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HOUSE ARMED SERVICES COMMITTEE
EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

STATEMENT OF
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BEFORE THE
EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE
OF THE
HOUSE ARMED SERVICES COMMITTEE
ON
THE FISCAL YEAR 2016 BUDGET REQUEST

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INTELLIGENCE, EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

Introduction

It is an honor to report on Department of the Navy (DoN) Science and Technology (S&T) and discuss how the President's FY 2016 Budget supports the Navy and Marine Corps (USMC). The FY 2016 Budget requests approximately $2 billion for Naval S&T. In building a Fleet/Force to achieve U.S. national security objectives, we march every step of the way with the Secretary of the Navy (SECNAV), Chief of Naval Operations (CNO) and Commandant of the Marine Corps (CMC) to balance S&T resources between a range of initiatives to support near-term advances in established operational areas – and to sustain long-term research that may prove disruptive to traditional operational concepts. Naval S&T objectives are to maintain technological superiority, avoid technological surprise, foster knowledge expansion, and spur innovative breakthroughs to ensure Sailors and Marines have the decisive technology advantage.

The FY 2016 Navy budget supports Department of Defense (DoD) missions outlined in our strategic guidance: *Sustaining U.S. Leadership: Priorities for 21st Century Defense*, and the *2014 Quadrennial Defense Review*. The CNO characterizes the principal tenets of Navy's mission as: Warfighting First, Operate Forward, and Be Ready. The Navy's overseas presence gives the President military and diplomatic options when responding to crises, while bolstering global stability through constructive engagement with allies and partners around the world.

The current fiscal climate requires the Navy to make tough choices between competing priorities. We are doing everything we can to balance current readiness against the need to build a highly capable future Fleet/Force. Our priority is to operate forward when and where it matters, always ready to address a wide range of threats and contingencies – and use S&T to enable the Navy and Marine Corps to maintain the technological edge necessary to prevail in any environment where we are called to defend U.S. interests. Six priorities guide development of the Navy's budget. We must: 1) maintain a credible, modern, survivable sea-based strategic deterrent, 2) sustain global forward presence, 3) preserve the means to win in one multi-phase contingency operation, while denying aggressor objectives in a second region, 4) provide adequate funding that ensures afloat/ashore readiness, 5) enhance the Navy's asymmetric capabilities in physical domains,

cyberspace and across the electromagnetic spectrum, and 6) sustain the industrial base. Everything we do, including S&T, is grounded in these responsibilities.

Sailors, Marines, civilians, and families are the foundation of the Navy's warfighting capability. Our people must be prepared, confident, and proficient. As the global demand for U.S. military presence stresses the fleet/force, this budget continues to provide services and support to ensure Sailors and Marines are resilient and ready. Our Optimized Fleet Response Plan (O-FRP) will better prepare units and crews by making deployments predictable and increasing operational availability. We invest in tactical trainers, simulators and smart technology to enhance training, communication and career management. We provide support for programs to ensure the safety, health, and well-being of Sailors and Marines. We are expanding development and fielding of live, virtual, and constructive training environments to provide more realistic training at less cost. We have evolved Information Dominance as a mainstream warfighter discipline by establishing the Navy Information Dominance Forces Command, responsible for readiness of intelligence, oceanography, meteorology, information warfare, networks, and space capabilities. All these programs depend on robust S&T investments in order to succeed.

Naval Science and Technology Strategy

The Naval S&T Strategy is regularly updated by Navy and USMC leadership to validate S&T alignment with current and future requirements. The Strategy identifies nine S&T focus areas: 1) Assure Access to the Maritime Battlespace, 2) Autonomy and Unmanned Systems, 3) Electromagnetic Maneuver Warfare, 4) Expeditionary and Irregular Warfare, 5) Information Dominance – Cyber, 6) Platform Design and Survivability, 7) Power and Energy, 8) Power Projection and Integrated Defense, and 9) Warfighter Performance. The Strategy charts our course as we navigate between existing systems and concepts of operations toward a warfighting capability to counter predicted threats in an increasingly complex, uncertain future. Starting with evolution of current systems through incremental improvement and spiral development of known technology, we move toward yet-to-be-discovered, disruptive, game-changing technologies. The Naval S&T Strategy aligns S&T investments with Naval missions and future capability needs by targeting *knowledge gaps* to fill *technology gaps* that address *warfighting capability gaps*.

Executing the Strategy

Naval S&T invests in four areas – Discovery and Invention (D&I), Leap Ahead Innovations (Innovative Naval Prototypes/INPs), Technology Maturation (Future Naval Capabilities/FNCs), and a Quick Reaction capability to respond to emerging requirements.

Discovery and Invention

Discovery and Invention (D&I) includes basic research (6.1) and early applied research (6.2). D&I develops fundamental knowledge, provides a basis for future Navy/Marine Corps systems, and sustains our Scientist/Engineer workforce. D&I develops knowledge from which INP, FNC, and Quick Reaction efforts are generated. Approximately 45 percent of ONR investments are in D&I, with about 60 percent of the total executed by academic and non-profit performers. D&I is peer reviewed by outside experts and overseen by ONR program officers and senior leadership. Investment decisions are guided by risk, impact, significance, originality, principal investigator, and budget resources. Our performers are consistently recognized by external organizations; for example, Dr. Mark Hersham of Northwestern University was a 2014 recipient of the MacArthur Genius Award for work combining chemistry, physics, electrical engineering and biology.

ONR's University Research Initiative (URI) includes the Multidisciplinary University Research Initiative (MURI), the Defense University Research Implementation Program (DURIP), and the Presidential Early Career Award for Scientist and Engineers (PECASE). MURI supports teams of researchers investigating topics that involve multiple technical disciplines. DURIP provides grants for the purchase of instrumentation necessary to perform research essential to the Navy. PECASE recognizes achievements of young scientists/engineers and encourages them to explore professions in academia and Naval laboratories. The Basic Research Challenge funds promising research not addressed by ONR's core program, while the Applied Research Challenge rewards the technical community for specific, measurable progress in new applied research. The Young Investigator Program supports scientists/engineers with exceptional promise for Naval research. Research opportunities for undergraduate and grad students, fellows, and future faculty members are provided by the Naval Research Enterprise Internship Program (NREIP), where participants

work at Naval laboratories and warfare centers. The In-House Laboratory Independent Research (ILIR) and Independent Applied Research (IAR) programs sponsor critical research and further the education of scientists and engineers at warfare centers. ONR also brings Historically Black Colleges and Universities and Minority Institutions (HBCU/MI) together with Naval laboratories and warfare centers to give students hands-on experience in Naval research.

Leap Ahead Innovations (Innovative Naval Prototypes)

Innovative Naval Prototypes (INP) total about 12 percent of the S&T budget. INPs are high-risk/high-payoff disruptive departures from established requirements and operational concepts that can dramatically change how Naval forces fight, while reducing acquisition risk. INPs are overseen by the Naval Research, Development, Testing and Evaluation (RTD&E) Corporate Board (Undersecretary of the Navy; Assistant Secretary of the Navy for Research, Development and Acquisition (ASN-RDA); Vice CNO; Assistant CMC; Director of Innovation, Test, and Evaluation and Technology Requirements; Deputy Assistant Secretary of the Navy for RDT&E; and Deputy Under Secretary of the Navy for Plans, Policy, Oversight and Integration). The goal is to prove concepts and mature technology in 4-7 years, allowing informed decisions about risk reduction and transition to acquisition programs. INP Program Managers and Deputies are from ONR and the acquisition community.

INPs include: Integrated Topside (InTop) will enable the Navy to operate in the electromagnetic spectrum while denying adversaries' ability to do the same through development of multi-beam, multi-function ultra-wideband apertures and Radio Frequency equipment for all ship classes. The Large Displacement Unmanned Undersea Vehicle (LDUUV) is developing a UUV capable of extended operations in the littorals. The Autonomous Aerial Cargo/Utility System (AACUS) is developing autonomous capabilities for rapid, affordable rotorcraft supply in permissive, hostile and GPS-denied settings. Electromagnetic Railgun (EMRG) has multi-mission potential for long-range land-attack, air defense, and anti-surface warfare against ships and small boats.

Technology Maturation (Future Naval Capabilities)

Technology Maturation is the critical component of our transition strategy. It consists of the Future Naval Capabilities (FNC) program, USMC Advanced Technology Development (6.3)

funds, Joint Non-Lethal Weapons Directorate (6.3) funds, Low Observable/Counter Low Observable funds, and Manufacturing Technology (ManTech).

FNCs are near-term (2-4 year), requirements-driven, delivery-oriented projects that deliver mature technologies to acquisition sponsors for incorporation into new or upgraded systems. FNCs use a collaborative process involving requirements, research, acquisition, and Fleet/Force communities to align this part of the S&T portfolio with Naval Capability Gaps identified by the Office of the Chief of Naval Operations (OPNAV) and the Marine Corps Combat Development Command (MCCDC). A gap is any capability required to achieve Naval objectives that are not achievable with current platforms, weapon systems, doctrine, organizational structure, training, materials, leadership, personnel or facilities and requires S&T investment to address.

FNCs align to functional areas (or "Pillars"): Sea Shield, Sea Strike, Sea Basing, FORCEnet, Naval Expeditionary Maneuver Warfare, Capable Manpower, Force Health Protection, Enterprise and Platform Enablers, and Power and Energy. Projects address specific gaps in those areas, with prioritization approved by a 3-Star Technology Oversight Group (TOG) representing OPNAV, USMC, U.S. Fleet Forces Command, ASN-RDA, and ONR. FNCs are based on D&I investments where technology can mature from Technology Readiness Level (TRL) 3 to TRL 6 in 3-5 years. Selection assesses related work in DoD, government agencies, industry and Naval centers of excellence, and focuses on the most pressing gaps – with funding changes based on successful transitions, reprioritization, new starts, and evolving Naval needs. As FNC products mature, TRLs change, moving products from 6.2 to 6.3 PEs. Year one is mostly 6.2; the final year mostly 6.3 – with a mix of 6.2/6.3 between. As FNC products transition to Advanced Component Development and Prototypes (6.4) and Engineering and Manufacturing Development (6.5), responsibility for development shifts from ONR to acquisition commands.

Approved FNC products have Technology Transition Agreements to document the commitment of the resource sponsor, acquisition program, and ONR to develop, deliver and integrate products into new or upgraded systems. Every product is measured by technical and financial milestones. All products must meet required transition commitment levels for S&T development to continue.

Products that no longer have viable transition paths are terminated with residual funding used to solve problems with existing projects, or start new projects in compliance with Navy priorities, charters, business rules and development guidelines. The measure of success is whether projects meet technology requirements and exit criteria, and whether acquisition sponsors have transition funds in programs to accept and integrate FNC products. The transition status of FNC products is monitored annually, with products terminated if the S&T is failing or the transition plan is no longer viable. For FY 2014, 244 FNC products completed development (a success rate of 87%), with 37 FNC products terminated before completion.

Results are evaluated by a Transition Review Board (TRB) consisting of Naval Reserve Officers representing Requirements, Acquisition and S&T communities. The TRB provides an objective, independent assessment of FNC products after successful transition or termination, analyzing the causes and residual value of unsuccessful transitions and deployments. Even in case of products which do not deploy, there is significant residual value in technology that can be leveraged for follow-on S&T efforts and made available for future transitions. Examples of FNC products include installation on the fifth Littoral Combat Ship (LCS) of high-power density waterjets designed to prevent rudder and propeller damage experienced on high-speed ships, and development of the High Velocity Projectile (HVP) for Electromagnetic Railgun (EMRG).

Quick Reaction S&T

ONR maintains quick-reaction capability for projects lasting 12-24 months that respond to immediate requirements identified by Fleet/Force or Naval leadership. TechSolutions provides short-term solutions to immediate operational and tactical requirements. Accessible via Internet and SIPRnet, TechSolutions accepts recommendations from Sailors and Marines about ways to improve mission effectiveness through the application of technology. TechSolutions uses rapid prototyping to meet specific requirements, with each project structured around definable metrics, and appropriate acquisition/test systems by integrated product teams. While neither a substitute for the acquisition process, nor a replacement for systems commands, TechSolutions prototypes deliver solutions to address immediate needs that can be easily transitioned to the Fleet/Force.

Technology development often occurs faster than DoD Planning, Programming, Budgeting and Execution (PPBE) can respond. Our Technology Insertion for Program Savings (TIPS) program provides current-year funding (inside the PPBE process), eliminating time lag in the PPBE cycle. TIPS provides up to $2 million for development efforts taking no more than two years, coupled with Fleet/Force support and resource sponsor commitment to fund moving the technology into the acquisition Program of Record (POR) or operating system. TIPS focuses on improvements that substantially reduce operating and support costs for warfighting systems.

In partnership with ONR, Naval Warfare Development Command (NWDC), Naval Postgraduate School, Naval War College and Marine Corps Warfighting Lab (MCWL) assess new warfighting concepts and technologies. Initiatives in support of our maritime strategy are applied, tested, analyzed and refined through war games, exercises, experiments and operational lessons learned.

S&T Highlights

The Naval S&T portfolio includes a range of projects and programs entering or about to enter the Fleet/Force. Examples follow (unless otherwise noted as INPs, most of these efforts originate through the FNC process).

Expeditionary Maneuver Warfare and Combating Terrorism

As the nation's crisis response force, Marines move quickly into unknown environments using the combined strength of the Marine Air-Ground Task Force (MAGTF). The S&T to support these challenges addresses the very unique aspects of operating forward with limited resources. ONR's key contribution to the Marines is executed through development of an S&T portfolio in Expeditionary Maneuver Warfare. Marine expeditionary forces must have an agile, smart, lethal and dominant technology advantage whenever and wherever necessary. With Marines forward-deployed, forward-based, and right-sized to respond to missions across a spectrum of operations from combat to Humanitarian Assistance and Disaster Relief, we need a middleweight force to launch from the sea and project power in anti-access, area-denial (A2/AD) environments.

Expeditionary warfare S&T is directed at unique challenges in communications and cyber issues at the tactical edge. Marines working at the tactical edge face challenges that require different S&T approaches to provide the small unit, distributed, expeditionary warfighter the information they need when and wherever they need it. This environment is challenging – and the ability to reach back for national assets can be limiting. Our efforts focus on tactical networking and the ability to manage a secure mobile network with little supporting infrastructure. We support S&T to develop and apply metrics that provide the most resilient and stable network structure, as well as methods of multilayer device security. Another challenge is to provide autonomous methods to optimize information discovery and delivery requirements in a heterogeneous network of audio, video, and text devices. This includes both hardware and software that small units need to operate. Small unit technology goals include reducing size, weight and power – while providing adaptable radio frequency electronics. We support technology to provide radio architectures that can quickly change between waveforms, and simultaneously transmit and receive more than one waveform. This work is defining a new regime of cyber at the tactical edge supporting research that will allow Marines to operate in cyberspace from any location with any infrastructure. As we increase technical capabilities in these areas, we envision a future where not only do we have complete knowledge of our operating area – but also an ability to coordinate weapons resources from any place at any time in support of forward operations.

In addition, we are working to provide new autonomous capabilities to the warfighter. Our expeditionary warfare S&T portfolio focuses on the difficult challenges of unmanned systems operating in a cluttered off-road ground environment. We continue to support development of dynamic perception systems to provide human-like awareness of situations and the environment. Human/machine interface continues to be a pressing research challenge. Our efforts continue to improve understanding of how to link high-level reasoning systems to the robotic control system so unmanned systems can deal with ambiguous data. For autonomous support of expeditionary troops, we are exploring the rapid launch of numerous unmanned air vehicles in heterogeneous swarms – programmed for multiple missions and distributed over the battlefield to support our men and women on the ground. This work in autonomy and unmanned systems continues to provide options for new warfighter capabilities. Our research also addresses technologies to

counter the threat of unmanned systems to our forces. In addition, we are exploring ways to bring directed energy capabilities to our ground forces. Size, weight and power requirements, along with the ability to operate on the move over varied terrain, provide unique challenges in development of lasers, electronics and stabilization.

Lightening the load for individual Marines and the Marine Air-Ground Task Force is critical, requiring technologies to enhance speed, agility and range; improve materials for body armor, helmets, and eye protection; and improve personal survivability by lessening vulnerability to Improvised Explosive Devices (IEDs) and mines. This includes vehicular stability and rollover mitigation to improve crew and platform survivability, and enhanced Medium Tactical Vehicle Replacement fuel efficiency – which reduces the number of vehicles and personnel involved in convoys. This extends operational reach, while saving untold lives and millions of dollars over the life cycle of these vehicles. In addition, we are building the ability to detect and avoid or neutralize explosive hazards at convoy speeds.

In the near-term, ONR continues to develop sensor systems to detect and track low level entities in urban clutter, improve situational awareness, enhance real time tactical decision making, as well as provide over-the-horizon, beyond line-of-sight, restricted environment communications. A long-term goal is to develop counter-tactical surveillance and targeting to remove the threat of direct-fire weapons. All this depends on our ability to develop robust communications ranging from direct peer-to-peer information exchange to providing the equivalent of commercial cellular network services across entire expeditionary environments. Automation of intelligence analysis, including automated indications and warnings, is a critical component of this effort. Every step we take down this path lightens the informational load for the individual Marine, while allowing them to increase the tempo of the intelligence cycle, enable a quicker and deeper understanding of the battlespace, and survive the brutal environment of combat.

We continue to explore technologies to provide autonomous logistics, and enhance fuel, water and maintenance self-sufficiency. On-demand, reduced logistics enable high operational tempo, and allows the Corps to out-maneuver and dominate any enemy. We are working to improve

packaging, provide autonomous material handling and shipping, utilize unmanned aerial system transportation when optimal, and provide small unit energy storage, as well as water purification. All this is dependent on logistics and transportation planning software, web based services that provide in-transit/total-asset visibility, and data integration from the command post and Sea Base all the way out to the tactical edge of the expeditionary force. There is a lot more going on here than loading a pallet.

Whether loading a pallet or building combat teams, ONR makes Human Performance, Training and Education investments to solve problems ranging from understanding individual functional movements to help reduce musculoskeletal injuries – to developing a training framework for the USMC Training and Education Command to maximize learning and skill acquisition at minimal cost. In these efforts, we work directly with the Marine Corps Warfighting Laboratory (MCWL) at Quantico, whose mission is to use war-games, experimentation, and technology assessment to validate a concept's viability – as well as identify opportunities for future force development.

Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR)

The proliferation of anti-access, area-denial (A2/AD) capabilities among potential adversaries drives the need for technologies that assure access for Naval forces. We have a requirement to project power despite A2/AD challenges and provide information dominance to the warfighter. Improved decision making is central to information dominance. We need highly flexible, open architecture, information and decision making capability with applications enabling operational and tactical forces to function with the same information across all warfare and mission areas. Information gathering and analysis will be largely automated and autonomously controlled so warfighters have more time to make decisions and execute plans. We are developing Electronic Warfare, Information Operations, Radar, Satellite, and Line of Sight Communications using: 1) open architecture Radio Frequency (RF) hardware/software to enable a broad industrial base to contribute to development of affordable systems, and 2) modular systems to enable technology to be scalable across platforms and reduce logistics, training, and maintenance costs.

The Navy must be able to access any domain – and possess the mix of kinetic and non-kinetic weapons necessary to prevail today and tomorrow. S&T improves our reach across all domains by enhancing C4ISR capabilities through development of new, more capable sensors, networks, and weapons. This can expand the role of small surface combatants and reconfigurable support ships by providing capabilities employed across the full spectrum of conflict. Reducing demand for large surface combatants and amphibious ships allows commanders to deploy adaptive force packages suitable to changing mission requirements. S&T enhances our ability to maneuver in the electromagnetic spectrum by providing our ships with better capabilities to intercept signals, conduct information warfare, and use jamming and deception to counter anti-ship missiles. We are aligning Navy networks with a more defensible DoD Joint Information Environment through installation of Consolidated Afloat Networks and Enterprise Services (CANES) on combatants and at Maritime Operation Centers, implementing Next Generation Enterprise Network (NGEN) ashore, and consolidating data centers. We are also establishing Navy "CYBERSAFE" authority to manage cyber security of networks, platforms, and systems.

ONR is developing Naval Tactical Cloud to enhance decision making in A2/AD environments. This includes the underlying information infrastructure as well as data analytics. ONR will transition technologies developed by Naval Tactical Cloud to the relevant Navy Programs of Record (POR), including CANES, Afloat Core Services (ACS), and the Distributed Common Ground System-Navy (DCGS-N). A key to Information Dominance is Cyber. In particular, understanding the interconnected cyber platforms and cyber security is essential to develop technologies that will enable cyber resiliency for mission assurance. ONR is developing S&T foundations for resilient cyber components, systems and platforms; trusted network, data, and computing infrastructure; and computer network defense.

The CNO called for the Naval Enterprise to develop a framework for electromagnetic maneuver warfare that will make spectrum an integral part of a strategy to deter, fight and win against near peer adversaries. This framework will bring together multiple functional elements in the domain of electro-magnetics: awareness, agility, reasoning and control. This will enable the commander to understand, utilize, shape, maneuver, attack and defend the electromagnetic spectrum.

Electromagnetic Maneuver Warfare (EMW) is a new warfighting concept necessitated by the emerging technologies that are enabling new capabilities in cyber and spectrum domains. ONR is developing S&T building blocks to support CNO's EMW vision: sensing, communications, electronic warfare, and in particular, machine learning and reasoning for integrated electromagnetic maneuver command and control across warfare and mission areas. The end state is one in which we provide commanders with multiple EMW options to meet objectives, including abilities to disrupt, destroy, deceive, degrade, deny and exploit adversarial systems.

Ocean Battlespace Sensing

Naval forces must be able to adapt to ocean, air, littoral and riverine environments. Changes in climate conditions create an emerging need for more accurate, long range forecasts for DoD and Naval operations. In the National Oceanographic Partnership Program, along with Air Force, Department of Energy, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and National Science Foundation, ONR invests in S&T to provide mobile autonomous environment sensing, match predictive capability to tactical requirements, develop systems that adapt to environmental variability, and integrate atmospheric and ocean models to enable better forecasts. S&T will improve understanding of surface wind impact on upper ocean dynamics and energy fluxes across ocean boundary layers, increase knowledge of Arctic environments, and enhance our ability to forecast operational conditions. The payoff is more safe and efficient Naval operations in maritime environments through improved immediate, seasonal, and long range forecasts. ONR's research is field-oriented, using oceanographic ships, aircraft, and autonomous air and undersea vehicles – including Navy-owned University-National Oceanographic Laboratory System (UNOLS) Ocean Class Research Vessels that ONR schedules and supports in partnership with NSF.

Contributing to our ability to understand and prevail in ocean environments, Navy operates several classes of Unmanned Underwater Vehicles (UUVs). ONR has invested in UUVs for several decades, with successful transitions to the acquisition community and Fleet in the areas of Naval Special Warfare, Mine Countermeasures, Explosive Ordnance Disposal, Intelligence, Surveillance and Reconnaissance (ISR), Anti-Submarine Warfare (ASW), and Oceanography.

These systems generally fall into three classes: Man-portable, Lightweight, and Heavyweight, with corresponding displacement and endurance.

In 2010, OPNAV N2/N6 (Navy's lead office for Information Dominance and CNO's designated lead for unmanned systems development) and ONR developed plans for a fourth class of UUVs, designated Large Displacement, to address new requirements. The plan delegates development of the Program of Record (PoR) to N2/N6, with ONR contributing technical risk reduction in autonomy and endurance (Power/Energy). As an INP, ONR will design and build five Large Displacement Unmanned Underwater Vehicles (LDUUVs) (two preliminary designs, two pier-to-pier vehicles, one submarine compatible vehicle).

The program is developing energy, autonomy and core systems to operate in a complex ocean environment near harbors, shorelines, and other high traffic locations. Goals include doubling air-independent UUV energy density, using open architecture to lower cost, and enabling pier to pier autonomy in over-the-horizon operations. Achieving these goals will reduce platform vulnerability, enhance capability and safety, and close gaps in critical, complex mission areas by extending the Navy's reach into denied areas. With respect to Power and Energy, for example, we are developing a long endurance, fuel cell-based power plant to be incorporated into LDUUV prototypes. Efficient fuel cell technologies will extend mission duration beyond 60 days, well beyond currently projected battery capabilities – with a demonstration scheduled in FY 2016.

While ONR LDUUV INP vehicles are not PoR LDUUVs, ONR will transfer the technology and some demo vehicles from the INP effort to the LDUUV PoR. The INP vehicles will conduct demonstrations and exercises to develop Tactics, Techniques, and Procedures (TTPs) for Fleet use. As part of the LDUUV plan, the Navy will use an existing UUV detachment to form an operational UUV Squadron. The squadron will be part of Submarine Development Squadron (DEVRON) 5 in Bangor, Washington, allowing development of TTPs by Fleet operators several years ahead of LDUUV PoR vehicle deliveries. This will help smooth transition to the Fleet.

In the case of S&T and Acquisition, current UUVs have been developed through acquisition programs where contractors design and build UUVs based on performance specifications issued by the Navy. As a result, there is a mature, competitive private sector industrial base for design, development, and maintenance of UUVs and associated sensors and payloads. The exception to this is ONR's technical risk reduction in endurance and autonomy, where there is no analogous commercial requirement. UUV maintenance and support is usually performed by Naval Surface and Undersea Warfare Center personnel except when overhaul is required. For overhaul, assets are often transferred to a private sector Original Equipment Manufacturer facility. Maintenance and support of UUVs requires special skills due to reliance on advanced technology R&D, and include autonomy, composites, software testing, high-density power and energy, integration of unique payloads, and microelectronics. For example, primary materials in ONR LDUUVs are fiberglass and carbon fiber, with a free-flood, modular design structure – in contrast to dry interior, high strength steel-hull submarines with which Naval shipyards have experience.

Sea Warfare and Weapons

ONR's major focus in this area is to improve air, surface, and undersea weapon performance. S&T investments provide options for advanced electrical systems, components, and survivable, agile, mobile, sustainable, manned and unmanned, surface and sub-surface sea platforms, and undersea weapons. Our Electric Ship Research and Development Consortium enlists academic institutions to develop electric power architectures and technologies for high power sensors and weapons, including directed energy weapons. ONR's undersea vehicle S&T includes R&D and deployment of long-endurance, air-independent power systems for unmanned undersea vehicles (UUVs). A key enabler of these capabilities is investment in naval materials. Investments focus on performance and affordability of materials for lightweight structures, corrosion and biofouling mitigation, maintenance cost-reduction, undersea acoustics, and energy/power-dense electrical energy conversion and storage. These efforts explore and apply fundamental materials physics to discover and develop materials meeting warfighting platform demands – such as investment in Integrated Computational Materials Engineering, a key element of the Lightweight and Modern Metals Manufacturing Initiative.

One of the most critical objectives for modern warfighting is to reduce the burden of weight on weapons systems and warfighters. This includes the development of resins, fiber architectures and additives that increase strength and durability of composite structures and structural metals. Well-designed composite structures can improve ship and vehicle strength, reduce weight, and increase fuel efficiency. This translates into faster ships and vehicles, with longer operational range, reduced acoustic/Electro-Magnetic/thermal signatures, and reduced total ownership costs.

New structural alloys face tremendous barriers to application driven largely by a lack of design guides and certifications, as well as cost and scale-up challenges. Accelerating time to market and fully leveraging these new materials requires an integrated approach. Design of the material and associated manufacturing processes for targeted components must be an integral element of system design and development. Using integrated computational materials engineering (ICME) (integrating materials information from computational tools, engineering product performance analysis and manufacturing-process simulation) enables halving overall time and cost needed to design new alloys, processing, and manufacturing into commercially viable components and systems. Further, application of ICME requires focus on specific components and performance metrics early in the project cycle, bringing industrial partners when projects are first formulated and increasing the likelihood of technology adoption.

To achieve these goals, ONR is leading the DoD Lightweight and Modern Metals Innovation Institute (LM3II). LM3II is part of the National Network for Manufacturing Innovation (NNMI) partnership between the Departments of Commerce, Defense, Education, and Energy; National Aeronautics and Space Administration and National Science Foundation. LM3II's focus is on taking a systems-level approach to the design and manufacturing of lightweight components and structures for enhanced system performance, greater energy efficiency, and lower life-cycle cost. LM3II will demonstrate advanced manufacturing capabilities to enable lightweight, reliable, survivable, fuel efficient, affordable, flexible systems for defense products. The computational tools, capabilities, workforce, and infrastructure can be expanded and applied to other products in the defense and commercial sectors. Long-term goals are to create and expand markets for lightweight products, and build partnerships with automotive, aerospace, energy, defense, and

recreational equipment industries that enable maturation and scale-up of modern metals. This will help to maintain global cost competitiveness for American industries, and technological leadership for national security.

As a public/private partnership, LM3II technical priorities originate with assessments of manufacturing technology, workforce, and economic development requirements by industry. LM3II develops priorities based on input from industry, academic and government partners to develop a portfolio to impact both core industry partners and the broader community. The R&D portfolio includes pre-competitive defense and commercial technologies, proprietary commercial development, provides small-to-medium enterprises access to broader technology and partners, and supports the start-up of new companies.

Warfighter Performance

People are the critical element in complex systems. They provide the ingenuity, collaboration, and determination necessary for operational effectiveness and resilience. Warfighter Performance S&T addresses a broad range of research questions and technology transitions that support Sailors and Marines afloat and ashore. These research areas include manpower, personnel, training and design approaches to enhance performance while reducing costs.

Advances in behavioral sciences, medical technologies, and modeling and simulation techniques are enabling new approaches to mission-critical questions such as: How do we train effectively, efficiently reducing the time and cost of pre-deployment training? How do we design intuitive systems that are easy to use, reducing the requirement for on-the-job training? How do we support decision making in distributed teams of people and autonomous agents? How do we mitigate the risks of putting our warfighters in harm's way, keeping them healthy and ready to fight? Can we avoid costs by looking at the trade space between people and technology in acquisition and operations?

Manpower and personnel simulations can help us design crew complements for new ships across a broad range of missions. Artificially intelligent tutoring systems can help new recruits learn

basic skills, while adaptive simulation-based training systems tailor training to the needs of individual Sailors and Marines. Immersive and augmented reality displays provide experiential learning opportunities using simulation to train as we fight. Automated performance assessment techniques enable instructors to evaluate readiness at the individual and team level and to focus their efforts efficiently and effectively on the knowledge and skills gaps of the individual warfighters where it's needed.

Mission scenario generation, distributed network simulations, and the advent of artificially intelligent forces can provide the capability for integrated fleet training exercises that extend the training ranges virtually and let students take risks not possible with live assets while reducing the logistical costs of large training exercises. Live, virtual, and constructive training exploits the benefits of real-world platforms and operators interacting with networked simulators and computer-synthesized forces to train on multiple platforms on multiple simultaneous missions. Scenario generation capabilities are becoming so realistic that planners can develop and evaluate new tactics, techniques, procedures, and concepts in simulation.

Intuitive, decision-centric, and user-friendly interfaces and decision support displays can reduce training requirements and associated costs while enabling more effective operational capability. Human-centered design enhances tactical, operational, and strategic decision making and planning. A deeper understanding of human intelligence, communication, and collaboration will enable better team performance and, ultimately, support peer-to-peer collaboration between human and artificially intelligent machines. Models of human social and cultural behavior will help defeat our adversaries and set the stage for more effective humanitarian assistance and disaster relief.

Medical technologies are needed to mitigate warfighter risk at sea, in the air, and in austere isolated environments. Medical modeling and simulation enables improvements in personal protective equipment such as body armor and hearing protection. Closed-loop medical monitoring and control systems can be a force multiplier for the hospital corpsman and field

surgeons who may be treating multiple casualties or evacuating Sailors and Marines long distances from the field to a Sea Base.

Naval Air Warfare and Weapons

ONR's Naval Air Warfare goal is to develop, demonstrate and transition technologies to expand Naval weapon system stand-off ranges and reduce engagement timelines to enable rapid, precise, assured defeat of moving land, sea and air targets. We invest in S&T to develop propulsion for high speed weapons requiring technologies associated with high acceleration, high temperature, and high strength materials. Development and ship integration of energy-intensive systems such as Directed Energy Weapons (DEW) and the Electromagnetic Railgun (EMRG) requires careful engineering. Ship integration considerations include space, weight, power, cooling, and stability, impact on combat systems, fire control, and interfaces. Technical maturity and integration will be accomplished through a measured allocation of ship services and interface with ship systems. Navy's near-term focus is on a Solid State Laser Quick Reaction Capability (SSL-QRC), which fielded the prototype system based on the Laser Weapon System (LaWS) aboard USS PONCE – and the Solid State Laser Technology Maturation (SSL-TM) program.

During a recent visit to Naval Surface Warfare Center, Dahlgren, the CNO called Railgun "our future surface weapon". This comment reflects his enthusiasm for the installation of Railgun aboard Navy surface combatants. In 2005, ONR initiated the first phase of a Railgun INP that quadrupled muzzle energy compared to previous guns, extended barrel life from single shots to hundreds of shots, demonstrated full-scale prototype launchers, developed reliable pulsed power technology with greater energy density, and began work on projectile component risk reduction. Maturation of technology was matched by growth in the mission for a Railgun weapon system. In addition to providing naval surface fire support, potential Railgun missions now include anti-air and anti-surface warfare – making Railgun a cost-effective, multi-mission weapon system.

The second phase of Railgun development began in 2012 to demonstrate an increase in barrel life while operating at a tactical firing rate. The shift from manual-loading operations to a firing rate of several rounds per minute requires an autoloader and thermally managed barrel, pulsed

power with active cooling, improved energy density, and modular packaging, and battery energy storage, also with active cooling. A national team has been assembled to accomplish these goals: Navy labs (Naval Surface Warfare Center Dahlgren, Carderock Division, and NRL), Army labs (Army Research Laboratory, Benet Labs, Fort Bliss, and Redstone Arsenal), Department of Energy labs (Sandia, Lawrence Livermore), Johns Hopkins Applied Physics Laboratory, contractors (BAE, General Atomics, Raytheon, L3), small businesses, and academia.

While Railgun INP focuses on barrel life and pulsed power development, three related programs, building on the success of and working in concert with the INP, contributed additional resources to develop other system components. The Hypervelocity Projectile program began development of a modular, precision-guided projectile (kinetic energy warhead) for Railgun that is compatible with Navy 5-inch guns. The Hypervelocity Projectile will have an aerodynamic flight body with thermal protection, a kinetic-energy-based warhead, and guidance electronics packaged to match internal space limits and survive high-g launch acceleration. Navy partnered with the Office of the Secretary of Defense Strategic Capabilities Office (SCO) to develop closed-loop fire control command guidance for the projectile, and a full-motion gun mount for land and sea use.

NAVSEA is executive agent for both land and sea based applications. NAVSEA-led systems engineering efforts and ship integration studies established feasibility of ship-board installations. The Navy's Sea Base program is contributing to mount design and will conduct demonstrations aboard a Joint High Speed Vessel (JHSV) utilizing components largely in common with those developed at Dahlgren. The JHSV's wide flight deck and large cargo bay will support the 2016 demonstration with only minor ship modification. These tests will provide risk reduction for the integrated common Railgun development approach, beginning in FY 2016 with manually loaded Railgun firing of a guided projectile. In 2019, we plan to do automated Railgun firing of guided HVPs against representative land and air targets for test purposes. At-sea tests are critical to gather data to support design reliability related to operation in marine environments, demonstrate multi-mission capability, and capture lessons for incorporation into full tactical design, allowing us to understand potential modifications before fully integrating the technology on ships. These

programs have an integrated schedule and organizational structure to leverage common elements and reduce risk and engineering costs.

Science, Technology, Engineering and Mathematics (STEM)

None of our achievements would be possible without our Science, Technology, Engineering and Mathematics (STEM) workforce. One reason workforce development is so important is because our STEM workforce is aging. Half of our science and engineering professionals are retirement eligible by 2020, with acute shortfalls in engineering, computer science and ocean engineering. We must rely on U.S. citizens for classified work, but the number of American citizen STEM graduates will not keep up with domestic or international competition for these workers. ONR evaluates Navy STEM investments with metrics measuring number of students, teachers, overall impact, and ability to meet Navy requirements in coordination with other STEM programs.

Navy support for STEM education is focused on long term health of the acquisition enterprise, our ability to sustain technological superiority, and the economic well-being of our nation. DoD and our industrial base partners are already active in promoting STEM education. This includes financial and institutional support, as well as volunteer work. While efforts to encourage young people to pursue STEM careers may seem far away from immediate national security concerns, in the long run our society and military are highly dependent on our ability to encourage students to enter and remain in technical career fields.

It cannot be emphasized enough that people are our greatest resource. STEM may be just the beginning in terms of education and academics, but it does not end there. STEM is the great multiplier of discovery, invention and innovation. While most of us are familiar with concepts such as the spiral development of weapon systems, we need to place greater emphasis on the manner in which intellectual capital is a similar force multiplier. Great people generate ideas, and new ideas generate greater new ideas. This generates exponential growth in intellectual capital and translates directly into a more capable S&T and R&D workforce. There is no more valuable investment we can make in Naval S&T than in the minds of our workforce, investments that result in greater productivity and innovation throughout Navy laboratories, warfare centers,

and in the academic and private sector. As people who work in these facilities and institutions move from place to place throughout their STEM careers, the Navy, the nation, and our Naval Research Enterprise partners, along with the Army, Air Force, Defense Advanced Research Projects Agency, and others government entities such as National Science Foundation and Departments of Energy and Homeland Security, benefit from their expertise and ability.

Naval Research Laboratory (NRL)

The Naval Research Laboratory (NRL) is the Navy and Marine Corps Corporate Laboratory and reports by law directly to CNR/ONR. Sponsored by ONR, the NRL base research program develops S&T to meet needs identified in the Naval S&T Strategic Plan. Research at NRL is the foundation that can focus on a broad spectrum of scientific areas to advance scientific understanding for DoN, and develops technology from concept to operation when high-priority, short-term needs arise. NRL is the lead Navy lab for space systems, firefighting, tactical electronic warfare, advanced electronics and artificial intelligence. As the Navy's in-house laboratory, NRL sustains skills and innovation in a world-class workforce. Among our great challenges is to modernize aging NRL infrastructure so it can continue to meet the emerging needs of our future Naval forces. This is especially important as the pace of S&T advancement accelerates rapidly across the rest of the world, and near peer competitors begin to arise, challenging our Naval superiority.

ONR Global

ONR recognizes that all sources of technical innovation are not located in the U. S. and works to improve technology outreach through global partners who assist in our pursuit of innovation and technological superiority. Investment in cooperative research can provide better products for our warfighters at reduced cost. ONR offices in London, Prague, Santiago, Sao Paulo, Singapore, and Tokyo coordinate activities with the other services and Assistant Secretary of Defense (Research and Engineering). We search for emerging S&T to meet current needs, as well as requirements for future capabilities. ONR Global establishes contacts with international S&T leaders, giving us new perspectives and helping identify trends and threats. It enables us to recruit foreign scientists and engineers in partnerships that benefit the U.S. and allies. ONR

Global Science Advisors relay Fleet/Force needs to the Naval Research Enterprise (Navy labs, warfare centers, affiliated universities) to facilitate development of solutions to transition back to the Fleet/Force. Participants include Naval engineers who coordinate experimentation, develop prototypes, explore transition options, and collaborate with the Fleet/Force to shape S&T investments. Our International Science Program gives U.S. scientists from academia, government and industry opportunities to engage and work with their international counterparts.

How We Do Business

Our processes and our people directly impact how we do business. DoD's Better Buying Power (BBP) initiative, led by Under Secretary of Defense for Acquisition, Technology and Logistics Frank Kendall, is based on the concept that continuous improvement is the best way to enhance performance of defense acquisition. Secretary Kendall's emphasis on achieving dominant capabilities through innovation and technical excellence dovetails perfectly with Navy's S&T, R&D and acquisition goals. They go together. Navy S&T acquisition professionals need to listen more carefully to feedback from industry and government. We need to get smarter about how to encourage innovation and technical excellence – with the overarching goal of ensuring that the Fleet/Force has dominant capabilities to meet national security requirements.

There is growing concern that U. S. technological superiority over potential adversaries is being threatened in ways we have not seen for decades. Our military depends on many capabilities that originated in the 1970s and 1980s. Although those capabilities have been enhanced and upgraded, many have not fundamentally changed. In addition, precision munitions, wide area surveillance, networked forces, and stealth technology all depend on a relatively small number of high value assets and platforms in space, on land, and at sea. Adversaries have had decades to develop tactics and systems designed to defeat U. S. forces. At the same time there has been a global leveling in the state of technology. Commercial technologies with military applications such as advanced computing, microelectronics, sophisticated sensors, and advanced materials, are widely available – but global information networks make protection of technical information more difficult, a fact that adversaries are doing their best to exploit.

The scope and complexity of defense acquisition means there are no simple solutions to the challenges we face: no set of rules tells us all we need to know. Acquisition professionals must be able to think on many levels, integrate data from many perspectives, balance competing needs, and satisfy many different stakeholders and customers. Our focus cannot stop with controlling cost, critical thinking and sound professional management, but must always look toward products we provide to the warfighters who depend on us to give them dominant battlefield capabilities. We must learn to be innovative and realistic in order to more consistently achieve affordable programs by forcing ourselves to do a better job of assessing whether a product can be afforded in future budgets – before the program begins. We need to analyze affordability gaps with the same scrutiny and rigor we devote to capability gaps. We must ask if we can sustain production while living within affordability caps, and control life cycle costs by improving our ability to understand cost structures, identify goals for cost reduction, and actually achieve the reductions.

We need to remove barriers to use of commercial technology. Some commercial technologies with military utility are advancing faster than comparable military technologies. However, for a variety of reasons many firms choose not to do business with the Navy or our prime contractors. Navy needs to understand these business barriers and find ways to reduce or remove them. This requires consultation with all our stakeholders to identify how we can improve communication between industry and government so both can be more productive. For example, both industry and government benefit from long-range planning, prototyping and experimentation, exploring innovative operational concepts, and preserving design teams. Current budget constraints are accompanied by high operational demands, international turmoil, the threat of extremist groups, and uncertainty about future spending – but allocating resources to sustain industry/government partnerships is a goal worth pursuing.

Technology insertion in program planning emphasizes both the supply of S&T projects and the demand of acquisition programs. Due to the pace at which technology associated with digital processing, radio frequency devices, optics, and networks is moving, Navy cannot continue using traditional acquisition approaches. Acquisition plans must allow much faster technology refresh cycles. In some cases we may completely replace earlier products, while in others we must plan

and design for periodic upgrades, even while development is still in progress. We must ensure that S&T and R&D investments are aligned as much as possible with insertion opportunities in products we acquire. This requires closer links between S&T and acquisition programs. ONR's late department director, Dr. Bobby Junker, was a national leader in advocacy of open systems architecture to stimulate innovation. This is closely related to designing for technology insertion, and ensures competitive sources have opportunities to provide superior products as components or subsystems to larger programs. We have pursued this goal with varying degrees of success, but must do an even better job of ensuring that our designs are modular – and government is in position to control all relevant interfaces so that competitors have an opportunity to win their way into Navy programs. This design feature has sometimes been traded away because of competing requirements, or lost because we failed to secure control and ownership of necessary interfaces – including those required for software integration.

We must increase the return on investment in Small Business Innovation Research (SBIR). ONR's SBIR program has had success helping small businesses make progress in technology development, but we must do a better job of helping small businesses transition from S&T and development to production. Small businesses remain one of Navy's most productive sources of innovation. Active oversight and management of SBIR goals, utilizing marketing, metrics, and improved communications, will ensure that Navy is more aware of small business capabilities – and that small businesses are more aware of Navy requirements. We need to utilize small businesses to the maximum extent possible, and are already doing so in areas as diverse as development and construction of combat ships and landing vessels, design and manufacture of airframe structural components, engineering and technical support, marine charter transportation, and non-nuclear ship repair. When we say Navy is open for business, it includes small business.

At the beginning of this year, ASN-RDA Sean Stackley reiterated the Navy's commitment to fostering a healthy small business industrial base because of the contributions small businesses make to the success and affordability of Navy programs and national security. He noted the overwhelming evidence that small businesses create more affordable outcomes and promote innovation and technical advancement. Both he and I want to continue the Navy's success in

meeting small business goals throughout the coming year. This effort will require program offices and purchasing commands to solidify and broaden the Navy application of contracting strategies that actively, directly engage small businesses in meeting program requirements. This is not just a matter of achieving program goals, but institutionalizing small business participation as prime contractors and sub-contracting partners at every level of every contract. I assure you that we engineers, not to mention scientists, demand to see measureable performance objectives when we set out to achieve a goal. In Secretary Stackley's words, "While the Navy leads DoD in SBIR and Small Business Technology Transfer (STTR) efforts, more deliberate stewardship of each phase of the program would lead to improved SBIR Phase III transitions and thus, greater return on investment from Navy R&D." I intend to help the Navy achieve this goal, which will be emphasized and achieved, in part, by designating each Deputy Program Manager as the Small Business Advocate responsible to identify opportunities for small business participation, and serving as technical point of contact for interested small businesses.

Conclusion

The FY 2016 President's Budget request will enable us to move toward enhanced capabilities, more effective partnership between research and acquisition, and strengthen partnerships with the Army, Air Force, DARPA and other DoD research organizations – as well as performers outside the Naval R&D system. Our S&T investments represent careful stewardship of taxpayer dollars that will achieve these goals, as well as significantly enhance the safety and performance of warfighters as they serve in defense of the United States. Thank you for your support.