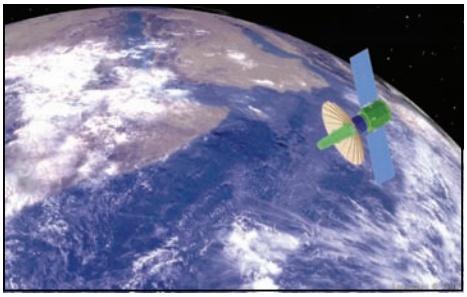
- Computer network attack
- Computer network defense
- Computer network exploitation

Information Space for Integrated C2, ISR and Combat Systems Decision Making

- Rapid accurate decision-making for C2/ISR/CS
- Machine reasoning and intelligence
- Distributed mission-focused autonomy for control of large information networks
- Data error management

Spectrum Dominance

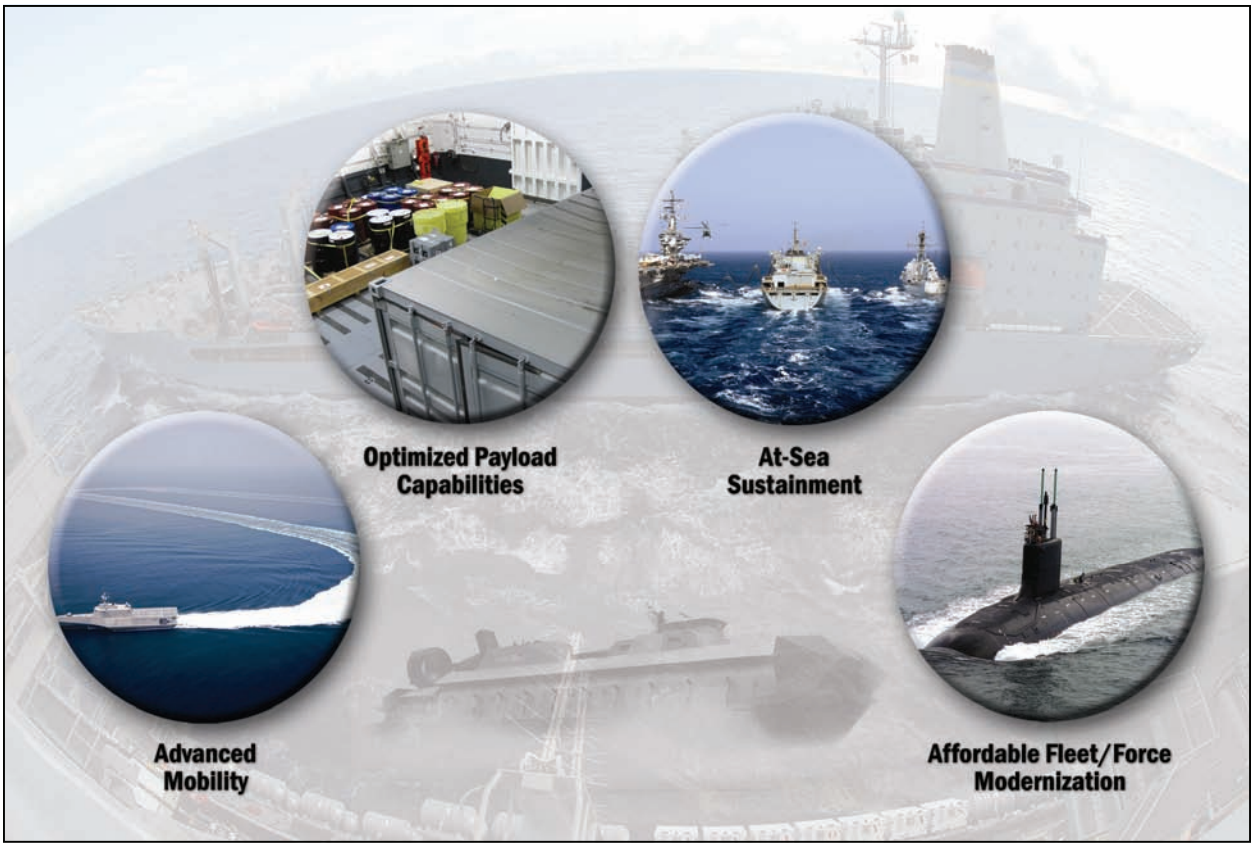
- Understanding the environment through sensing
- Control of the opponent's battlespace picture through control of the spectrum
- Electronic protection via networking and robust sensors



TacSat-4 is a Navy-led joint mission to provide operationally relevant capabilities and to enable Operationally Responsive Space. TacSat-4 provides 10 ultra-high frequency channels that can be used for any combination of communications, data exfiltration or Blue Force tracking. Notably, TacSat-4 provides communications-on-the-move with legacy radios and provides a wideband "Mobile User Objective System-like" channel, but not MUOS capability, for early testing.

(illustration by Bob Sternberg and Tom Walsh)

Platform Design and Survivability



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

Vision: Develop agile, fuel efficient and flexible platforms capable of operating in required environments. Enable manned and unmanned Naval platforms and forces to operate in hostile environments while avoiding, defeating and surviving attacks.

Description: This focus area is driven by the development and delivery of platform concepts, systems and component technologies that improve the performance and control of military platforms (including ground vehicles) to meet operational requirements under all environmental conditions. Platform mobility centers on understanding hydromechanics, aerodynamics, electro-mechanics, electrodynamics, 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. It also encompasses the systems required to provide and distribute power for the platform and its sensor and weapon systems. Design methods and analytical tools that enable the integration of these complex, and often contesting, disciplines into effective and efficient platforms are essential. The development of design tools capable of rapidly analyzing and evaluating novel air,

ground and sea/coastal/riverine platforms with advanced system performance characteristics is a high priority. High-performance computational resources are required to improve the capability to conceive and develop advanced, high-performance platforms. Survivability will require hardened, reacting and damage-tolerant platforms and system architectures that may include automation to minimize impact of a successful attack. An important element in this focus area is assuring skilled and experienced design personnel and technical specialists, trained to rapidly and efficiently apply sophisticated knowledge and tools, are available to the Naval engineering community.

Objectives:

Advanced Mobility

- Advanced platform design focused on efficiency, agility and affordability
- Autonomous and unmanned vehicle mobility
- Platform survivability and signature reduction
- Platform stealth
- Survivable platforms

Reliable, Efficient, Long-Range, High-Speed Platforms with Optimized Payload Capabilities

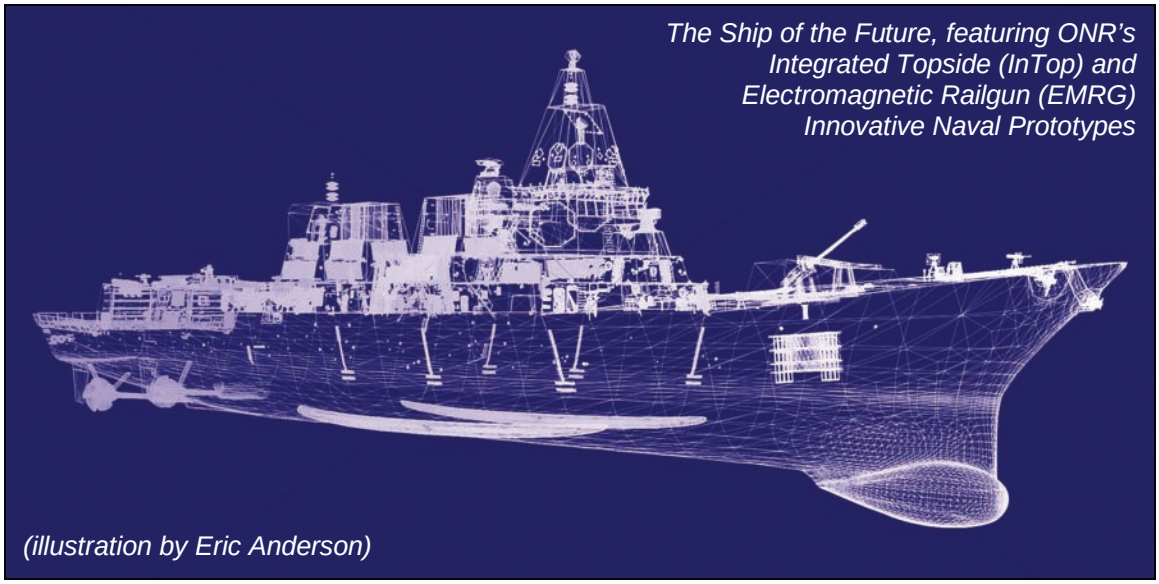
- Modeling and simulation tools
- Efficient ship design analysis tools
- Modular platforms

At-Sea Sustainment

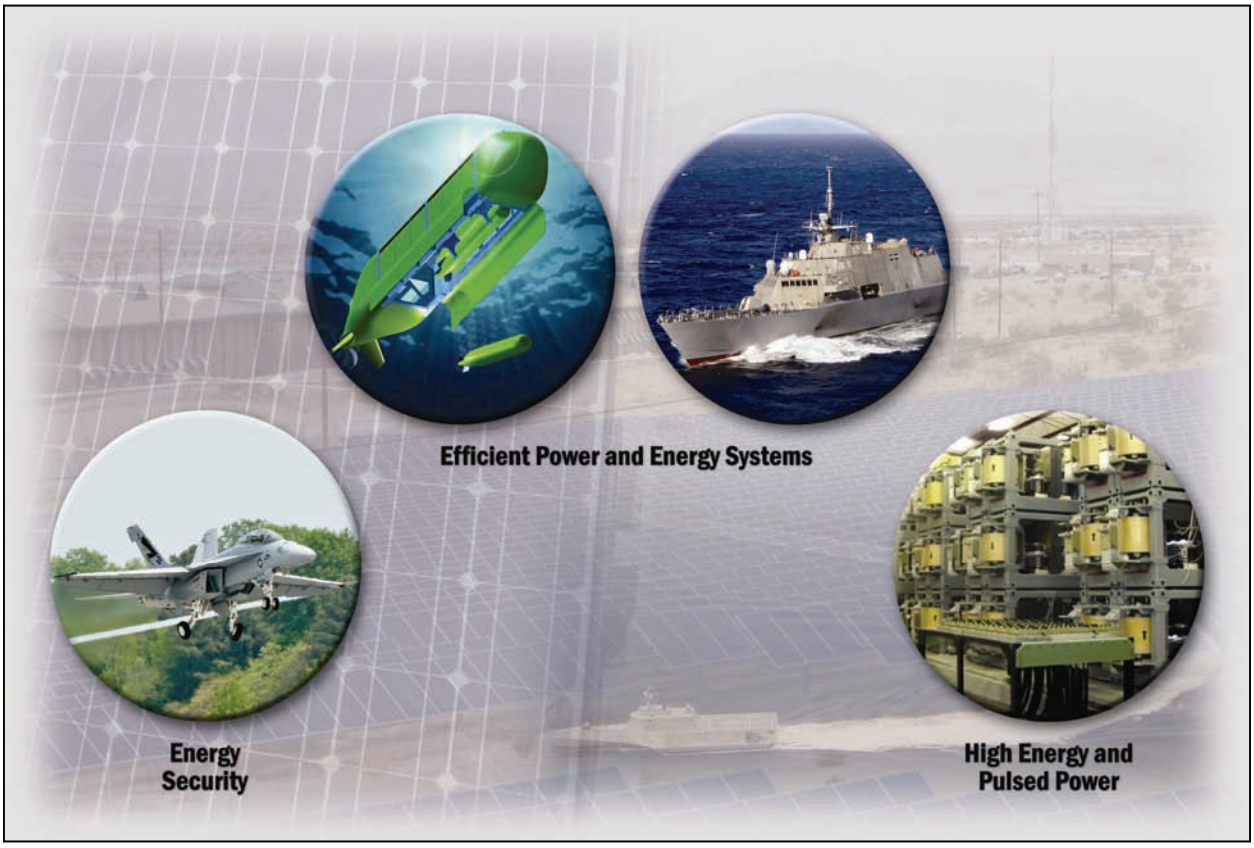
- Payload and weapons movement
- Integrated comms

Affordable Fleet/Force Modernization

- Technology upgrades during midlife overhauls
- Technology opportunities proven through Fleet demonstrations



Power and Energy



Strategic Drivers: The increasing global demand for energy, over-reliance on foreign sources of fossil fuel, 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 alternative fuels. Increased electrical power requirements, distribution and switching are needed to support future ship designs, weapons and support systems. 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: The guiding principles for the ONR Power and Energy Focus Area are contained in the "Department of the Navy's Energy Program for Security and Independence"[5] and "A Navy Energy Vision for the 21st Century"[6]. To meet the energy challenges for the Department of Navy, ONR has partnered with the Department of Energy, Department of Agriculture and all DoD Services to ensure innovative, state-of-

[5] http://greenfleet.dodlive.mil/files/2010/10/Navy-Energy-Vision-Oct-2010.pdf

[6] https://navyenergy.navfac.navy.mil/publications/POLICY_GUIDANCE/business_plan/Naval_Energy_Strategic_Roadmap.pdf

the-art, S&T that rapidly transitions from laboratories to military end users. New systems with higher energy densities are being enabled through new material breakthroughs and innovative architectures specifically developed for the Naval environment and mobility requirements.

Naval 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 electromagnetic weapons operate on continuous and pulsed high power that cannot be met with today's generation, energy storage, and distribution systems. ONR has invested in technologies increasing energy and power densities and new power system architectures with the capability to instantaneously direct power when and where it is needed across the propulsion and weapons systems. In coordination with the Navy's Task Force Energy Office and the Marine Corps' Expeditionary Energy Office, and under the guidance of the Secretary of the Navy's mandate to sail the "Great Green Fleet" by 2016, ONR is continuing to validate new scientific testing methodologies and predictive tools to accelerate the adoption of new blends of logistic alternative fuels for use in Naval engines. We have focused research to provide the predictive tools to the Force to establish timely and cost-effective alternative fuel certification in the maritime environment. Additionally, we are actively pursuing technologies and systems to achieve the goals and objectives set forth in the *Marine Corps Expeditionary Energy Strategy and Implementation Plan.* ONR is assuring long-endurance power for unmanned undersea vehicles for extended-range mission requirements through the development of fuel cells, hybrid-electric power systems and advanced batteries.

Objectives:

Energy Security

- Alternative and renewable energy sources
- Future alternative fuels
- Resilient power networks and systems for platforms and infrastructure

Efficient Power and Energy Systems

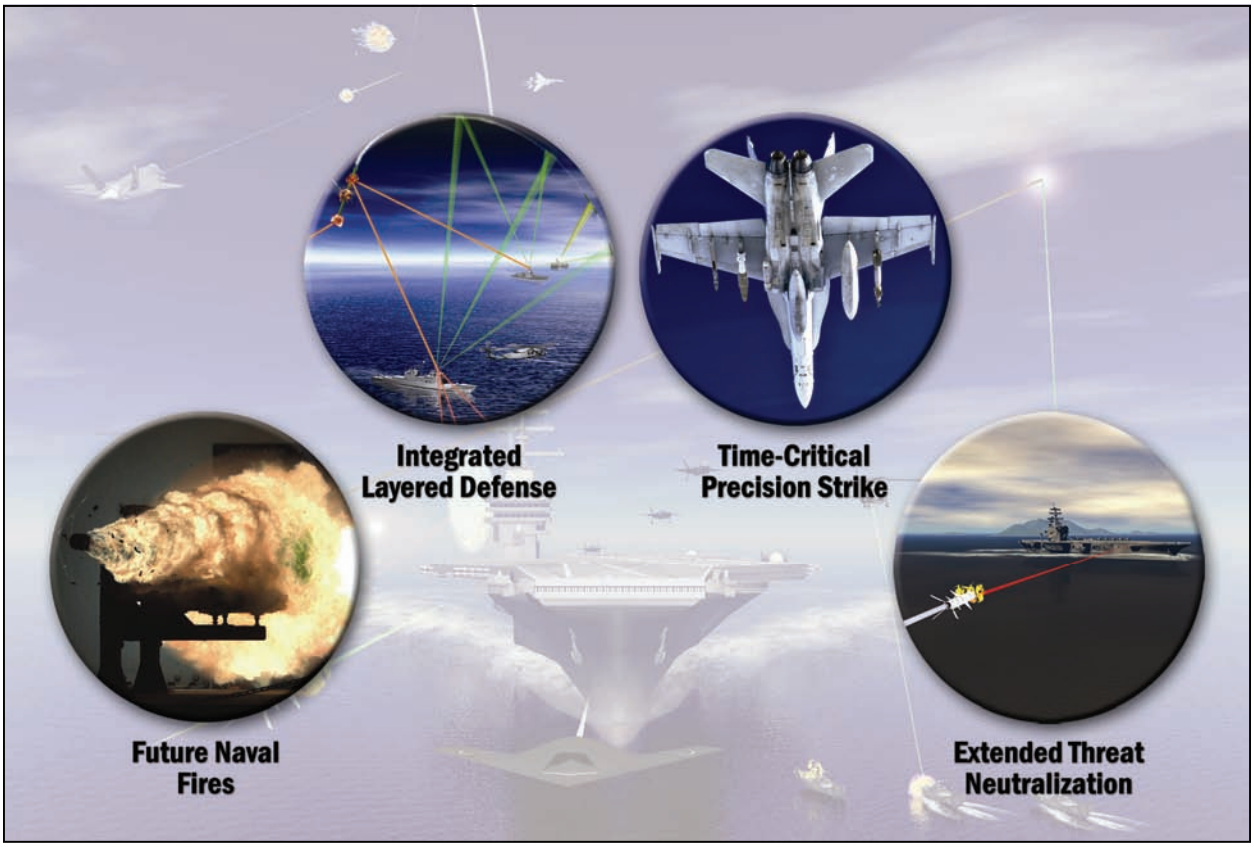
- Materials, devices and architectures to increase efficiency and power density on platforms and reduce weight for personal power
- Efficient power conversion, switching, distribution, control and thermal management
- Efficient power generation equipment, including engines, generators, motors and actuators
- Electrochemical, thermal and kinetic energy storage

High Energy and Pulsed Power

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

Solar array at a forward-operating base

Power Projection and Integrated Defense



Strategic Drivers: Adversaries will capitalize on conventional and asymmetric capabilities that incorporate mobility, range, speed and deception. Naval platforms must have integrated defensive capabilities to defeat these growing complex threats. At the same time, the Fleet/Force must be able to effectively strike targets with survivable and scalable weapons that have sufficient range, speed and accuracy to complete the mission while reducing risk to our warfighters without endangering non-combatants or creating unnecessary collateral damage.

Vision: Enhance extended-range power projection capabilities and integrated layered defense by improving manned and unmanned Naval platforms, enabling forces to complete missions in hostile environments by avoiding, defeating and surviving attacks. Demonstrate improvements in standoff indirect precision fires on time-critical targets, while limiting collateral effects through the use of electromagnetic kinetic projectiles, hypersonic missile propulsion, scalable weapons effects, directed energy and hypervelocity weapons.

Description: The development and delivery of scalable, decisive effects are critical; this effort includes targeting, decision support and precision strike by air, surface and undersea platforms. This Focus Area strives for significant enhancements in Naval time-sensitive strike capabilities to enhance the ability of Naval forces to damage,

seize or destroy enemy forces at extended ranges in the littorals, deep inland and on the high seas. Power projection emphasizes the employment of these capabilities at a speed, rate and distance that defeats any adversary's ability to conduct effective operations against us despite his use of mobility and deception to neutralize our efforts. The ability to strike is negated without the ability to defend platforms against attack. Incoming attack spans the range of small arms and handheld weapons, swimmers, small boats, to ballistic and cruise missiles and undersea threats. Integrated defense will include detection, identification and soft- and hard-kill defeat. Technologies must address an integrated layered defense approach, extending the reach beyond the threat damage range with speed-of-light response and neutralization. Future multi-mission weapons systems will provide both offensive and defensive capabilities. Asymmetry works both ways; there is elegance in killing a million-dollar cruise missile with directed energy for the price of a gallon of fuel.

Objectives:

Future Naval Fires

- High-volume, precision direct and indirect fires to extended ranges
- Deep/unlimited magazine

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

- Detection and determination of threat intent
- Hard/soft kill, lethal/non-lethal countermeasure options
- Autonomy-aided, reliable 360-degree threat targeting and tracking
- Autonomy-aided decision-making and battle management aids

Time-Critical Precision Strike

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

Extended Threat Neutralization Capabilities

- Speed-of-light engagement through electronic warfare, directed energy and hypervelocity weapons
- Extend standoff beyond the threat damage range
- Counter-Low Observable (LO), counter small boats and unmanned threats
- Anti-swimmer and improvised unmanned technology

A Boeing F/A-18E/F Super Hornet launches from USS Ronald Reagan *(CVN 76) while a McDonnell Douglas F/A-18 Hornet flies overhead.*

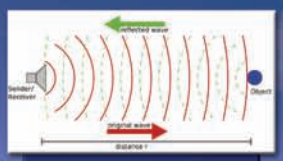
(illustration by Bob Sternberg)

Naval S&T Milestones

ACCOMPLISHMENTS ACROSS ALL DOMAINS

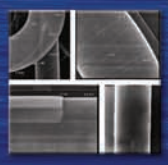
Powered by Naval Research TM/SM

1920s



Sound Navigation and Ranging (SONAR)

Remotely Flown Pilotless Aircraft



Gamma-Ray Radiography

NRL Commissioned

1930s

Plan-Position Indicator

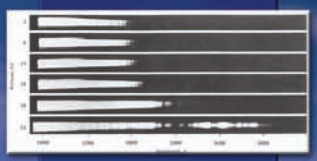
Uranium 235 Production

First Concept for a Nuclear Submarine

First U.S. Radar Patents

1940s

First Detection of X Rays from the Sun



First Far-Ultraviolet Spectrum of the Sun

Principles of Modern Fracture Mechanics

Synthetic Lubricants

ONR Founded 1946

1950s

First Unmanned Helicopter

Vanguard I Launched

Project Whirlwind Digital Computer

Particle Accelerators

Vertical Take-Off and Landing

1960s

Timation and NAVSTAR GPS

Owens Valley 40m Radio telescope

Aqueous Film Forming Foams (AFFF)

First U.S. Intelligence Satellite

SEALAB I and II

Bathyscaphe *Trieste* reaches 35,800 ft.

Virtual At-Sea Training (Live-Fire Combat Skills)

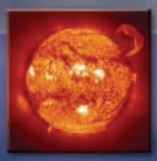
LCS Networked Tactical Training System

Nobel Prize to Dr. Jerome Karle, NRL

Navy Aerosol Analysis and Prediction System

High Temperature Superconductive Degaussing

Free Electron Laser



Coronal Mass Ejection

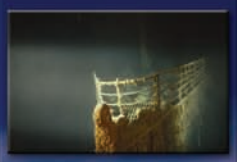
High-Energy Magnets

Clementine Spacecraft

Hyperspectral Imager for Coastal Oceans

Tactical Microsatellite

Mobile Robots



ONR-funded Tech finds RMS *Titanic*

Interactive Multisensor Analysis Training (IMAT)

SHARP Reconaissance

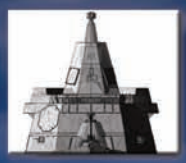
Large Displacement Unmanned Underwater Vehicle

Excimer Laser Technology

Global Atmospheric Prediction System

High-Strength Low-Alloy Steels

Dragon Eye UAV

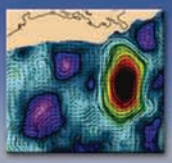


Integrated Topside (INTOP)

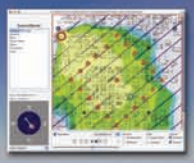
Far Ultraviolet Lunar Camera

Sidewinder Air-to-Air Missile

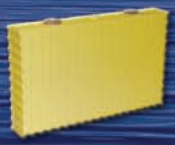
Neural Networking Computer Chips



First Operational Global Ocean Model



CBR Sensors for Fleet Security

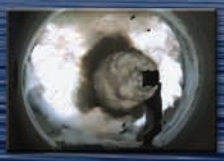


Lithium Batteries

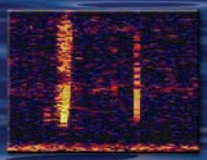
Contributed to Aegis Combat System

Ultra-high Strength Steel

QuikClot® Combat Gauze

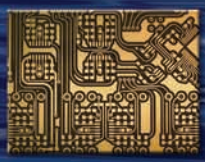


World-record Setting 33 MJ EMRG Shot



SOund SUrveillance System (SOSUS)

1970s



Acoustic Microscopy

1980s

Hull Anti-Fouling Coatings

1990s

Remote Environment Monitoring UnitS

2000s

Anti-Torpedo Torpedo

2010 & BEYOND

Total Ownership Cost

Strategic Drivers: The fiscal realities of decreasing budgets and the ever-increasing costs of manpower, materials, labor and fuel present significant challenges for the DON. To ensure our Naval forces continue to maintain global dominance, future platforms and combat systems must be affordable to acquire, operate and maintain over their entire life cycle.

Vision: Support the goal to reduce Total Ownership Cost (TOC) by developing and aiding the insertion of technology to reduce platform acquisition cost, reduce lifecycle and sustainment costs and achieve crew manning requirements. Total Ownership Cost includes all costs associated with the research, development, procurement, operation, and disposal of platforms, combat systems and associated elements over the full lifecycle.

Description: This Focus Area is aimed at significantly improving affordability of current and future Naval systems by reducing TOC while not adversely affecting system performance and while improving platform and combat systems' availability and readiness to execute assigned missions. To effect TOC reduction, major cost drivers over a platform's life cycle must be understood early in system development and programs initiated in the early stages of S&T to enable significant affordability improvement over the lifecycle of a system.

For platform affordability, developing viable solutions before Milestone A of the platform's acquisition process is the goal. Modeling and simulation to validate ship and platform designs, provide total platform definition, improve manufacturing and fabrication processes and achieve overall schedule compression offers large cost reduction potential. The development and use of open architecture approaches to shipboard and support software enable systems that can be delivered and maintained efficiently. Reducing platform and combat systems' lifecycle costs facilitates longer operational availabilities. Major goals in the lifecycle cost area include improvements in corrosion and wear protection, elevated temperature coatings and improved metallic and nonmetallic materials. Attention to and definition of maintenance and repair processes early in system development can positively impact maintenance and repair schedule compression to result in improved platform and combat systems availability. With respect to crew manning requirements and operations, smart systems to control and monitor energy consumption, as well as the health of critical systems, can support both manning and resource conservation. Effective training and reliable man-to-machine interfaces will allow for more effective use of platform resources and potentially reduced operational cost or an expanded operational capability. For ship and submarines, clean hull technology will result in more effective use of energy usage and additional deployment time.

Objectives:

Platform Affordability

- Advanced platform design methods, design validation tools and tools to aid in rapid total platform definition
- Open architecture approach to platform hardware and software
- Cost-reducing, innovative manufacturing technologies
- Manufacturing and assembly sequencing and spatial modeling and simulation methods
- New affordable materials

Lifecycle and Sustainment Cost

- Advanced corrosion-prevention materials and advanced coating processes
- Improved wear materials
- Extended-life elevated temperature materials, coatings and systems
- Advanced repair and maintenance processes to maximize ship, airframe and vehicle availabilities

Crew Manning and Operational Capabilities

- System and energy monitoring automation
- Robust hardware and software to support improved platform condition-based maintenance
- Improved training methods
- Enhanced human-equipment interface development

Warfighter Performance

Strategic Drivers: Increasing personnel costs, effective crew manning requirements, distributed access to enormous data sets and a dynamic asymmetric threat all drive an increased focus on warfighter performance, effectiveness and efficiency.

Vision: More effective point of injury care for Sailors and Marines. Enhanced health and warfighter performance both afloat and ashore. Highly efficient and effective human-system performance aided by new technologies created through the exploitation of biological design principles. Enhanced warfighter and system performance with reduced personnel costs as a result of the right information being provided to the right people with the right skills at the right time in the right jobs.

Description: This Focus Area will ensure warfighter readiness through enhancing medical technologies in the field, developing effective simulation-based training and creating computational cognitive models that accurately represent human training requirements and total ownership costs. The skill, intelligence, adaptability and health of our Sailors and Marines are critical to mission success. Warfighters must be recruited, assigned and trained effectively and efficiently to ensure optimal performance while reducing personnel costs. Combat systems must exploit the differing strengths of human and machine elements to provide needed capacity across all warfighting conditions. Decision support systems must supply the right information

to the right people at the right time. Training and analytical tools must be extended to address the irregular warfare challenges posed by nontraditional social, political, economic, ethnic and religious factors that can affect operations. Improvements to helmet, body armor and eye and ear protection must be designed to ensure comfort and ease of employment. Responding quickly and effectively to combat injury is imperative. Health and fitness must be preserved to ensure warfighter resilience against physical and psychological threats in both peace and war. Biological-inspired design principles should be exploited to create new technologies to enhance warfighter effectiveness.

Objectives:

Manpower, Personnel, Training and Education

- Training technologies to enhance fundamental information-processing abilities in young adults
- Techniques to shorten training time, reduce training costs and maximize training impact
- Tools and techniques to achieve ubiquitous, engaging, scenario-based training
- Personnel recruitment, selection, assignment, retention and professional development models and tools that enhance workforce diversity and mission capability

Human System Design and Decision Support

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

Bio-Engineered Systems

- Engineer biologically-inspired intelligent sensors and autonomous systems
- Computational cognitive models for intelligent systems
- Synthetic biology for materials development and energy production
- Create and exploit advances in brain-based processors to enhance combat systems design

Warfighter Health and Survivability

- Enhanced first responder capability at point of injury and en-route care to reduce combat casualties
- Reduce incidence of noise-induced hearing loss and potentially restore hearing
- Advanced materials and improved design for lightweight body armor and equipment
- Mitigate health and performance risks in undersea operations

5. Implementation

The ONR S&T portfolio must balance a range of complimentary but competing imperatives. On the one hand, Basic and early Applied Research (BA 6.1 and BA 6.2) must address relevant Naval concepts and technologies to foster advancements in established operational areas. On the other hand, ONR is charged with maintaining a far-reaching complement of research efforts to guard against technological surprise and to create strategic advantages over any potential adversary. In this case, maturing technologies and concepts are supported through application of Applied Research funding (BA 6.2) until the most promising projects transition into Advanced Development (BA 6.3). Integrated into this structured path is a dedicated effort to apply BA 6.2/BA 6.3 funds toward crafting solutions for immediate needs, which may or may not be successful, but address requirements too significant to ignore. Prioritizing and focusing the science and engineering strength of the NRE on both the long-term and immediate needs of the Naval Services and the nation dictates a seamless alignment with established goals and the vision to explore phenomena that hold promise for creating "the next big thing."

Discovery and Invention (D&I): This part of the S&T continuum (time horizon 5 to 20 years) consists of Basic and early Applied Research, which form the "Petri dish" to germinate the next generations of Naval technological capabilities. In 2010 ONR researchers were awarded the Nobel Prize in Physics for Basic Research efforts in the hydrogenation of graphene. This seemingly esoteric effort offers great promise across a spectrum of immediate applications in practical superconductors, advanced electronics and improved sensors. More specific areas of research emphasis include autonomous sciences where ONR efforts have produced a family of unmanned vehicles that operate from the seabed to the airspace over the battlefield. ONR research in computational neuroscience has produced autonomous underwater robotic systems and the Smart Fence for border and installation protection. A bio-inspired science effort has produced a microbial fuel cell capable of powering small undersea sensors.

Recognizing the need to network advancements in all warfighting capabilities, the D&I portfolio contains a substantial investment in information technology sciences. NRE breakthroughs in this arena include Composeable FORCEnet, space-based microwave imagery and enhanced weather forecasting and storm prediction. Underpinning the phenomenology of the routine physical world is the advanced computing effort that addresses a range of topics including the mathematics of rare events. This endeavor has significantly closed knowledge gaps in subatomic material studies, which enabled advancements in semiconductors leading to successful development of technologies such as spintronics, an electronics game-changer with applications in surveillance, reconnaissance, electronic warfare and targeting/engagement. Rounding out the D&I portfolio is the multi-discipline exploration of materials. The acoustic metamaterials projects have produced advancements in sensors, noise reduction and stealth coatings. Integrated computational material sciences produced breakthroughs in precision time and timekeeping and generated Nobel Prizes for ONR researchers in 1997, 2001 and 2005. Recent research in wide bandgap semiconductors led to the development of Gallium chips used in the next-generation E-2D AEW radar system.

Another payoff has been the development of materials with high-fracture toughness, an enabling Force protection technology for counter-IED sciences.

In August 2010 ONR established a peer review process for the D&I portfolio. The peer review process addresses awards in the second or third year of execution in the following areas:

- ONR Department Core D&I programs,
- Multidisciplinary University Research Initiatives (MURI),
- Young Investigator Program (YIP), and
- Presidential Early Career Awards for Scientists and Engineers (PECASE).

Peer review is a process conducted by scientific and technical experts who provide an independent assessment of the scientific merit of the research being conducted. The objective of the program is to enhance the overall quality and value of ONR's Basic Research programs and to increase the likelihood of success by receiving feedback from an independent panel. 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, and
- Budget resources.

Results are reviewed by the Program Officer, Division Director, Department Head and DoR and adjustments made to the projects as needed. The Department Head presents the results of the peer review to CNR, VCNR and the Executive Director.

Sustaining a viable S&T workforce is a cornerstone of the D&I community, with attracting and retaining exceptional talent in leadership positions at the top of this requirement pyramid. One of the most successful programs for ensuring the superior quality of our efforts is the Basic Research Challenge (BRC). The BRC program was established to competitively select and fund promising research programs in new areas not addressed by the current Basic Research program. The program stimulates new, high-risk Basic Research projects in multidisciplinary and departmental collaborative efforts, and

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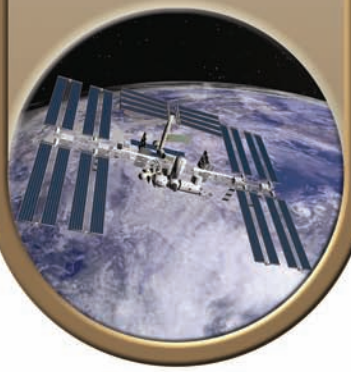
Real-Time/Fault-Tolerant Computing

As computing moved away from single processors/single thread of control toward more concurrency and synchronization in uncertain environments, problems of efficient resource utilization and especially timing under uncertainty became critical.

For the past 20-plus years, ONR's Software and Systems Basic Research program has invested in developing new theories and practices for computing and addressing the challenges of new technologies in new computing environments. Nearly all modern operating systems provide real-time scheduling based upon ONR-sponsored research. Many task scheduling problems that previously caused system crashes and deadlock have been eliminated.

ONR-sponsored Real-Time/Fault-Tolerant algorithms have been incorporated in new software analytical tools, techniques and methodologies used on Virginia-class submarines, the Joint Strike Fighter, SBIRS High and NASA's Mars Rover.



funds topics that foster leading edge science and attract new principal investigators and organizations. BRC awards are for a period of 4 years. Topics are submitted by ONR program officers and are selected for BRC awards by ONR's Director of Research. Towards the base of the research pyramid are those academic scientists and engineers who are in their first or second full-time tenure-track or tenure-track-equivalent academic appointment. ONR's Young Investigator Program (YIP) seeks to identify and support nascent scientists and engineers who show exceptional promise for doing creative research. The objectives of this program are to attract outstanding faculty members of Institutions of higher education to the DON's research program, to support their research, and to encourage their teaching and research careers.

Leap Ahead Innovations: Innovative Naval Prototypes and SwampWorks projects comprise the bulk of this S&T investment component. These are technology investments that are potentially "game-changing" or "disruptive" in nature. In this investment category we are willing to accept higher risk in an effort to produce higher payoffs for the warfighters.

- **Innovative Naval Prototypes** – These programs explore late BA 6.2 and BA 6.3 technologies that can dramatically change the way Naval forces fight. Programs in this category may be disruptive technologies that, for reasons of high risk or radical departure from established requirements and concepts of operation, are unlikely to survive without top leadership endorsement, and unlike FNCs are initially too high-risk for a firm transition commitment from the acquisition community. INPs are identified based on a balanced combination of Naval need and technology exploitation. Investments are planned with the critical mass needed to achieve a level of technology maturity suitable for transition in 4 to 8 years. Program Managers (PM) are primarily selected from ONR, and in order to help facilitate the transition to the acquisition community, Deputy PMs are typically chosen from the Acquisition community. The CNR, in consultation with senior Navy and Marine Corps leadership, identifies candidate INPs that are then forwarded to Naval S&T Corporate Board for approval/disapproval.

- **SwampWorks** – These programs, although potentially high-risk and disruptive in nature, are smaller than INPs and are intended to produce results in 1 to 3 years. SwampWorks efforts have substantial flexibility in planning and execution, with a streamlined approval

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Virtual Maintenance Performance Aid for the Littoral Combat Ship (VMPA)

Fifteen years of Basic and Applied Research in training and modeling and simulation have resulted in optimized training strategies, modular training architectures and high-fidelity, physics-based models of the Littoral Combat Ship-1 (LCS-1) gas turbine, that accurately models turbine function as well as a broad range of possible mechanical casualties.

The strategies, architecture and model were incorporated into a self-paced or instructor -paced Readiness Control Officer training system, enabling trainees to virtually traverse LCS-1 engineering spaces and access technical procedures.

Instructors can generate cascading casualties and quantitatively assess multiple students simultaneously. VMPA has been transitioned with PMS-501 funding to SWOS and LCS CLASRON.

process, shortening the innovation time cycle. Although a formal transition agreement is not required, SwampWorks programs should have strong advocacy outside ONR, either from the acquisition community or the Fleet. Frequently, SwampWorks products are inserted into Fleet experimentation and, if successful, can provide the impetus for new acquisition requirements. A portion of the SwampWorks efforts is involved in Quick Reaction S&T.

Acquisition Enablers (AE): This portion of the S&T portfolio centers on the FNCs that typically have a 3 to 5 years time horizon. The FNC program matures technology into requirements-driven, transition-oriented products in the late stages of Applied Research and Advanced Technology Development. The FNC program represents the requirements -driven, delivery-oriented portion of the Naval S&T portfolio. FNC investments directly respond to Naval S&T gaps that are generated from Navy and Marine Corps requirements analyses after receiving input from NRE stakeholders. Enabling Capabilities (ECs) and associated technology product investments of the FNC program are competitively selected by the three-star Technical Oversight Group (TOG) chartered by the Naval S&T Corporate Board that represents the requirements, acquisition, research and Fleet/Force communities of the Navy and Marine Corps.

The FNC program provides a continuance of Basic Research and early Applied Research by maturing technologies from a Technology Readiness Level (TRL) of 3 or 4 to a TRL of 6. All FNC investments are managed by two-star-chaired Integrated Product Teams (IPTs) that oversee the Naval pillars of Sea Shield, Sea Strike, Sea Basing, FORCEnet, Naval Expeditionary Maneuver Warfare, Enterprise and Platform Enablers, Power and Energy, Capable Manpower and Force Health Protection. Each EC is aligned to a specific pillar, and each technology product is aligned to an EC. At the lowest level, each technology product is measured against both technical and financial milestones. Annually, each technology product is reviewed in depth for technical performance and development status by the CNR against goals that have been approved by the TOG. Each technology product is also reviewed annually by its two-star-chaired pillar IPT for transition planning and adequacy and transition commitment level. All FNC products must meet required transition commitment levels for S&T development to continue in accordance with the goal of making every dollar count. Transition issues and required adjustments are reported annually by the CNR to the TOG, which establishes investment

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JDAM Assault Breaching System (JABS)

Novel mine and obstacle breaching capability was achieved after years of Basic Research into explosives characterization, standoff delivery, explosive channeling, explosive loading soil response modeling and mine and obstacle vulnerability.

The highly successful Joint Direct Attack Munition (JABS) is now operational in the Fleet for mine and obstacle clearance in the Beach Zone and Surf Zone following blast effects flight tests on mines and obstacles in a tactical threat lay-down.

Further research developed stable trajectory methods and demonstrated deeper-water, lethality-extending capability into the Very Shallow Water to a depth of 40 feet, which transitioned to PMS-495 in 2010.

priorities for the FNC program.

The non-FNC funding in this component is commonly referred to as “AE other.” It includes: approximately two-thirds of the Marine Corps BA 6.3 funds, all of the Joint Non-Lethal Weapons Directorate BA 6.3 funds, the majority of the Low-Observable/Counter Low-Observable (LO/CLO) funds and ManTech. These funds also foster acquisition program success.

The ManTech program is critical to reducing the acquisition cost of current and future platforms, a key goal of the Navy and Marine Corps. As a result, in 2006, ManTech adopted an affordability investment strategy and is currently focused on affordability improvements for the following major acquisition platforms: VIRGINIA Class Submarine (VCS), CVN 78 Class Carrier, Littoral Combat Ship (LCS) and DDG 51 Class Destroyer. A secondary focus supports the Joint Strike Fighter (JSF). ManTech helps these programs achieve their respective affordability goals, both acquisition and Total Ownership Cost, by transitioning needed manufacturing technology resulting in a cost reduction or cost avoidance for these key platforms.

ONR manages the DON’s SBIR program. SBIR funding is based on a congressionally mandated percentage of the RDT&E appropriation. Since SBIR is not programmed as part of the DON POM, it is not included in ONR’s investment portfolio. However, SBIR also serves to enable acquisition efforts.

Quick Reaction and Other S&T: This includes quick-reaction projects (time horizon 12 to 24 months) responsive to the immediate needs or compelling innovation identified by the Fleet, operating Forces or Naval leadership.

- **TechSolutions** – This program addresses Fleet or Force input with research to provide an S&T solution that meets or exceeds the need with short-term programs and rapid solutions. Accessible through the Internet and SIPRnet, TechSolutions accepts recommendations and suggestions from Sailors and Marines working at the tactical level on ways to improve mission effectiveness through the application of technology. TechSolutions uses rapid prototyping of technologies to meet specific requirements. 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

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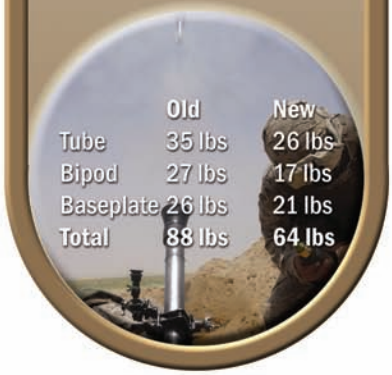
Lightweight 81mm Mortar System

Ten years of Advanced Weapons Material Basic Research on a nickel-based alloy — Inconel 718 — produced a longer service-life, twenty-seven percent lighter Lightweight 81mm Mortar System and reduced the 81mm tube unit cost by approximately $42,000.

Inconel 718 can withstand very high temperatures (1,100 °F) while maintaining high-tensile strength at a sustained rate of fire, unlike previous steel cannons, allowing elimination of cooling fins on both 60mm and 81mm mortar tubes and thinner tube wall thickness.

A redesigned aluminum base plate and bipod provide additional weight savings and commonality of design, function and training. Flowforming/coldworking also resulted in a fifty percent manufacturing cost reduction.



for the systems commands, TechSolutions aims to provide the Fleet/Force with prototypes that deliver solutions to address immediate needs and can be easily transitioned by the acquisition community.

- **Experimentation** – The Naval Warfare Development Command (NWDC), Naval Postgraduate School, Naval War College and Marine Corps Warfighting Lab (MCWL), in partnership with ONR, explore future warfighting concepts and evaluate the capability potential of emerging technologies. The CS-21 and the Naval Operational Concept 2010 (NOC 10) specify that initiatives and ideas in support of the overall maritime strategy must be applied, tested, analyzed and refined over time through war games, exercises, experiments and operational lessons learned. In support of that effort, Commander, U.S. Fleet Forces Command (USFF), in coordination with Commander, U.S. Pacific Fleet (CPF), leads the Fleet-led Experimentation (FLEX) program, a continuous process of Fleet-led experimentation.

  The intent of the FLEX program is to rapidly convert:

  - Innovative concepts,
  - Fleet Concepts of Operations (CONOPS),
  - New tactics, techniques and procedures (TTP), and
  - Technologies validated and refined by experimentation into recommended changes in doctrine, organization, training, materiel, leadership development, personnel, facilities and policy (DOTMLPF-P) actions.

  The FLEX program will focus on warfighting capability improvement through experimentation, delivering potential solutions that will have significant impact within the Future Years Defense Plan (FYDP). FLEX will be focused at both operational and tactical levels of warfare, across the full range of military operations, to enhance warfighting capabilities or to fill a current or future capability gap. FLEX is distinct from, but may inform and be informed by, developmental or operational testing requirements associated with Programs of Record (POR) or early experimentation conducted within the Naval S&T program.

  MCWL conducts concept-based experimentation in coordination with the operating forces in order to develop and evaluate tactics, techniques, procedures

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High-Strength Low-Alloy (HSLA) Steels

The U.S. Navy's two newest shipbuilding steels, HSLA-65 and HSLA-115, are the result of more than twenty years of Basic and Applied Research into alloy design, fabrication methods and advanced structural steels' relevant material properties.

The Navy-certified higher-strength and more durable HSLA-65 is a replacement for High Strength Steel (HSS) in various Aircraft Carrier (CVN) structural applications. Beginning with CVN 78, 17,500 long tons (LT) of HSLA-65 are incorporated into the CVN designs, providing a weight savings of approximately 1,500 LT.

The Navy also certified HSLA-115, a higher-strength alternative to HSLA-100, for use in portions of the flight deck, starting with CVN 78, resulting in an 87 LT reduction in flight deck weight.

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.

- **Rapid Technology Transition** – The intent of this program is to rapidly transitions technology into DON acquisition POR to meet emergent/urgent Naval needs. The pace of technology development is faster than the DoD Planning, Programming, Budgeting and Execution (PPBE) process. RTT is structured to provide current-year funding (inside the PPBE process), eliminating the time lag (up to 2 years) inherent in the PPBE funding process. Efforts are selected annually by a DON two-star/SES Executive Review Group. The general scope of an RTT effort is funding up to $2 million total for a development effort taking no more than two years to complete, strong Fleet and Force support, along with resource sponsor commitment to fund the costs to transition the technology into the acquisition POR.

- **ONR Science Advisors** – This program, funded in Quick Reaction, is comprised of twenty-five scientists and engineers that serve the Navy and Marine Corps major commands around the world at the senior staff level.

- **Response to Urgent Universal Need Statements (UNS)** – ONR responses to Urgent UNS and threat-based demands from senior Fleet/Force leadership that can be addressed within twenty-four months are included in the Quick Reaction component of the investment portfolio. These efforts may involve the rapid maturation of emerging/existing technologies from one of the other components of the investment portfolio or the adaptation of a commercial off-the-shelf (COTS) product.

Speed to Fleet: This concept accelerates insertion of maturing technologies into the Fleet/Force to address critical Naval needs, providing initial advanced capability to the warfighter while allowing the acquisition process to address doctrine, organization, training, material, leadership and education, personnel and facilities (DOTMLPF) issues. This nontraditional approach accelerates transition of prototype Technology Readiness Level (TRL) 6 S&T products from Advanced Technology Development (BA 6.3) to Research and Development (R&D) Advanced Component Development and Prototypes (BA 6.4) and enables extended user experiments in a relevant operational environment. Military end-user evaluations provide valuable lessons and direct feedback to the S&T and acquisition communities. Additionally, this process will enable the Fleet/Force to develop, test and refine CONOPS and evaluate integration with existing warfighting capabilities. Successful demonstrations will build Fleet/Force support for the technology, identify lifecycle implications across the DOTMLPF spectrum and provide risk mitigation for acquisition. These technologies can either be complete systems or components. Limited quantities may be retained by the Fleet/ Force to provide interim capability until the formal acquisition process procures the system/components and provides the requisite lifecycle sustainment. In 2009, to enable faster transition of technology, Congress provided the Navy the ability to place

BA 6.4 funding as an option on an S&T contract to facilitate the transition from S&T to R&D (Section 819 of the National Defense Authorization Act for Fiscal Year 2010)[7]. This can significantly shorten the current contracting process as well as support the goal of rapid transition of technologies.

Examples of Speed to Fleet projects that provide initial capabilities to the Fleet/Force: *The MK 18 MOD 1 SWORDFISH is a small (two-person portable), low-cost UUV, for U.S. Navy Explosive Ordinance Disposal Forces; the Compact Rapid Attack Weapon (CRAW) is a lightweight anti-submarine torpedo designed to be deployed from the Fire Scout Unmanned Aerial Vehicle; the Transportable Electronic Warfare Module (TEWM) installed on USS* Sampson *during RIMPAC 2010 provides surface ships a layer of protection from kinetic and non-kinetic attack; and the U.S. Marine Corps Mobile Modular Command & Control Vehicle (M2C2) provides command and control elements with efficient, broadband connectivity for voice and data communications.*

Naval Research Laboratory (NRL): NRL is the corporate research laboratory for the Navy and Marine Corps and conducts a broad program of scientific research, technology and advanced development. NRL has served the Navy and Marine Corps and the nation for over 87 years and continues to anticipate and meet Naval strategic interests in the 21st century, a period marked by global terrorism, shifting power balances and irregular and asymmetric warfare. The broad-based core scientific research at NRL serves as the foundation that can be focused on any particular area of interest to rapidly develop technology from concept to operation when high-priority, short-term needs arise. 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. The breadth of the research also facilitates quick assimilation of critical ideas and technologies being developed overseas for exploitation or countermeasures.

The lines of business at NRL include: sensors, electronics and electronic warfare, materials, battlespace environments, undersea warfare, information systems

[7] Public Law No: 111-84

technology, space platforms and technology transfer. The Laboratory conducts Basic and Applied Research pertaining to Naval environments of earth, sea, sky, space and cyberspace. Investigations range widely, from monitoring the sun's behavior, to survivability of critical Naval space assets, to analyzing marine atmospheric conditions, to measuring parameters of the deep oceans. Detection and communication capabilities benefit by research that exploits new portions of the electromagnetic spectrum, extends ranges to outer space and provides a means of transferring information reliably and securely, even through massive jamming. Submarine habitability, lubricants, fuels, shipbuilding materials, firefighting and the study of sound in the sea have remained steadfast concerns, as have explorations within the fields of virtual reality, superconductivity, biomolecular science, engineering, autonomous systems and nanotechnology.

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

Global Technology Awareness: 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. This allows us to capitalize on the global intellectual capacity that can provide innovative solutions to Naval challenges and also to maintain awareness of potential technological surprises and threats. To take advantage of the rapid pace of global innovation and to ensure that Naval S&T challenges benefit from the broadest range of ideas and approaches available, ONR builds strategic collaborations that connect U.S. research and development organizations, such as NRL, DARPA, NASA, NSF, warfare centers and the Fleet/Force with international academia, industry, government laboratories and research consortia.

Many tools are used to build these linkages to the global technology community. These include: direct scientific engagement by ONR Global (ONRG), NRL and ONR scientists; establishment of international agreements and exchanges between government research agencies, often facilitated by the Navy International Programs Office; multilateral collaborations (e.g., The Technical Cooperation Program (TTCP), North Atlantic Treaty Organization (NATO)), *etc.*); and many other *ad hoc* arrangements. In addition to these diverse approaches, Naval S&T has an international arm

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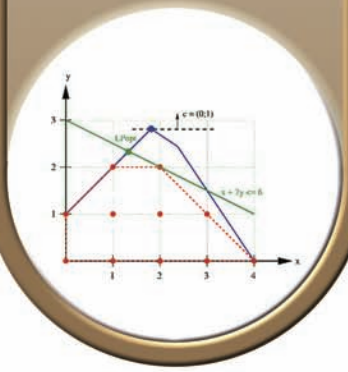
Resource Optimization

For more than twenty years, ONR's Resource Optimization Basic Research program has developed new mathematical techniques for mixed-integer programming (MIP) problems previously believed to be intractable. Many Navy resource allocation challenges can be framed as MIP.

Sustained investment has produced algorithms that are 30,000 times faster, independent of computing technology improvements. Fast, flexible and robust MIP-based decision aids can be built for real-time operational use.

Transitioned products include the Land Attack Planner that incorporates mission priorities and timings, Vertical Launching System configurations, launch directions and other factors and optimally assigns Tomahawk missiles to targets and the Logistics Planner that optimally plans daily transport resupply operations.



since 1946, ONR Global, to enhance collaboration and access.

ONR Global: ONRG provides worldwide S&T-based solutions for current and future Naval challenges. ONRG maintains a physical presence on four continents and leverages the expertise of more than 50 scientists and engineers. The command reaches out to the broad global S&T community and the operational Fleet/ Force commands to foster cooperation in areas of mutual interest and to bring the full range of possibilities to the Navy and Marine Corps. The ONRG Command Headquarters is in Singapore, and the four additional worldwide offices are critical to international engagement. Figure 5 depicts the organization's global presence. ONRG deploys scientists and engineers around the world to develop partnerships between the international and U.S. research communities in areas of Naval relevance; to discover leading-edge scientific advances and innovation; and to communicate emerging national and regional technology trends to avoid potential technology surprises. ONRG has been engaged in more than 70 countries over the past five years.

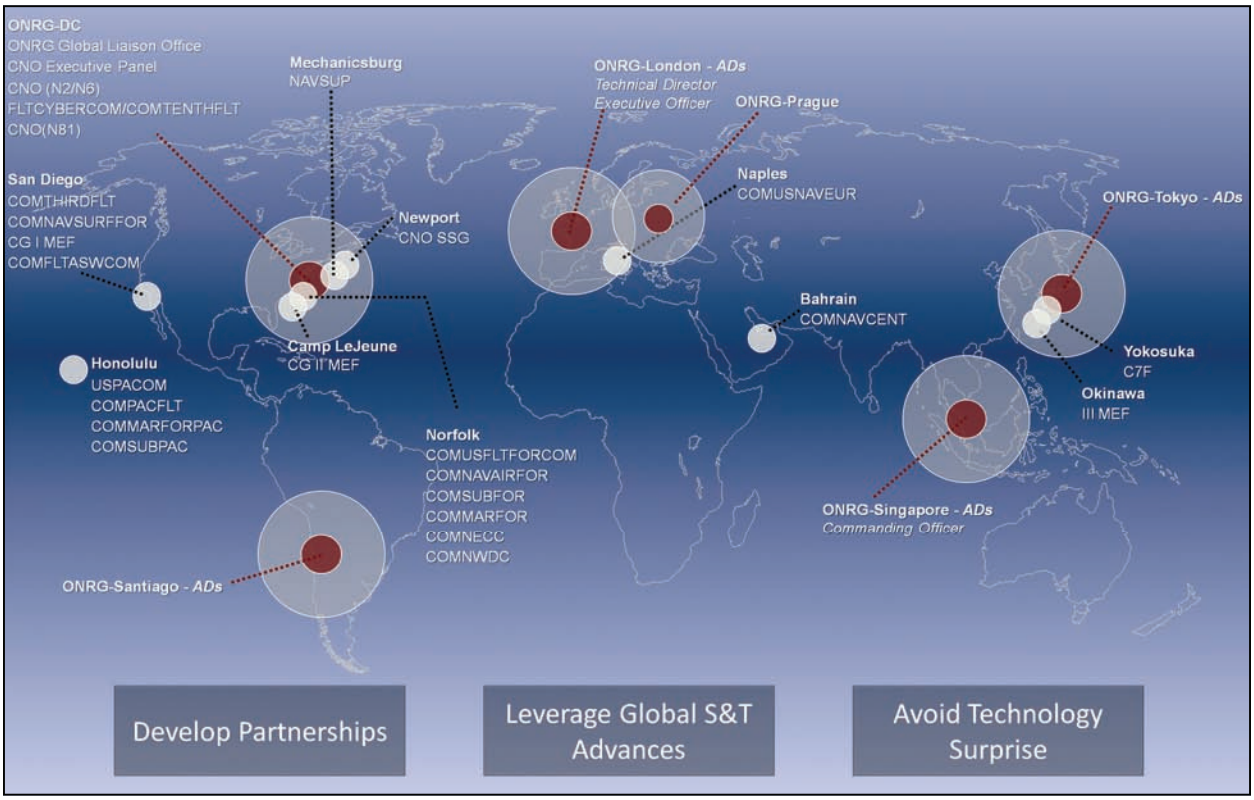


Figure 5. ONR Global Presence

ONRG sponsors programs that support exchange visits, conferences and workshops and provides seed funding for innovative technologies that address the needs of the Navy and Marine Corps and enhance the S&T programs of ONR and NRE.

- The Visiting Scientist Program supports short-term travel opportunities for foreign/international scientists to the United States to socialize innovative S&T ideas or findings with the NRE.

- The Conference Support Program financially supports foreign or international workshops, conferences and seminars of Naval S&T interest.

- The Naval International Cooperative Opportunities in Science and Technology Program (NICOP) provides direct research support to international scientists to help address Naval S&T challenges. NICOPs support the insertion of innovative, international S&T into core ONR and NRE programs.

ONRG is staffed by Associate Directors in the worldwide offices who promote collaboration with international scientists and by Science Advisors at major commands that identify Fleet/Force needs and implement technology solutions. Both serve as the CNR's science ambassadors abroad.

Associate Directors are typically scientists or engineers with doctorates working across government, academia and industry. They serve a 2- to 4-year tour in which they visit international S&T institutions to develop access and find cutting-edge S&T at the fundamental research level, assess international innovation in areas of Naval interest, provide global technical assessment, follow trends in S&T and track technological development in specific geographical areas. The Associate Directors recommend innovative researchers to be awarded research grants.

Science Advisors are embedded within the Fleet/Force to facilitate global awareness, to ensure that operating Force capability needs are quickly and effectively communicated to the Naval S&T community and to facilitate the timely delivery of Naval S&T solutions to the Fleet/Force. Their primary duties include: communicating Fleet/Forces capability needs to ONR, NRL and the NRE; applying S&T to Fleet/Force problems; functioning as Naval Commanders' direct link to various S&T organizations; assisting in prioritizing Command S&T needs; developing prototype solutions; and solving transition path options. Science Advisor tours are 1 to 3 years in length, highly competitive and sought-after developmental assignments for future NRE civilian leaders, allowing selected scientists and engineers to work directly with the operational forces and gain hands-on experience through Command-level engagement, Naval exercises and demonstrations both at-sea and in the field. There is a threefold return on ONR's investment in Science Advisors:

- Support S&T requirements of Naval Commanders and senior staffs,

- Facilitate reach-back to ONR, NRL, NRE, UARCs and other Services,

- Leverage their experience and Fleet/Force awareness when making executive-level decisions over the remainder of their careers in the Naval science and engineering workforce.

Naval Research Enterprise: Across the broad spectrum of technical challenges posed by the Navy's operational environments, ONR's commitment to excellence in S&T demands the ability to reach out and employ resources in government, academia and industry research organizations in the United States, as well as those made available by the efforts of ONRG throughout the world. Future operational security in Naval environs depends upon a cadre of dedicated and competent scientists and

engineers who can deliver superior warfighting capability to our Sailors and Marines. Those scientists and engineers are resident at NRL, the Naval Warfare and Systems Centers, Federally Funded Research and Development Centers (FFRDC), UARCs, colleges and universities, innovative businesses and industry laboratories that, together, form an association known as the "NRE."

In addition to responding to requirements from our warfighters, the NRE must meet long-term emerging needs and mitigate the risk of technological surprise. The NRE helps with visibility into the evolution of knowledge in the basic sciences while fostering a culture of transferring technological capability into the hands of Naval warfighters. The DON's sustained commitment to S&T enables ONR and the entire NRE to focus on building knowledge through discovery and invention. Additionally, it sustains the highly skilled and dedicated people required for systems, platforms, sensors and weapons needed to carry out current and future missions. Our intention is to enhance collaboration across the NRE through networking and knowledge management.

National Naval Responsibilities: The Navy and Marine Corps operate on, above, under and from the sea. The maritime environment extends from the sea floor to space and includes the land battlespace that is reached from the sea. It is complex and challenging, and it makes Naval operations inherently difficult and dangerous even under the best conditions. The DON has therefore historically placed great emphasis on maintaining a vigorous S&T program in those areas where research is critically important to maintaining Naval superiority. Many of those areas, uniquely important to the Navy and Marine Corps, are simply not addressed by research investments from the other Services or, for that matter, from the National Science Foundation, the National Institutes of Health, other federal research establishments or even private industry. This means that the health, strength and growth of our scientific and technical capabilities in those fields depend upon the DON. On behalf of the DON, ONR must ensure continuing U.S. leadership in these vitally important scientific and technical disciplines. It does so through research, recruitment and education, all done with a view to sustaining an adequate base of talent and the critical infrastructure necessary to carry out research and experimentation. In consultation with experts drawn from the National Academies and elsewhere, ONR identifies and coordinates designation of NNRs in consonance with the other Services and DoD.

There are five NNRs:

Ocean Acoustics

- Focuses investments in shallow water acoustics, high-frequency acoustics and long-range/low-frequency propagation
- Supports improved shallow-water ASW, wide-area surveillance, enhanced SSBN security and rapid environmental assessment

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 weapons' effectiveness and increased weapons load-out on Naval platforms

Naval Engineering

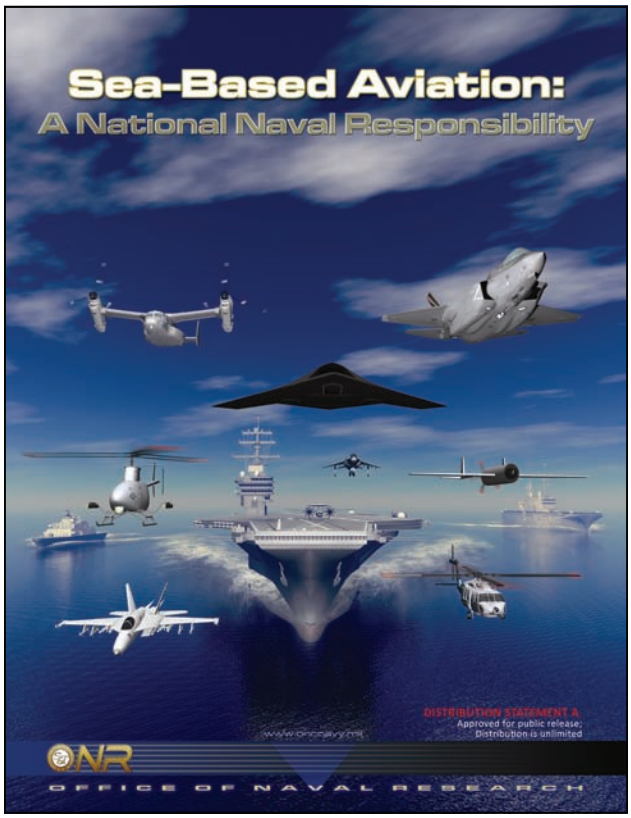
- Conducts major field experiments that integrate various technologies into innovative ship concepts
- Supports improved ship design tools and better analytics for platform affordability assessments

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 in contaminated water, as well as optimized submariner and diver performance

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



Two other areas have been proposed for designation as NNRs. Precision Time and Timekeeping has been nominated and is nearing approval based upon the Service's history of maintaining the nation's time standard at the Naval Observatory. Similarly, Electro-magnetic communications across the ocean-air interface centers on the challenges of communicating with the Navy's undersea platforms. These proposed NNRs are in the review process and

nearing submission to the other Service Science Boards for endorsement.

Science and Engineering (S&E) Workforce: The quality of Naval research depends upon nurturing and sustaining a well-educated, highly experienced and motivated workforce. These professionals must respond to both immediate and strategic military technology requirements and maintain a high degree of excellence in the face of many demographic and resource challenges. In order to meet the technological needs of the warfighter, developing the skills of the Naval S&E workforce is of critical importance. 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 DoD-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 (ILIR), the Independent Applied Research (IAR) and the 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 not only seek to improve the Naval workforce, but also allow these S&Es to better manage and oversee their industrial and academic partners as they seek solutions which deliver game-changing advantages to DoD and the nation. This body of talent must constantly reinvent itself, staying abreast of new technologies in the increased acceleration of discovery and invention. In order to attract and retain highly qualified individuals, the 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.

Science, Technology, Engineering, and Mathematics (STEM): The basic building block for the future workforce is a robust, strategic commitment to STEM education and outreach. The U.S. is the world's technology leader, and the 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 diverse ideas and approaches. The S&T

DISCOVERY and INVENTION
...where creativity thrives

Autonomous Intelligent Networks and Systems (AINS)

Basic Research in control theory, network science and computational intelligence performed research in decentralized, collaborative unmanned air systems, distributed sensing and control networks and aggressive maneuvering, vision-based tracking and road-following. Algorithms for decentralized control transitioned to a 6.2 autonomy program and then a Future Naval Capability program to support small unit tactical intelligence needs.

In the Applied system derived from AINS theoretical advances, the user tells the system what to do, and the Unmanned Aerial Vehicles decide how to do it effectively. Out of range or after the loss of an individual vehicle, AINS will allocate tasks between vehicles and execute autonomously in a way that fails gracefully if communications or individual vehicles are lost.

workforce is at the heart of this innovation process. In response to the increasing demand for top STEM talent worldwide and the upcoming retirement of large numbers of Naval STEM professionals, the Navy and Marine Corps have committed to doubling the Naval investment in STEM by 2015. This includes exciting STEM education and outreach programs that will increase participation by students and teachers, allow for hands-on and meaningful learning experiences, meet the underserved members of our nation where they live and dramatically increase the reach and impact of the Naval Services.

Development and Sustainment: The researcher base program and S&E workforce programs support the NRE as a whole. The ONR website provides specific information for these opportunities. 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 in the NRE through education programs, grants, contracts and cooperative agreements with Historically Black Colleges and Universities/Minority Institutions. ONR's SBIR/Small Business Technology Transfer programs reach out to tap the innovation provided by small business. Combining people with different attributes, temperaments, backgrounds and skills will foster the creativity needed to address new and developing threats. The NRE must ensure it maintains a culture that supports and 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 skills broader than specific technical expertise. As the S&T strategy shifts and realigns itself in response to a more dynamic operating environment, it creates a need to ensure the workforce and its support systems evolve on a parallel track. Marrying great technical expertise and experience with world-class academic training will be critical to developing and sustaining the S&E leaders of tomorrow. We must expand the conceptual model of lifelong learning and increase the use of adult learning techniques to maintain interest and expand effectiveness of current training programs.

Interagency Coordination and Alliance: Naval S&T investment is coordinated though the Defense S&T Reliance 21 Program and similar cooperative programs to leverage efforts by other Services and DoD agencies and to achieve economies and synergies. Each year, 10 to 15 percent of the DON BA 6.2/BA 6.3 program supports multi-service/agency-funded and managed projects to develop technologies and capabilities that have DoD-wide relevance. Key joint programs currently being funded

include the Versatile, Affordable, Advanced Turbine Engine Program to develop the next-generation of high-efficiency, high-thrust-to-weight-ratio turbine engines and the Weapons of Mass Destruction Detection Program that addresses national maritime and port security through the development of technologies for standoff detection of WMD's and component nuclear materials on ships at sea.

ONR's senior leadership and program officers routinely meet with other service counterparts to exchange information and identify opportunities to collaborate or to conduct complementary research efforts, and ONR has recently proposed periodic "geek fighter" talks among the service labs. In addition, ONR and NRL program managers reach out to the larger technical community and collaborate with non-DoD agencies such as NSF, NASA and DOE. ONR also coordinates with the United States Coast Guard (USCG) and has an officer on-site who serves as direct Coast Guard liaison and helps coordinate ONR efforts with the Department of Homeland Security in global maritime domain awareness and in combating terrorism.

Measuring Success: Measures of S&T success should include metrics that represent the key outputs: knowledge, transitions, and people, as depicted in Figure 6. Metrics help manage high-risk revolutionary S&T. They also communicate the value of the Naval S&T investment to senior leadership.

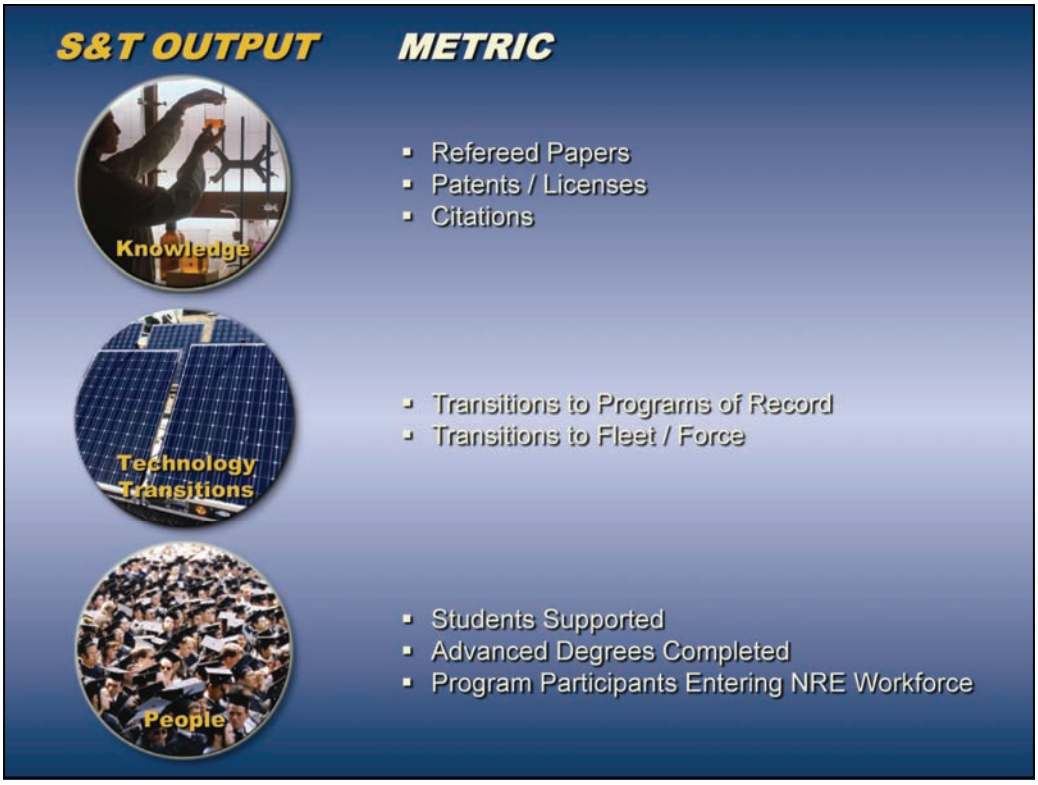


Figure 6. Metrics to Evaluate S&T Portfolio

Business Processes: More than 80 percent of ONR-sponsored S&T is awarded to external performers in academia, industry and the NRE; therefore, efficient and effective business processes are vital to achieving our S&T objectives. Business operations include:

- Grant and contract administration,
- Contracting activities and policy,
- Acquisition and research business policy,
- Information and statistical reporting processes,
- Human resource management,
- Intellectual property policy with patent and trademark oversight, and
- Stakeholder communication and engagement.

6. Execution

The Naval S&T visions and objectives articulated in Section 4 collectively represent the overall roadmap for our S&T investments. Bringing this vision to fruition requires the best efforts of the entire ONR team. Section 5 provided a brief explanation of the management processes for the four major categories of the S&T investment portfolio. The Focus Areas include investments from all parts of the S&T portfolio and cut across ONR's departmental organization. This section provides a snapshot of the process that ONR uses to manage the Focus Areas in order to execute the Naval S&T Strategic Plan.

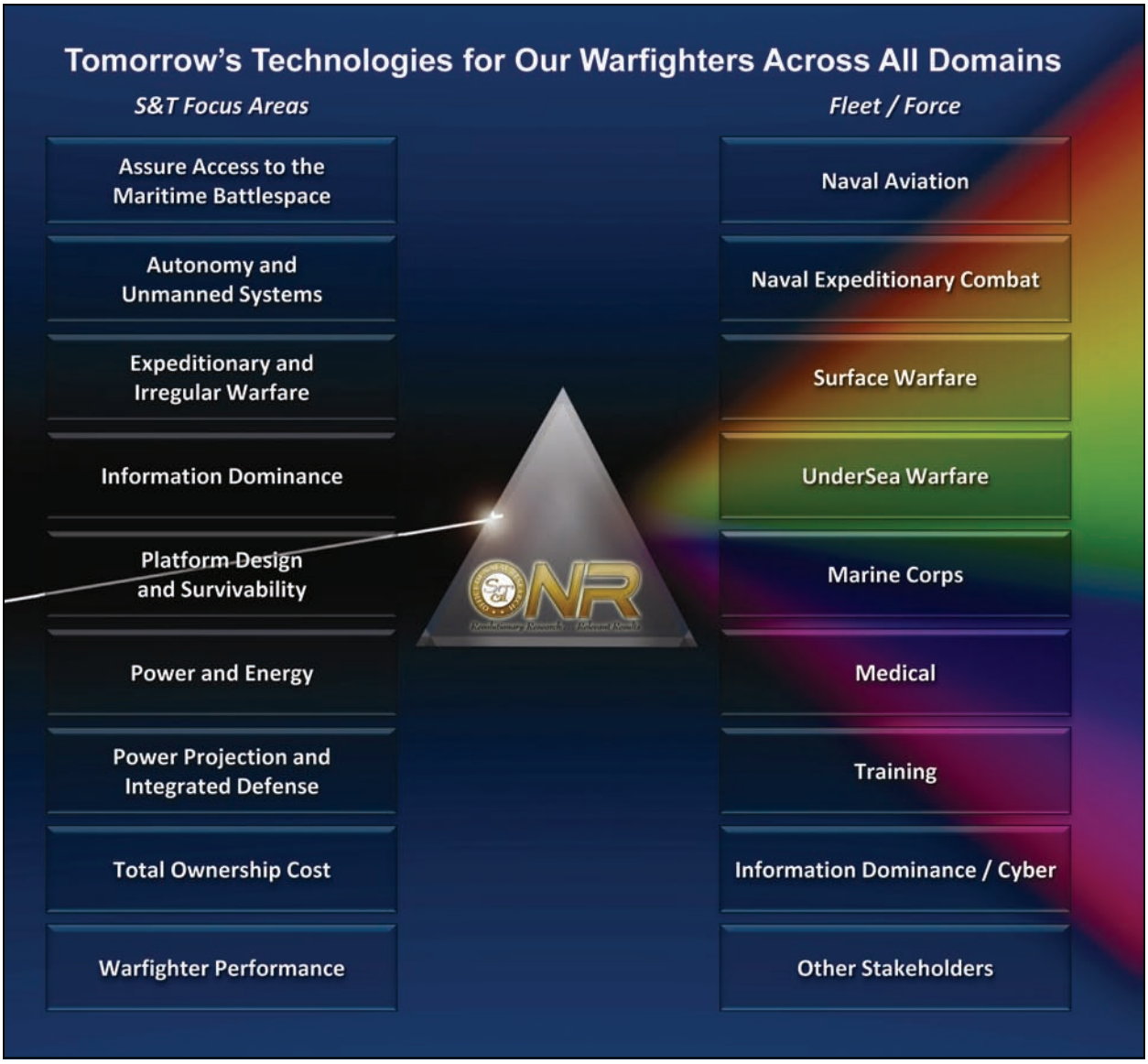
Management of Focus Areas:

- Each of the nine Focus Areas is assigned a Focus Area Leader, a Senior Executive Service S&T manager, who is given broad authority to work across ONR departmental lines.

- The Focus Area Leader is responsible for generating detailed roadmaps that articulate the progression of products from Basic Research through transition to identified customers.

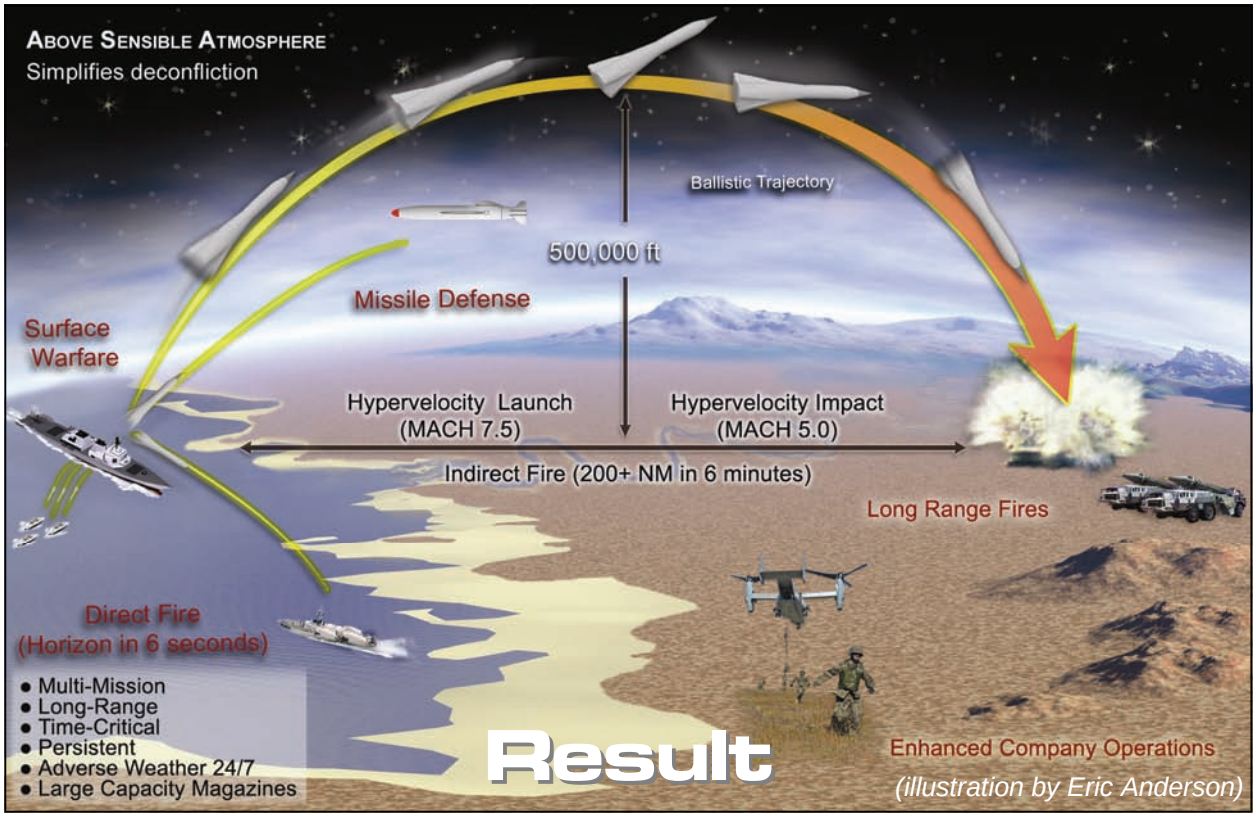
- ONR leadership subjects each Focus Area to an annual review. Each Focus Area is scrutinized not only for how well it is executing its roadmap, but also for how well that execution lines up with the strategy and vision. Programs and projects that are not executing or that are found to be out of line with the vision are at risk of being terminated and their resources re-allocated.

The supporting processes for bringing the S&T visions and objectives to reality are the key to the successful implementation and execution of the Naval S&T Strategic Plan. They represent the intersection of Navy and Marine Corps visions, challenges and opportunities provided by advances in S&T. Our investments over time will ensure the continued technological superiority advantage of Naval forces, so that no Sailor or Marine will ever find themselves in the middle of a fair fight.


Tomorrow's Technologies for Our Warfighters Across All Domains
S&T Focus Areas
Assure Access to the Maritime Battlespace
Autonomy and Unmanned Systems
Expeditionary and Irregular Warfare
Information Dominance
Platform Design and Survivability
Power and Energy
Power Projection and Integrated Defense
Total Ownership Cost
Warfighter Performance
ONR
Fleet / Force
Naval Aviation
Naval Expeditionary Combat
Surface Warfare
UnderSea Warfare
Marine Corps
Medical
Training
Information Dominance / Cyber
Other Stakeholders

7. Summary

The overriding goal of this Naval S&T Strategic Plan is to provide the vision and key objectives guiding the essential S&T efforts that will assure the continued supremacy of U.S. Naval Forces in the 21st century. This plan implements the current guidance and direction of senior civilian and military leadership. It focuses and aligns Naval S&T with Naval missions and future capability needs that address the complex challenges presented by both rising peer competitors and irregular/asymmetric warfare. It puts us on a path toward maturing and transitioning enhanced Naval capabilities, such as persistent ISR and dominance of the electronic warfare spectrum, and toward pursuing revolutionary advances, such as speed-of-light weapons. This strategy will be reviewed and approved by the Naval S&T Corporate Board every two years to ensure its continued relevance. It provides a means and framework to communicate with decision makers and the various external communities that interact with Naval S&T. Inside ONR, this plan will guide our investment planning and decisions. It is also intended to broaden our reach into the scientific community as well as into industry. The plan will be posted on the ONR website (www.onr.navy.mil) for easy access by industry and academia and to help IRAD investments.



The ONR-funded Maritime Laser Demonstration (MLD) program is developing laser-based, proof-of-concept technology to meet the specific survivability and self-defense capability requirements of U.S. Navy surface combatants for the defeat of small boat threats.

(U.S. Navy photo by John F. Williams)

Appendix A: References and Web Links

References

National Strategic Documents

- National Security Strategy (May 2010)
- National Defense Strategy (June 2008)
- National Military Strategy of the United States of America, 2011
- Quadrennial Defense Review (2010)
- The National Strategy for Maritime Security (2005)
- National Plan to Achieve Maritime Domain Awareness (2005)

Joint and Naval Strategic Documents

- Joint Operating Environment (2010)
- Department of the Navy Objectives for FY 2011 (2010)
- CNO Guidance for 2011
- The 35th Commandant's Planning Guidance (2010)
- Marine Corps Vision & Strategy 2025 (2008)
- A Cooperative Strategy for 21st Century Seapower (2007)
- Naval Operations Concept (2010)
- Marine Corps Operating Concept (2010)
- Sea Power 21 (2002)
- Naval Power 21...A Naval Vision (2002)

Defense S&T Documents

- Marine Corps Science & Technology Strategic Plan (2009)
- Navy Expeditionary Combat Enterprise Strategic Plan (2011) – NOTAL

- Naval Aviation Enterprise S&T Objectives (2010) – NOTAL
- Surface Warfare Enterprise S&T Strategic Plan 2010 - NOTAL
- UnderSea Warfare S&T Strategic Plan (2010) – NOTAL
- Naval Special Warfare S&T Strategic Plan (2009) – NOTAL
- Air Force Chief Scientist Report, Technology Horizons: A Vision for Air Force Science & Technology During 2010-2030 (2010)
- Army Science and Technology Master Plan (2010) – NOTAL
- United States Marine Corps Expeditionary Energy Strategy and Implementation Plan (2011)

Web Links

Point of Contact Listing: http://www.onr.navy.mil/About-ONR/Leadership.aspx

For more information on the following topics, please see the associated websites:

- **FNC:** http://www.onr.navy.mil/Science-Technology/Directorates/Transition/Future-Naval-Capabilities-FNC.aspx
- **SBIR at ONR:** http://www.onr.navy.mil/Contracts-Grants/small-business.aspx
- **SBIR at Navy:** http://www.navysbir.com/
- **ManTech:** http://www.onr.navy.mil/Science-Technology/Directorates/Transition/Manufacturing-ManTech/Planning-Execution.aspx
- **RTT:** http://www.onr.navy.mil/Science-Technology/Directorates/Transition/Technology-Transfer-T2.aspx
- **TechSolutions:** http://www.onr.navy.mil/Science-Technology/Directorates/office-innovation/tech-solutions-innovation.aspx
- **SwampWorks:** http://www.onr.navy.mil/Science-Technology/Directorates/office-innovation/swampworks-innovation.aspx

Appendix B: Naval S&T Research Areas

Naval S&T Focus Area	Objective Categories	S&T Research Areas
Assure Access to Maritime Battlespace	• Achieve and Maintain Undersea Dominance • Improve Mobile Autonomous Environmental Sensing • Match Environmental Predictive Capabilities to Tactical Planning Requirements • Maximize Systems Performance via Adaptation to the Environment	• Anti-Submarine Warfare Surveillance • ASW Performance Assessment • Bio-sensors, Bio-processes and Bio-inspired Systems • Electronic Warfare Attack • Functional Materials • Intelligent and Autonomous Systems • ISRT-ESM • Large Vessel Stopping • Littoral Geosciences, Optics and Biology • Marine Mammals • Marine Meteorology • Mine Neutralization • Nanometer Scale Electronic Devices and Sensors • Navigation and Precision Timekeeping • Networked Sensors • Non-Lethal Weapons • Ocean Acoustics • Physical Oceanography • Solid State Electronics • Space Environmental Effects • Spacecraft Technology • Unmanned Air Vehicles • Unmanned Sea Vehicle Technologies
Autonomy and Unmanned Systems	• Human/Unmanned Systems Collaboration • Perception and Intelligent Decision Making • Scalable and Robust Distributed Collaboration • Intelligence Enablers and Architectures	• Intelligent and Autonomous Systems • Unmanned Air Vehicles • Unmanned Sea Vehicle Technologies
Expeditionary and Irregular Warfare	• Irregular Warfare Battlespace Awareness • Influence Operations Enablers • Expeditionary and Distributed Operations • Irregular Threat Countermeasures	• Communications and Networks • Counter IED • Electronic Warfare Attack • Expeditionary Firepower • Expeditionary ISR • Expeditionary Logistics • Expeditionary Maneuver/Individual Mobility • Information Processing, Discovery, Integration and Presentation • Intelligent and Autonomous Systems • Nanometer Scale Electronic Devices and Sensors • Non-Lethal Weapons Training, Education and Human Performance • Expeditionary C4 • Precision Strike • Social, Cultural and Behavioral Modeling • Special Warfare/EOD • Unmanned Air Vehicles • Unmanned Sea Vehicle Technologies

Naval S&T Focus Area	Objective Categories	S&T Research Areas
Information Dominance	• Information Space for Integrated C2, ISR and Combat Systems Decision Making • Spectrum Dominance • Computer Network Operations • Communications and Networks • Computational Environment Architecture	• ASW Surveillance • Automated Image Understanding • Bio-sensors, Bio-processes and Bio-inspired Systems • Communications and Networks • Computational Analysis • Decision Support Tools • Human Factors Organizational Design and Decision Research • Information Assurance and Anti-Tamper • Information Processing, Discovery and Presentation • Intelligent and Autonomous Systems • ISRT-ESM • Nanometer Scale Electronic Devices and Sensors • Navigation and Precision Timekeeping • Networked Sensors • Solid State Electronics • Spacecraft Technology • WMD Detection
Platform Design and Survivability	• Advanced Mobility • Reliable, Efficient, Long-Range, High-Speed Platforms With Optimized Payload Capabilities • At-Sea Sustainment • Affordable Fleet/Force Modernization	• Advanced Naval Power Systems • Advanced Sea Platforms • Air Propulsion • Air/Ground Vehicles • Expeditionary Logistics • Expeditionary Maneuver • Functional Materials • Human Factors, Organizational Design and Decision Research • Intelligent and Autonomous Systems • Seabase Enablers • Structural Materials • Unmanned Air Vehicles
Power and Energy	• Energy Security • Efficient Power and Energy Systems • High Energy and Pulsed Power	• Advanced Naval Power Systems • Air Platform Power • Bio-derived Materials and Systems • Functional Materials • Personal Power • Power Electronics

Naval S&T Focus Area	Objective Categories	S&T Research Areas
Power Projection and Integrated Defense	• Future Naval Fires • Integrated Layered Defense Across the Entire Detect-to-Engage Continuum • Extended Threat Neutralization Capabilities • Time-Critical Precision Strike	• Advanced Energetics • Air Platform Survivability • Directed Energy • Electromagnetic Guns • Electronic Warfare Attack • Expeditionary Firepower Torpedo Defense • Expeditionary Force Protection • Functional Materials • High-Speed Weapons Technologies • ISRT-ESM • Mining • Non-Lethal Weapons • Precision Strike • Sea Platform Survivability • Solid State Electronics • Undersea Weaponry
Total Ownership Cost	• Platform Affordability • Lifecycle and Sustainment Cost • Crew Manning and Operational Capabilities	• Advanced Naval Power Systems • Advanced Sea Platforms • Affordability/Reduced Platform Lifecycle Cost • Air/Ground Vehicles • Bio-sensors, Bio-processes and Bio-inspired Systems • Complex Software Systems Tools • Environmental Quality • Information Assurance and Anti-tamper • Intelligent and Autonomous Systems • Manufacturing Science • Materials, Computation and Prediction • Power Electronics • Structural Materials
Warfighter Performance	• Manpower, Personnel, Training and Education • Human-system Design and Decision Support • Warfighter Survivability and Operational Health • Bio-engineered Systems	• Bio-sensors, Bio-processes and Bio-inspired Systems • Casualty Care and Management • Casualty Prevention • Human Factors, Organizational Design and Decision Research • Manpower and Personnel • Training, Education and Human Performance • Undersea Medicine

Appendix C: Acronyms

ACMC	Assistant Commandant of the Marine Corps
AIW	Asymmetric and Irregular Warfare
ASN	Assistant Secretary of the Navy
ASW	Anti-Submarine Warfare
BA	Budget Activity
C2	Command and Control
C4	Command, Control, Communications and Computers
CBRNE	Chemical, Biological, Radiological, Nuclear and High-yield Explosive
CIED	Counter Improvised Explosive Device
CNR	Chief of Naval Research
COP	Common Operating Picture
DARPA	Defense Advanced Research Projects Agency
D&I	Discovery and Innovation
DO	Distributed Operations
DoD	Department of Defense
DOE	Department of Energy
DON	Department of Navy
EC	Enabling Capability
ECO	Enhanced Company Operations
EMIO	Enhanced Maritime Intercept Operations
EO	Electro-optical
EOD	Explosive Ordnance Disposal
EW	Electronic Warfare
FNC	Future Naval Capabilities
GPS	Global Positioning System
IAR	In-House Applied Research

IED	Improvised Explosive Device
ILIR	In-House Independent Research
IM	Insensitive Munitions
IR	Infrared
IRAD	Industry Research and Development
ISR	Intelligence, Surveillance and Reconnaissance
ISRT - EM	Intelligence, Surveillance, Reconnaissance and Targeting - Electromagnetic
IW	Irregular Warfare
LO/CLO	Low-Observable/Counter Low-Observable
ManTech	Manufacturing Technology
MCCDC	Marine Corps Combat Development Command
MCM	Mine Countermeasures
MCWL	Marine Corps Warfighting Laboratory
MDA	Maritime Domain Awareness
MIO	Maritime Interception Operation
M&S	Modeling and Simulation
MIW	Mine Warfare
NAE	Naval Aviation Enterprise
NASA	National Aeronautics and Space Administration
NECC	Naval Expeditionary Combat Command
NECE	Naval Expeditionary Combat Enterprise
NATO	North Atlantic Treaty Organization
NM	Nautical Miles
NRAC	Naval Research Advisory Committee
NRL	Naval Research Laboratory
NRE	Naval Research Enterprise
NSB	National Science Board

NSF	National Science Foundation
NWDC	Navy Weapons Development Command
OA	Operational Adaptation
ONR	Office of Naval Research
OPNAV	Office of the Chief of Naval Operations
RDA	Research Development and Acquisitions
RTT	Rapid Transition Technology
SBIR	Small Business Innovation Research
SIGINT	Signals Intelligence
S&T	Science and Technology
STEM	Science, Technology, Engineering and Mathematics
STOM	Ship to Objective Maneuver
SWE	Surface Warfare Enterprise
TOG	Technology Oversight Group
TTCP	The Technical Cooperation Program
UARC	University Affiliated Research Center
USMC	United States Marine Corps
USW	UnderSea Warfare
VCNO	Vice Chief of Naval Operations
VTOL	Vertical Take-off or Landing
VSTOL	Vertical/Short Take-off or Landing
WMD	Weapons of Mass Destruction

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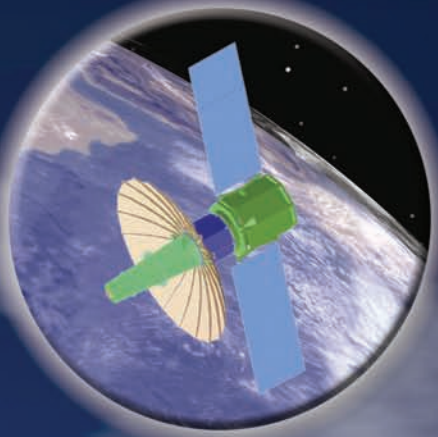

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