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STATEMENT TESTIMONY OF

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SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

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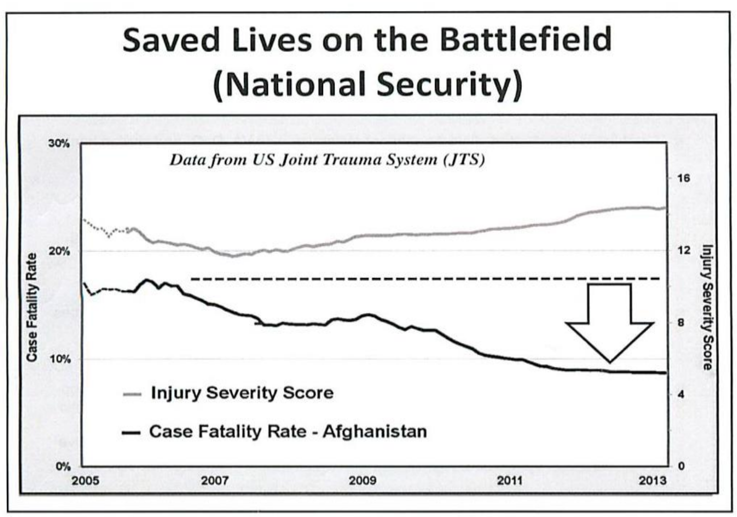
Introduction

Thank you Chairman Wilson and Ranking Member Langevin, I am very proud to be here once again to represent the 100,000+ personnel in the Department of Defense (DoD) Research and Engineering (R&E) enterprise.[1] This enterprise includes the scientists in the DoD laboratory, the engineers in the DoD product centers, and the developmental testers in the DoD test ranges. These government personnel work with the entire R&E enterprise encompassing industry, academia, other government labs and Federally Funded Research and Development Centers. This is a community that has been challenged in many ways over the last several years—but they continue to perform remarkably well.

Before getting into specific issues, I think it is important to provide evidence that the long term science and technology (S&T) program does provide incredible value for the Department. I was recently briefed by the medical science and technology program, and the progress that they have made. The chart below demonstrates the progress. This chart shows the severity of injury and fatality rate in Iraq and Afghanistan from 2005 to 2013. Although the severity of injury, shown in the light gray line, continues to increase, the graph shows the fatality rate decreasing shown by the black line. The fatality rate continues to decline. We contend the decline in fatality rate is due in part to the long-term advances and delivery from the medical S&T community. While the reason for the decrease in fatality rate is multi-faceted, I am comfortable in stating the long-term investment in military medical S&T saved countless lives.



[1] Research and Engineering encompasses Science and Technology (Budget Activities 1-3) and Advanced Component Development and Prototypes (Budget Activity 4)

Macro scale Changes in the National Security Environment

While our S&T community has performed well over the recent past, the overall national security environment is changing in several fundamental and challenging ways. For the first time in several decades, the United States is seeing erosion of our technologically-based military advantage. There are a number of factors that are causing this erosion. Simultaneously to the erosion of technological superiority, is the current unstable budget climate under which we are all living. The combined result of these factors is increasing the risk to our national security. In fact, Secretary of Defense Ash Carter addressed this confluence during his recent Fiscal Year 2016 Budget Posture hearing before the Senate Armed Services Committee. Dr. Carter said:

> *"For decades, U.S. global power projection has relied on the ships, planes, submarines, bases, aircraft carriers, satellites, networks, and other advanced capabilities that comprise our military's unrivaled technological edge. But today that superiority is being challenged in unprecedented ways.*
>
> *Advanced military technologies, from rockets and drones to chemical and biological capabilities, have found their way into the arsenals of both non-state actors as well as previously less capable militaries. And other nations – among them Russia, China, Iran, and North Korea – have been pursuing long-term, comprehensive military modernization programs to close the technology gap that has long existed between them and the United States."*

During this hearing, Dr Carter also addressed the impact of the sequester stating:

> *"A return to sequestration in Fiscal Year 2016 would affect all aspects of the department, but not all equally.*
>
> *More than one-third of the Fiscal Year 2016 cuts would come have to come from Operations and Maintenance accounts, with unavoidable reductions in readiness and our ability to shape world events in America's interest. Let me put this more plainly: allowing sequestration to return would deprive our troops of what they need to accomplish their missions.*
>
> *Approximately half of the cuts would have to come from the department's modernization accounts, undermining our efforts to secure technological superiority for U.S. forces in future conflicts. Because there are bills that DoD absolutely must pay – such as the*

salaries of our troops – many capabilities being developed to counter known threats from highly capable adversaries would be delayed or cancelled, deepening our nation's vulnerabilities at a time when the world is growing more dangerous, not less. Sequestration would put a hold on critical programs like our Aerospace Innovation Initiative, the Next Generation Adaptive Engine, the Ground-Based Interceptor missile defense kill vehicle redesign, and several space control efforts."

Clearly, Dr. Carter has linked the erosion of technological superiority and the budget instability. While the budget instability is not the only reason for the erosion of technical superiority, it is a contributing factor.

Erosion of Technology Based Superiority

Over the past two decades, the United States and our allies have enjoyed a military capability advantage over any potential adversary. Capabilities like precision weapons, stealth, wide area surveillance, and networked forces led to a dominant U.S. military capability that was first demonstrated in the 1991 Gulf War. The United States and our allies have maintained this dominant advantage for over two decades. That is a remarkable timespan to maintain a dominant military capability. This era of dominance is waning. A number of factors are causing the erosion of this technologically based superiority.

First, other nations studied very intently how the United States destroyed the fourth largest Army in the world during the first Gulf War, and have developed asymmetric responses designed to prevent the United States and allies from massing and projecting power. These capabilities, known as anti-access /area-denial capabilities are being developed by several nations—and are focused on preventing the United States and our allies from using those capabilities that give our force strength. In particular, countries like China and Russia have fielded and are developing accurate ballistic and cruise missiles with sophisticated seekers that operate in many new parts of the electromagnetic spectrum and threaten our forward deployed high value operational assets – aircraft carriers, air fields, and logistics nodes. We are also being challenged in air-to-air capabilities, space systems, across the electromagnetic spectrum, in cyberspace, and in undersea warfare.

It is not just our assessment that the technology-based advantages the United States and our allies have enjoyed are at near term risk[2]. In fact, the 2014 DoD Annual report to Congress on Military and Security developments involving the People's Republic of China states the PRC continues to pursue a

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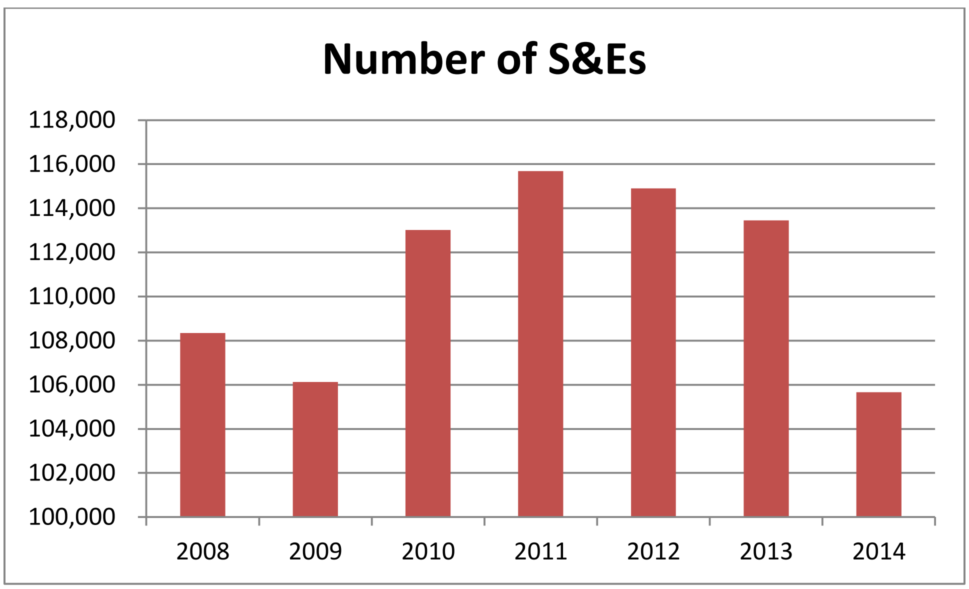
[2] Risk here is defined in terms of how difficult it will be for the US to conduct/complete a mission without loss of life or platforms. Increased risk, therefore, means increased probability of loss of life or weapons system.

long-term, comprehensive military modernization program designed to improve the capacity of its armed forces to fight and win short-duration, high-intensity regional contingencies. Preparing for potential conflict in the Taiwan Strait, which includes deterring or defeating third-party intervention, remains the focus and primary driver of China's military investment. However, the Chinese People's Liberation Army (PLA) is also placing emphasis on preparing for contingencies other than Taiwan, including potential contingencies in the South and East China Seas. China is investing in military programs and weapons designed to improve extended-range power projection and operations in emerging domains such as cyberspace, space, and electronic warfare. Current trends in China's weapons production will enable the PLA to conduct a range of military operations in Asia, well beyond China's traditional territorial claims. Thus, the first factor impinging upon our technologic superiority is the development of asymmetric anti-access/area denial capabilities by a number of nations.

A second factor that leads to erosion of United States technological superiority is funding instability and decline. We will discuss the overall Fiscal Year 2016 budget request later in this testimony, but in the macro scale, the recent funding instability and decline is impacting delivery of capabilities. Technological superiority depends upon a steady stream of investments in research and development. In constant Fiscal Year 2015 dollars, the Research and Development accounts have declined from $88 billion in Fiscal Year 2009 to $64 billion in Fiscal Year 2015. This level of decline, during a period where the United States is still at war, impacts the delivery of new capabilities most severely. While the DoD request in Fiscal Year 2016 increases to $70 billion, this is still over a 20% reduction in the last six years. The same is true in S&T, where, in constant year dollars, we have fallen from $13 billion in Fiscal Year 2011 to $12 billion in the Fiscal Year 2016 budget request. We understand that there are pressures on the budget, but R&D is not a commodity that can be easily adjusted. Honorable Frank Kendall, Under Secretary of Defense for Acquisition, Technology, and Logistics uses the phrase “R&D is not a variable cost.” What that means is whatever it will cost to develop a capability, it will cost. The R&D budget is variable, but the cost of R&D is not. If the budget goes down, delivery will be impacted. Over the past decade, the budget has declined precipitously. Coupled with the rise in capabilities developed by others, the nation is at increased national security risk.

Third, technological superiority relies on developing capabilities more rapidly than potential adversaries. Yet, over the last decade, the US and the West have been focusing on counter-insurgency. Other nations have had time to focus on developing their capabilities on countering US/allied systems. The ability of others to adopt and apply advanced commercial technologies (digital electronics, advanced data processing) is closing the capability gap. Simply, it is easier to close a gap than maintain the advantage. For example, other nations have fielded systems that negate US advantage in precision navigation and timing through denial of GPS by electromagnetic jamming; others have learned how to use digital radio frequency memory jammers to reduce our capabilities in radar and air-to-air systems. Other nations are developing more complex, networked integrated air defense systems (IADS) operating throughout the electromagnetic spectrum to keep the US and allies from operating in international air space. There are other examples, but the point is the US focus was placed on counter-insurgency for the current fight, while other nations have not had the same focus. This has contributed to an erosion of our conventional military advantage.

Fourth, technological superiority depends on having and maintaining access to world class scientists and engineers (S&E), a factor that has been impacted by the recent budget difficulties. One of the most valuable assets supported by R&D dollars are scientists and engineers. If the R&D budget declines, the number of scientists and engineers supporting the DoD declines. Since 2008, as derived from the Defense Manpower Data Center (DMDC), the number of scientists and engineers in the DoD has declined, as shown in the following graph:

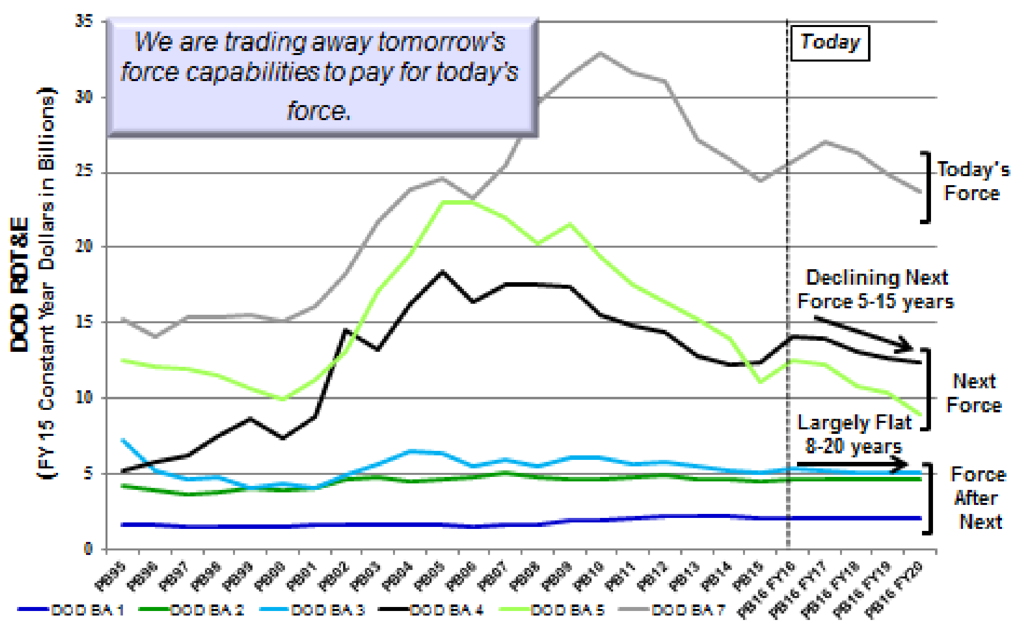


In short, the DoD has lost 10,000 scientists and engineers since 2011. Of greater concern is the loss of scientists and engineers coupled with the average age of DoD S&E. Beginning in 2013, the average age of DoD S&Es started to climb. A workforce that is simultaneously getting smaller and older is a concern—it suggests that we are not hiring or retaining younger workers

Data from the Defense Manpower Data Center (DMDC) and the Office of Personnel and Management’s FEDSCOPE indicates that the decrease in engineers was caused by retirement (50%), resignation (25%), or transfer to other government agencies. These numbers, by themselves, are not necessarily troubling given the recent federal budget challenges. An additional factor that we are concerned about is the age of the Department’s technical workforce. Over half of our technical acquisition workforce is retirement eligible within the next 10 years. We simply have to emphasize shaping our future workforce to continue to meet future challenges.

The R&E enterprise talent pool includes our industry partners. The chart below shows the evolution of RDT&E budget lines over the past several decades. Briefly, the accounts Advanced Component Development and Prototypes (Budget Activity 4), and System Development and Demonstration (Budget Activity 5) support engineers. The chart shows that there has been a steady decline in Budget Activities 4 and 5 over the past decade. In part to make up for this, we have reoriented the Assistant Secretary of Defense for Research and Engineering's Joint Capability Technology Demonstrations (JCTD) program and Service programs to do more demonstrations and prototypes. By increasing prototypes and demonstrations, we keep the pipeline for engineers open.

DOD RDT&E – PBR1995-PBR2016



Finally, technological superiority is not something that is gained instantaneously; it takes steady effort, with slightly higher risk programs, over a period of time. This infers that the DoD needs to continue to generate new talent through Science, Technology, Engineering, and Mathematics (STEM) education programs. Yet, the long-term outlook for supply of S&Es that can work in national security is decreasing, by all appreciable metrics. There is anecdotal evidence that positions are going unfilled because we don't have qualified candidates. The DoD will not fix the STEM gap by ourselves. However, the Department has a significant role in the national STEM program. The Department is working hard to increase its pool of STEM talent through innovative programs and validated methods, and that will attempt to ensure a workforce that is more technologically knowledgeable, capable, and representative than ever before.

Several priority initiatives are underway to focus on STEM activities, including the Department's Better Buying Power (BBP) 3.0 STEM effort, and the Science, Mathematics and Research for Transformation (SMART) scholarship-for-service program.

The BBP 3.0 STEM effort focuses on improving the professionalism of the total acquisition workforce by increasing DoD's support for recruitment, workforce planning, education, and training. Ongoing activities include the development of a strategic STEM communication plan, establishing a quarterly award program for local STEM recognition, maintaining broad awareness through STEM activity surveys, and sharing best practices from the survey. The effort also focuses on expanding the DoD STEM Executive Board to add emphasis on engineers – the core of our acquisition workforce and the Board's development of measureable goals and objectives.

The SMART program provides a direct pipeline to the DoD workforce by focusing on disciplines critical to national security functions. Over 1,600 SMART scholarships have been awarded since the inception of the program in 2005, with 77% of SMART scholars currently working beyond their service commitment. Fiscal Year 2015, scholarship awards are being increased by 25% over the previous year to better attract these high quality applicants. We see good value in this service-for-scholarship program and appreciate the support Congress has given our STEM efforts.

<u>Department of Defense Fiscal Year 2016 Budget Request</u>

The Fiscal Year 2016 budget request for Science and Technology (S&T) is $12.3 billion—well above the Fiscal Year 2015 budget request of $11.5 billion, and even above the Fiscal Year 2015 enacted $12.2 billion budget. Similarly, the RDT&E budget increases from $64 billion to $70 billion; and reflects continued and new investments in key capability areas.

The following tables show the change in S&T funding from Fiscal Years 2015 to 2016. The first table shows S&T by appropriation category. The second table shows the change from Fiscal Year 2015 to 2016 by Component. In short, Fiscal Year 2016 continues the trend favoring more mature S&T (Budget Activity 3) at the expense of basic research activities. This is not as serious as it appears. Historically, Basic Research has been funded at about $1.5 billion per year in constant year dollars so we are still well above historical averages.

	PBR 2015 ($M)	Fiscal Year 2015 Appropriated ($M)	PBR 2016 (Fiscal Year 2015 CY $)	% Real Change from Fiscal Year 2015 Appropriated (Fiscal Year 15 CY $)
Basic Research (BA 1)	2,018	2,278	2,089 (2,049)	-10.05%
Applied Research (BA 2)	4,457	4,648	4,713 (4,622)	-0.55%
Advanced Technology Development (BA 3)	5,040	5,326	5,464 (5,359)	0.61%
DoD S&T	11,515	12,252	12,266 (12,030)	-1.81%

Table 1— Defense Budget for Science &Technology; Research & Engineering; and DoD Top Line Budget (Fiscal Year 2015 Appropriated and PBR 2016).

	PBR 2015 ($M)	Fiscal Year 2015 Appropriated ($M)	PBR 2016 (Fiscal Year 2015 CY $)	% Real Change from Fiscal Year 2015 Appropriated (Fiscal Year 15 CY $)
Army	2,205	2,555	2,201 (2,159)	-15.51%
Navy	1,992	2,155	2,114 (2,073)	-3.80%
Air Force	2,129	2,282	2,378 (2,332)	2.22%
DARPA	2,843	2,845	2,901 (2,845)	0.00%
Missile Defense Agency (MDA	176	195	224 (220)	12.61%
Defense Threat Reduction Agency (DTRA)	473	481	485 (476)	-1.09%
Chem Bio Defense Program (CBDP)	407	430	394 (386)	-10.12%
Other Defense Agencies	1,289	1,310	1,569 (1,539)	17.47%
DoD S&T	11,515	12,252	12,266 (12,030)	-1.81%

Table 2 - Service and Agencies S&T Budgets (Fiscal Year 2015 Appropriated and PBR 2016)

Embedded in the funding for Defense Agencies is the funding for programs operated by my office. I would like to highlight a few themes in the OSD funding lines. First, we have increased the funding for demonstrations and prototypes in S&T from $320 million in Fiscal Year 2015 to $347 million in Fiscal Year 2016. This includes an increase in funding for Joint Capability Technology Demonstrations and Quick Reaction Special Projects. I also note that we have dramatically increased funding in the Advanced Component Development and Prototype funding account for the Strategic Capabilities Office (SCO) from $190 million in Fiscal Year 2015 to $470 million in Fiscal Year 2016. I will present some details later in this testimony, but will also note the SCO increase is to support acceleration of specific innovative capabilities, most of which are classified. Taken together, we end up increasing demonstrations and prototypes within the Office of the Secretary of Defense (OSD) portfolio by over $300 million in the Fiscal Year 2016 budget request.

Two other individual program lines in our OSD lines are worth highlighting. In Fiscal Year 2016, we increased our request for Applied Research for the Advancement of S&T Priorities program to $48 million. This program specifically supports the Reliance 21 process to develop and implement integrated S&T execution plans, as described later in this testimony. I view this as the most significant effort to increase efficiencies in the DoD S&T program. Finally, we slightly increase the bundle of programs supporting STEM and STEM-like activities in Fiscal Year 2016. Taken as a whole, our Fiscal Year 2016 budget request in OSD is aligned with DoD priorities that supports increased demonstrations, increased efficiency in our DoD-wide S&T program, and increasing STEM activities to bring along the next generation.

Response to the Emergent Challenges to the DoD

As we have discussed, the rise of capabilities of other nations, coupled with the overall decline in DoD investment accounts, places our technological superiority at risk in ways we have not seen since the Cold War. Consequently, the Department is taking several steps to better respond to the emerging challenges. The response comes at both the Departmental level, and also at the functional R&D/S&T level. At the DoD level, Secretary Hagel announced the Defense Innovation Initiative (DII) in November 2014. Embedded in the DII is the focused Long Range Research and Development Planning Program (LRRDPP) effort to determine if and where new S&T investment is needed for future capabilities. Prior to the announcement of DII and LRRDPP, my office worked with the Components to establish a DoD-wide Research and Engineering Strategy, and had initiated a process, called Reliance 21, to integrate the S&T programs of the DoD in those cross-cutting technology areas where all Services have an investment.

Defense Innovation Initiative (DII) and Long Range R&D Planning Program

In November 2014, the Secretary announced the Defense Innovation Initiative (DII) as a new Department-wide effort to identify and invest in novel ways to sustain and advance the Department's military superiority for the 21st Century and improve business operations throughout the Department. The initiative has five major lines of effort, which include People, Wargaming, Operational Concepts, Business Practices, and a new Long-Range Research and Development Planning Program (LRRDPP). Also consistent with the DII is enhanced use of prototyping, demonstrations, and experimentation to more rapidly mature and field technology and future systems.

The LRRDPP is an effort to reach out to the broadest possible community to identify technologies that can shape future military systems and capabilities. The LRRDPP effort will help the RDT&E community prioritize its investments, protect the S&T investments with the highest potential impact, and increase the return on our S&T investments. To initiate the LRRDP effort, a Request For Information was released in December 2014 to solicit the public's input on five focus areas: Space Technology, Undersea Technology, Air Dominance and Strike Technology, Air and Missile Defense Technology, and Other Technology-Driven Concepts; the first deadline for responses was mid-January but will remain open for new ideas and concepts. The LRRDPP will complete its initial review in Summer 2015.

DoD Research and Engineering Strategy

In spring 2014, we released the Defense R&E Strategy, which laid out the technical priorities for the DoD. Simply, the Department conducts R&E for three main reasons:

1. Develop capabilities to mitigate existing and emergent threats. This highest priority would include electronic warfare, missile defense (both cruise and ballistic), cyber, preservation of space capabilities, counter weapons of mass destruction, and so forth.

2. Develop capabilities to build affordability into existing and future systems. This includes expanding the use of prototypes and demonstrations to reduce risk in early acquisition, expanded use of open systems, modeling and simulation, developmental planning, and systems engineering.

3. Develop capabilities that deliver technology surprise to potential adversaries. This would include, but is not limited to, such areas as autonomy, human cognition, quantum sciences, and hypersonic flight.

While the DII was released after the R&E Strategy, I contend that the enduring principles of the strategy are well aligned with DII, and we were moving in the DII direction before DII.

Reliance 21

A frequent criticism of the S&T program is that there is duplication among the Services. I don't believe this is a pervasive problem, but we have to protect against duplication and continue to seek efficiency. In 2013, we reinstated "Reliance 21", a process to allow the Services and Defense Agencies, looking across all the projects, to optimize their output. Under Reliance 21, we have divided the overall S&T program into 17 discrete "Communities of Interest" (COI). Each COI represents a technical area where the Services and Defense Agencies are investing. We have asked the senior executive Service leaders responsible for a technology area to lead the COIs and to develop an integrated S&T plan.

In 2014, the first COIs delivered roadmaps in Sensors, Electronic Warfare, C4I, Engineered Resilient Systems, Cyber, and Autonomy. In May 2015, the second set of COIs will deliver detailed integrated plans in Weapons, Space, Air Systems, Materials, Biomedical and Counter WMD. I believe people will seek to optimize their work, and get the most output possible from whatever resources are available. Reliance 21 provides the construct to optimize S&T. As mentioned previously, the Applied Research for the Advancement of S&T Program provides funding to make Reliance 21 real.

Specific Prototyping and Demonstration Efforts Supporting Innovation

Throughout the whole continuum of guidance, one thread continually comes back to the technical community to address—the expanded use of prototypes and demonstrations to develop new and affordable capability. In the Fiscal Year 2016 budget request, we have aligned at least $4.5 billion as "innovation technology" efforts, which includes prototypes and demonstration capabilities. One of the key pillars of regaining US technological superiority is to take more risk in the systems the Department develops. One way to do this is through the enhanced use of prototyping and demonstrations across the Department. These may be called prototypes, demonstrations, Future Naval Capabilities, Army Technology Demonstrations, or other names; at the end of the day, we expect expanded use of these efforts to develop new capability and retire risk; and to allow use/testing by the operational force, and could lead to a big capability advantage. The DoD has initiated a number of significant prototypes and demonstrations. I will highlight a few and parse them through the R&E strategy lens of "mitigate, afford, surprise".

Prototypes and demonstrations that support mitigating current and near future threat

My Emerging Capabilities and Prototyping (EC&P) Office has started several Joint Capability Technology Demonstrations (JCTD) to investigate delivery of communications and imagery from small satellites tactically relevant. Two of these projects, the Space and Missile Defense Command (SMDC) Nanosatellite Program (SNaP) and Kestral Eye (KE) are both being executed by Army's SMDC. While both of these are demonstrations, they are pushing back the boundaries of disaggregated space.

There currently is no beyond line of sight communications for disadvantaged users in remote areas with only portable radios, particularly when on the move. SNaP is a low earth orbit nanosatellite that will provide assured beyond line of slight communication, enabling mission command on the move and allowing tactical leaders to synchronize action, seize the initiative and maintain situational awareness. It provides user service on demand with minimal training requirements. Three SNaP satellites were delivered to Cal Poly University on 16 March 2015 with a launch date scheduled for 27 August 2015 to support an operational utility assessment for US SOUTHCOM. This capability will provide limited (spot beam) communications in a jammed environment.

Kestrel Eye is a small, 25 kilogram class satellite that provides "good enough" 1.5 meter resolution visible imagery. Both imagery tasking and delivery is controlled directly by the COCOMs to ensure sufficient timelines for near real-time situation awareness and decision-making in the field. Kestrel Eye provides near continuous coverage over an area of responsibility with four satellites and two airplanes. The production cost of less than $1.5 million for a Kestrel Eye enables an affordable constellation for persistence. The first KE is on track for an International Space Station (ISS) launch in December 2015. The second KE Block is on track for an April 2016 launch. These satellites will be used to support an operational utility assessment for PACOM.

My EC&P Office is also developing a "small fast intercept" surface launch intercept missile to determine if we can field a counter missile system for less than $1 million each. Low Cost Missile Defeat (LCMD) is a ballistic missile defense system. During the Phase I assessment, the Government team conducted an in-depth system design and advanced maturation of critical components to provide the mission performance baseline leading to a validated Concept of Operations (CONOPS). The LCMD system is formulated to integrate into the existing national Ballistic Missile Defense (BMD) architecture and make maximum use of existing sensors and fire control components of weapon systems already fielded. LCMD is not designed as a replacement to existing BMD systems, but rather as a lower cost complementary/augmentative component of existing BMD assets. The projected cost of the interceptor is an order of magnitude less than current upper-tier BMD interceptors, but have a comparable or larger engagement envelop.

The Army is developing a High Energy Laser-Mobile Demonstrator (HEL-MD). This high energy laser weapons system will demonstrate low cost capability for counter rockets, artillery and mortars (C-RAM); counter unmanned air vehicles (C-UAV); counter intelligence, sensors and reconnaissance (C-ISR); and counter cruise missile (C-CM) missions. In 2014, the Army tested this system at White Sands Missile Test Range, NM and Eglin AFB, FL and successfully engaged over 90% of targets. HEL-MD is scheduled to be integrated into an Army program of record (the Integrated Fire Protection Capability Increment II) in the 2020's.

The Navy has an Innovative Navy Prototype (INP), the Electromagnetic Rail Gun. This comprises a launcher, pulsed power system and battery energy storage system capable of firing a Hyper Velocity Projectile (HVP) 110 NM at a firing rate of 10 rounds per minute. The Electromagnetic Rail Gun is being jointly developed by the Office of Naval Research and Naval Warfare Center, Dahlgren, VA. This multi-mission system is designed to support integrated air and missile defense and provide Naval Surface Fire Support to troops ashore and to conduct anti-surface warfare, both line-of-sight and over-the-horizon. We expect a sea demonstration aboard a Joint High Speed Vessel in the summer of 2016. The OSD Strategic Capability Office has partnered with the Navy to test the applicability of Rail Gun for point defense, with a demonstration expected in 2017.

The Air Force's Automated Navigation and Guidance Experiment for Local Space (ANGELS) program launched in July 2014. The ANGELS program examines techniques for providing a clearer picture of the environment around our vital space assets through safe, automated spacecraft operations above Geosynchronous Earth Orbit (GEO). Equipped with significant detection, tracking and characterization technology, ANGELS launched in July 2014. ANGELS is evaluating techniques, tactics and procedures for improved Space Situational Awareness. Post launch, ANGELS conducted a series of subsystem tests and qualifications resulting in the successful completion of checkout on 17 October 2014. On 30 October 2014, ANGELS entered rendezvous and proximity operations around a Delta-IV upper stage with a closest approach between 15 and 20 kilometers, allowing for further qualification and refinement of spacecraft subsystem performance. ANGELS, when fielded operationally, will allow us to better protect our space assets.

Finally the Navy's Innovative Naval Prototype (INP) Laser Weapon System (LAWS) is another solid state laser system under development. The Navy demonstration uses a fiber laser, as compared to the Army heat capacity laser. LAWS uses an infrared beam from a tunable solid-state laser array to either destroy a target (full power) or to degrade or cripple the sensors of a target (low power). The prototype is designed for long-term deployment as Surface Ship Self Defense on a DDG-51 FLT IIA against low cost, swarming small boats and lethal UAV (Armed Drones) threats. This system was demonstrated aboard the USS Ponce in 2014, and is moving to the next set of tests in 2016.

Prototypes and demonstrations that support enhancing affordability of current and future systems

My EC&P Office has developed a series of demonstrations that address directly affordability and performance by developing new technologies or modifying existing commercially available capabilities. I will mention a few. The first, Steel Tiger, is a commercially developed maritime radar which has been modified with Department of Defense capabilities to perform specific maritime surveillance missions. In testing, this system achieved all its intended performance objectives at a fraction of the cost of more traditional military systems. Specific details are classified but the system offers a low cost option for the maritime environment. The second is the development of the Accelerated Nuclear DNA Equipment (ANDE) which enables automated rapid DNA profiling while minimizing analytical complexity and user manipulations for employment in a field, rather than laboratory environment. About the size of a desktop printer, ANDE enables fully automated analysis of a buccal (cheek) swab in about 90 minutes. Following successful evaluation of ANDE in late 2014, the capability is now deployed operationally with more systems to be procured by DoD. ANDE can replace a significant amount of the costly laboratory infrastructure required to perform forensic DNA analysis in a forward deployed field environment. The Departments of Homeland Security and Justice were both participants in the ANDE program and are evaluating the system's ability to support their unique mission requirements. Finally, the Stiletto is a maritime demonstration craft that assesses a wide variety of capabilities in a realistic environment. Manufactured of composite material with a significant amount of internal deck space and capable of high speeds (50 knots plus), Stiletto is easily configurable to support both government and commercial evaluation of technologies or concepts. The return on investment for DoD is early insight and risk reduction of systems, concepts and technologies developed under DoD sponsorship or by the commercial sector which have resulted in early transitions into programs of record or fielded prototypes.

The Army's Multi-Mission Radar (MMR) research and development effort began in 2002 as an Advanced Technology Objective in S&T. The MMR addresses the feasibility of combining the functionality of multiple radars into a single radar system that can perform multiple missions. The MMR Advanced Technology Objective program goals were to design, build and test a cost-effective multi-mission capable radar that can operate in an operational environment, resemble a tactical system, and prove producibility. This program went into production in 2012 and is currently being fielded.

The Air Force's Adaptive Engines program is a new engine architecture offering approximately 25% reduced specific fuel consumption. This technology began its development in 2007 under the Adaptive Versatile Engine Technology (ADVENT) program. ADVENT was an Air Force science and technology effort that demonstrated the technical feasibility of adaptive engine technology. Ground testing of the ADVENT engine demonstrated greater than 20% reduction in fuel consumption. Having proved the concept, the Air Force started the Adaptive Engine Technology Demonstration (AETD) program in Fiscal Year 2013. AETD is the follow-on to ADVENT and was designed to accelerate the maturation of adaptive turbine engine concepts with the goal of achieving technology and manufacturing readiness levels to enable the demonstration and validation of the new engine architecture. Due to the success of the ADVENT and AETD programs, the Secretary of Defense last year announced a $1.3 billion next generation jet engine program that would serve as the follow-on to AETD and advance the AETD designs through extensive ground testing for future integration and flight test. This new program is called the Adaptive Engine Transition Program (AETP) and will begin with an award for two different engines in Fiscal Year 2016. This will help ensure that the most cost-effective solutions to the challenges of engine operability, durability, sustainability, and air platform integration are achieved while reaching the fuel efficiency and thrust goals set for the program. Additionally, developing two different engines will help sustain a healthy industrial base enabling the Air Force and the Department of Defense to have multiple vendors, including second and third tier vendors, to meet development and production needs for legacy and future platforms. We expect a demonstration engine ready to enter Engineering & Manufacturing Development phase in the early 2020's.

We are also addressing affordability through our Engineered Resilient Systems (ERS) effort, an OSD-sponsored program. While not a prototype, the design tools enable design of future prototypes and acquisition programs. A Resilient System is reliable and effective in a wide range of contexts, is easily adapted through reconfiguration or replacement, and has predictable degradation of function. The goal of ERS is to buy down acquisition risk and support affordability decisions by evaluating potential systems and their costs against future uncertainties. A consortium across DoD, industry, and academia, led by the US Army's Engineer Research and Development Center, is executing the initiative. ERS integrates the power of advanced modeling, simulation, big-data analytics, and visualization across the workflow used by engineers, managers, and decision makers to define and explore the acquisition trade-space much more fully than ever before. This technical underpinning, when fully mature, will provide the Department with the ability to quantify the impacts of new threats, technology disruptors, and missions on requirements generation, engineering design, prototype analysis, and lifecycle cost management.

Although only in its second year, ERS has already provided capabilities that are in use by the RDT&E communities in support of DoD acquisition activities. Using High Performance Computing capabilities, ERS allows for 1,000 times the number of parameters and scenarios to be considered in setting requirements, and assessing affordability. For example, the Navy Sea Systems Command, Carderock, Maryland, recently used ERS in a ship Analysis of Alternatives by analyzing how dozens of interdependent potential requirement variables would impact cost. Over 22,000 combinations were assessed, giving the Navy robust data with which to base affordability tradeoff decisions.

This positive outcome demonstrated some of the ERS methodology potential. The Navy has since used and continues to use an improved version of the ERS ship design set-based design process and tools for other design studies.

I would like to mention one additional effort we have initiated within the Deputy Assistant Secretary of Defense for Research and Engineering Developmental Test and Evaluation office. Again, this is not a prototype or demonstration but will enable getting more value out of the prototypes and demonstrations the Department conducts. A vital element of S&T and R&D is to develop an early test program to better build knowledge throughout the early cycles of prototypes and demonstrations. This knowledge informs critical decisions along the way that guide the maturing technology or system, and steer it towards utility, manufacturability, availability, and affordability. This knowledge is built through experimentation, analysis (to include modeling and simulation), testing, assessment, and evaluation – all of which are elements of developmental test and evaluation (DT&E). Therefore, DT&E should start at the earliest stages of development (i.e. analysis of alternatives, assessment of technology maturity, early risk reduction) and mature from early experimentation and assessment to support research, to rigorous test and evaluation to inform the systems engineering and development process, to supporting continuous evaluation throughout the system's life cycle. The Department has launched a set of initiatives that we call Shift Left to indicate that DT&E is moving early in the research, development, and acquisition process to help build the essential knowledge base for each significant effort. DT&E is no longer just about verifying specifications or assessing readiness for operational test. It is about making sure that decision-makers at all levels have the right knowledge at the right time from when a development is a researcher's bright idea to when it is in the warfighter's hands and beyond.

Prototypes and demonstrations that develop technology surprise

While mitigating current threats and developing affordable systems are important, we are also asked to develop new systems that provide a leap-ahead technology. Under Secretary of Defense for Acquisition, Technology and Logistics Frank Kendall has initiated a new Aerospace Innovation Initiative (AII) to ensure that the United States can maintain air dominance in future contested environments. The AII includes a new program to demonstrate advanced aircraft technologies in X-planes (AII-X) as well as the on-going and previously mentioned Advanced Engine Technology Program (AETP). AII's goals include strengthening the critically important design teams in the defense industrial base and reducing the lead time for future systems.

DARPA will lead AII as a DARPA/Air Force/Navy program to develop and demonstrate technologies enabling cost-effective air warfare capabilities necessary to defeat future near-peer threats. This program will develop and fly two X-plane prototypes that demonstrate advanced technologies for future aircraft. Teams will compete to produce the X-plane prototypes, one focused on future Navy operational capabilities and the other on future Air Force operational capabilities. The X-planes will not be Engineering, Manufacturing and Development prototypes or have residual operational capabilities. The result of a successful development and demonstration X-plane program will inform future aircraft system acquisitions.

The AII effort builds on the recently completed Air Dominance Initiative (ADI) study. In this effort, DARPA worked closely with the Air Force and Navy to convene leading warfighter and technology experts for a fresh look at what will be needed to extend U.S. air dominance in the face of fast-moving potential adversary capabilities. This group determined that no single new technology or platform could deter and defeat the sophisticated and numerous adversary systems under development. Instead, future U.S. capabilities will build on an integrated system of ISR, weapons, communications, electronic warfare, cyber, and other advanced technologies. We are excited about the probability that AII offers in demonstrating new capabilities through prototypes.

In late 2013, under Reliance 21, we recognized the need for a program that would address a significant emerging technology area in a meaningful way. Working with the Service S&T Executives, the DoD leadership decided to fund a research pilot initiative in the technical area of autonomy. To address this, I allocated $15 million per year for three years to competitively fund autonomy projects run by the DoD laboratories. This program, called "Autonomy Research Pilot Initiative" solicited proposals from DoD researchers. Out of a pool of 30+ proposals, our S&T Executives selected seven projects, involving 15 DoD laboratories. The seven projects involved diverse projects like Autonomous Squad Member; Revolutionizing Human-Autonomy Integration; and Autonomous Collective Defeat of Hard and Deeply Buried Targets. When ARPI completes in 2016, we will have built a unified DoD autonomy research team. In short, we are building an autonomy research team from the disciplines of electrical and mechanical engineering, computer science, neural science, data handling, and sensors. We are in the process of identifying our second pilot initiative to start in Fiscal Year 2016.

The final leap-ahead technology I would like to mention is hypersonic fight. The Air Force's High-Speed Strike Weapon (HSSW) program is an umbrella program that will conduct air-launched and boost-glide weapon demonstrations in the 2018-2020 timeframe. The HSSW will enable a responsive strike capability on time-critical, heavily defended targets and achieves high survivability through altitude, speed and stealth. The Air Force and DARPA are jointly leading the Department in the development of hypersonic flight. In 2010 and 2013, the AF successfully flew the X-51A waverider demonstrator. The 2013 flight was particularly noteworthy, in that it was the first demonstration of a powered scramjet that accelerated through climb, and stayed ignited for over 200 seconds at Mach 5. X-51A showed hypersonics can be a reality. In fact, the X-51A led to the joint DARPA/Air Force Hypersonic Advanced Weapons Capability (HAWC), a developmental demonstration to fly 500 miles at Mach 6 and hit a target by 2019. When HAWC works, the DoD will be ready for a program of record in an air breathing scramjet hypersonic missile. Simultaneously, the AF and DARPA are collaborating on a tactical boost glide, a system to fly several hundred miles at Mach 9+ by 2019.

Although not a prototype or demonstration, I would also like to highlight some of the exciting progress we are making in quantum technology-based applications to national security. This past year we have demonstrated a prototype compact gyroscope based on cold-atom technology. This is a new technology, and has the potential to bring high-accuracy navigation solutions to a wide class of military platforms at a fraction of the cost of existing systems. It addresses the growing denial vulnerability of the GPS system. To more effectively pursue the broadest set of applications using advances in 21st century quantum technology, we have initiated a close partnership with the United Kingdom, as they have recently announced a £300 million quantum initiative that will span quantum sensing, to metrology, to simulation, to precise time keeping, and that holds promise of a new set of applications with both defense and economic benefits. We kicked off this collaboration with a jointly sponsored US-United Kingdom workshop in February 2015.

DoD S&T Successful Transitions

I want to highlight some recent successes of the DoD S&T program. In short, there are always critiques of our S&T program. I believe it is important to recognize that the DoD S&T program has developed, delivered, and sustained the greatest military the world has ever seen. This military has been without even a close peer since before 1991. In fact, if you look at what the Department S&T program has delivered, it is remarkable. The internet, stealth, precision weapons, the world's most dominant navy (both above and below water), night vision devices and advanced microelectronics were all driven by the DoD S&T program.

While the focus of the past 15 years has been on counter-insurgency, there are still some incredible capabilities that the DoD has developed and fielded. I would like to highlight a few recent successes for counter-insurgency:

The Persistent Ground Surveillance System (PGSS) project was a rapid JCTD start (less than 60 days to start) to develop a low-cost alternative for an integrated, Intelligence Surveillance Reconnaissance (ISR) system to provide persistent overwatch, threat detection, and alerting at selected forward operating bases (FOBs). The first PGSS system was fielded in March 2010 at a coalition FOB in Afghanistan and directly supported U.S. Forces-Afghanistan priority missions. The PGSS JCTD was completed at the end of Fiscal Year 2010 and transitioned to the Army. Originally, 31 systems were requested; however, their value was quickly realized and a total of 59 systems were delivered to theater.

These systems have provided in excess of 398,000 hours of persistent surveillance. PGSS aerostats with sensor payloads augmented by sensors on towers permitted sharing of situational awareness among coalition forces and directly contributed to identifying 1,328 insurgents (832 confirmed enemy killed and 208 enemy wounded in action); 13,400 pounds of home-made explosive material identified; 686 IEDs identified; many weapons; 29 high value targets detained, killed or wounded in action.

DARPA's Nexus 7 (N7) program applies forecasting, data extraction, and analysis methodologies to develop tools, techniques, and frameworks for the automated interpretation, quantitative analysis, and visualization of social networks. The N7 program was deployed to theater from September 2010 through 2014. The N7 Analysis Cell was initially embedded within Joint Operations Information Center-Afghanistan (JIOC-A). During the deployment the Nexus 7 team supported a wide array of coalition entities including the following: ISAF Coalition J2, Afghanistan Threat Finance Cell (ATFC), RC(SW), RC(S), IJC, Afghan Assessments Group (AAG), Combined Forces Special Operations Component Command – Afghanistan (CFSOCC-A), and the Kandahar Intelligence Fusion Center (KIFC).The N7 program final support role was analysis for the ISAF Afghan Finance Threat Center with a forward deployed representative and stateside analysis support until March 2014. The program served as a springboard for the development of several follow-on Big Data research programs and some of the tools developed by N7 were installed for use at the US Army Intelligence and Security Command. Nexus-7data scientists were forward deployed and embedded with operational units in the Afghan Theater in order to apply advanced data science and technology to enable the processing, analysis, and visualization of operational and intelligence data. Direct interaction with users allowed for the application of advanced analytical techniques and the development of products in order to support rapid decision-making by deployed contractors focused on the financial, informational, and social/tribal networks in Afghanistan. Lessons learned from this experience resulted in DARPA's follow-on XDATA Program and the development of a robust, open source repository of software and tools that can be applied to various crisis and contingency operations. XDATA tools are currently in use and have been adopted by several intelligence communities and law enforcement organizations and are continuing to advance the application of data science to significant national security issues like counter-threat finance and counterterrorism.

DARPA also provided the Vehicle and Dismount Exploitation Radar (VADER) which consists of an airborne radar and an exploitation system that uses the radar return to detect, track, and classify ground moving vehicles and dismounts with high reliability from a UAV or small manned aircraft**.** After completing CONUS testing in 2009, where VADER took part in a Department of Homeland Security demonstration along the Mexico-Arizona border, the system was deployed OCONUS in 2010. Sensor systems were mounted on a variety of small manned airborne platforms, such as the DHC-6 Otter, and have participated in nightly support OCONUS missions through 2014. The VADER system has a Wide area Ground Moving Target Indicator (GMTI) and Synthetic Aperture Radar (SAR) sensor that tracks moving vehicles and dismounts. The system is capable of operating during the day, night and all weather conditions and provides dismount detection at 20km+ with 5km x 5km field of regard and a 100 km2 survey envelope for vehicle tracking. The SAR imagery provides significant resolution at 20km ranges to even enables change detection. The VADER system was in continuous operation in Afghanistan beginning in December of 2011.

The Air Force Research Laboratory led Automatic Ground Collision Avoidance System (AGCAS) saved an F-16 and its pilot with the Air Force's S&T program in ground collision avoidance technology. This occurred on 10 November 2014 in theater during a ground attack run. The system protects pilots by taking temporary command of the aircraft and executing an automatic recovery maneuver when it detects that an impact with terrain is imminent. The system constantly compares the trajectory of the F-16 with a terrain profile generated from on-board digital terrain elevation data (DTED). If the system detects a threat, an evasion command is issued. If no action is immediately taken by the pilot, the system automatically assumes control. The recovery includes an abrupt roll-to-upright followed by a 5g pull until clearance of the terrain is assured. Auto GCAS can also be overridden by the pilot at any time. The system incorporates a "Pilot Activated Recovery System" (PARS) function which provides a disoriented pilot with a way to manually engage an automated recovery. The early save of an aircraft using the system so soon after fleet installation is an important milestone for the long-running Auto GCAS effort, which aims to reduce losses from controlled flight into terrain by up to 90%. According to the Air Force, 26% of aircraft losses and 75% of all F-16 fatalities are caused by such accidents. Based on historic accident rates, the Air Force predicts Auto GCAS has the potential to save 10 lives, up to 14 aircraft and $530 million over the projected remaining service life of US F-16 fleet.

Prize Authority

Innovation is not just in the domain of the government. It also comes from the private sector. One significant way to reach the commercial sector is through the use of prize authorities. I would like to thank Congress for extending Title 10, section 2374a Prizes for advanced technology achievements that allows the Department to award cash prizes in recognition of outstanding achievements in basic, advanced, and applied research, technology development and prototype development that have the potential for application to the performance of the military missions of the Department of Defense.

With Congress extending the Prize Authority, the Army just released a Request for Information to conduct a High Energy Laser (HEL) Rodeo in November 2015 at White Sands Missile Range to defeat Mortars and Unmanned Aircraft. This effort is in parallel to the Army and other Service HEL development efforts, and allows an evaluation of participant's ability to develop a HEL system for tactical and combat ground vehicles. The Army intends to award $1-5 million to the participants based on their ability to defeat mortar and unmanned aerial vehicle targets. Based on our knowledge of the industrial Independent Research and Development programs, we expect several vendors to provide technologies that could accelerate fielding of an operation high energy laser system.

Summary

This is an interesting time for DoD Science and Technology, with operational challenges increasing at a time when budgets are flat or declining. Meeting the national security needs requires we develop and adopt a multi-faceted strategy. We have done so through the Defense Innovation Initiative, Long Range Research and Development Program Plan and Reliance 21. While all of this change is on-going, the Department is increasing our use of demonstrations and prototypes and has a number of exciting new projects in the pipeline. I am proud of the professionals in the R&E enterprise to include industry and academia partners who are making this change happen, and I am eager to see these prototypes deliver real capabilities for use by our warfighters.