

**DEPARTMENT OF DEFENSE APPROPRIATIONS  
FOR FISCAL YEAR 2017**

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**WEDNESDAY, APRIL 20, 2016**

U.S. SENATE,  
SUBCOMMITTEE OF THE COMMITTEE ON APPROPRIATIONS,  
*Washington, DC.*

The subcommittee met at 10:31 a.m., in room SD-192, Dirksen Senate Office Building, Hon. Thad Cochran (chairman) of the subcommittee, presiding.

Present: Senators Cochran, Shelby, Blunt, Daines, Moran, Durbin, Tester, and Schatz.

DEPARTMENT OF DEFENSE

DEFENSE INNOVATION AND RESEARCH

**STATEMENT OF FRANK KENDALL, UNDER SECRETARY OF DEFENSE  
FOR ACQUISITION, TECHNOLOGY AND LOGISTICS**

OPENING STATEMENT OF SENATOR THAD COCHRAN

Senator COCHRAN. The subcommittee will come to order.

We want to welcome our panel of witnesses today to our hearing on the budget request for defense appropriations on the fiscal year 2017 defense innovation and research budget request. We appreciate very much the attendance of our panel, others who are here today, and members of our committee.

We are specifically pleased to welcome Mr. Frank Kendall, Under Secretary of Defense for Acquisition, Technology and Logistics; Mr. Stephen Welby, Assistant Secretary of Defense for Development, Research and Engineering; and Dr. Arati Prabhakar, Director of Defense Advanced Research Projects Agency, or DARPA.

Today, we look forward to learning more about the science and technology investments proposed in the fiscal year 2017 budget. This subcommittee has been a strong advocate of science and technology investments and has ensured funding to make certain our Nation can maintain its role as the world's leader in technology and innovation.

We want to continue to receive input from experts at the Department of Defense, so they can inform committee action as we do our work.

We appreciate your joining us today to testify as our committee continues to evaluate the budget request.

[The statement follows:]

## PREPARED STATEMENT OF SENATOR THAD COCHRAN

The hearing will come to order. We welcome our panel of witnesses today to a hearing on the fiscal year 2017 budget request for Defense Innovation and Research. We are specifically pleased to welcome: Mr. Frank Kendall, Under Secretary of Defense for Acquisition, Technology and Logistics; Mr. Stephen Welby, Assistant Secretary of Defense for Development, Research and Engineering; and Dr. Arati Prabhakar, Director of the Defense Advanced Research Projects Agency.

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We appreciate your joining us today to testify as our committee continues to evaluate the budget request.

Now I will turn to the Vice Chairman, Senator Durbin, for his opening remarks.

Senator COCHRAN. I am pleased to yield to the distinguished Vice Chairman of the subcommittee, Senator Durbin, for any remarks.

## STATEMENT OF SENATOR RICHARD J. DURBIN

Senator DURBIN. Thanks, Mr. Chairman. I am pleased to join you in welcoming our witnesses to discuss defense innovation and research.

Thanks to Mr. Kendall, Mr. Welby, and Dr. Prabhakar for their testimony. We are looking forward to hearing from our witnesses on innovations the department is undertaking.

I am very concerned with the state of our Federal investment in research and development. We have gone from a high watermark of 17 percent of the discretionary budget for research and development to 9 percent. From the 1960s through the 1980s, Federal spending on research and development (R&D) averaged 1.52 percent of gross domestic product (GDP). Now, 0.08 percent. So we have seen a steady decline that has led to a cumulative \$1.5 trillion research investment deficit.

What are we thinking? While our investments are on the decline in the United States, other nations are surging ahead. China has increased funding, and R&D is on track to surpass the United States in research and development in a little over 5 years.

I sponsored two bills to reverse the innovation deficit, the American Cures Act, the American Innovation Act. The Cures Act would increase medical research for National Institutes of Health (NIH), Centers for Disease Control (CDC), Department of Defense, and Veterans Affairs (VA) at the rate of GDP inflation plus 5 percent a year. Similarly, the American Innovation Act would set science and technology funding at the rate of inflation plus 5 percent for the Department of Energy, the Department of Defense, National Science Foundation, National Aeronautics and Space Administration (NASA), and National Institute of Standards and Technology (NIST).

Let me go out on a limb and say, if we did this 5 percent real growth in research and development for 10 straight years, America would light up the scoreboard. We would repay over and over again the cost of so many things that we are enduring today, hopelessly enduring, because of the lack of research.

Last year, with the support of my colleagues, this subcommittee increased medical research in the Defense Department by 5 percent in real growth terms. I thank the chairman. He has been a real leader on this.

We also added \$220 million to defense basic research last year, bringing the defense science and technology (S&T) funding to a total of nearly \$13 billion. That is an increase of \$950 million and a real increase of just over 5 percent.

I am hoping to hear from our witnesses about any technology deficits and the challenges we face.

Secretary Carter has introduced new ways to push innovation into Defense R&D, such as a new partnership with In-Q-Tel. These are promising initiatives, but our challenge is both to see how they pay off and to keep making innovation a priority.

I have given a lot of speeches about research and innovation. The last point I want to make is advice from a man named Jack Valenti. Some of you remember Jack Valenti. He worked for President Lyndon Johnson, headed up the motion picture alliance. He said every good speech includes six words, "Let me tell you a story."

You need to tell us a story, a story we can share with everyone, about how this investment of taxpayer dollars makes us a better Nation, makes us safer, and continues to keep America in the lead.

We look forward to your testimony.

Senator COCHRAN. Thank you, Senator.

Let me call our witnesses to the table.

We welcome you, Mr. Frank Kendall, Under Secretary of Defense for Acquisition Technology and Logistics; Mr. Stephen Welby, Secretary of Defense for Research and Engineering; Dr. Arati Prabhakar, Director of Defense Advanced Research Projects Agency.

We appreciate very much you being here today and the work you have assumed responsibility for in our government.

So let's proceed.

#### SUMMARY STATEMENT OF FRANK KENDALL

Mr. KENDALL. Thank you, Mr. Chairman. Chairman Cochran, Vice Chairman Durbin, distinguished members of the committee, we appreciate the opportunity to testify today.

Mr. Chairman, I would like to ask that our written testimony be admitted to the record.

Senator COCHRAN. Without objection, it's so ordered.

Mr. KENDALL. Thank you, sir.

Scientists and engineers from across the department's research and development organizations work hard every day to advance our Nation's defense technologies.

The department's current focus on innovation is much broader than just innovation and technology. However, our emphasis on innovation reflects our belief that we must do everything we can to maintain our military technological superiority.

Technological superiority isn't just about technology. Military superiority directly correlates with innovation in operational concepts and organizational constructs. It correlates with all the things we do to be efficient and productive in every aspect of the defense enterprise, from human resources management to the use of informa-

tion technology. We depend on innovation for a healthy and robust industrial base, stable and adequate budgets, sound technology investment decisions, and an effective defensive 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 innovation efforts.

In the areas of acquisition, technology, and logistics, for which I am responsible, we have for the last several years undertaken a program of continuous improvement anchored by three successive iterations of better buying power initiatives, the most recent of which is focused on innovation and technical excellence.

The department as a whole has been pursuing innovation across-the-board under the Defense Innovation Initiative originally announced by Secretary Hagel and endorsed by Secretary Carter.

Secretary Carter has introduced the Force of the Future human resource initiatives, which are intended to provide innovative approaches to more effective recruiting and retention, particularly in high-demand specialties like cyber and information technology.

Secretary Carter has emphasized the department's efforts to accelerate the transition of technology from commercial nontraditional sources into Department of Defense (DOD) through the Defense Innovation Unit—Experimental, or DIUx, which was established last year. DIUx also serves as a vehicle to facilitate relationships and tap into sources of intellectual capital from across the country.

In addition, the Secretary is establishing a defense innovation board composed of leading experts in commercial management and technology.

Under leadership of Deputy Secretary Work, the department has been investigating opportunities for a third offset strategy that would provide an enduring operational advantage and strengthen conventional deterrence through the application of emerging technologies and novel operational concepts.

All of these efforts are integral parts of a larger whole, which is focused on bringing more innovation into the Department of Defense.

Why is there such an increased focus on innovation? The reason is the growing recognition that the United States' longstanding military technological superiority is being challenged by peer or near-peer competitors in a way that we have not seen since the Cold War.

Controlling costs and increasing efficiency and productivity are always important, and the department remains focused on improvements in these areas.

Our first responsibility, however, remains to ensure the United States has and will continue to have dominant military capabilities relative to any potential adversary.

I am deeply concerned about the adverse trends in maintaining U.S. military technological superiority. I have testified about that before to this committee.

The department-wide focus on innovation, technical excellence, and acquisition process improvement is intended to help sustain our long-term competitive advantage and make the most effective use of the resources provided by the Congress.

The Department's ability to maintain the Nation's technological superiority for the 21st century depends on the research and development investments reflected in our budget request. We were able to increase our research and development request in the PB-17 budget by about \$3 billion over the previous year's appropriation level.

This budget increases the use of prototyping, demonstrations, and experimentation to help the department more rapidly mature technology and to assess the impact these innovative technologies can have on our future force.

Our investments create options for future investments in full-scale development and production. We will have to rely on the Congress and the work of this committee and others to remove the threat of sequestration and provide the next administration with the resources that will be needed to place these innovative technologies into the hands of our warfighters.

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 on innovative capabilities to preserve our technology edge.

We are confident that the initiatives being pursued on the department's various innovation efforts, including a research and development strategy reflected in the President's budget submission and DARPA's efforts to help shape our technological future, will all position the department for an increasingly competitive national security environment.

Let me close by thanking the committee for its strong support of the department's efforts, as the people we lead work to discover, design, and deliver the technological capabilities our warfighters need in order to protect the Nation.

Thank you.

[The statement follows:]

PREPARED STATEMENT OF HON. FRANK KENDALL, HON. STEPHEN WELBY AND  
DR. ARATI PRABHAKAR

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.

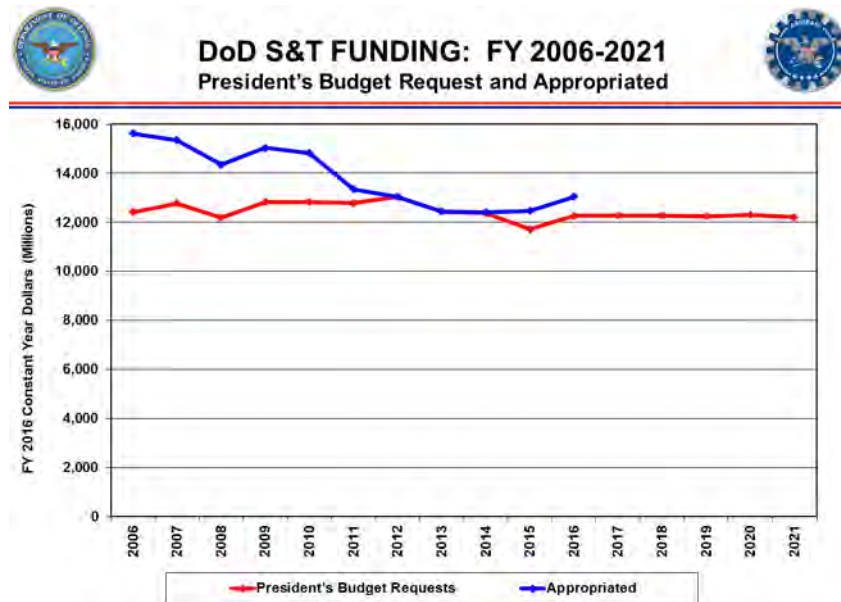
## DEFENSE STRATEGY REQUIRES FOCUS ON FUTURE TECHNOLOGIES

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.

[The chart follows:]



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 2006 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.

[The table follows:]

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
<b>TOTAL S&amp;T</b>	<b>12,251.8</b>	<b>12,266.3</b>	<b>12,500.8</b>	<b>234.4</b>	<b>12,755.7</b>	<b>12,981.8</b>	<b>13,298.8</b>	<b>13,441.1</b>	<b>64,978.1</b>
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
<b>TOTAL</b>	<b>12,251.8</b>	<b>12,266.3</b>	<b>12,500.8</b>	<b>234.4</b>	<b>12,755.7</b>	<b>12,981.8</b>	<b>13,298.8</b>	<b>13,441.1</b>	<b>64,978.1</b>

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:

- \$2.102 billion in Basic Research investment, which is an increase of \$12.9 million 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.
- \$4.815 billion in Applied Research investment, which is an increase of \$102.2 million from the fiscal year 2016 budget request.
- \$5.584 billion in Advanced Technology Development investment, which is an increase of \$119.3 million 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

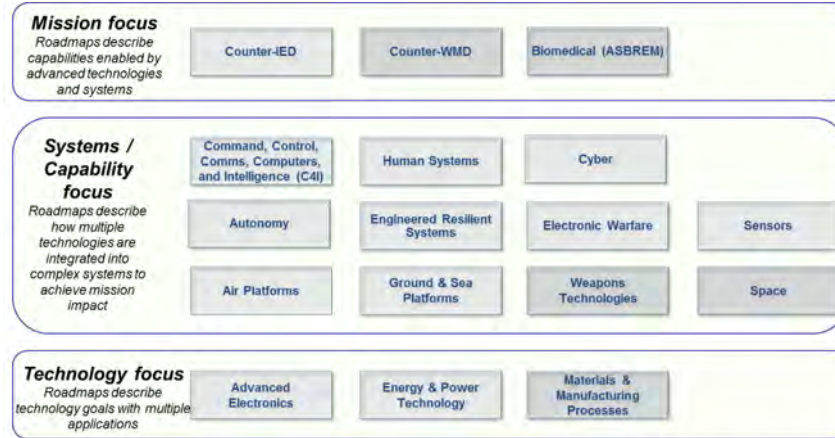
- Marine Corps Ground-Based Air Defense On-the-Move (GBAD) system, which is a vehicle-based, high-energy laser for the 21st century Marine. Directed energy will enable our naval forces to fight at the speed of light.
- Naval Tactical Cloud research is providing the framework and large-data analytics 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 U.S. 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, collocated 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 fiscal year 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 U.S. 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 proto-

types. 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.

Senator COCHRAN. Thank you very much.

Mr. Stephen Welby, Secretary of Defense for Research and Engineering.

**STATEMENT OF STEPHEN WELBY, ASSISTANT SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING**

Mr. WELBY. Chairman Cochran, Vice Chairman Durbin, and distinguished members of this committee, I am pleased to have the opportunity to provide testimony on the Department of Defense fiscal year 2017 science and technology program and our efforts to increase innovative solutions to support the warfighter.

As Mr. Kendall noted, we are at a pivotal moment in history where the advanced technical capability and capacity that the Nation has relied upon to provide us with unmatched advantage on any battlefield is now being challenged, challenged by the military technology investments being made by increasingly capable and increasingly assertive powers.

Our department-wide focus on technology innovation seeks to identify and invest in unique capabilities to sustain and advance the department's military superiority for the 21st century.

As Secretary Carter said in his remarks on the budget at the Economic Club of Washington on the 2nd of February, we must take the long view and seize the opportunities for the future in order to sustain our lead in full spectrum warfighting.

Today, the department employs over 39,000 scientists and engineers in 63 defense laboratories, warfare centers, and engineering centers across 22 States, all working every day to sustain our ability to support and field critical military technology that often has no commercial equivalent.

Our laboratories have produced important innovations in vital defense areas, such as electronic warfare, propulsion, and weapons design. And maintaining this unique technical expertise is critical for ensuring the department's ability to prepare for future threats.

However, we cannot innovate and bolster our future technological superiority from within the department alone. Our defense laboratory enterprise touches the broadest range of emerging concepts through our deep engagement with academia, industry, and our international partners to keep the DOD smart, knowledgeable, agile, and responsive in the face of new and emerging threats.

This includes outreach to the vibrant and growing commercial innovation community, a community that often does not consider applying their emerging technologies to the national security sphere.

This year's 2017 presidential budget request contains \$12.5 billion for science and technology, which includes \$2.1 billion for basic research and confirms the department's commitment for a stable and robust DOD science and technology program that is aligned with DOD priorities and supports increased investments in those technology development demonstrations required to prepare the de-

partment for an increasingly competitive global security environment.

The budget submission also continues to ensure that the department is developing the innovative technical capabilities that are going to inform our future options and sustain our U.S. technological superiority.

Our department's strength is in our people, and we must continue to recruit and retain the best and brightest military and civilian scientists and engineers, and harness their innovative spirits to give our military forces the warfighting edge.

Ultimately, our goal must always be to ensure that our soldiers, sailors, airmen, and marines always have the scientific knowledge, the decisive technology, the advanced systems and tools, the best care and the materiel edge to succeed whenever they are called upon. Our research and engineering enterprise measures its success in the security of our Nation and in the success of our warfighters.

I would like to thank the committee for your continued support of the department's science and technology efforts as we work help to help shape that future.

Thank you.

Senator COCHRAN. Thank you very much.

We now recognize Dr. Arati Prabhakar, director of Defense Advanced Research Projects Agency. You may proceed.

**STATEMENT OF DR. ARATI PRABHAKAR, DIRECTOR, DEFENSE ADVANCED RESEARCH PROJECTS AGENCY**

Dr. PRABHAKAR. Thank you both very much. And thanks to the members of the subcommittee. It is great to be here today with Mr. Kendall and Mr. Welby.

DARPA is just one part of the department's science and technology efforts, so what that means is we work very closely with our colleagues across DOD (Department of Defense). We also work directly with defense companies and commercial companies, with universities and labs of all sorts.

So we are very much a part of this wide research and technology ecosystem. Within that ecosystem, DARPA has one particular role, and that is to make the pivotal early investments in breakthrough technologies for national security.

Today, as Mr. Kendall and Mr. Welby have just described, we do that work in a shifting global security landscape that is filled with technologies moving at a furious pace. I wanted to give you one concrete example to bring that to life, and it is a very specific example about aircraft self-protection.

When our aircraft go out today on a mission, they have a set of jamming profiles. These are very specific frequencies and waveforms that they can transmit to jam the adversary and protect themselves. But today when they go out, sometimes they will encounter a radar that is transmitting a signal that doesn't match anything in their library. And if that happens in a time of conflict, it leaves them dangerously unprotected.

Now today, to upgrade that system takes weeks to months to years before we can generate that upgrade and get it out to all the aircraft to give them that protection against that one specific new

threat. That really just reflects the simple fact that when those systems were built, we were in a world in which the adversary didn't change that often.

But, of course, that is the problem. Today, that slow-moving world is gone. And in fact, it is just not that hard anymore to modify a radar. In fact, it is the same wireless technologies that have brought communications and the Internet to billions of people around the world that are now being repurposed to modify radars.

So a program at DARPA is taking a completely new approach to this problem.

Onboard the aircraft, our system looks across the radio spectrum. It uses artificial intelligence to learn what the adversary radar is doing. And then right there on the spot, it generates a specific jamming profile to counter that specific threat.

What all of that means is that our aircraft will be able to protect themselves immediately in the battlespace, even when the environment around them is changing.

To me, that is just one small example among many about how powerful it can be when you invent new technologies and then apply them to solve these kinds of problems.

There are many, many more examples across the DARPA portfolio. We have work that ranges from radical new military systems.

For example, we just christened a ship a couple weeks ago that will navigate across the oceans without a single sailor on board, and it also includes research that is harnessing everything from photons to algorithms to even living cells, to create new possibilities that no one could have even imagined before today.

So I would be happy to talk about any of that, but I just wanted to conclude my opening remarks this morning by thanking you all for the support that you give us, the trust that you place in us, along with the support that we get from senior leadership in the department. This is why DARPA is able to create breakthrough technologies for national security.

I very much look forward to your questions. Thank you.

Senator COCHRAN. Thank you very much.

Let me start the questioning by asking you, Dr. Prabhakar, what processes have you observed that enable technology transition? And what are recent examples of successfully transitioned technology?

Dr. PRABHAKAR. Thank you, Mr. Chairman, for the question.

Tech transition is always something that requires two parties, and those of us who are creating new technologies are always working. From the moment we know the technologies might work, we are always looking for our partners across the Defense Department who can team up with us and start pulling those technologies forward.

The important shift that I would tell you is going on today in the department is, in recent years, in times of war, most of our transition pull came for applications of our technology direct to theater. And we're very proud of some of things that we were able to do, tracking insurgent pickup trucks from the air, or helping commanders understand stability operations.

The shift that is happening today in the department, I think it is a very healthy one. We're finding today a much greater appetite from the services to work with us on the kinds of technologies that

can counter very sophisticated nation-state peer adversaries. And I am very much a part of the third offset strategy and other strategic directions that are starting to move the focus in the department.

Just to give you one example of that, I mentioned our self-driving ship in my opening remarks. This is a vessel that has the capability to navigate away from the pier by itself. It is not joystick controlled. It will have the autonomous capability to navigate and to follow the rules of the oceans to avoid collision. It is able to have a very long range. It can go many tens of thousands of nautical miles.

That means that we're now going to have a vessel that allows the Navy to start thinking about, number one, doing some of today's manned missions for a tiny fraction of the operating cost. But even more exciting, I think, is when you start thinking about the new kinds of missions that you might be able to do with teams of these unmanned ships, perhaps working in collaboration with manned ships.

That kind of exploration is the focus of a joint effort that we now have with the Office of Naval Research. For the next 2 years off the coast of San Diego, we'll be doing a lot of the experimentation to see what this amazing new technology really can deliver for the Navy.

Senator COCHRAN. Senator Durbin.

Senator DURBIN. Thanks, Mr. Chairman.

I'm going to ask the panel, but I think it's primarily Mr. Kendall, with the decline of the Soviet Union, we entered into some agreements for a lot of reasons to engage the Russians in providing us with technology of value to us. We were trying to divert their talent from creating that technology for one of our enemies and trying to find some basis for a positive relationship between the Russians and the United States.

One of those dealt with the RD-180, the rocket engine that we have used to launch countless numbers of satellites successfully into space. Several years ago, it was the opinion of both the authorizing and appropriating committee that it was time to build an American engine that could compete or replace the RD-180. For 2 successive years, we have been appropriating the money for the planning and building of that engine.

There is a war or debate, let's say a war of words, and a debate in Congress on the Senate side between the authorizing committee and the appropriating committee as to the fate of the RD-180 Russian rocket engine. There is at least a belief in the authorizing committee that we should stop cold, not buy any more of these Russian engines.

What I have heard from the Department of Defense is that would leave the United States vulnerable, vulnerable to two possibilities, that we might then be at the mercy of a sole source, perhaps SpaceX, or that we would be forced to use engines not appropriate for a launch, like the Delta engine, and that may be more expensive if we go down that route rather than use RD-180 Russian engines while we're in transition. The transition, we think, will last 5 years to build a new American engine.

I would like your comments on this state of play, in terms of the use of RD-180s in transition, whether 5 years is reasonable, and if we fail to use RD-180 engines, what it would mean to our security and cost.

Mr. KENDALL. Thanks, Senator Durbin.

We've had conversations about this in the past. As you know, this is a very complicated subject. But the department's goals have never changed. We want assured access to space, which means we should have two ways to get our satellites into orbit, so that if one of them has a major failure and we have a big gap in capability, we still have another way to get to space.

So number one is having assured access to space, meaning two sources.

We want competition to keep cost down. We're discovering that with the advent of SpaceX into the launch business for the department, that it's driving prices down substantially. So competition is very important to controlling cost.

We also want to get off of the RD-180 as quickly as we can. We don't want to have that dependency on a Russian source for our space launch vehicles.

The way we would like to move forward, and we think it is the best way from a business perspective, is through public and private partnerships for launch services.

The department doesn't buy either rockets or engines. It buys transportation services to get our satellites into space.

What we'd like to do is nontraditional. It's a commercial model, basically, which says that we will provide funds to close the business case for companies that will then guarantee us future launches at a reasonable price.

That's the nature of the business agreement that we want to reach. And the funding that we asked for in 2017 would allow us to do that, if it's appropriated.

The other way we could go is to just buy another engine. We could buy an engine for the Atlas rocket, and engines come together with rockets. You can't just take an engine and put it onto some rocket. It's designed for a specific rocket. We could buy a replacement engine for the RD-180 to use on the Atlas rocket.

That would be effectively subsidizing one company and providing them with a major investment for that specific rocket. We don't think that is the right way to go. We'd like to have a more competitive approach.

There may be a new engine in this, but we'd also like to get to launch vehicles that are more cost-effective and affordable to us.

Going forward with something that replaces Atlas with a more cost-competitive solution is, we think, the right approach in that regard.

The other alternative that is being talked about is the use of Delta, which is a much more expensive rocket, which has some capability to launch payloads that are comparable to the capabilities of the Atlas system, but at a much higher price, \$30 million, \$40 million, \$50 million per launch.

It is a judgment I would leave to the Congress as to whether it is worth the total cost of going to Delta, which would be over \$1 billion, depending on what estimates you make, and there are some

estimates that are much higher than that. It would be over \$1 billion that we would be paying out of our budget to avoid essentially buying RD-180s.

I don't think that is a good tradeoff. I'd rather buy a few more RD-180s to get us through the necessary transition period until we can have more modern and affordable launch services without it.

Senator DURBIN. So I'll just close, because my time is up, but I wanted to illustrate here, if I can, by this chart.

If we don't use Russian engines in transition while we're building this American engine, we're forced to use Delta engines through the United Launch Alliance. And that, we estimate, will cost, as Mr. Kendall said, between \$1 billion and \$2 billion more while we're building this new American engine, rather than using the cheaper Russian engine in transition.

What does \$2 billion mean? We can replace every Humvee in the Marine Corps, increase pay raises for our troops by 2.1 percent for the next 5 years with the difference that we would pay for Delta, keep the A-10 flying for 5 more years, double the funding for National Guard equipment by 10 to 20 space launches under full and open competition.

I don't want to continue to subscribe to this Russian engine any longer than we have to, but I think it is shortsighted for us to just say, as some in the authorizing committee have said, "We're cutting them off cold turkey. We're finished with them."

If we can use them in transition to an American-made engine, we will have real competition between SpaceX and ULA or whatever company emerges from that, and then we can have the competition in dual-sourcing, which you say is important for our security.

Thank you, Mr. Chairman.

Senator COCHRAN. Thank you, Senator.

We'll now recognize the distinguished Senator from Montana, Mr. Daines.

Senator DAINES. Thank you, Mr. Chairman.

And thank you for coming today to testify about defense innovation and research. Throughout history, our country has depended on being one step ahead of our adversaries, and that relies heavily on the ability of our equipment and technology to be the very best possible. So thank you for the work you're doing here.

Coming from a State like Montana—and by the way, our technology industry is rapidly growing—I understand the importance of the work you do and encourage you to come out and take a look at the work we're doing out in Big Sky Country sometime.

I was told in this very seat 2 months ago by Secretary James that the Ground-Based Strategic Deterrent program was on track and that it would hit its first milestone by April.

Well, it's April, and I'm told now there is an issue.

I have a bicameral group of congressional members ready to send a letter expressing their concern. Have the Department of Defense and the Air Force dropped the ball on this? When I am told something is going to be on track, I expect it to be so.

And as you know, we've been trying to get this worked out over the past week, but I'd like to see the committee get some resolution even here today.

Secretary Kendall, would you have an update on the new timeline for the GBSD Milestone A?

Mr. KENDALL. Certainly, Senator.

I think there's some confusion about the difference between what we call a milestone and what we actually do. So let me explain what we're actually doing.

The GBSD program is on track. It's very important that we proceed with that, and we do it in a timely way. So we're not slowing the program down at all.

The next thing we will actually do is to release an RFP to industry for the first phase, which is risk reduction. That will happen very shortly. We're very close to doing that.

I can call that the Milestone A. My initial idea was to wait until I got the bids in. I want to see what the companies are going to offer us, in terms of the activities they would do in that phase. I had considered shifting Milestone A until just before the award of the contracts, as opposed to at this time.

I am happy to do the Milestone A now, associated with the RFP release. The only problem I have with that is a firm legal requirement that before I do a Milestone A, I have to have an independent cost estimate. So I have to satisfy that legal requirement in order to have the Milestone A as a dot on the wall of something you did.

Senator DAINES. Right.

Mr. KENDALL. That does not slow down releasing the RFP to industry, which is the substance of what we're doing.

So I'm going to hit Milestone A as soon as I can.

Senator DAINES. Okay. So what's your best forecast today on when you would hit Milestone A?

Mr. KENDALL. I think the actual decision of releasing the RFP is a couple weeks away. The decision to call it a Milestone A and sign a document that says I've hit a Milestone A is dependent upon the cost analysis office giving me an independent cost estimate. That is a little bit further away.

Senator DAINES. Okay, and what is further away? Just, again, are we talking days, weeks, a month?

Mr. KENDALL. I would guess a month or 2.

Senator DAINES. A month or 2, so April, May, by June, we would have Milestone A, worst-case scenario?

Mr. KENDALL. I would say, as an estimate, probably by June. Again, I don't control that timeline, because of the legal requirement that I have to satisfy.

Senator DAINES. Okay. All right. I'll move on.

I want to talk about radio batteries here for a moment. I've spoken on this committee before about the importance of lowering the weight that our servicemembers carry. From creating more injuries in the long run to decreasing their combat effectiveness, I think the weight our soldiers carry is a serious threat to the future of warfare, especially when soldiers witness Al Qaeda fighters in sneakers with no armor.

The average infantry marine carries 20 pounds of batteries on a 72-hour mission. This is because they carry a battery that looks like it can run my pickup. In fact, I have one of these batteries here. This weighs nearly 5 pounds. Additionally, there's a non-

rechargeable version of this battery that costs more to dispose of it than even purchase it.

My question for Dr. Prabhakar and Secretary Welby, what programs are you funding in your budget this year to get lighter and more cost-effective batteries to soldiers in the field? The marines are asking the question.

Dr. PRABHAKAR. I will start and then turn over to Mr. Welby.

Senator Daines, I understand the problem, and I completely share your frustration. This is an area where DARPA has had prior investments many years ago. We don't have current activity in the area for a couple of reasons.

One is because of Advanced Research Projects Agency Energy (ARPA-E) in the Energy Department who is investing in battery technology, among other areas. And they have been great about trying to get some of their advances into DOD.

The other reason is just a very deep science reason. To everyone's mutual frustration, it has been one of the most intractable problems of really increasing energy and power density in these systems. And in contrast to the electronics that seems to get better and better all the time very quickly, battery technology has just been on a much more gradual improvement curve, so it continues to be a very challenging problem.

Senator DAINES. How high of a priority is this?

Dr. PRABHAKAR. I think if we saw great ideas in this area that we thought could have a revolutionary impact, we would be all over it. But we are not really seeing a lot of those.

Senator DAINES. I have to wrap up here. I'm out of time.

This gets back to looking at what the private sector is doing here to solve some of these problems. They are moving quickly and more nimbly. Let's make sure we are in sync with what is going on with the best technologies.

For example, I know that there are new barrels that have been developed now that are 3 pounds lighter. They are carbon-wrapped. They dissipate heat fire. They shoot tighter groupings, so that they are more accurate and lighter. And there is another example.

In fact, one of those barrel manufacturers is right in Montana. We have a bunch of special operations guys that are designing these things. They are building them in Montana.

That is an example where the private sector is moving a whole lot faster than our procurement process. So I just encourage you to continue to stay engaged here with the nimbleness and the speed which innovation is occurring here in the country, because lives are at stake here for the U.S. military.

Thank you.

Senator COCHRAN. The time of the Senator has expired.

The distinguished Senator from Montana, Mr. Tester.

Senator TESTER. Thank you, Mr. Chairman. You get us back to back.

I appreciate you guys being here. I appreciate your testimony. I do have a follow-up question on the GBSB.

We are looking at the comprehensive weapon system, flight system, ground launch systems, weapons system command-and-control, the whole ball of wax.

What Senator Daines did point out is correct. Milestone A, which may be no big deal, but it may be a big deal, the question is, are we on track to complete this in the way that you had in mind to begin with?

Mr. KENDALL. Senator, we are on track. We are approaching the program with some sense of urgency. It is early stages, and the first substantive work will be some risk reduction work and some preliminary design work.

So we want to get out an RFP, request for proposal, get bids in, and have multiple teams do that first phase. So we are moving aggressively to make that happen.

Senator TESTER. I appreciate that.

Are there any deadlines that we should be aware of that you are going to be facing in the future?

Mr. KENDALL. I think what we have to do on the GBSD is look carefully at some cost tradeoffs. We have, as you know, the big affordability issue with recapitalizing the entire triad coming up.

Senator TESTER. Right.

Mr. KENDALL. So as we go through this process, particularly the preliminary stages over the next year or 2, we are going to be looking at ways where we can control cost on the system. It is going to be an expensive system by any metric. So that is going to be one of the things we look at very carefully.

It is a system of systems. It is not just the missile. It is also the infrastructure, including the command and control. So we have to look at all of that.

Senator TESTER. I appreciate that, and I applaud it and support what you are doing.

I want to talk a little bit more parochial than that. I want to talk about some helicopters.

In Malmstrom Air Force Base, we are using Vietnam-era helicopters. There are some problems with that. I am sure you are fully aware of that.

It is my understanding that the Air Force is looking into a sole-source provider contract to get those helicopters there quicker, the Black Hawks. We have been told they will be there no later than 2019. In reality, when do you expect them to be there?

Mr. KENDALL. I can tell you that the Air Force is looking at accelerating that procurement. Our initial plan, and what we funded in the budget, was to do this allocation of force as an interim step and then to bring in new helicopters a little bit later. We have a lot of existing helicopters, obviously, that could be applied to that and some existing units.

We are trying to accelerate that. So we are looking at alternative acquisition strategies that would allow us to accelerate that and get those replacement helicopters much more quickly.

I haven't made a final decision on that, but I expect it very, very soon.

Senator TESTER. You expect a final decision on the definite time certain for the arrival?

Mr. KENDALL. A final decision on whether to revise the plan we put in the budget and go with something that accelerates that plan.

Senator TESTER. Just tell me, and if you don't know, you don't know, but if you were to accelerate that plan, what kind of acceleration are you talking? Are you talking months? Are you talking potentially a year?

Mr. KENDALL. More than a year.

Senator TESTER. More than a year?

Mr. KENDALL. More than a year. We could accelerate from currently what is in the budget more than a year.

If we did a reprogramming and we bought helicopters off of an existing multiyear, we could go quite quickly. It takes about 2 years to get delivery once you put the orders in, so there is that factor. But that would accelerate substantially from what we put in the budget.

Senator TESTER. We have a couple guys in this committee that will help you accelerate, if you are willing to do that.

Mr. KENDALL. I understand, sir. Thank you.

Senator TESTER. All right, very good.

I want to talk a little about the ranking member's question on the rockets. You said you need two ways to get into space. I assume that is the RD-80 and the Delta, those are the two ways?

Mr. KENDALL. The two ways we have in mind right now for Atlas class launches is SpaceX with Falcon 9 and Atlas using the RD-180. That is the interim solution until we can replace the RD-180.

Then presumably SpaceX would still be in the business and then possibly ULA with a follow-on system or somebody else.

Senator TESTER. I got you, and I don't know what kind of agreement you have with Russia, but Russia is Russia.

And you said that if you were to quit cold, it would be a problem. If you were to quit that motor cold, it would be a problem. The ranking member made that point, too.

What if it is not our choice? What if it is theirs? Then what do we do? What if it is their choice? What if they say no more?

Mr. KENDALL. That is a concern. At this point, that has not been something that they have threatened us with, as far as I know.

The company involved has a number of engines on order for military or commercial purposes, so assuming that that contract is fulfilled, I think there would be, in fact, enough engines available to get us through this interim period.

We do have some risks, and one of the reasons we want to get off the RD-180 is to remove the risk that they would withhold them for us. We need a few years to make that happen.

Senator TESTER. I just hope that we learn from this going forward, because I just don't think this is really—the optics are horrible. And from a security standpoint, I don't think they are much better than horrible. And so I hope we learn from this going forward.

Thank you for your work. I appreciate it. Maybe I will come back and ask the other two questions.

Mr. KENDALL. Yes, sir.

Senator COCHRAN. The distinguished Senator from Kansas, Mr. Moran.

Senator MORAN. Chairman, thank you very much.

Mr. Secretary, Mr. Welby, my understanding is that Navy staff as well as your R&D staff believe that a University Affiliated Re-

search Center (UARC) for Wichita State University will help leverage their unique capabilities and their talented people, and that there is no other entity, and this is me speaking now, there is no other entity in the world that has the self-qualification authority for materials in DOD procurement.

WSU is, undoubtedly, uniquely qualified to do more work that is timely and less costly for the department.

And I want to make certain that staff recommendations are making their way to your desks, that is that the bureaucracy is not slowing down a designation process that is supposedly designed to expedite the acquisition process.

Mr. Welby, Wichita State University has the ability to develop composite patchwork to fix the urgent structural problems with the F-18. If you had the ability to directly access those solutions to fix the F-18 and support the warfighter in the cockpit, would you use it?

Mr. WELBY. Senator, I am well-aware of the capabilities of Wichita State, that include kind of remarkable work on nondisruptive tests for composites, the large-scale structural test capabilities they have out there.

To date, I have not received a request from the Navy for sponsorship for that work, but should we receive requests, we would expeditiously move on it, if we received it.

Senator MORAN. Mr. Secretary, and maybe, Mr. Welby, one of the things I want to make certain is that we are not so parochial that we have somebody unable or unwilling to make that request.

The Navy visited Wichita State recently and came away with a significant positive impression of what the capabilities are.

Mr. Secretary, it is my understanding that either of your offices can formally designate a DOD primary sponsor for each UARC to assist in policy and contractual oversight. So I think you have the ability to do this. And what I would say is that WSU is, in fact, number one among U.S. universities in privately funded aeronautical research and development, and that as a second source to our bigger contractors and your efforts to improve the purchasing capabilities, the efficiency, this better buying strategy seems to me to be very compatible with getting rid of the middleman out of this process. And the goal here is to get you all to make that designation and to allow the Department of Defense to acquire the technologies that Wichita State has to offer.

So I am going to submit a question for you, Mr. Secretary, for the record, asking a number of details. I would appreciate your formal response. I am going to ask you to address cost savings within the university R&D labs, what labs are currently addressing F-18 readiness, and university partnerships that you can designate to be in the best interest of the department overall.

I believe you have the power to move this forward, and I would request that you do so. It is in the best interests of the department, and most importantly, it is in the best interests of our warfighters to do so.

And finally, Mr. Secretary, I would ask that you and I meet personally to have a conversation about this.

Mr. KENDALL. I am happy to do so, Senator.

[The information follows:]

I believe the Senator's questions on University Affiliated Research Centers and Laboratory Partnerships were answered in the Questions for the Record. As I stated during the hearing, I would be happy to meet with the Senator to discuss this further. His staff may coordinate with the appropriate Department of Defense Legislative Affairs liaison to schedule such a conversation.

Senator MORAN. Thank you very much.

Thank you.

Senator COCHRAN. The distinguished Senator from Hawaii, Mr. Schatz.

Senator SCHATZ. Thank you, Mr. Chairman.

Secretary Kendall, and to both of you, thank you for your testimony.

The Defense Department has made a lot of progress in protecting itself from hackers and cyberattacks, but we also know that vendors can be vulnerable. They have access to highly sensitive information, and we need to take precautions to protect that information.

Secretary Kendall, do you know, among your vendors and within our supply chain, prime and subprime contractors, how vulnerable they are to cyber breaches?

Mr. KENDALL. We are very concerned about that, and we have taken steps to try to provide mandatory standards. We have provided mandatory standards to industry to implement to provide greater protection.

Classified information is pretty well-controlled, and the standards there exist and are verified. Unclassified information, which can still have a great deal of damaging effect if it is stolen through computer hacking, is a big problem. So is the problem of inserting things into the supply chain.

So we are trying to take steps. We are taking steps to increase our security there. We are moving away from a voluntary reporting of attack system to a mandatory reporting of attack system. And we are moving to much more stringent standards for protection of sensitive information.

Senator SCHATZ. A couple of questions on that.

In the procurement process, you now have these minimum standards. Is there any thought to scoring according to somebody's ability to protect against cyberattacks? In other words, to say it is insufficient to meet the minimum standard but rather we are going to actually give you a better score in the procurement process depending on how good you are at this.

Mr. KENDALL. Generally, we have taken comply with a certain acceptable level as our approach. That is something we enforce through contracting.

Senator SCHATZ. What happens if there is a cyber breach? Are they then in violation of the contract, if they don't meet the minimum standards, if there is a breach? Or what is the process?

Mr. KENDALL. It depends upon the nature of what happened, how serious a response is. We have a wide range of responses. It would be a breach of contract if they had not put adequate defenses in place.

If they had failed to follow the terms of their contract, there are a number of things we can do, all way up to terminating the contract, all the way to barring or suspending them.

Senator SCHATZ. How often does that happen?

Mr. KENDALL. Generally speaking, what we would do in the case of a cyber violation that was not dramatic would be just to insist that they comply with the contract. And we could withhold payments for that, for example, until they did so.

Senator SCHATZ. I guess my concern more generally is that as the vulnerability increases, because the world is changing, that your procurement systems, not because it is anybody's fault, you have legacy contracts, you have legacy processes and procedures. And my question is, are you done with updating your processes, procedures, sort of statutory rule requirements, all of that?

It seems to me that the wheels of government turn a little more slowly than we would prefer, in terms of getting up to speed. So whether it is about disclosing a cyber breach, or whether it is what recourse you have in the case of a breach, I am just wondering whether you are all the way to where you want to go and whether you need any assistance on the authorizing or appropriating side to kind of accelerate.

The curve in terms of the threat is going like this, and I can't imagine that the government is necessarily catching up with it.

Mr. KENDALL. It is a work in progress. I think we will always be modifying our standards as the threats change and emerge.

I don't think we need legislative help at this point in time. I think we can, through our contracting provisions with the regulatory authority that we have, put adequate measures in place.

It is going to take some time, because we are doing it as we issue new contracts. We are using the contracting vehicles to do it.

But the provisions that we put out recently, the industry gave a very, very strong reaction about how difficult it was, how difficult it was to flow it down to all their suppliers, not just to do it for themselves, and they asked for some more time to comply. So we did relax the time constraints a little bit, just in the face of the reality of that.

But this is something we care about a lot, and we are going to continue to be aggressive about putting these in place and enforcing them.

Senator SCHATZ. So I would just like you to keep in touch with us about any legislative help that you may need and just to be straight with us. This challenge is not your fault, but it is impossible for me to imagine that you have all the way caught up.

I understand it is a work in progress. I would like to know where we are in that process.

It also seems to me that the kind of minimum requirements—"you are cyber secure; therefore, you may apply for a DOD contract"—may not suffice in the long run. We may want to incentivize private sector companies for being even better than the minimum requirements, because that seems to be checking a box, and obviously, that is not what we are intending to accomplish here.

Mr. KENDALL. We would consider that approach. We look at past performance of contractors, seeing how well they have done over time as a source selection consideration.

But I would be happy to have a separate conversation with you and brief you in more detail on what we are doing in this area.

Senator SCHATZ. Thank you.

Senator COCHRAN. The time of the Senator has expired.

The distinguished Senator from Alabama, Mr. Shelby.  
 Senator SHELBY. Thank you, Mr. Chairman. Mr. Chairman, I ask that my opening statement be made part of the record.  
 Senator COCHRAN. Without objection, it is so ordered.  
 [The statement follows:]

PREPARED STATEMENT OF SENATOR RICHARD C. SHELBY

Thank you Mr. Chairman, and I join you in welcoming our esteemed panel this morning. Secretary Carter has recently testified concerning today's diverse and complex security environment.

With threats around the world ranging from ISIL and rogue nations on one end, to increasingly assertive near-peer competitors on the other, it is an important time to focus on innovation and investments in our advanced capabilities.

Innovation of course is nothing new to Alabama, which hosted the Advanced Research Projects Agency (ARPA) going back to 1958, managing development of Saturn V moon rocket. And the American people understand the importance of investing in advanced technologies both to protect our men and women in uniform, but also because of the value of deterrence.

Whether our Nation is making investments in high-energy laser capabilities, advancing our abilities in hypersonics, or pressing improvements to our homeland and deployed missile defense systems, when we field superior capabilities, we give our potential adversaries more reasons to pursue peace, and our military more options to win any fight.

I look forward to hearing more about the important work from our panel today. Thank you, Mr. Chairman.

Senator SHELBY. Secretary Kendall, I want to be associated with the remarks and questions that Senator Durbin propounded just a few minutes ago.

We have had before this Appropriations Subcommittee on Defense testimony by the Secretary of Defense, right here, the Secretary of the Air Force, and in a closed session, the Director of National Intelligence, all on the same wavelength to say that there would be a gap, they believe, if we just stop cold and look the other way and not buy the Russian engines.

We all want to get rid of the dependence to some extent on the Russian engine. I think that is a given. But we are dealing with more than optics here. We are dealing perhaps with some real implications of national security, are we not, sir?

Mr. KENDALL. Yes, we are. I don't know of anyone who is specifically advocating immediately stopping. We do have authorization for some number of engines. And this committee has helped us in that regard also.

But there are two things at stake here. One is the risk we would be running if we stopped immediately. That would be substantial. If we stop using, we don't have enough Deltas on order right now to meet all our needs. So we would become entirely dependent upon the only other certified provider. If there was a malfunction, an anomaly, an accident, whatever, where we lost that source for a while, we would not have a way to get these payloads into space.

The other thing is the cost. Delta is a much more expensive system. The estimates do vary widely. It depends upon how soon you start using Deltas instead of Atlases or Falcon 9s, and how long you use them and how many you use. So given the uncertainty about that, there is a wide range of numbers.

I have not seen any numbers below \$1 billion, in terms of total cost. On a per launch basis, it is multiple tens of millions. So there is that impact.

We would have to find the funding. Senator Durbin talked about the opportunity costs. But there is a real cost associated with changing, which are the things we are currently asking for in our budget that we would have to stop doing. So it would actually be a net loss.

Senator SHELBY. It could be a national security cost plus a physical cost, could it not?

Mr. KENDALL. Yes, exactly.

Senator SHELBY. How much, roughly, do we buy from Russia? I know we buy more from Russia than just these engines. We buy a lot of things from Russia, do we not? Small arms and so forth?

Mr. KENDALL. We are buying Russian equipment. We have often through other countries, not directly from Russia, for the Afghan military, for example, or the Iraqi military, or for some of the groups that we are arming to help with us in Syria.

So there are some purchases for that, generally not directly from Russia but through other countries.

We did by Mi-17 helicopters for the Afghan military. We have committed to stop doing that. We are not buying any more. We are looking at the long-term health of that fleet and what we want to do about that and considering our options there.

I am not aware of any major, direct purchases that specifically influence the U.S. military. Again, we don't buy the engines. We buy the launch services. A private supplier buys the engines.

Senator SHELBY. We understand. Indirectly.

Mr. KENDALL. But I am not aware of any other dependency on Russia that is similar to the RD-180 dependency.

Senator SHELBY. Let's talk about the replacement engine, which this committee has funded the research and development. And we are going to continue to do it, even more than was asked for, if I recall, Senator Durbin, on this.

Realistically, where are we today on the development of the replacement engine? And in your judgment, which you have had a lot of experience and you have two distinguished people here with you, what are we talking about in time?

Mr. KENDALL. We're talking about a few more years. The best estimate is 2021, possibly 2022. But we have to start.

And one of problems we have right now is that because this has become—I will be blunt about this—fairly politicized, it is very difficult to get the Congress to agree across the various committees that have jurisdiction.

Senator SHELBY. Yes.

Mr. KENDALL. We have started some contracts on propulsion systems, most of which is going toward first stage propulsion. But at the end the day, we don't want to buy an engine. We want to buy launch services.

Senator SHELBY. That is right.

Mr. KENDALL. So we are trying to, in this budget request in 2017, get authorization and appropriations that will allow us to get on with some public-private partnerships for the launch services we need, which will certainly incorporate an engine that is not the RD-180. But that is what we are trying to buy, and that is I think the most efficient way for us to proceed.

Senator SHELBY. Thank you for your testimony and your service.

Dr. Prabhakar, is that right?

Dr. PRABHAKAR. I grew up in Texas, sir, so there is nothing you can do to my name that has not been done.

Senator SHELBY. Thank you for your service.

In your prepared statement, you highlight Chinese and Russian investments in sophisticated ballistic and cruise missiles, weapons of the future.

Could you please share with the committee how important it is for the United States to also advance our own supersonic weapons to deter or compete with potential adversaries? In other words, we can't fall behind, can we not?

Dr. PRABHAKAR. Absolutely.

Senator SHELBY. Speak to that issue.

Dr. PRABHAKAR. I will certainly start and turn it over to my colleagues who have a broader perspective.

Absolutely, and I think what you are highlighting is just one dimension of the shifting global environment that we are all focused on and is behind a lot of the department's thinking in the third offset strategy, for example, a recognition that while we had our heads down focused on two ground wars, counterinsurgency, counterterrorism for an extended period of time, that the rest of the world didn't stand still. In fact, they have learned how we fight and have advanced their own technologies, have used globally available technologies, have become far more formidable future potential adversaries.

And it is not just missiles. I think that is one important part of it, but really the entire collection of capabilities that people have today really demand some fresh thinking on our side, if we are going to counter that and deter and defeat, if necessary, those kinds of advanced capabilities.

Senator SHELBY. The failure of us as a Nation—and a lot of it starts here, in this committee, funding—fail to fund the advanced technology, which goes to the national security system, that could put our Nation at risk down the road, could it not?

We can't defend this Nation with yesterday's weapons when you have potential competitors or adversaries moving to the next level.

Dr. PRABHAKAR. Absolutely.

Senator SHELBY. Secretary Kendall, do you have a comment?

Mr. KENDALL. That is essentially correct. The idea of the third offset strategy is to pose a new problem to potential adversaries that they haven't solved and will take them some time to solve.

The problem that we posed to potential adversaries in the first Gulf War was how to deal with precision munitions, how to deal with stealth network systems, wide-area surveillance centers.

People have had a long time to try to figure out how to deal with that set of capabilities that we demonstrated so dramatically. What they have figured out is that our ability to deliver those things depends upon a relatively small number of targetable assets: aircraft carriers, forward airbases, logistic nodes, et cetera, and satellites.

So they have built the systems to target those capabilities, so we need to respond with the next round, if you will, in this two-sided game that we are playing. It is not a game; it is very serious.

That is what the third offset strategy is all about.

It is a much more difficult thing to do today because of the leveling of technology in the world, largely because investments in the commercial sector are much more prominent, and a lot of that has military applicability, but also because of the economic capabilities of some of our potential adversaries.

China is not the China of 20 years ago, in terms of its financial capability. It is much more robust, and they are investing very strongly in strategic capabilities this way.

Russia fueled largely by energy income has also been making some significant investments.

So longer term, I would be more concerned about the one that is a greater economic power. But setting that aside, both are investing in capabilities that are very clearly designed to defeat our way of fighting, in particular in our way of projecting power. And we need to counter that.

The third offset strategy is based on the idea that we need to be as creative and innovative as we can to find some new ideas and new technologies that we can apply and new operational concepts that will pose a very difficult problem for the people who have been investing in ways to defeat us.

Senator SHELBY. We found out in 1945 that the Germans were, overall, much farther advanced than we were, dealing with missiles and so forth. We got a treasure trove when we brought those scientists here to this country, did we not?

Mr. KENDALL. Sir, that is a very good point, because I think we have gotten very comfortable with the idea that we are militarily dominant technologically. The idea that we can be challenged—Senator Durbin and I have had conversations about this in the past—that we can be challenged in terms of technological superiority is something that people don't take very seriously initially until you show them what is actually going on.

Senator SHELBY. That could be a failing, couldn't it?

Mr. KENDALL. Yes.

Senator SHELBY. Thank you, Mr. Chairman.

Senator COCHRAN. Thank you.

The distinguished Senator from Illinois, Mr. Durbin.

Senator DURBIN. Thanks, Mr. Chairman.

I want follow up on this RD-180 conversation, because there are some other elements here that we ought to bring out on the table.

SpaceX is largely developing whatever they are developing with private sector investment. Now we have ULA, which was a combination of Boeing and Lockheed, which received substantial subsidies from our government to create the company and to develop the engines which we use to launch satellites.

Now we are talking about the next generation of rocket propulsion and engines. And it appears there are two players, Blue Origin with Jeff Bezos and Aerojet. My understanding is that Blue Origin is either in league with ULA or talking to ULA about developing this next engine, next rocket opportunity, with private funds.

But Aerojet, I think you have referred to it, at least obliquely, in your comments here, Aerojet is talking about developing this new engine with more Federal subsidy, with the Air Force being a player. You called it a public-private partnership.

So stepping back from this for a moment and talking about reliability of source, which is important, and competition, don't we put a finger on the scale if we say that one of the competitors is going to be subsidized by the Federal Government?

Mr. KENDALL. I wouldn't refer to the contracts we have had as subsidies. We paid for something, and we got something delivered for that.

In the case of ULA, what we paid for was their capacity to provide launches, and then separately for individual launches that they provided us with. So I wouldn't refer to either of those as subsidies, per se. We get value for our money.

What we would do with the public-private partnership—

Senator DURBIN. You can get value for a subsidy, there is no question about it.

Mr. KENDALL. Fair enough, Senator. I cede the point.

Senator DURBIN. The point I am making is that we put money on the table to keep ULA in business, let them merge and grow.

Mr. KENDALL. Yes.

What would we do with public-private partnerships is contract not with the engine companies but with the launch service providers. They would then choose the engines to go into whatever they would offer to us as the way they would do launches in the future.

So in the case of ULA, they are not an engine company. They would have to select someone. I know they are working with Blue Origin. I think they are also working with other companies. They have looked at the other engine that you alluded to.

We would look at their proposal as we would at other proposals. If SpaceX wants us to help them fund their development to provide more of this capability, we could do that. But what we want in return for our money is—and this would be done competitively, so we are not just going to hand out money. We are going to do this on a competitive basis.

What we want in return for that investment, if you will, are guaranteed launches at a reasonable price in the future, because that is ultimately what the government wants.

Senator DURBIN. I follow you, but there are two different models, are there not, between Blue Origin and Aerojet?

Mr. KENDALL. There are two different technologies for engines. One is a methane-based technology, and the other is not.

Senator DURBIN. I am talking about funding. It is my understanding that Blue Origin through Mr. Bezos has said we are paying whatever it costs to develop this alternative delivery. And Aerojet has said we are counting on the Air Force stepping in and helping us pay for developing this new alternative.

Mr. KENDALL. Those are private investment decisions. And I think in the case of Mr. Bezos, I can't speak for him, but I believe he is anticipating a very large market for space launch, which will recover his investment. I don't think it is intended as a gift. He expects to recoup it.

Senator DURBIN. It is not a private market decision if one of the competitors says we can only compete with, to use the word again, the Air Force subsidy that helps us.

Mr. KENDALL. Again, it is competitive. So cost is a factor to us. If we are getting very large private investments on the one hand that are reducing the cost of one option, and we are not getting them on the other hand, we are going to go with a lower cost option in all likelihood.

Senator DURBIN. We are talking about 5 years, 2021, 2022. Are you thinking of both Blue Origin and Aerojet when you make that calculation?

Mr. KENDALL. They are both possibilities, and one thing I think we need to take into account is how much risk we are running if we are only funding one option.

Both of these are relatively early stage development programs. There are some events coming up in the next few months with Blue Origin which will give us a much better sense of how mature that technology is. So that will help us make a decision about the best way to go with both public-private partnerships.

Senator DURBIN. In the meantime, Senator Shelby and I at least share the view, I hope others do as well, keeping the RD-180 in the mix allows us to have at least the reliability of source during this conversation.

Mr. KENDALL. That is right. Until we get to a point where we are confident where we are going to go, the most economic thing by far for us is to buy a few more RD-180s.

The cap on that number, we are authorized nine today. We have said up to 18. I am hoping that the number would be less than that, but we would like to have the authority to buy up to 18 or use up to 18.

Senator DURBIN. Thank you.

Senator COCHRAN. Thank you, Senator.

The distinguished Senator from Kansas, Mr. Moran.

Senator MORAN. Mr. Chairman, thank you again.

Mr. Welby, your response to my earlier question was, "If the Navy made the request, you would welcome that." That is my paraphrase of what you said.

And, Secretary Kendall, while I was asking my questions, you were nodding, which I took as to be in agreement with what I was saying. You are nodding again, so that makes me feel more comfortable.

My question is, Mr. Secretary, is this something that you can do more than simply wait for the Navy to make this request? Do you have the desire to proceed in a more rapid way than what has transpired so far?

Mr. KENDALL. Senator, you are catching me flat on this one, because I was not aware of this. I can certainly look into it and see what the situation is and where it is and talk to the Navy about their plans and see what their intentions are. I can be more proactive than just wait.

Senator MORAN. I would like you to be more proactive and persuasive, assuming that you would confirm that your nodding of your head is in agreement with the concept that I am promoting.

Mr. KENDALL. I don't know the details of what Wichita State has to offer. I am not that familiar with it. Mr. Welby seems to be more so.

But we get a lot of value out of our UARCs. Some of them have endured for a long time. Others have not stuck around for one reason or the other. But generally speaking, we get a lot of value out of them.

So I would be happy to consider whatever Wichita State is considering offering.

Senator MORAN. Thank you, Mr. Secretary.

In my view, we are in this bureaucratic stage in which nothing is happening. Mr. Welby indicates he would welcome a request. We need to get the request made. And I also believe that you have the ability to proceed without the request.

So I would like to follow up, as I said with you earlier, on this topic.

Mr. KENDALL. We do need a service sponsor who is willing to take on working with UARC, getting it set up, and handling some of the administrative things and so on. So I do need that sort of assistance from a service for this.

But I have to talk to the Navy about where they are.

Senator MORAN. Thank you very much.

Let me turn to a different topic. Mr. Secretary, you are familiar with the light attack intelligence, surveillance, and reconnaissance jet aircraft called the Scorpion. We have had conversations about this.

It is, to me, a prime example again of your efforts at better buying power in which industry partners are willing to step up to the plate, invest resources in a need for the department.

The good news is that the Scorpion is in their accreditation process, which is a critical step.

My interest now is hearing your perspective on the next steps necessary to on-ramp this acquisition process. How do we move the Scorpion from accreditation into the ideal acquisition process?

Mr. KENDALL. The central ingredient there is a requirement from a service for the capability. I know that the Air Force is taking a look at it. Right now, it is not in their budget to buy Scorpion.

I have seen the aircraft. I have been in the aircraft. And I applaud what Textron did to go fund it and build it on their own initiative.

We did lean forward to help with the accreditation process, so that they get a military airworthiness certification, I believe.

So I think that is under way. We have found a way to do that.

The Air Force, I think, is interested, but I don't know that they are ready to take the budget, given the budget constraints we have, and apply it to that.

We generally have been taking force structure out as opposed to putting it in, and Scorpion, while it has some really interesting capabilities for light attack, I don't know if that fits into our future plans or not right now.

I can't do the acquisition without a requirement from the service for the capability.

Senator MORAN. Mr. Secretary, thank you. And thank you for your help on the accreditation process.

Thank you, Mr. Chairman.

Senator COCHRAN. Thank you, Senator.

The distinguished Senator from Alabama, Mr. Shelby.

Senator SHELBY. Secretary Kendall, we were talking about the engines. Could you just describe or at least—all of you are engineers or physicists. But the two engines that Senator Durbin, that are in development, that we are talking about, what are the properties of those at this point? Is it a different methodology to develop? Or what is it? They have to be different.

Mr. KENDALL. The basic difference is they use different fuels. The Blue Origin uses methane, and I think liquid-oxygen, liquid-hydrogen for the competitor.

Senator SHELBY. Give us an example.

Mr. KENDALL. An example of?

Senator SHELBY. The fuel.

Mr. KENDALL. Methane, in the case of Blue Origin, and liquid oxygen, I think, hydrogen for the other.

Senator SHELBY. Mr. Welby, you are in this area. What are the variants of this?

Mr. WELBY. Senator, they are both comparable engines, within the same gross thrust class. They are at comparable levels of maturity, at this point. Both teams are pursuing development, is my understanding.

Senator SHELBY. From an engineering standpoint, both of them would work? Is that correct? Or do you think they would?

Mr. WELBY. Both of them require further maturation, would require testing and evaluation. But both of them are reasonable approaches to pursue.

Mr. KENDALL. There are design tradeoffs between the two choices of fuel. It is not entirely a preference. There is some advantage to methane, but it considered a higher risk in some areas, I think.

Steve, is that correct?

Mr. WELBY. I think they are both viable options.

Mr. KENDALL. Yes, they are both viable options, as far as we are concerned. But neither one has a proven capability yet.

Senator SHELBY. Secretary Kendall, will you and your staff continue to work with this subcommittee on ensuring that the department, Secretary of Defense, intelligence, everything, can acquire the engines that you say you need for national security?

Mr. KENDALL. We are very happy to work with the Congress on that. We would really like to get through the current disagreements that are happening about the way ahead, so we could settle on a path and have some stability and move out on it.

Senator SHELBY. We want to get through it, but we don't want to jeopardize anything for American security to do that.

Mr. KENDALL. I completely agree with that, Senator.

Senator SHELBY. Thank you.

Thank you, Mr. Chairman.

Senator COCHRAN. Thank you very much.

#### ADDITIONAL COMMITTEE QUESTIONS

This concludes the hearing today for this panel of witnesses. We appreciate your contributions to our understanding of the work that is being done in the Department of Defense, by you and the talents and hard work you bring to the challenges.

We thank you for your service.

[The following questions were not asked at the hearing, but were submitted to the Department for response subsequent to the hearing:]

QUESTIONS SUBMITTED TO MR. FRANK KENDALL III

QUESTIONS SUBMITTED BY SENATOR JERRY MORAN

UNIVERSITY LAB PARTNERS

*Question.* Please explain the actual and potential cost-savings that result from partnerships and the work conducted by university research & development (R&D) labs. Provide the names of such university labs and particularly those, if any, currently addressing F-18 fleet readiness.

*Answer.* DOD is engaged in broad range, mission-oriented research that requires expertise in multiple scientific and technical disciplines that can be accessed best at universities. DOD collaborations with universities on research and development (R&D) provide a breadth and depth of research that DOD cannot accomplish or reasonably afford on its own. Several examples of university laboratories that conduct R&D for the Department include University Affiliated Research Centers (UARC)s, such as Johns Hopkins University Applied Physics Laboratory (APL), Pennsylvania State University Applied Research Laboratory (ARL), and Georgia Tech Research Institute (GTRI). APL and ARL are sponsored by the Navy to conduct systems engineering and integration-related research and development. GTRI is sponsored by the Army to conduct R&D on information technology as well as testing and evaluation of new systems. UARC)s are organizations affiliated with universities or colleges that are established by DOD to accomplish the following objectives: maintain essential research, development, and engineering of "core" capabilities (as defined by their sponsor); maintain long-term strategic relationships with their DOD sponsors; and operate in the public interest, free from real or perceived conflicts of interest. We do not currently have data on any university laboratories addressing F/A-18 fleet readiness on behalf of DOD.

Additionally, Defense Advanced Research Projects Agency (DARPA) works with a variety of universities to explore and understand the potential of fundamental technologies to advance the state-of-the-art for national security. Cost-savings is not the primary emphasis of DARPA-sponsored research at universities. DARPA is not addressing F-18 fleet readiness.

UNIVERSITY AFFILIATED RESEARCH CENTER

*Question.* Of the university labs that partner with the Department of Defense on R&D, which are designated as a University Affiliated Research Center (UARC).[?] What are the benefits to a UARC designation?

*Answer.* There are 13 DOD-sponsored University Affiliated Research Centers (UARC)s.

*Navy-sponsored UARC)s*

Johns Hopkins University Applied Physics Laboratory  
 Pennsylvania State University Applied Research Laboratory  
 University of Texas Applied Research Laboratory  
 University of Washington Applied Physics Laboratory  
 University of Hawaii Applied Research Laboratory

*Army-sponsored UARC)s*

Georgia Tech Research Institute  
 Massachusetts Institute of Technology Institute for Soldier Nanotechnologies  
 University of California Santa Barbara Institute for Collaborative Biotechnologies  
 University of Southern California Institute for Creative Technologies

*MDA-sponsored UARC*

Utah State University Space Dynamics Laboratory

*NSA-sponsored UARC*

University of Maryland Center for Advanced Study of Language

*DASD(Systems Engineering)-sponsored UARC*

Stevens Institute of Technology Systems Engineering Research Center

*STRATCOM-sponsored UARC*

University of Nebraska National Strategic Research Institute

Each DOD component makes its own determination of the strategic need for technical research capacity and capability as balanced across the Defense Industrial Base, Government laboratories, and academia. The Assistant Secretary of Defense for Research and Engineering has the authority to approve a request for the establishment of a new UARC if a DOD component has submitted a request and provided sufficient justification to support the request. DOD may establish a long-term strategic relationship with a university for a UARC that will provide and maintain engineering, research, and/or development capabilities that are essential to the Department's mission and operations. The designation of a UARC only approves its establishment. The benefits to the DOD component do not occur until after the UARC has been established and accrue over time once it begins supporting DOD requirements. As the long-term strategic relationship between the DOD sponsor and the UARC is built, the UARC gains comprehensive knowledge of its DOD sponsors' requirements and increases its ability to be responsive to evolving requirements and to provide a quick-response capability. This capability and the requirements to operate with independence and objectivity, free from real or perceived conflicts of interest, are the ultimate benefits for the Department.

The establishment of a UARC requires a long-term commitment from a DOD component of at least \$6 million per year for 5 years. The DOD component that considers establishing a UARC will have to weigh the costs to develop and maintain the long-term strategic relationship against the potential benefit. The component may determine that it is more advantageous to satisfy its requirements through a contract with the university.

#### UNIVERSITY AFFILIATED RESEARCH CENTER

*Question.* Is there a university or universities that currently partner with the Department of Defense on R&D that yield cost-savings and efficiencies that the Office of the Secretary of Defense for R&D would recommend a UARC designation?

*Answer.* There are numerous universities that perform research for DOD. Currently, there is not a request from a DOD component to establish a new long-term strategic relationship with a university for a University Affiliated Research Center (UARC). A DOD component may be able to satisfy its technical requirements through a contract, avoiding the cost of establishing and maintaining the long-term strategic relationship. The establishment of a UARC requires a long-term commitment from a DOD component of at least \$6 million per year for 5 years.

#### OFFICE OF THE SECRETARY OF DEFENSE AUTHORITY

*Question.* If [a] Service or Component does not take the necessary steps to seek a partnership with a university lab through a University Affiliated Research Center (UARC) designation that yields cost-savings and efficiencies for the Department of Defense, does the Office of the Secretary of Defense for R&D believe it has the authority to “. . . formally designate a DOD Primary Sponsor for each UARC to assist in policy and contractual oversight.” This excerpt from OSD UARC guidance offers leverage to OSD to designate a DOD Primary Sponsor, i.e. a Service or Component.

*Answer.* While the DOD UARC Management Plan states the Director of Defense Research and Engineering, now the Assistant Secretary of Defense for Research and Engineering (ASD(R&E)), has the authority to designate an appropriate organization as a UARC and a primary sponsor for each UARC. This only happens after a DOD component has demonstrated a significant need for the creation of a UARC strategic relationship. The Department has never approved the establishment of a new UARC without a DOD component identifying a significant need for the long-term strategic relationship and the funding for proposed engineering, research, or development requirements. The establishment of a UARC requires a long-term commitment from a DOD component of at least \$6 million per year for 5 years. The ASD(R&E) would not want to unilaterally approve the establishment of a new UARC without a DOD component identifying and justifying a significant need for the long-term strategic relationship and committing to provide the minimum required resources within the 5-year period.

*Question.* If the Office of the Secretary of Defense for R&D believes it does [have] the authority to designate a Primary Sponsor for a university lab that yields cost-savings and efficiencies for the Department of Defense and that OSD supports as a UARC, would OSD execute that authority? Under what conditions would OSD not execute that authority if cost-savings and efficiencies for the Department were a result of the UARC designation for such university.

*Answer.* The Assistant Secretary of Defense for Research and Engineering (ASD(R&E)) has the authority to approve a request for the establishment of a new

UARC if a DOD component has submitted a request and provided sufficient justification to support the request. The establishment of a UARC requires a long-term commitment from a DOD component of at least \$6 million per year for 5 years. The ASD(R&E) would only approve a new UARC that has been requested by a DOD component with sufficient justification.

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QUESTIONS SUBMITTED BY SENATOR SHELLEY MOORE CAPITO  
NATIONAL SECURITY TECHNOLOGY ACCELERATOR

*Question.* In 2015, the Department of Defense created the National Security Technology Accelerator (NSTA) at the National Defense University to provide Technology Domain Awareness to the military and support the development of innovators and creative problem solvers who are capable of meeting the technology challenges of the future. Just recently, the Director of DOD's Strategic Capabilities Office reinforced the immediate and pressing need to advance such capability when he testified to the Senate Armed Services Committee that the eventual winner in any future conflict will be the side whose people adapt best to chaos. Put another way—people trump technology. Fully supporting this effort to ensure that the U.S. maintains and extends its historical military technology-edge, Congress included directive language in the fiscal year 2016 National Defense Authorization Act and allocated funding in the fiscal year 2016 Omnibus Appropriations bill to help the DOD initiate the NSTA.

What is your vision for NSTA in the next 5 years, and 10 years?

*Answer.* DOD leadership is committed to the proposition that aggressive action should be taken to guarantee the military-technology superiority of the U.S. military in any future conflict. To underwrite this objective, the Department has taken steps to expand accesses to leading sources of technology in the commercial marketplace by lowering barriers to entry and developing new opportunities for civil-military industry collaboration. The NSTA is an important part of the Department's strategy to engage the commercial marketplace and promote civil-military industry integration through the development of a national security innovation corps—a network of people who collaborate across Government and industry in the execution of projects that establish viable, high-tech industry capabilities for defense and commercial markets. Over the next 5 years, NSTA will develop and deploy education, collaboration, and technology acceleration resources in collaboration with a network of national research universities. The outcome of this initial phase will be a diverse ecosystem of collaborators inside and outside of DOD who successfully execute dozens of projects that grow high-tech industry capacity in areas relevant to the Nation's defense and overall economic health. By 2026, NSTA will scale its activities through additional university and industry collaborations in order to develop the national security innovation workforce and position DOD at the center of an integrated, high-tech, civil-military market.

*Question.* Is the DOD on track in developing a fiscal year 2018 Program Objective Memorandum to support the sustainment of the National Security Technology Accelerator (NSTA) effort across the Future Year Defense Program (fiscal year 2018–2022)?

*Answer.* The Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy and the Joint Staff are actively exploring the development of a fiscal year 2018–2022 Program Objective Memorandum for the NSTA as part of the overall NSTA implementation strategy.

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QUESTIONS SUBMITTED TO MR. STEPHEN WELBY

QUESTIONS SUBMITTED BY SENATOR THAD COCHRAN  
HIGH PERFORMANCE COMPUTING

*Question.* I understand the Department is requesting additional funding in the fiscal year 2017 President's Budget for prototyping and demonstrations. This emphasis on prototyping weapons before starting large acquisition programs is a way to decrease the risk of technology not being ready in time and on budget. Often, new supercomputing technologies can save development costs by optimizing prototypes or simulating real world tests. Should the Department continue to invest in virtual prototyping using its high performance computing assets?

*Answer.* Yes, virtual prototyping with high-performance computing, or HPC, continues to provide a valuable advantage for the Department. For example, the De-

partment is realizing significant savings and more effective use of wind tunnel tests by using virtual prototypes and HPC. Prototyping reduces technical risk and accelerates the adoption of transformative capabilities. Virtual prototypes and HPC compound these benefits; for example, lowering the cost to build and test prototypes, reducing traditional acquisition timelines, and optimizing trade space analyses to produce more effective and resilient systems.

Continued virtual prototyping and HPC investments will allow the Department to implement physics-based and discrete event simulation based prototyping in the Service engineering and test organizations. This capability would help the Department create highly realistic, physics-based and network models of defense systems in mission-relevant environments. This enables analysis and evaluation of critical performance metrics using computational methods, improving current prototyping methods and overall acquisition outcomes.

In addition, these environments help virtual prototyping become commonly used in direct support of weapon systems engineering, provide invaluable hands-on training, and improve the technical abilities of the defense test and engineering workforce. Continued virtual prototyping and HPC investment aligns with the Department's long-term goals for reducing technical risk and delivering affordable, technologically superior warfighting capabilities.

#### ENGINEERED RESILIENT SYSTEMS

*Question.* The Department of Defense has prioritized using advanced modeling and data analytics, which lead to higher fidelity acquisition programs. What are the benefits of using those types of processes?

*Answer.* The Department is emphasizing development of Engineered Resilient Systems, or ERS, which uses advanced modeling and data analytics to allow weapon system acquirers and developers to refine system designs in a virtual environment. ERS approaches allow programs to refine system designs more responsively and therefore create designs that are less sensitive to changes in an adversary's tactics and capabilities.

Use of ERS capabilities allows programs to generate and assess many potential designs across a wide range of options. The open tool-integration architecture allows engineers to examine trades in design parameters, system performance and affordability across an extended mission space, using visualization tools to identify promising designs and key parameters. These new computational and model-based frameworks adapt and integrate advanced design and modeling approaches from government, industry, and academia.

Within the DOD acquisition process, these tools and techniques foster increased collaboration between government and industry teams in research, development, and acquisition, where technical accuracy and consistency are provided by the depth of the digital artifact, not by the written word. A tool-independent integration framework allows those teams to use their own toolsets to create digital artifacts to improve the quality of the design and facilitate transition to the next stage of the acquisition life cycle. These activities reduce risks resulting from different interpretations of the design and allow multiple viewpoints to be demonstrated and examined well in advance of traditional hardware prototypes. The technical collaboration space, whether applied solely within DOD or with industry partners, can help understand potential impacts to the warfighter's mission space, to include adaptive and reactive threats, changing environmental conditions, and emerging military operations.

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QUESTION SUBMITTED TO DR. ARATI PRABHAKAR

QUESTION SUBMITTED BY SENATOR THAD COCHRAN

DARPA VERTICAL TAKE-OFF AND LANDING AIRCRAFT

*Question.* Defense Advanced Research Projects Agency created a program in early 2013, called X-Plane, to determine if a new type of vertical take-off and landing aircraft could be produced that could substantially increase speed, useful load, and efficiency. Could you talk about ongoing efforts of this particular program and the impact this demonstration aircraft will have on advancing breakthroughs in aviation technology?

*Answer.* The Vertical Take-Off and Landing (VTOL) Experimental Aircraft (X-Plane) program continues to pursue multiple configurations and subsystem technologies with potential to greatly impact the future of vertical flight. Phase I efforts began in November 2013 with Aurora Flight Sciences (Manassas, VA), The Boeing

Company (Ridley Park, PA), Karem Aircraft (Lake Forest, CA), and Sikorsky Aircraft (Stratford, CT) and concluded in November 2015 with successful preliminary design reviews, which included results from analysis and testing efforts to verify the designs for a distributed electric propulsion tilt wing/canard; tilt duct with embedded body fans; tilt rotor; and tail sitter configurations, respectively. Various degrees of testing were performed in Phase I to include wind tunnel tests, hardware fabrication and bench testing, and a subscale flight test demonstrator to inform design decisions and validate computational design tools and simulations. Multiple Phase I performers had viable concepts for further development, but funding availability led to the selection of a single performer to continue on to Phases II/III for the detailed design, fabrication, and testing of their 12,000-pound demonstrator aircraft.

Aurora Flight Sciences was selected for Phases II/III and was awarded the 30-month, \$89 million contract in March 2016. Aurora is continuing to conduct flight tests of its subscale vehicle demonstrator, built in Phase I, to verify the flight control laws and simulations for their unique distributed electric propulsion configuration at Webster Outlying Field in Patuxent River, MD. For Phases II/III, the generation and distribution of 3 MW of power to 24 electric fans on the main wing and canard is one of the core technologies of Aurora's configuration. Rolls-Royce LibertyWorks (Indianapolis, IN) and Honeywell (Tucson, AZ) are major subcontractors for this program to assist in the integration of an AE1107C engine, new gearbox, and 3 newly designed MW generators. ThinGap (Ventura, CA) is also an active subcontractor for the development and manufacturing of the light-weight electric main wing and canard fan motors. Significant subsystem tests are planned during the execution of Phase II to validate the design of the power generation and distribution system while also validating the electric motors prior to flight testing. Aurora is working to meet the program's performance metrics while also providing a platform to greatly advance the state of the art of aviation. Flight testing and verification of the program's objectives is planned for 2018. Due to the large number of fans and control effectors, the vehicle can be further used to test advanced and adaptive flight control laws to optimize performance and efficiencies for use on future over-actuated concepts and configurations. The in-flight validation of electric propulsion at a relevant scale opens up the aircraft design space to remove the geometrical constraints of mechanical drive systems while also creating a pathway to all-electric aircraft.

The flight test demonstrator will prove numerous technologies that have never been flown before. In particular, the aircraft will be the first to fly with electric distributed propulsion at the 12,000-pound size class and be the first to fly with light-weight 1 MW generators.

#### SUBCOMMITTEE RECESS

Senator COCHRAN. The Defense Subcommittee will reconvene on Wednesday, April 27, 2016, at 10:30 a.m., to receive testimony from the Secretary of Defense and the Chairman of the Joint Chiefs of Staff.

Until then, the subcommittee stands in recess.

[Whereupon, at 11:42 a.m., Wednesday, April 20, the subcommittee was recessed, to reconvene at 10:30 a.m., Wednesday, April 27.]