Testimony

Before the Senate Appropriations Subcommittee on Defense

Witness Statement of

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NOT FOR PUBLICATION UNTIL RELEASED BY THE SUBCOMMITTEE

Chairman Cochran, Vice Chairman Durbin and distinguished members of the subcommittee, we appreciate the opportunity to testify today. I am joined here by Mr. Stephen Welby, Assistant Secretary for Research and Engineering; and Dr. Arati Prabhakar, Director of the Defense Advanced Research Projects Agency. Scientists and engineers from across the department's Research and Development (R&D) organizations work very hard every day to advance our nation's defense technologies. The Department's current focus on technical innovation reflects our belief that maintaining our technological superiority is critical to the future security of the United States and our allies. Our technological superiority directly correlates with a healthy and robust industrial base, stable and adequate budgets, sound technology investment decisions, and an effective defense acquisition system. We look forward to the opportunity to discuss the Department's progress in each of these areas, and our roles in leading and managing the Department of Defense (DoD) Technology Innovation efforts.

This written testimony includes a summary of the continuous improvement being made across the Defense Acquisition enterprise under the Better Buying Power 3.0 initiatives, which are focused on innovation and technical excellence. We also provide an overview of the Research, Development, Technology and Engineering (RDT&E) investments promulgated by the Assistant Secretary for Research and Engineering (ASD(R&E)), and a short summary of many of the programs being pursued by the Director, Defense Advanced Research Projects Agency (DARPA). All of these efforts are integral parts of a larger whole and contribute to the Defense Innovation Initiative, which was originally announced in 2014 by Secretary Hagel, and which has been expanded upon and strengthened by Secretary Carter and Deputy Secretary Work through initiatives such as "Force of the Future" and "The Third Offset Strategy."

We would like to begin, however, by discussing the reason it is so crucial for our acquisition system to be more effective in addressing emerging asymmetric challenges: the risk that the United States faces today of losing its advantage in military technological superiority when measured against our nation's potential adversaries. Our first responsibility is to ensure the United States has, and will continue to have, dominant military capabilities relative to any potential adversary. We are deeply concerned about the adverse trends in maintaining U.S. military technological superiority. The department-wide focus on innovation, technical excellence, and acquisition process improvement are intended to help sustain our long-term competitive advantage and make most effective use of the resources provided by the Congress.

CHALLENGES TO PRESERVING U.S. MILITARY TECHNOLOGICAL SUPERIORITY

The United States and our allies have long enjoyed a military capability advantage over any potential adversary. The military's capabilities in precision strike weapons, stealth, wide area surveillance, and networked forces emerged from what Deputy Secretary Work has described as the second "technology offset strategy." This mix of capabilities was originally designed to counter the overwhelming quantitative advantage possessed by Warsaw Pact mechanized forces. It proved decisive when first deployed in the First Gulf War in 1991. The United States has had great success with this suite of capabilities; but the contest is never one-

sided, and any military advantages that depend on specific technologies is inevitably temporary. The globalization technology in general and the increasing ability of potential adversaries to invest in military modernization have in part leveled the playing field. Potential adversaries have taken advantage of fast-moving broadly available commercial technology—as well as on technology often acquired through cyber theft and espionage. Potential adversaries have also carefully studied the American way of war to identify weaknesses and vulnerabilities to exploit.

No nation paid more attention to the technologies and operational concepts used by the United States in the First Gulf War than China. Our intelligence estimates in the early 1990s suggested that, while China might be a concern in the future because of its accelerating economic growth, it would take 15 to 20 years for China to become a peer competitor. It is now 20 years later and the intelligence estimates were accurate. China has developed and fielded a number of advanced weapons designed to defeat U.S. power projection forces. Many more are in development. These systems include a range of capabilities, but foremost among them are accurate and sophisticated cruise and ballistic missiles designed to attack high value assets, specifically the aircraft carriers and forward bases that the United States depends on for power projection. These weapons fielded in large numbers and coupled with advanced electronic warfare (EW) systems, modern air-to-air missiles, extensive counter-space capabilities, improved undersea warfare capabilities, fifth generation fighters, and offensive cyber weapons, pose a growing and serious threat to U.S. and allied power projection forces.

China is not the only nation of concern. Russia is fielding or developing advanced systems including highly effective air defense systems, fifth generation fighters, land and surface ship attack cruise missiles, state-of-the art submarines, electronic warfare and cyber weapons. Russian doctrine, organization, and equipment are also turning toward a greater reliance on tactical nuclear weapons—a disturbing trend. Recent operations in Syria have demonstrated the effectiveness of Russian modernization efforts, enabling Russia to conduct U.S.-style power projection operations with precision weapons and sophisticated airborne capabilities. All of these modernization investments are targeted at challenging our ability to project power to deter aggression, enforce international norms and defend U.S. and allied interests. Proliferation of these capabilities to states such as Iran and North Korea also poses a national security risk for the United States and our friends and allies.

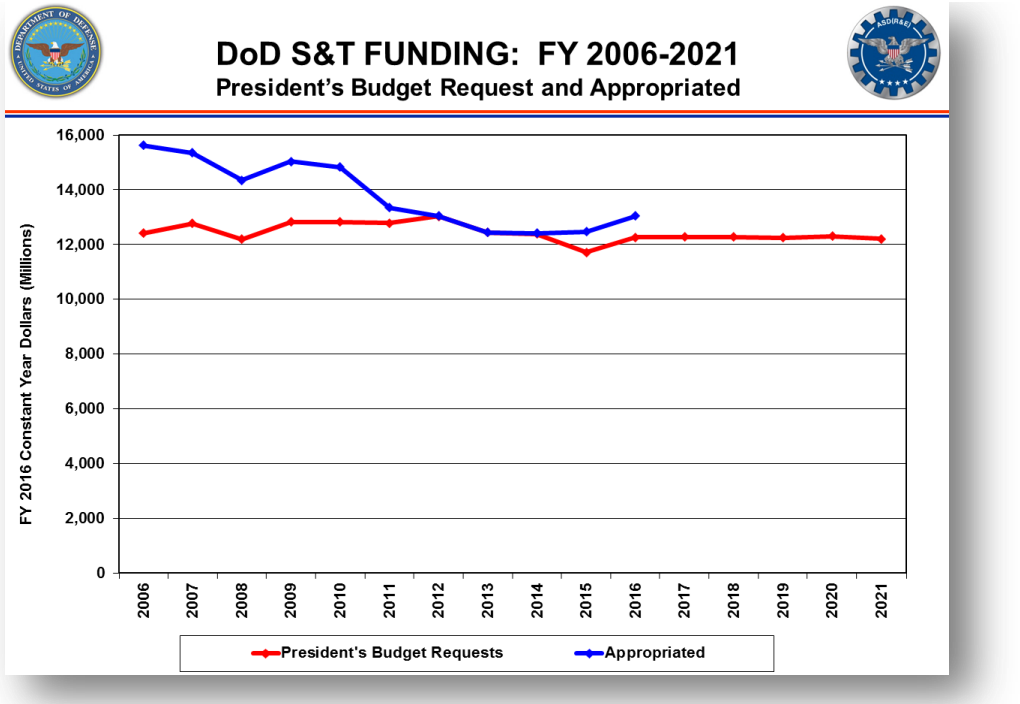
To be clear, we do not anticipate or foresee a military conflict with China or Russia. That would not be in anyone's interest. However, we also never want the United States to be in a situation of inferiority or even parity with respect to conventional military power. Regional rivalries and security dilemmas would compound, and the possibility of a conflict due to a miscalculation would increase. In addition, weapons developed by more capable powers will inevitably proliferate to more likely opponents. Iran, for example, is known to be acquiring precision missile capabilities that threaten our forces in the Persian Gulf as well as our allies and friends in the region.

DEFENSE STRATEGY REQUIRES FOCUS ON FUTURE TECHNOLOGIES

Future capabilities will be joint in nature and leverage the ability to rapidly synchronize simultaneous operations conducted in the space, air, sea, undersea, ground, and cyber domains using manned and unmanned systems. Emerging tools based on breakthroughs in artificial intelligence, autonomy, computer science, advanced electronics, communications systems, sensors, and other fields will enable new operational concepts. These concepts will support faster and more effective decision making, enable improved coordination of operations across warfighting domains, support the use of collaborative teams of manned and unmanned systems, and integrate electronic warfare and cyber operations. When fielded, these capabilities are intended to provide a "Third Offset Strategy" that will enable our forces to operate from longer ranges, with less risk to our servicemen and women, and with much higher relative effectiveness against emerging threats than current systems.

CRITICAL INVESTMENTS IN OUR FUTURE

To address these challenges, and to support the technology needs of the current force, the President's Fiscal Year 2017 budget submission continues to demonstrate strong support for sustaining a robust DoD Science and Technology (S&T) investment. The chart below depicts DoD funding over the last decade and as proposed in the current budget submission over the Future Year Defense Program.



As evidence of this commitment to a strong DoD S&T capability and capacity, the Fiscal Year 2017 budget request for S&T is $12.5 billion, 1.9 percent above the Fiscal Year 2016 budget request and 2.4 percent of the Defense topline ($524 billion). In real terms, the Fiscal Year 2017 S&T budget request is 25 percent higher than the Fiscal Year 2000 budget request of $9.8 billion. The table below details the proposed DoD S&T budget by year and breaks out investment by budget category and by S&T account.

Table 1. FY 2015 - FY 2021 Budget ($ Millions)

Program	FY 2015*	FY 2016**	FY 2017	Δ FY16-17	FY 2018	FY 2019	FY 2020	FY 2021	Total FY17-21
Basic Research (6.1)	2,277.7	2,088.9	2,101.8	12.9	2,228.3	2,268.4	2,302.6	2,329.0	11,230.2
Applied Research (6.2)	4,647.8	4,713.2	4,815.4	102.2	4,961.5	5,048.4	5,136.3	5,221.1	25,182.6
Adv Tech Dev (6.3)	5,326.3	5,464.2	5,583.5	119.3	5,565.8	5,665.1	5,860.0	5,890.9	28,565.4
TOTAL S&T	**12,251.8**	**12,266.3**	**12,500.8**	**234.4**	**12,755.7**	**12,981.8**	**13,298.8**	**13,441.1**	**64,978.1**
Army S&T	2,554.8	2,200.5	2,266.6	66.1	2,321.1	2,371.2	2,425.2	2,475.4	11,859.4
Navy S&T	2,155.3	2,114.4	2,141.1	26.7	2,168.3	2,176.3	2,205.8	2,237.6	10,929.0
Air Force S&T	2,281.7	2,378.4	2,486.0	107.6	2,571.3	2,634.2	2,756.0	2,701.5	13,148.9
Defense-Wide S&T	5,260.0	5,573.1	5,607.1	34.0	5,694.9	5,800.2	5,911.9	6,026.6	29,040.7
TOTAL	**12,251.8**	**12,266.3**	**12,500.8**	**234.4**	**12,755.7**	**12,981.8**	**13,298.8**	**13,441.1**	**64,978.1**

Source (FY2017 -FY2021): CIS 5 January 2016

** FY 2015 Enacted (base), no OCO*

*** FY 2016 President's Budget (base), no OCO*

The Department's Fiscal Year 2017 S&T budget request is aligned with DoD priorities and supports increased focused investments on the technology development and demonstration required to prepare the Department for an increasingly competitive global security environment. The Fiscal Year 2017 S&T budget request includes:

- $2.102B in Basic Research investment, which is an increase of $12.9M from the Fiscal Year 2016 budget request. Much of this investment supports the Department's engagement with academic institutions in the foundational research efforts that drive future innovation.

- $4.815B in Applied Research investment, which is an increase of $102.2M from the Fiscal Year 2016 budget request.

- $5.584B in Advanced Technology Development investment, which is an increase of $119.3M from the Fiscal Year 2016 budget request. This additional investment provides for increased emphasis on prototyping and experimentation to reduce program risk.

DRIVING VALUE TO THE WARFIGHTER THROUGH SCIENCE AND TECHNOLOGY

Over the last year we have continued to make progress strengthening both our internal capabilities and our connections to external innovation centers. Key activities of note from 2015 include:

- In 2015, the Department continued to focus efforts on developing advanced capabilities to address emerging electronic warfare (EW) challenges, to evaluate these capabilities, and to mature them for future operational adoption. One example of these efforts is the successful Vigilant Hammer experimentation campaign. Vigilant Hammer provided a cost effective, joint opportunity to explore and assess U.S. emerging capabilities to fight in a complex, congested, and agile electromagnetic spectrum. Vigilant Hammer provided the S&T community with unprecedented access to the representative dense signal environment in which U.S. systems will operate in the future.

- Navy-funded research delivered a Solid State Laser to the USS PONCE last year, successfully demonstrating destruction of surface and air targets by a directed energy weapon operating in the maritime environment. Leveraging the lessons learned from this operational demonstration, we are moving forward to mature the technology required to deploy a 150 kilowatt laser on future Navy platforms. Additionally, we will continue our ground combat laser research work with the Marine Corps Ground-Based Air Defense On-the-Move (GBAD) system, which is a vehicle-based, high-energy laser for the 21st century Marine. Directed energy will enable our naval forces to fight at the speed of light.

- Naval Tactical Cloud research is providing the framework and large-data analytics support for Navy platform cyber defense solutions such as the Resilient Hull, Mechanical, and Electrical Security system (RHIMES). RHIMES is a cyber-protection system designed to make shipboard mechanical and electrical control systems resilient to cyber-attacks. This technology is a critical warfighting enabler, ensuring assured access to critical information by keeping our Navy and Marine Corps “cyber doors locked.”

- R&D is driving the state of the art in autonomy continues to extend Naval capability in new ways. Later this year, the Navy plans to demonstrate an at-sea capability of our Low-Cost Unmanned Aerial Vehicle (UAV) Swarming Technology (LOCUST) to launch, form, control and task 30 small UAVs in an offensive swarm. The Navy will also take the next step in undersea autonomy, conducting a long endurance submerged transit test of

our hybrid fuel cell powered Large Diameter Unmanned Underwater Vehicle (LDUUV).

- Using its Rapid Innovation Process, the Air Force Research Laboratory recently developed and deployed the Long Endurance Aerial Platform (LEAP). LEAP provides a revolutionary, low-cost, low acoustic signature, persistent aerial ISR capability to address Combatant Command and U.S. Special Forces ISR gaps by converting a proven, fuel-efficient Light Sport Aircraft into an Unmanned Aerial System. The Air Force Research Laboratory completed the development and flight testing of the Spiral II design, which has a takeoff weight of 1,650 pounds with endurance of more than 30 hours, and carries a beyond-line-of-sight satellite communications, command and control data relay along with day/night imaging full motion video and radio direction finding payloads. Based on its successful testing, U.S. Special Operations Command requested, and the Office of the Under Secretary of Defense for Intelligence funded, an operational evaluation of the system in the U.S. Central Command (CENTCOM) theater of operations. In a very short period of time, the Laboratory procured the hardware for a complete system of four air vehicles and has deployed them to the field.

- The Air Force S&T Program is also working to harness new technology to demonstrate that new, advanced capabilities can be rapidly delivered in a cost effective manner. For example, the Low Cost Attritable Aircraft Technology (LCAAT) program is leveraging recent developments in advanced manufacturing, such as 3D printing, to rapidly design, build, and field near-term expendable or limited-life unmanned air platforms as single assets or in autonomous or manned/unmanned teams to detect, deny, and/or disrupt the enemy. This approach bends the cost curve in our favor by enabling the United States to deploy weapons systems to destroy or degrade the systems of our adversaries and protect those of our armed forces and of our allies at a small fraction of the cost of current manned and re-usable systems. The low-cost attritable aircraft will provide an A2/AD operations capable system, and offer near-term ISR/strike capability in remote regions where forward basing is difficult or prohibited.

- With an increasingly adaptive enemy, one who has watched how the US fights for the past 15 years, it is imperative for us to understand our own technology and system vulnerabilities – those aspects that could be exploited and used against us. The Army S&T Enterprise has embraced this challenge. A key aspect of the Army's initiative is the use of S&T red teaming - challenging our systems with an emulated enemy, one who can employ innovative and adaptive methods to disrupt our planned capability. These efforts have the potential for significant cost savings, as they permit potential future vulnerabilities to be identified, evaluated and mitigated long before system designs are finalized or systems are fielded.

- The Army S&T community continues to pursue technologies that are clustered under the category materials-by-design. This research changes the paradigm of material science by providing the capability to select and create material properties and responses, essentially building new materials from the atom up. The ability to manipulate matter at any scale and create desired properties across a wide range of material classes

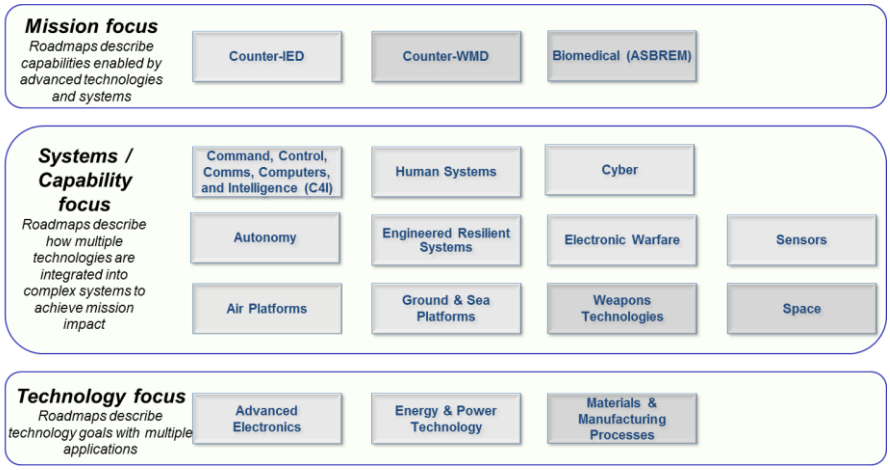
(structural, electronic, energetic) can reduce the time of materials-based discovery to capability delivery by half and at a fraction of the cost of what it is today. The result is a materials-by-design capability for ballistic protection, energetic materials and electronic materials, built using a multiscale approach heavily leveraging computational materials science. The ability to design material properties can lead to specialized capabilities such as high energy disruptive explosives with three to 10 times more energy than a current explosive (RDX) at a lower cost.

- The Army S&T Degraded Visual Environment Mitigation (DVE-M) effort addresses the risk of loss of vertical lift aircraft and risk of occupant injury and death due to loss of situational awareness under degraded visual environments. These environments include aircraft induced effects such as "brownout" and "whiteout" (the blowing of sand/snow due to the rotor wash as the pilots come in for a landing), and environmental effects that impair visibility such as snow, rain, fog, and darkness. The Army is pursuing a multi-disciplined approach to identifying and integrating technologies to support operations into DVE-developing and evaluating novel sensors, flight controls, cueing (visual, aural, and tactile) and real-time computing environments. The Army's DVE-M strategy will demonstrate these technologies in increasingly complex environments, culminating in a demonstration of 360-degree situational awareness throughout the flight envelope of vertical lift systems. The application of this technology will provide a game-changing capability that may rival the impact of the introduction of night vision capability into the operational forces.

In order to ensure we remain at the forefront of S&T, we must also be connected to the global community by continuing to forge relationships with our international partners. The DoD S&T community continues to engage globally with allies and partners, and with key academic and technology institutions worldwide. Among our global engagements, we continue to support multilateral S&T cooperation through the NATO alliance and through The Technical Cooperation Program (TTCP) with the United Kingdom (U.K.), Canada, Australia and New Zealand. The Department continues productive bilateral S&T cooperation, and in the last few weeks has concluded annual reviews of ongoing collaborative S&T efforts with a number of partner nations. As an example of the benefits of the cooperation, the U.S./U.K. Multi-disciplinary University Initiative (MURI) effort supports projects that are competitively selected with DoD supporting U.S. Academic institutions and the U.K. Ministry of Defense (MoD) supporting U.K. researchers who then collaborate in areas of mutual U.S. DoD and U.K. MoD interest. We have also continued to focus on strengthening U.S.-India defense cooperation. Over the past year, the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) has sponsored five workshops with India covering a wide range mutual interest areas: cognitive sciences, autonomy, directed energy, materials, and munitions (including counter-improvised explosive devices). Over 30 potential S&T projects from these workshops are currently under consideration for co-development.

As we execute our plans for the rest of this fiscal year and into Fiscal Year 2017, ASD(R&E) continues to provide oversight of the Department's comprehensive S&T investment portfolio through the Reliance 21 framework. Reliance 21 provides a forum to synchronize,

coordinate, and deconflict Service and Agency S&T activities. In the last year, we improved joint planning and coordination of S&T activities among the Department's senior S&T leadership to achieve efficiencies and improve the effectiveness of our support to the Operating Force. This collaborative process captures the interests and activities of the entire R&E enterprise in a collection of 17 Communities of Interest (COIs). The COIs maintain awareness of their respective portfolio areas by reviewing and assessing the alignment of current and planned R&E programs, identifying gaps, and helping to prioritize R&E funding efforts to meet the technical challenges of the DoD in their respective portfolio areas. Each Reliance 21 COI represents specific cross-domain technology areas with a rotating steering group lead and draws upon subject-matter experts from across the Department working in the relevant technology area. The Reliance 21 framework, its S&T Executive Committee, and technology area COIs are key mechanisms that support ASD(R&E) integrated oversight of the Department's S&T investments.



DARPA'S ROLE IN DRIVING DISRUPTIVE INNOVATION AND PREVENTING TECHNOLOGICAL SURPRISE

For nearly six decades, DARPA has played a particular role in this community of government innovators, and in the larger U.S. technology ecosystem: to pursue extremely challenging but potentially paradigm-shifting technologies in support of national security. Today DARPA continues to create the technologies needed to offset the advanced threats that our military and our Nation will face in the years ahead, and to develop the next generation of advanced military capabilities to deter and if necessary defeat highly sophisticated adversaries.

The agency's current strategic framework and descriptions of our major areas of investment are outlined in "Breakthrough Technologies for National Security," which also describes DARPA's approaches to ensuring that advances are successfully transitioned to the military Services, commercial enterprises or other research entities for further development in ways that best serve U.S. national interests. DARPA's portfolio of more than 200 active programs can be aligned around three major investment areas: Rethinking Complex Military Systems, Mastering the Information Explosion, and Nurturing the Seeds of Technological Surprise. These programs can be further grouped by technological maturity: those capabilities

that are already being piloted or used ("Adoption and Impact"), those that are currently in development ("Technical Progress"), and those that represent fresh investment directions ("New Opportunities").

The small subset of these programs discussed below provides a sense of the nature and mix of these investments.

DARPA'S EFFORTS FOCUSED ON RETHINKING COMPLEX MILITARY SYSTEMS

The unparalleled technological capability that has enabled U.S. military and security superiority comes with a price: spiraling increases in complexity. Today, many high-end military platforms are so complex they take decades to produce and years to upgrade. In a world in which pace is inexorably increasing, and in which other economic and manufacturing sectors have recognized the benefits of systems modularity, rapid-fire iterative improvements and faster hardware- and software-system upgrades, the military's current approach to managing complexity is inadequate. It risks leaving the United States vulnerable to adversaries developing more nimble means of adopting technology.

Today DARPA is turning the tables on complexity, creating engineering architectures and approaches that deliver significantly greater combat power, but with a technical elegance that also allows for flexibility in the field and fast upgrades.

Representative programs in this area include:

- Cognitive Electronic Warfare (EW) (Maturity: Adoption and Impact)
  DARPA's Advanced RF Countermeasures (ARC) and Behavioral Learning for Adaptive Electronic Warfare (BLADE) programs are investing in the technologies needed to rapidly react to dynamic electromagnetic spectrum signals from adversary radar and communications systems. These programs are applying machine learning—computer algorithms that can learn from and make predictions from data—to react in real time and jam signals, including new signals that have not yet been cataloged. DARPA is working with the Services to transition technologies derived from the field of cognitive electronic warfare into the F-18, F- 35, Army Multi-Function EW program, and Next Generation Jammer.

- Unmanned Surface Vessel for Long-Duration Missions (Maturity: Technical Progress)
  The Anti-Submarine Warfare (ASW) Continuous Trail Unmanned Vessel (ACTUV) program has designed, developed and constructed an entirely new class of ocean-going vessel—one able to traverse the open seas for months and over thousands of kilometers without a single crew member aboard. The 130-foot ship, now known as Sea Hunter, is designed to robustly track quiet diesel electric submarines. But of broader technical significance, it embodies breakthroughs in autonomous navigational capabilities with the potential to change the nature of U.S. maritime operations. Specifically, ACTUV is endowed with advanced software and hardware that enables full compliance with maritime laws and conventions for safe navigation—including international regulations

for preventing collisions at sea, or COLREGS—while operating at a fraction of the cost of manned vessels that are today deployed for similar missions. ACTUV was recently transferred to water at its construction site in Portland, Oregon. It was christened on April 7, 2016, with open-water testing scheduled to begin this summer off the California coast.

- Space Robotics and Modular Systems at Geosynchronous Orbit (Maturity: Technical Progress)
  DARPA's Phoenix program is developing innovative technologies and systems that will make it possible to reimagine operations in geosynchronous Earth orbit (GEO), 35,000 kilometers above the Earth. This is the orbit where the highest priority military satellites operate, and commercial satellites there generate more than $100 billion annually in revenue. DARPA is developing a variety of space robotics technologies, including assembly, repair, asset life extension and refueling in the harsh GEO environment; low-cost modular satellite architectures that can scale almost infinitely; and a standardized payload orbital delivery (POD) mechanism designed to safely carry a wide variety of separable mass elements to orbit— including payloads, satlets and electronics—aboard commercial communications satellites. Phoenix has now ground tested the world's first modular satellite, called eXCITe, and prepared it for launch in 2016. In addition, a prototype of a POD mechanism to deliver low-cost rideshare to GEO has also been constructed and is being readied for launch in mid-2017.

DARPA'S EFFORTS FOCUSED ON MASTERING THE INFORMATION EXPLOSION

The accelerating growth of digital data, and the Nation's increasing reliance on information systems in every sector of society, present a challenge and an opportunity. The opportunity is to derive from this massive trove the myriad associations and causalities that, once unveiled, can provide insights into everything from the predicted arrival of a new strain of influenza to the plans for a terror attack halfway around the globe. The challenge is how to separate these valuable signals from noise, and how to be able to trust the information and information systems upon which we now rely for virtually every function.

DARPA is developing novel approaches to deriving insights from a wide variety of datasets, and is developing technologies to ensure that the data and systems with which critical decisions are made are trustworthy.

Representative programs in this area include:

- Research on Fresh Approaches for Computer Security (Maturity: Adoption and Impact)
  DARPA's Clean-slate design of Resilient, Adaptive, Secure Hosts (CRASH) program was a basic research effort that designed new computer systems that are highly resistant to cyberattack. The technology development has recently concluded, and CRASH-developed software is now being incorporated in the commercial and military arenas. One university performer started a company based on CRASH research; this

led to an announcement from HP in September 2015 that its new line of printers would feature this software to enhance their security. DARPA is coordinating transitions to the Navy and the Defense Information Systems Agency (DISA). For example, the aforementioned software is now being transitioned to the Naval Surface Warfare Center to protect shipboard control systems from cyberattack, and other CRASH software is being transitioned to offer similar protection for DoD command and control servers. Additionally, the Department of Homeland Security and the Air Force Research Laboratory have been working together to test and evaluate CRASH technology in multiple devices. Because the cyberattack surface is vast and diverse, each of these transitions makes a contribution to the Nation's cybersecurity by taking a class of threats off the table.

- Cyber Grand Challenge (CGC) (Maturity: Technical Progress)
  It typically takes months or years for a software bug to be identified and patched—a period of time increasingly being taken advantage of by digital miscreants, and a vulnerability window not likely to shrink as long as the process for identifying and repairing such flaws remains mostly manual and artisanal as it is today. CGC is a DARPA-sponsored competition that aims to accelerate the development of automatic defensive systems capable of reasoning about flaws, formulating patches, and deploying them on a network in real time. By acting at machine speed and scale, these technologies may someday overturn today's attacker-dominated status quo. Seven teams from across the United States qualified last year to compete in the CGC final event, which will take place live on stage, co- located with the DEF CON 24 conference in Las Vegas on August 4, 2016.

- Communicating with Computers (Maturity: New Opportunities)
  A new and powerful wave of artificial intelligence (AI) is sweeping commercial and military applications today. Based on recent major advances in machine learning—research that was sponsored in part by DARPA—this generation of AI is fueling fields as disparate as search, self-driving cars and financial trading in the commercial world and battle management, electronic warfare, cybersecurity and information operations in the national security realm. Despite this significant technical progress, however, the ways in which humans interact with machine systems are still quite limited compared to human-to-human interactions. DARPA's Communicating with Computers (CwC) program is a basic research effort to explore how to facilitate faster, more seamless and intuitive communication between people and computers—including how computers endowed with visual or other sensory systems might learn to take better advantage of the myriad ways in which humans use contextual knowledge (gestures and facial expressions or other syntactical clues, for example) to enrich communication. Ultimately, advances from this program could allow warfighters, analysts, logistics personnel and others in the national security community to take fuller advantage of the enormous opportunities for human-machine collaboration that are emerging today.

DARPA'S EFFORTS FOCUSED ON NURTURING THE SEEDS OF TECHNOLOGICAL SURPRISE

From its earliest days, DARPA has scoured the research community for new science and engineering insights and invested in programs to reveal radically advanced technological capabilities from those fertile research areas. That tradition holds true today.

- Accurate, Specific Disease Diagnostics on the Spot (Maturity: Adoption and Impact)
  The challenge of tracking the spread of infectious disease is exacerbated by the fact that the only way to know precisely which pathogen ails a patient is to draw blood, send it to a lab, and often wait days to hear the result. The Mobile Analysis Platform (MAP) point-of-care diagnostic device is a simple, rugged, handheld, battery-operated instrument that rapidly identifies a range of infectious diseases. Developed under DARPA's Prophecy program, it enables low-cost and robust molecular diagnostics within 30-45 minutes in areas where neither a laboratory nor a secure cold chain is available. And because the device provides instant wireless transmission of test results and location data, it can provide invaluable real-time epidemiological data during outbreaks of fast-moving diseases such as Ebola. DARPA is already engaged in clinical testing of the device with the Naval Health Research Center and the U.S. Military HIV Research Program, and will conduct testing with the Marine Corps Warfighting Laboratory this year during military exercises in the United States and West Africa. In addition, DARPA recently initiated development of a MAP assay for the Zika virus.

- Revolutionizing Prosthetics (Maturity: Technical Progress)
  Over the past year, DARPA has built on previous work in its Revolutionizing Prosthetics program to achieve several new and groundbreaking advances that promise to make a difference for wounded warriors and for countless other people with disabilities. Earlier work developed a sophisticated, modular prosthetic arm that could be easily controlled by the user—a prosthetic that earned FDA approval—and demonstrated the first direct, real-time decoding of neural motor control signals from patients to operate such an arm with near-natural control. A newer focus has been on providing users of prosthetics limbs with a sense of touch by sending tactile information from mechanical fingertips to the brain. In September, DARPA reported its first success in this domain, when a 28-year-old man who had been paralyzed for more than a decade as a result of a spinal cord injury became the first person to "feel" physical sensations through a prosthetic hand directly connected to his brain. The advance points to a future in which people living with paralysis or missing limbs will not only be able to manipulate objects by sending signals from their brain to robotic devices, but will also be able to sense precisely what those devices are touching.

- New Tools to Fight Ebola (Maturity: Technical Progress)
  The FY 2015 Consolidated and Further Continuing Appropriations Act provided funds for DARPA to pursue technologies relevant to the Ebola outbreak, leveraging platform capabilities in the ADEPT program that aims to outpace infectious diseases. As a result of that additional support, DARPA was able to achieve a number of milestones in quick

order, including completion of a study showing that a novel DNA-based vaccine could protect non-human primates against a lethal Ebola challenge, completion of a Phase I human safety trial for a DNA-based vaccine, identification of highly protective antibodies retrieved from U.S. Ebola survivors, commencement of manufacture of a protective Ebola antibody, and successful demonstration of potentially therapeutic levels of DNA-encoded Ebola antibodies in small animals.

- Neural Engineering Systems Design (Maturity: New Opportunities)
  The science fiction dream of linking the brain directly to the outside world has in recent years started becoming a reality—initially through the development of implantable medical devices such as deep brain stimulators used today to treat Parkinson's disease and other conditions and, more recently, through work by DARPA and others to develop brain-machine interfaces that allow amputees and people living with paralysis to operate robotic prosthetic arms and hands with their thoughts. Even state-of-the-art brain-machine interfaces, however, have relatively small capacities compared to the enormous computing power of today's digital systems and of the brain itself—a situation that has been likened to two supercomputers trying to talk to each other through an old 300-baud modem. DARPA's Neural Engineering System Design (NESD) program stands to dramatically enhance research capabilities in neurotechnology and provide a foundation for new therapies and other capabilities by developing small, implantable systems that can communicate clearly and individually with any of up to one million neurons in a given region of the brain. In addition to that hardware challenge, NESD aims to develop the advanced mathematical and neuro- computation techniques to transcode high-definition sensory information between two contrasting languages—the brain's cortical neuronal representations and the ones and zeros of electronic systems—and then compress and represent those data with minimal loss of fidelity and functionality.

To build upon the previous initiatives, last year I introduced BBP 3.0, which emphasized technical excellence and innovation. As mentioned in the preceding sections, we must ensure that the US maintains its technological edge and superiority. With that in mind, BBP 3.0 is focused on anticipating and planning for emerging threats through stronger partnerships between the acquisition, requirements, and intelligence communities; strengthening cybersecurity throughout the product lifecycle; removing barriers to commercial technology utilization; improving the return on investments in DoD laboratories; and increasing the productivity of corporate Independent Research and Development (IR&D), among others. Within the area of workforce professionalization, we are working to strengthen organic engineering capabilities, ensure our development program leadership is technically qualified to manage research and development activities, improve our ability to understand and mitigate technical risk, and increase our support for Science, Technology, Engineering, and Mathematics (STEM) education.

To address emerging threats and challenges, we are increasing the emphasis on being more responsiveness through closer integration of requirements, intelligence, and acquisition. We must recognize that threats are dynamic and constantly evolving, and we must stay ahead of the threat curve. We will increase the use of modular designs, open architectures, and

competition to spur innovation and ensure that our designs can accommodate upgrades that keep us ahead of potential adversaries at affordable cost.

In the area of cybersecurity, we are working to address all elements of security throughout the program's lifecycle to include design, manufacturing/production, and logistics and sustainment. We are also working with industry to address cybersecurity concerns in the vast supply chain. While we have made progress in these areas, more action is needed.

Another area where we are making progress is increasing productivity in research and development investments that lead to product development. This includes bolstering our focus on science and technology, advanced components, and early prototypes. The productivity of our in-house laboratories, external research efforts funded through contracts and grants, and the IR&D conducted as a reimbursable expense by private industry, are being assessed and evaluated with a goal of maximizing returns while driving down costs.

We are also working to encourage greater innovation and investments in innovation in industry. One area where we are making inroads is providing industry with draft requirements earlier, thereby allowing industry the opportunity to ask questions, provide feedback, and to make well-informed investment decisions. The Department will also contract with industry for early concept definition work to better inform requirements decisions and analyses of alternatives. We have released guidance for defining "best value" in monetary terms so that industry will have a better understanding of what the government is willing to pay for enhanced performance. This knowledge should spur innovation by giving industry a solid understanding of the competitive advantage available to firms offering innovative ways of achieving higher performance at acceptable costs.

Finally, as aforementioned, we are working to increase professionalism in the acquisition workforce, recognizing that a strong engineering and scientific acquisition workforce is essential to achieving effective innovation and management of development programs. Technical risk management is at the core of cutting edge weapon system development programs, and the Department cannot simply transfer this responsibility to industry. Well-trained and technically qualified personnel, with relevant backgrounds in science, engineering, or other technical fields, should be managing our development programs. The Department cannot be an intelligent customer who insists on high levels of performance without developing and maintaining a cadre of technically qualified managers, and would like to work with the Congress to create greater incentives to recruit, grow, and retain professionals with specialized technical qualifications.

CONCLUSION

All of our efforts to increase innovation and improve acquisition outcomes are efforts to swim against the current of inefficiencies exacerbated by constant sequestration induced budget uncertainty and the consequential turmoil it creates. We must restore balance to the Department, but we cannot do so until our plans and future budgets are better aligned. Until that occurs, modernization investments, particularly research and development, will suffer. This

means that development programs will be stretched out inefficiently and that production rates will be well below optimal for many programs. Uncertainty about future budget levels makes it impossible to determine where the optimal balance between force structure, readiness and modernization lies. In this environment the tendency is to hang on to assets that the Department may not ultimately be able to afford, and where the assets may also be technologically ineffective against our adversaries.

Near-term efforts to shift the Department's focus to address emerging near-peer competitors have focused on maturing technologies, developing new systems concepts, and preparing to experiment with prototype systems that rely on automation and artificial intelligence as central elements of a third offset strategy. These efforts establish a hedge position for the Department – they allow us to evaluate new materiel concepts, develop operational concepts for their deployment, increase the maturity of the underlying technology, and provide knowledge to reduce the risk of follow-on efforts. Delivering new materiel capabilities to the force to maintain our technical edge will require investment beyond technology prototyping and near term gap-fillers. The Nation will face critical investment decisions over the next decade. We must increase our investment in conventional modernization to deliver, equip and train a relevant force with these new capabilities; or, we will be forced to make hard choices about what portion of the current force capability and capacity we trade to create headroom to afford the new technically advanced capabilities required to ensure our competitive military advantage. The resources for this new wave of modernization are not reflected in current budget planning.

The challenge to our Nation's technological superiority is not a tomorrow problem—it is here today. The Department remains committed to ensure our Military is prepared for any future conflict and we are committed to work closely with Congress to stimulate innovative capabilities that preserve our technological edge. We are confident that the initiatives being pursued under the Department's innovation efforts, including the Better Buying Power Initiatives, the strong support for the Department's Research and Development Strategy reflected in the President's Budget Submission, and DARPA's Strategic efforts to help shape our technological future, will position the Department for an increasingly competitive national security environment.

The Fiscal Year 2017 President's Budget request will enable us to move toward driving a culture of technical innovation across the Department, will help us prepare for an increasingly competitive global National Security environment, and will foster a whole-of-department coordinated effort across Army, Navy, Air Force, DARPA, and other DoD research and engineering organizations

Let me close by thanking the committee for its strong interest in and support of the Department's efforts as we work to discover, design, and deliver the technological capabilities our warfighters will need to shape the future.