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# HEARING

ON

# NATIONAL DEFENSE AUTHORIZATION ACT FOR FISCAL YEAR 2016

AND

# OVERSIGHT OF PREVIOUSLY AUTHORIZED PROGRAMS

BEFORE THE

## COMMITTEE ON ARMED SERVICES
## HOUSE OF REPRESENTATIVES

ONE HUNDRED FOURTEENTH CONGRESS

FIRST SESSION

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SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES HEARING

ON

# DEPARTMENT OF DEFENSE FISCAL YEAR 2016 SCIENCE AND TECHNOLOGY PROGRAMS: LAYING THE GROUNDWORK TO MAINTAIN TECHNOLOGICAL SUPERIORITY

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HEARING HELD
MARCH 26, 2015

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# DEPARTMENT OF DEFENSE FISCAL YEAR 2016 SCIENCE AND TECHNOLOGY PROGRAMS: LAYING THE GROUNDWORK TO MAINTAIN TECHNOLOGICAL SUPERIORITY

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HOUSE OF REPRESENTATIVES,
COMMITTEE ON ARMED SERVICES,
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES,
*Washington, DC, Thursday, March 26, 2015.*

The subcommittee met, pursuant to call, at 10:35 a.m., in room 2212, Rayburn House Office Building, Hon. Joe Wilson (chairman of the subcommittee) presiding.

## OPENING STATEMENT OF HON. JOE WILSON, A REPRESENTATIVE FROM SOUTH CAROLINA, CHAIRMAN, SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

Mr. WILSON. I am pleased to welcome everyone here today for this hearing on the fiscal year 2016 budget request for science and technology [S&T] programs within the Department of Defense [DOD].

We are all aware of the intense downward budget pressure the Department is under these days in the ever-growing universe of threats that we are forced to deal with. Science and technology programs are part of the modernization investments that keep the Department prepared and ready to deal with those threats and ensure that when we send our soldiers, sailors, airmen, and marines into harm's way, we make sure they are never in a fair fight because technology is on their side.

But defense sequestration jeopardizes that technological superiority and our ability to outmatch and outclass potential adversaries. I agree, we cannot ignore today's concerns, including readiness, equipment recapitalization, and the health and welfare of our service members.

Nor can we expect to raid our modernization accounts to pay those bills. That is like taking money from the retirement accounts to pay the mortgage today. There are short-term rewards, but you create an even bigger problem down the line.

I say that to make the point we understand why science and technology is important, should be protected, but also recognize that in this budget environment we will continue to be under pressure. The fiscal year 2016 budget request for science and technology is seeing a modest increase, but that request was also well above the budget caps set by defense sequestration.

If we have to remain at sequestration levels, I fear the adverse impact it will have on our science and technology programs. Not only will we have to defer sought-after and important programs, but we will continue to defer the hiring of needed scientists and en-

gineers, defer investments in necessary equipment, and defer building or upgrading facilities that support world-class research and world-class researchers.

I know that I have painted a bleak picture, but it is only to punctuate how important we think science and technology is to our national security and the defense of our great Nation. Every time we push off research one year—one more year, we give our adversaries another year to catch up with us.

With that, I would like to welcome our distinguished panel of witnesses for their thoughts on this topic.

Mr. Alan Shaffer, Principal Deputy to the Assistant Secretary of Defense for Research and Engineering; Ms. Mary Miller, Deputy Assistant Secretary of the Army for Research and Technology; Rear Admiral Mat Winter, United States Navy, Chief of Naval Research; Dr. David Walker, Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering; Dr. Arati Prabhakar, the Director of the Defense Advanced Research Projects Agency, DARPA.

I would like to turn now to our ranking member, who will be here any moment, and he is on the way. And his staff is very trustworthy, and they promised me he is on the way.

But Mr. Langevin should be here any time. But he has indicated to proceed, and we shall because of the voting schedule that we may be facing today.

I would like to remind our witnesses that your written statements will be submitted for the record, so we ask that each of you summarize your comments to 5 minutes or less.

Mr. Shaffer, we will begin with you, and we look forward to your opening statement. Before we do, though, I understand that you will be retiring from government service at the end of May to take a position as the chief science—chief scientist of the NATO [North Atlantic Treaty Organization] Science and Technology Organization. What a great honor.

You have been a good friend of this committee, and so I would like to thank you for your many years of service in the Air Force, your public service within the Department, and we wish you and your family best wishes in the future. Godspeed.

[Applause.]

## STATEMENT OF ALAN R. SHAFFER, PRINCIPAL DEPUTY, ASSISTANT SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

Mr. SHAFFER. Thank you very much, sir. It has been a pleasure to serve and I will continue to serve in the NATO capacity.

Chairman Wilson and committee members, I am proud to be here once again to represent the 100,000-plus scientists and engineers in the Department of Defense. Although this is a community that has been challenged in many ways over the last several years, they continue to perform remarkably well.

I want to start with a somewhat unusual story and share with you the value of long-term science and technology. I was recently briefed about the progress made in combat casualty care. In Iraq and Afghanistan from 2005 to 2013 the average severity of injuries to our young forces increased by 25 percent, but the fatality rate was cut in half.

We contend the decline in fatality rate is due, in part, to the long-term advances and delivery from the medical science and technology community, which includes contributions from everyone at this table.

While our S&T community has performed very well in the recent past, the national security environment is changing in fundamental ways. For the first time in several decades, we are seeing an erosion of our technologically based military advantage.

Secretary Ash Carter addressed this during his fiscal year 2016 budget posture, when he said:

"For decades, U.S. global power projection has relied on the ships, planes, submarines, bases, aircraft carriers, satellites, networks, and other advanced capabilities that comprise our military's unrivaled technological edge. But [today] that superiority is being challenged in unprecedented ways.

"Advanced military technologies, from rockets and drones to chemical and biological capabilities, have found their way into the arsenals of both non-state actors as well as previously less-capable militaries. And other nations—among them Russia, China, Iran, and North Korea—have been pursuing long-term, comprehensive military modernization programs to close the technology gap that has long existed between them and the United States."

Dr. Carter also addressed the impact of the sequester, stating, "A return to sequestration in fiscal year 2016 would affect all aspects of the Department, but not all equally. . . .

"Approximately half of the cuts would have to come from the Department's modernization accounts, undermining our efforts to secure technological superiority for U.S. forces in future conflicts. . . . Sequestration would put on a hold on critical programs, like our Aerospace Innovation Initiative, the Next-Generation Adaptive Engine, the Ground-Based Interceptor missile defense kill vehicle redesign, and several space control efforts."

As you noted, the 2016 budget request for science and technology increases to $12.3 billion. We have focused on S&T investments in advanced technology development to provide more prototypes and demonstrations.

Our recent emphasis in demonstrations is now producing results across the DOD. I will highlight just a few of our noteworthy demonstration programs.

My Emerging Capabilities and Prototype Office has started several joint capability technology demonstrations for communications and imagery from small, tactically relevant satellites. The Space and Missile Defense Command Nanosatellite Program, known as SNaP, is a low Earth orbit nanosatellite that will provide assured, beyond-line-of-sight communication, enabling mission command on the move.

Three SNaP satellites were delivered this March with a launch date scheduled for August 2015. The Kestral Eye is a 25-kilogram satellite that provides good-enough 1.5-meter visible imagery for less than $1.5 million.

Both imagery tasking and delivery is controlled directly by battlefield commanders, and this provides a real augmentation to our tactical ISR [intelligence, surveillance, and reconnaissance] capability. Kestral Eye will launch this December.

The Army is developing a high-energy laser mobile demonstrator to demonstrate low-cost capability for counter rockets, artillery, and mortar. In 2014, the Army tested this system twice and successfully engaged roughly 90 percent of the targets. We are now on a path for protective lasers to be fielded in the Army's Indirect Fire Protection Capabilities Increment II.

The Navy's Innovative Naval Prototype Laser Weapons System is another solid state laser under development. The Navy demonstration uses a fiber laser, as compared to the Army's heat capacity laser. The system was demonstrated aboard the USS *Ponce* in 2014 and is moving forward to its next set of field demonstrations.

Finally, the Air Force's Adaptive Engine program is a new architecture, offering roughly 25 percent reduction in specific fuel consumption. Since 2007, we have moved from the Adaptive Versatile Engine Technology, ADVENT, program to the Adaptive Engine Technology Demonstration, and in 2016 we will commence with the Adaptive Engine Transition Program [AETP], which is out of S&T, but a 6.4 program moving towards engineering, manufacturing, and development program of record early next decade.

A frequent criticism of the S&T program is that there is duplication among the services. I don't believe that this is a pervasive problem, but in 2013 we reinstated Reliance 21, a process to allow the services and defense agencies looking across all projects to optimize their output.

Under Reliance 21, we have divided the overall S&T program into 17 communities of interest [COI], and they have—they are developing integrated science and technology roadmaps or plans. These COIs are adjusting programs at the execution level.

This is, indeed, an interesting time for DOD science and technology, with operational challenges increasing at a time when budgets are flat or declining. Meeting the national security needs requires we develop and adopt a multifaceted strategy.

This strategy is in place. I am proud of the professionals and the entire R&E [research and engineering] enterprise, and look forward to continued achievements from our dedicated workforce.

I also very much value working together with each of these science and technology executives to deliver the most that we can from the overall Department of Defense.

Thank you, sir.

[The prepared statement of Mr. Shaffer can be found in the Appendix on page 29.]

Mr. WILSON. Thank you very much, Mr. Shaffer.

Ms. Miller.

## STATEMENT OF MARY J. MILLER, DEPUTY ASSISTANT SECRETARY OF THE ARMY FOR RESEARCH AND TECHNOLOGY

Ms. MILLER. Chairman Wilson, Ranking Member Langevin, and distinguished members of the subcommittee, thank you for this opportunity to discuss the Army's science and technology program for fiscal year 2016.

I came before this committee last year and spoke to the difficult choices that the Army faced balancing force structure, operational

readiness, and modernization. This continues to be a significant challenge.

The velocity of instability around the world has increased. The Army is now operating on multiple continents simultaneously in ways unforeseen just a year ago.

Our adversaries continue to invest in technology to counter or evade our strengths, and what used to take our enemies months and years to disrupt may now take only days.

The Army has developed a new Army operational concept, "Win in a Complex World," to address this new environment. Within the Army, however, the research, development, and acquisition accounts are 34 percent less in fiscal year 2016 than we projected just 4 short years ago, adding to this challenge.

Despite this dramatic reduction in our modernization accounts, the Army leadership has continued to protect the science and technology investment as the key to the Army of the future. The S&T enterprise is committed to providing soldiers with the technology to win.

The contributions from the almost 12,000 scientists and engineers that work within the S&T enterprise span the gamut from fixing immediate problems to forecasting for the future. I would like to take this opportunity to highlight a few of these areas.

The Army relies on our science and technology enterprise to rapidly solve current problems for our troops in the field—problems such as redesigning body armor to better fit female soldiers in Afghanistan. These soldiers were faced with armor that caused abrasions, restricted their movement, and even impacted their ability to correctly seat their rifles on their shoulder when shooting. The S&T community developed an armor system designed to fit smaller torsos, which is now becoming the new standard for female soldiers today.

We are also called upon to improve our current system capability. Efforts like the Advanced Affordable Turbine Engine, now the Improved Turbine Engine program of record, will provide Apache and Black Hawk critically needed operational improvement in both hot and high altitude conditions.

We also drive down risk for emerging programs of record by bringing forward new capabilities that are not only technologically achievable, but also affordable. Our efforts with the Third Gen FLIR, forward-looking infrared, are a great example of where we developed a technical solution that gave us increased range for both detection and ID [identification]—range that exceeds that of our enemy—while investing in the manufacturability of this system to provide an unprecedented, affordable, all-weather capability that recently transitioned into the I–FLIR program of record.

Before a program even gets started, however, S&T provides the technical understanding of the art of the possible, ensuring our requirements are both achievable and affordable.

Our Joint Multi-Role [JMR] Technology Demonstrator effort will produce two flight demonstrators in fiscal year 2017 to inform affordable requirements for the Department of Defense's next-generation rotorcraft. The Future Vertical Lift planned program of record is envisioned to meet 70 percent of the current DOD rotorcraft

needs, and the JMR Tech Demo is ensuring that we get these requirements right.

With an increasingly adaptive enemy, one who has watched how the U.S. fights for the past 13 years, it is imperative for us to understand our own technology and system vulnerabilities—those aspects that could be exploited and used against us. Our Army science and technology enterprise has embraced this challenge, as well.

A key aspect of this initiative is red-teaming, challenging our systems with an emulated enemy—one who can use innovative and adaptive methods to disrupt our planned capability. These efforts have the potential for significant cost savings, as vulnerabilities are mitigated before system designs are finalized and systems are fielded.

We also work to understand the global technology environment by establishing tighter connections to each other through Reliance 21, that you just heard about, through increasing our engagement with the Intelligence Community and accessing nontraditional thinkers through our technology war-gaming, focused on what could be possible in the 2030 to 2040 timeframe.

Finally, we continue to seek and develop new and game-changing technologies for the future. For instance, our "materials by design" basic research effort will provide the capability to select and create material properties and responses, essentially building new materials from the atom up.

Of course, none of this would be possible without the scientists and engineers that make up the Army S&T enterprise. I am honored to represent the men and women who apply their expertise on a daily basis to creatively solve difficult national security challenges and provide the flexibility and agility to respond to the many challenges that the Army will face.

Our focus remains on our soldiers. We consistently seek new avenues to increase the soldiers' capability and ensure their technological superiority today, tomorrow, and decades from now.

Thank you again for all that you do to support our soldiers. Thank you.

[The prepared statement of Ms. Miller can be found in the Appendix on page 52.]

Mr. WILSON. Thank you very much, Ms. Miller.

We now proceed to Admiral Winter.

## STATEMENT OF RADM MATHIAS W. WINTER, USN, CHIEF OF NAVAL RESEARCH

Admiral WINTER. Good morning, Chairman Wilson and Ranking Member Langevin, and distinguished members of the subcommittee. As previously mentioned, I am Rear Admiral Mat Winter, the new Chief of Naval Research [CNR], and it is an honor to address you all and discuss our Department of the Navy's science and technology investment strategy, which, I will add, is fully supported by the President's fiscal year 2016 budget request.

Though I have only been the CNR for less than 90 days, I have had years of experience in the science and technology arena as a producer and as a consumer; as a scientist, a computer scientist, and a mechanical engineer by trade; as a combat A–6 Intruder

bombardier/navigator and as a major weapons program manager; also a Naval Warfare Center commander at China Lake and Point Mugu; and most recently as our PEO [program executive officer] for unmanned aviation and strike weapons.

With that experience, I come to the table in this job with a unique perspective that understands explicitly how our S&T investments enable our workforce to discover, develop, and deliver the breakthrough technologies to support our sailors and marines, which is absolutely essential. They operate in what I refer to as our three fleets: the current fleet underway, the fleet under development, and our future fleet. It is absolutely imperative that we have a strategy that links these three fleets together fiscally, operationally, and technically.

We recently released our Department of the Navy updated S&T strategy that does just that. It focuses our efforts into nine relevant, game-changing research areas to provide that clarity to the research enterprise and the broader S&T community that includes our academia and our small business industry partners.

Additionally, the strategy defines our workforce engagement and development initiatives to build a strong, knowledgeable workforce based on the fundamentals of STEM [science, technology, engineering, and mathematics], ensuring that we have the relevant intellectual capital to solve our hardest problems. This strategy guides our planning, execution, and decision-making to ensure we have the right people with the right skills in the right jobs, and the organizational alignment to ensure efficient execution, communications, and decisive leadership.

To that point, I am a goal-oriented leader. I hate inefficiencies.

I am executing our S&T mission with the required rigor and accountability so our warfighter maintains that decisive technological advantage to fight the fight and keep the peace. But as equally important, it is—we need our scientists and engineers to maintain the decisive technological advantage in our laboratories.

In the 85 days I have been on this job I am coming to realize what an honor and privilege it is to lead this incredible team of over 4,000 technical professionals in the naval S&T community across our Naval Research Enterprise and those embedded with our academia and industry partners. By all measures—and since I am an engineer, I like to measure things—the work they are engaged in is some of the most influential and game-changing technology research in the Department and albeit around the globe.

For example, the demonstrated and revolutionary electromagnetic railgun; our breakthrough, game-changing, forward-deployed laser cannons, that has been mentioned previously; the medical research focused on traumatic brain injury solutions; advanced materials research; synthetic biology; advanced algorithmic autonomous behavior; electromagnetic warfare—it goes on and on.

My scientists are making contributions that are making marked differences not only to our warfighters, which is important, but to our Navy and Marine Corps and this great country. How do I come to that conclusion? As an engineer—and I like to measure things—but I like metrics. We have got to be able to measure things and show progress.

Our S&T domain, though, really is a squishy area of basic and applied research. With flubber and flux capacitors, hard to put metric to those types of investments.

So how do we do that? Some would say it is transition of S&T products to get to our warfighters.

That is true, but I don't think that is the complete answer. I think we need to look at all of the spectrum of S&T transition.

I can point to our Department of the Navy S&T metrics that show 87 percent of our S&T products transition into acquisition, and the majority of those transition to the warfighters' hands. That is not trivial, and that is a good success rate.

But there is 13 percent, and those will be looked at as failures. I say it is different. I say that gives us latent benefit.

That 13 percent provides new knowledge that has never been known before. It allows us to populate the intellectual capital to solve hard problems, manifests into over 60 Nobel Peace—Nobel Prize winners. We also have 300-plus patents a year in the Department of the Navy that make sure we husband our intellectual capital and continually get return on investment.

And we also transition technologies to the shelf. They are on the shelf so that when an emerging requirement manifests itself, we have a ready-to-go solution to transition. So that is a transition—latent transition activity, as well.

The problem I see as we bring that together is the "Valley of Death" is more of a moat, and it is a bridge, and it is something that we need to continue to work through together. To that end, it is apparent that we don't—we leave nothing to waste.

When you visit our Navy and Marine Corps, everything you see originated at some level with S&T—everything from Old Ironsides to the first radars, from nuclear propulsion to our biofuel alternatives, from the Sidewinder missile to the RGPS [Relative Global Positioning System] capabilities and railgun and lasers. All have the origins within the Naval Research S&T domain, and we are proud of that.

These are relevant technological successes. Some are old, some are new, but they are a true cumulative impact from discovery and invention, to application and experimentation, to demonstration and fielding. They work.

And our naval scientists, along with our small business industry partners and our academia university colleagues here and around the globe, make it happen. I invite you and your staffs to come join us and observe firsthand, in our Navy Warfare Centers and our labs, the technologies and the accomplishments that our scientists are executing.

We will continue to pursue our S&T efforts with innovative research and disruptive thinking, always trying to make existing systems more effective and affordable. That is very important.

And in doing so, we remain aligned to our senior leadership. The CNO [Chief of Naval Operations] and Commandant's recently released "Cooperative Strategy for the 21st Century Seapower" is underpinned by this S&T strategy.

We can't afford to do business as usual—just can't do that. And we can't wish away the technological advantages of emergent global actors that are challenging our warfighting supremacy.

The CNO's strategy provides us the framework to think and act differently, and we are. We must be committed as a country to pursuing the technological solutions for tomorrow today.

It is essential to tie that technical to the tactical to the strategic, and we in the Navy and the Marine Corps are committed to ensuring our S&T resources that you and your congressional colleagues provide us gets the most bang for the buck by giving our sailors and marines that technological advantage on the battlefield.

Ladies and gentlemen, I thank you for your time and your continued support of our S&T efforts, and I look forward to taking your questions. Thank you.

[The prepared statement of Admiral Winter can be found in the Appendix on page 70.]

Mr. WILSON. Thank you, Admiral Winter.

We now proceed to Dr. Walker.

**STATEMENT OF DR. DAVID E. WALKER, DEPUTY ASSISTANT SECRETARY OF THE AIR FORCE FOR SCIENCE, TECHNOLOGY, AND ENGINEERING**

Dr. WALKER. Thank you, Chairman Wilson, Ranking Member Langevin, and members of the subcommittee. I am pleased to have the opportunity to provide testimony on the Air Force's fiscal year 2016 science and technology program.

This has been an exceptional year for science and technology in the United States Air Force. Last summer our Secretary and Chief published a new "America's Air Force: A Call to the Future"—a 30-year strategy for the Air Force, which really highlights science and technology and how it is required to achieve the strategic goals that they set forward.

Our fiscal year 2016 President's budget request is an increase of 14 percent over our previous request, at a $2.4 billion level. The Air Force leadership recognizes the excellent work that S&T has done in the past and recognizes the need for S&T to achieve the future they want. And characterizing our S&T program, Major General Masiello, the commander of the Air Force Research Lab, has put it in three Rs: responsive, relevant, and revolutionary.

The responsive piece is, how do you be responsive to the warfighter's need in the field today? An excellent example of this is a—Air Force S&T provided a capability to the special operations troops operating in Afghanistan by integrating the sensor payload onto a tactically remote piloted vehicle that provided a unique and unprecedented capability for identifying IEDs [improvised explosive devices], weapons caches, and enemy, and has resulted in significant support within the theater.

On the revolutionary front, the adaptive engine technology that Mr. Shaffer addressed earlier is one of the great revolutions coming out that will really change warfighting by providing significant fuel efficiency in addition to greater thrust out of the existing family of fighter engines. This has grown out of an ADVENT program, our first program which was pure S&T. That program completed last summer and has proven a greater than 20 percent savings in fuel just from an S&T large engine buildup that we ran with General Electric.

The follow-on to this is the Advanced Engine Technology Development program, which is ongoing this year and next year, which will continue to move forward this technology. And then as part of the Aerospace Innovation Initiative, under the Defense Innovation Initiative, we have the follow-on program, which is the Advanced Engine Transition program.

These really promise to bring this technology not only through the S&T, but on forward into actual prototyping to prove that this technology in a full-up flight-sized engine really works.

The one problem, of course, is under the BCA [Budget Control Act] that—the AETP program, the follow-on program, is still above the BCA levels.

Another revolutionary area we are working is in nanotechnology. One of the game-changers that we are working right now is in flexible, wearable sensors—the ability to put a bandaid-like patch onto an individual and be able to detect fatigue, cognition, their performance indicators, by pulling biomarkers through the skin. This is enabled by the nanoprinting of nanoparticle inks onto these markers and actually building up smart electronics into a bandaid-like, flexible, electronic patch.

Has great future not only for the Air Force and how we use it, but all the services, and for the medical industry as a whole, so there is tremendous capability that we are working.

We are also addressing relevant warfighter needs. This is a problem that, as you work in the midterm requirements—near and midterm requirements—how do we make sure that what we are doing in Air Force technology is really supporting what the warfighter needs?

A good example of this, and working with the Air Combat Command [ACC] and their desire to go after hard and deeply buried targets with existing capability on existing airplane platforms, we need to have smaller, more compact systems. So the High Velocity Penetrating Weapon was a program that we put together to do this. Been very successful, and now it has transitioned that technology into the follow-on program that ACC is now looking at in their AOA [analysis of alternatives].

We also last July launched the ANGELS, or the Automated Navigation and Guidance Experience for Local Space, which is really focused on how do we do geosynchronous space situational awareness, which requires somewhat of an autonomous capability. So the ability to detect, track, and characterize space objects on geosynchronous is really moving us forward in our capability for the space situational awareness of the future.

To do this we really have to have a talented workforce. We have taken advantage of the new authorities that have been given to us by the HASC [House Armed Services Committee] and the SASC [Senate Armed Services Committee].

In addition, we built a strategic plan both for building our engineering workforce, but also for helping build the STEM workforce across the Air Force as a whole, really trying to build the STEM ambassadorship of the Air Force across the Nation to develop the talent that we need.

In closing, the Air Force 2016 President's budget really requests the science and technology to make sure that we can remain re-

sponsive, revolutionary, and relevant in the future. On behalf of the scientists and the engineers of the Air Force S&T enterprise, I want to thank you for your continued support of our S&T program and look forward to any questions you have.

Thank you.

[The prepared statement of Dr. Walker can be found in the Appendix on page 97.]

Mr. WILSON. Thank you, Dr. Walker.

We now proceed to Dr. Prabhakar.

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

Dr. PRABHAKAR. Thank you, Mr. Chairman, Mr. Langevin, members of the subcommittee. It is great to be here with my colleagues and I appreciate the chance to talk with you today.

DARPA is part of this Defense Department science and technology community; we are also part of the larger national and global technology ecosystem. But within those communities DARPA has one particular role, and that is to make the pivotal early investments in new technologies that show what is possible so that we can take huge strides forward in our national security capabilities.

And I will just share with you this morning a couple of brief examples that I hope will bring that mission to life. One is some of our work that is being put to work in one of today's challenges—namely, the fight against ISIL [Islamic State of Iraq and the Levant]. This program that these tools derive from is called Memex.

Memex set out to build some software tools that allow for a very different kind of search through public Web sites—deep, domain-specific search. So what that means is that a user using these tools, it lets them do two new things.

One is to see Web sites out beyond those that are indexed by commercial search engines like Google or Bing—public Web sites, but those that aren't really reached by these commercial search engines. And then secondly, this tool automatically maps patterns and linkages, relationships across vast numbers of Web sites—very enabling, powerful technology for analysts.

These technologies, these tools, have already been used by the law enforcement community in some work in the arena of human trafficking. That has led to indictments and at least one conviction.

Today the same tools are in operational use to understand linkages among ISIL Web sites, as well.

A second very different example is about driving U.S. technological superiority to—so that we can deter or defeat a sophisticated peer adversary. And, you know, I think we all know that ever since radar helped win the Battle of Britain, we have all understood that controlling the electromagnetic spectrum is foundational to warfighting.

And in fact, today U.S. military RF [radio frequency] arrays are the envy of the world. That is not by accident; it is because of the joint investments in S&T across all of our activities here represented at the table.

And I think that is a tremendous advantage that we have, but it is also the case that the rest of the world doesn't stand still, and so today we see other capabilities developing around the world that

put our advantage, you know, at risk. So today what that—you know, what that translates to is that in a highly contested environment against a sophisticated adversary, they will now have the ability to jam our systems, essentially rendering our forces blind in the heat of battle.

So one of the efforts that is underway at DARPA today, in close partnership with our service colleagues, is really to create the next generation of capability for controlling the electromagnetic spectrum. This is new work at the level of devices, new systems architectures, new algorithms, new manufacturing technologies, all of which together I think can give us a chance to move into a future—not just a future where we can operate in the electromagnetic spectrum, but a future where we can control the electromagnetic spectrum in real time in the battlespace, and I think giving us that—the kind of substantial advantage that all of our investments are really about.

Those are just a couple of examples across a much wider portfolio at DARPA. You have our new report that just came out that offers a broader perspective across the portfolio. I am happy to talk about any of that.

But I also want to take a couple minutes and talk with you about what it takes for us to deliver on our mission. Your support in so many ways across many years has been essential to that.

First and foremost is our people. We have had a flexible hiring authority that this committee helped create a number of years ago. Last year in legislation you allowed us to use more of our positions within our fixed head count using this flexible technique.

And this is a—this hiring authority is just essential for everything that we do at DARPA. It lets us get access to the kind of people who have the potential to be really great DARPA program managers, and that really is our lifeblood. So I am very appreciative for your support of that capability.

Secondly, turning to the budget, again, your support in recent years has been critical to stabilizing our budget post sequestration, and the President's budget request this year at $3 billion essentially continues that stabilization. It is essentially, in real terms, the same level as what was appropriated last year.

Again, I will ask for your support of the President's budget-level request.

And I don't have to tell you about sequestration, Mr. Chairman. You mentioned it in your opening remarks, but you know well that if we can't avert sequestration it will take a significant toll on the work that we are doing.

Let me just finish by saying that my comments today have focused on the challenges that face our Nation today and into the future. All of us here at this table take those threats very seriously.

At the same time, for us we are very fortunate that our daily work is about solutions, and all of us come to work every day to find creative ways to rise above these dangers. And because of that, it is our responsibility but also our privilege to do this work of harnessing advanced, powerful technologies for our Nation's security.

So thanks again for the chance to be here with you. I am happy to answer questions along with my colleagues.

[The prepared statement of Dr. Prabhakar can be found in the Appendix on page 103.]

Mr. WILSON. Thank you, Dr. Prabhakar.

And indeed, we have been joined by the ranking member. He got here within 14 seconds of the beginning of the hearing.

Mr. James Langevin.

**STATEMENT OF HON. JAMES R. LANGEVIN, A REPRESENTATIVE FROM RHODE ISLAND, RANKING MEMBER, SUBCOMMITTEEE ON EMERGING THREATS AND CAPABILITIES**

Mr. LANGEVIN. Thank you, Mr. Chairman. And I apologize for being a little bit late.

I was actually off site with Bloomberg News doing an interview and talking about one of our favorite topics—cybersecurity. And it ran just a little bit behind.

But I do want to thank you, Mr. Chairman, for holding this hearing today.

And, of course, I want to thank our witnesses for being here to discuss the Department of Defense's science and technology budget request for fiscal year 2016, and I appreciated hearing your testimony here this morning already.

Maintaining the United States technological edge is a priority for the House Armed Services Committee and, most especially, for this subcommittee. And I thank my partner and the leader in this effort, Chairman Wilson.

As budgets grow smaller we recognize the necessity of continuing a robust investment in S&T. The seeds of innovation that we plant with our investments today grow into the game-changing capabilities of tomorrow.

Conversely, if we fail to properly invest, we will be dealing with the consequences for decades. Emerging technologies born of past and current investments, like directed energy and other high-energy weapons, have the potential to deliver paradigm-shifting capabilities to our warfighters that in many ways upend traditional warfighting concepts and tradeoffs.

And, Secretary Shaffer and others, I appreciate you mentioning those capabilities today, particularly on directed energy.

So these capabilities not only give us a warfighting advantage, but can serve as a deterrent to our adversaries. Today we are engaged around the globe with enemies like Al Qaeda and ISIL, its associate affiliates, and other terrorist groups. Our S&T investments over the last decade have been instrumental in delivering the capabilities our forces need to defeat such enemies and protect them from rudimentary yet effective weapons like improvised explosive devices.

Other potential adversaries require different capabilities, some more suited to traditional warfare concepts and others more—for more unconventional warfare, like cyber. Ensuring our investments align with requirements is key, and I look forward to continuing to discuss and hear from the witnesses about the Department's approach to emerging challenges and new domains.

In addition to investing in technology, we must invest in, of course, our workforce and our future workforce. Recruiting and re-

taining top talent in the Department's S&T community is truly a bedrock of maintaining technological superiority.

Now, over the years the Congress has provided the Department of Defense with many tools to do just that through IPA [Intergovernmental Personnel Act] programs, internships, and other unique personnel opportunities. I know you each in your various ways are engaged in growing that workforce, and I appreciate those efforts.

Also crucially important to our technological superiority is ensuring that the Department has knowledge of the innovative work being done by entities other than large corporations typically associated with defense, and that it is able to transition that work to become new capabilities.

Opportunities provided under the auspices of programs such as the Rapid Innovation Fund [RIF] of course have proven to be a win-win for the Department, small businesses, labs, and our warfighters. As the witnesses are no doubt aware, the Rapid Innovation Fund program authorization will expire at the end of this fiscal year, and I am certainly committed to reauthorizing this program and would appreciate if the witnesses could provide their thoughts on the success of this program and examples for the record.

With that, let me just again thank you all for the work that you are doing. I think that this subcommittee is one of the more interesting in Congress, and I know you all appreciate the work that you do and that of your workforce, and I hope you will convey our appreciation to the people that you oversee.

With that, Mr. Chairman, I want to thank you for, again, holding this hearing, and I yield back.

Mr. WILSON. Thank you very much, Mr. Langevin.

And we will now begin the 5-minute process, and Kevin Gates is going to be strict, including on me in particular because we have votes any second, and so we are always at the will of how the votes occur.

I think it is very appropriate, Mr. Shaffer, that you actually began with military medicine. The American people need to know the survival rates that have been achieved, which are unprecedented in conflict.

It was so inspiring to me visiting the theater field hospitals, visiting Landstuhl, visiting Bethesda, Walter Reed, and to see the survival and then the prosthetics that were developed so that young people who were injured had—and—have fulfilling lives, and to see people with injuries that are just utterly catastrophic by barbarians who, as cited by Jim, the improvised explosive devices—these were designed as unprecedented, I believe, ever for the maximum personal injury of not just military but civilians. Just a heinous enemy that we are facing.

But the success, and so by beginning with that was fantastic.

We actually, with your help, we have made progress relative to the issue of defense sequestration. Initially most people couldn't even pronounce the word "sequestration," and then—but the good news is that, particularly now, the American people I think understand the threat of defense sequestration, where half of the sequestration is in one department—Department of Defense—and the ef-

fect that this has with the other budget cuts that have been implemented.

But, in fact, as an indication of success—and 2 months ago I wouldn't have thought this, but last night we had a vote on a budget that would actually substantially roll back sequestration. But the way that we have been successful is not just generically discussing the threat, but specifically.

So if each one of you could identify a specific example of where sequestration will lead to a problem, and beginning with Mr. Shaffer.

Mr. SHAFFER. Thank you very much, sir. And thank you for the vote last night.

I think that there are two real issues with sequestration. First, with all the must-pay bills, as Dr. Carter noted, over half the cuts of sequestration would come from modernization accounts. Embedded in that are some of the things that you heard about today that would go away.

So the Aerospace Innovation Initiative, which actually has two stools underneath it—this is a DARPA-led, for right now, DARPA-Air Force-Navy program that is designed to build the next generation prototype flying platform, and that is about all we can say about that. But also, the next-generation turbine engine that will give us 25 to 30 percent savings. Both of those projects will end.

The real ripple effect is with the reduction in procurement accounts and the reduction in our 6.4 and 6.5 accounts. Engineers are being laid off. Once you lose the design engineers in the aerospace industry and the turbine engine industry they don't come back.

So think about a Department of Defense with no significant, long-term research project for the next generation of air capability. That is what sequestration means, sir.

Mr. WILSON. The morale effect, I can't even imagine.

Ms. Miller.

Ms. MILLER. I will echo what Mr. Shaffer said. Clearly sequestration will impact yet again our modernization accounts.

We are in a situation where we have to have force structure and operational readiness. We have to support our soldiers that are out there on the line, and we will.

But what we sacrifice is those improvements to our existing capability, the restoral of the capabilities that are coming back out of theater now that we are committed to restoring so we can utilize.

But I will take you in another direction. We had a dramatic impact on our workforce with the last sequestration, and even the indication that we might do this again, we are already starting to see indications that our workforce, which has been under a considerable amount of strain and still doing what needs to be done to protect our soldiers, they are now looking at whether or not it is really worth staying.

And so I expect that we will lose, again, some of our best and brightest engineers because they will either look for more security somewhere else or, frankly, we have got a large contingent that are close or eligible to retirement that will choose to do so without passing on that extreme knowledge that we need to pass down to our younger generation.

We are currently still under a hiring limitation. It is a one-for-six for the Army; we can only hire one when we lose six. That is a dramatic impact on our ability to make sure we keep the best and brightest available for meeting the needs of the Army.

Thank you, sir.

Admiral WINTER. Mr. Chairman, I will echo—the workforce is definitely a critical area, but I won't just repeat that. I will go towards a naval optic.

As we focus to our Pacific operating area, if our modernization accounts are reduced, those programs of record that are delivering naval capabilities for our marines and our sailors are underpinned by our S&T investments of our technology maturation future naval capability efforts. Those naval capability efforts are ensuring that we maintain and expand our undersea domain supremacy, which is absolutely critical for that area of operations.

Likewise, being able to ensure that we can have power ashore with our marines, enabled by those systems, will all be at risk as those modernization accounts are reduced and the effectivity of our S&T investments to be able to bring long-range torpedo, underwater unmanned vehicle constellations, communication—over-the-horizon communication and targeting for at-range threats, being able to bring the ship connector capabilities with our marines and our Navy vessels. They are all at risk, sir, and our S&T investments will not be able to enable that technological advantage.

So coupled with the workforce degradation and our ability to do the true, I will say underwater and electromagnetic warfare efforts—that would be the biggest impact to the Department of the Navy.

Thank you, sir.

Mr. WILSON. Doctor.

Dr. WALKER. I want to echo on the workforce impact is the biggest impact I see that will have a lasting effect if we go through a sequestration again. We are still feeling the impact of that today in our workforce from the previous sequestration we went through.

As we go forward, the modernization accounts will pay the brunt of this in the Air Force for the same reasons that my colleagues have already spoken of.

On the S&T side, we are right now transitioning this engine technology out of S&T into a 6.4 program. That will be lost, losing that ability to bridge out of S&T, which we are trying to build.

Furthermore, some of our programs which are in the 6.3 level in S&T and high-powered microwaves and advanced lasers upon aircraft will also suffer significantly if we go back into sequestration again.

Mr. WILSON. Thank you for the specifics.

And, Dr. Prabhakar.

Dr. PRABHAKAR. I will mention three specifics. One thing we found a few years ago in sequestration is that at the end of our programs, when we were prepared to do flight demos or trials at sea, one of the big problems we had was that because of sequestration those trials got delayed. And then the follow-on effect, because of the way we work with the services at test ranges, et cetera, often that led to not only delays but, in fact, overall increased costs, which was quite deleterious.

Our workforce issue is very similar. For us, our people come only for 3 to 5 years, so it is somewhat of a retention issue, but really the bigger problem is trying to recruit people into this sort of tumultuous environment is not very helpful.

And I think to me the most fundamental danger in these process—none of these specific cuts are the end of the world. The problem is that they just continue this erosion, this corrosion of our ability to do our mission. And a lot of our focus is to reach out to a very broad technical community, engage them in this important business of national security. When things like sequestration happen it is such a negative message to people who don't already live in this world and whom we really need to attract to this mission.

Mr. WILSON. Thank each of you.

And we now proceed to Mr. Langevin.

Mr. LANGEVIN. Thank you, Mr. Chairman.

Again, thanks to all our witnesses for your testimony.

So for the panel, the Rapid Innovation program, which I spoke about in my opening statement, as you know, was authorized in section 1073 of the National Defense Authorization Act for fiscal year 2011. The merit-based, competitive program accelerates the fielding of technologies into military systems in support of requirements, and there are so many examples of successful projects, such as the Navy's port security barrier intrusion detection system, which helped mitigate gaps in the system from being exploited.

As I stated in my opening remarks, I am championing reauthorization for the Rapid Innovation Program since it expires at the end of this fiscal year. Let me ask, in your opinion, has the program been valuable to the Department, and how so?

Mr. SHAFFER. Yes, sir. Thank you.

RIF has, indeed, been valuable. We held maybe a month ago, maybe 6 weeks—time kind of blurs together—we held our annual review of the RIF program. And now we are far enough into it that we are starting to see the results.

So we are getting about, on the whole, 60 to 70 percent transition rate. I think we are also getting to reach out and touch companies that might not otherwise want to work with the Department of Defense.

And the program has been kind of transformed over the last 3 years, where it is jointly run by acquisition and S&T people. In fact, the funding is not in the S&T lines; it is in the—our 6.4 accounts, our advanced capability development and prototyping accounts.

And we put it there specifically to bridge that gap of getting good, new technologies into our acquisition programs of record, but using the intelligence and the smarts of our S&T community to manage and conduct the source selection.

So I am seeing very positive things from it. Mr. Kendall, my boss, has asked me for a recommendation, and depending upon what—where we end up with for funding targets for the year, we are going to try to fund it ourselves. Don't know if that will happen, but we are going to try.

Mr. LANGEVIN. Thank you. That is very helpful.

Ms. MILLER. Within the Army I would say that we are finding RIF is an added flexibility that we might not otherwise have. As

Mr. Shaffer mentioned, it allows us to reach those industries that we might never have otherwise engaged or been able to engage because, you know, we are kind of the big Army and looking for big things.

But some of the efforts that we have put out there, we kind of laid out to industry what our problems were and we got some interesting approaches on how to solve them. And I will give you two examples of success.

We had a small company that looked at a problem that we had with our FMTV [Family of Medium Tactical Vehicles] systems. We were up-armoring the cabs of our FMTV—and that is a good thing, protecting the soldiers. However, over time the doors on the FMTV started to sag, and we were causing damage to the added weight on the cab frame.

So we put out a problem and got a response through the RIF process that gave us a cab-stiffening assembly that passed all of our tests so far. We have now transitioned it to the PM [program manager] for FMTV; he is going under—undergoing testing to see whether that will now become part of his program of record to retrofit onto those existing FMTVs that have up-armored cabs. And that was on the order of about a $2.5 million investment from us in the RIF, and well worth it.

Another quick example is a handheld, pocket-sized quantitative electroencephalogram. It is essentially this weird-looking thing that slips over your head and you can use it in the far-forward theater.

What it is helping us to do is provide an objective assessment on neurological injury. So this is kind of the far-forward idea, are we—did we get some sort of mild traumatic brain injury? Is there something that would warrant our soldier now getting a more rigorous look by a medic? Something that we need to know to make sure that we have provided appropriate health care for the soldier in the far-forward environment.

Just two examples, sir.

Mr. LANGEVIN. Great examples. Thank you.

Admiral.

Admiral WINTER. Sir, I will echo—RIF is very value-added. And as a previous program manager, the flexibility of not just having resource, but having a resource that allows you to go tackle those design issues that you would otherwise wait at a future spiral, allows you to pull in capabilities sooner to your warfighter.

Examples like our Navy high-energy chiller that allowed us to identify a smaller size and weight and footprint to be able to cool our high-energy avionics electronics on ships. That small investment of a hundred—couple hundred thousand dollars will show huge dividends downrange for the recurring costs for all of our ships.

And the ability of the program manager to reach out to small business—and 90 percent of our engagement in RIF for the Department of the Navy is with small business. And that is a tenet from Mr. Stackley on down, to engage at that small business base.

Things such as our verification and validation capabilities. Right now we have to put things on jets, go out and check and see if they fit in the aerodynamic environment. We populate those aircraft

with very expensive verification and validation instrumentation suites.

We gave that challenge to a very small—to a small business. They came back with a USB [universal serial bus]-sized stick—solid state, vibratory, wireless verification and validation capability, that for about $300,000 we are saving $5 million a year.

So that kind of innovative thinking that is facilitated by a very small investment from a RIF perspective, giving not only program managers but small industry the flexibility and the opportunity, and I think we need to continue this program.

Thank you.

Mr. LANGEVIN. Very valuable. Thank you.

Dr. WALKER. The RIF has been very useful to the Air Force, as well, particularly in bringing in new and innovative businesses to solve problems that we didn't have a solution for. So far, we have had over 2,600 white papers that have been submitted to our call. We have put out about 94 projects out of these papers of selecting the best and most promising ones.

And what it has allowed us to do was to really reach out to non-traditional small business as well as our traditional SIBRs [Small Business Innovative Research] and STTRs [Small Business Technology Transfer] participants and help transition technologies into programs of record to solve problems that are annoying problems but we are not—have not risen to the level that they were actually going after them with their large acquisition program.

The F–35 has been the recipient of several great ideas that have allowed them to reduce costs or fix problems on the production line that, as I say, are annoyances, but once you do it you realize that this is a much better way to solve the problem. And the leveraging for a small investment, investing millions to get savings in the hundreds of millions, has been really valuable.

So we really do like the program. As has been said, we have moved this to be an acquisition program with lab support, and look forward to continuing with it.

Mr. LANGEVIN. Thank you.

Nothing with you, Dr. Prabhakar? Okay.

Dr. PRABHAKAR. DARPA is not involved in this—it is a services program.

Mr. LANGEVIN. Very good.

Thank you all.

Thank you, Mr. Chairman.

Mr. WILSON. Thanks, Mr. Langevin.

Now proceed to Congressman Rich Nugent, of Florida.

Mr. NUGENT. Thank you, Mr. Chairman. I thought maybe it would be Mr. Franks first, but that is okay.

It is in order? Okay.

This is a question—this committee and the larger committee last year in the 113th Congress appropriated $220 million for the sole purpose of accelerating the development of a domestic rocket propulsion system. However, thus far, neither the Air Force nor the Department of Defense has moved expeditiously to accomplish the task.

And since passage of last year appropriations act, I specifically want to know what has the Air Force done with the advanced liquid rocket booster engine to replace the RD–180?

Dr. WALKER. I will have to take that for the record, sir, as far as the acquisition program does not fall under my purview.

[The information referred to can be found in the Appendix on page 120.]

Dr. WALKER. However, under the S&T program, which we are continuing, we have been working the component technologies that are required to enable that type of capability in the future. Have had a strong program over the past decade that will allow us then to move into an oxygen-rich liquid rocket in the future.

So the investments we made in the past and investments we are continuing in this year's budget are really focused on giving us the capability to go to the next generation of liquid rocket engines.

Mr. NUGENT. Well, I appreciate that and certainly look forward to your response outside of the committee. Obviously, you know, it was very important to this committee that we get away from the Russian engine, where we shouldn't be relying upon that technology in particular.

But the next question, then, is on directed energy. And I know the chairman and ranking member are very invested in directed energy.

Last year Congress directed the Air Force to deliver a CHAMP [Counter-electronics High-powered Microwave Advanced Missile Project] system on surplus cruise missiles, and Congress set aside $10 million just for the purpose of getting the technology out of the lab and to our warfighters. We have had numerous combatant commanders testify to the fact that CHAMP would be a, you know, an excellent addition to their inventory, and particularly since what we are recommending is obviously—and I understand where the Air Force is at—they would like to see a long-term solution to that problem in regards to a delivery vehicle and maybe some additional upgrades.

But, you know, we just met with the lab and folks that, A, have—obviously we have tested this particular item. We have surplus cruise missiles that were deactivated from the nuclear force that at least would get that technology out to our combatant commanders in a very short period of time.

We have proven that it works. They have upgraded it, actually, from the lab.

As a bridge to when we get this reusable delivery vehicle, or maybe something that we really want to have 10 years out, but gives a bridge right now for, you know, a fraction of the cost to at least get it out to the combatant commanders. To us, you know, S&T is so important, but we also have to be able to provide it out into the field, and whether it is, you know, 80 percent, 90 percent, or 100 percent, this issue is, you know, if it is at least fieldable to assist those combatant commanders, then we ought to be doing it.

And so we are really concerned—I am, in particular—in regards to that we are not—excuse me—that we are not actually following through when we have the ability to. Do you have an answer for me?

Dr. WALKER. At this point in time the Air Force is still looking at the technology and where the right point is to transition it. That said, from a science and technology perspective, we are looking at how do we continue to improve the capability? So we are leveraging the $10 million that you provided to, one, take the things that we saw in the demonstration with the CALCM [conventional air-launched cruise missile] size system, and to improve on those so that if we did decide to go with the program with the current system we would be able to make a better system.

In addition——

Mr. NUGENT. I don't disagree with that. I mean, I think that we have the ability to do multiple things at a time, and one is if you can field it and get it out to the combatant commands, particularly with the nation-state threats that we face today with Russia and China, I would think it would be to our benefit to take advantage of at least the technology we have today.

We can absolutely continue to do the research and development to improve it, but I also know within that short period of time we have also already made an improvement to the original CHAMP that was tested. So there are some great avenues.

I would really like to see the Air Force work on that technology, get it out to the warfighter. Those that have testified in front of the main committee that—said that they would welcome that technology to have in their toolkit to protect America.

And I know you want to do that, and I understand all the competing interests within the Air Force, but I would, you know, to the Air Force I would suggest that we absolutely, in a cost-effective manner, at least roll it out so our combatant commanders have the use of CHAMP in the future, because we don't know what our next crisis is going to be.

So with that, Mr. Chairman, I appreciate your time.

And, Dr. Walker, if you could get back to me on both of those issues I would appreciate it. Thank you.

Dr. WALKER. Yes, sir.

[The information referred to can be found in the Appendix beginning on page 120.]

Mr. WILSON. Thank you very much, Sheriff Nugent. And we appreciate your passion as a dad of service members.

You can tell why he is into this, and so we are so grateful.

We have Congressman Aguilar, of California.

Mr. AGUILAR. Thank you, Mr. Chairman. I appreciate the hearing and the opportunity to hear the discussion and the testimony.

My first question had to do with sequestration, but I think that that has been tackled by the ranking member and the chairman quite well. And I appreciate your honesty and also the specifics that you have offered on programs that could face possible reductions. I think that is very helpful for us moving forward.

Dr. Prabhakar, can I—can you tell me how that is pronounced first? That is my first question.

Dr. PRABHAKAR. Prabhakar is correct.

Mr. AGUILAR. Prabhakar.

Can you talk a little bit about managing risk and taking chances? Often government is risk-averse and safe, but DARPA seeks to engage, measure, and to create new capabilities. Can you

talk about how you foster that within your department and, you know, what possible tools that you need in order to continue that mission?

Dr. PRABHAKAR. Taking risk ends up being core to executing on our mission. We don't love risk. We actually like to try to beat it down and kill it off. But we need to be able to tackle it simply because we come to work to do the things that are going to have a huge impact.

And, you know, I always tell my program managers, "If you have a high-impact idea that doesn't involve taking a lot of risk, let's do it," because that is really the business we are in. But often, of course, as soon as you do those you have to move into the technologies that have a lot more risk if you are really going to reach for these kinds of dramatic changes in capability.

So it is part and parcel of our mission. And very much to the nature of your question, I think it is essential for us as an organization to nurture the culture about being fearless about taking risk but then structuring programs to kill it off, to get—to build these technologies to a point that they are no longer risky, that they really can show their value so that they can be adopted and actually get in the hands of warfighters and make a difference.

So how does that actually happen in practice? It happens in the way, in particular, that we structure our programs.

Our program managers may define a very aggressive goal—maybe it is a new way to launch satellites on orbit on a 24-hour notice, or maybe it is a way to build a firebreak to stop infectious disease. It could be whatever the DARPA program is.

But with that ambitious goal is—the program is structured with very carefully thought-out milestones along the way to tell us if we are on track, are we making progress. And that allows our program managers to stop the projects that aren't working, redirect the efforts to more fruitful areas. When we see something that is working it allows us to put more resource and move faster in that area.

And that kind of very hands-on, structured program is how we try to make that journey from high-risk to actually achieving the impact.

Mr. AGUILAR. Additional tools that you think might be necessary moving forward that can maintain that culture?

Dr. PRABHAKAR. You know, the tools that this committee has already helped us with I think are critically essential—number one, bringing in people from all different parts of the technical community. Not just those who already live in the DOD S&T world, but people who come with backgrounds in commercial companies or having done startups or people out of universities—those different perspectives are very helpful.

Our ability to contract with entities that aren't normally in the business of doing business with the Federal Government through other transactions authority, that is another way that allows us to reach farther in terms of technology and, you know, get access to some of these bleeding edge technologies.

So I think a lot of the critical pieces are in place. I will tell you the single most important thing to allow us to keep taking risk is when we fail and when our projects don't work to—you know, we try to acknowledge that and say, "Yes, it—that didn't work. We

stopped it; now we are going to move on to something more productive."

And I think when—your allowing us to fail so that we can keep going and take that next step is actually the most——

Mr. AGUILAR. We need to be able to embrace that occasionally, as well. So thank you very much.

I will yield back, Mr. Chairman, so someone else can get a question.

Mr. WILSON. Thank you very much.

And in consultation with the ranking member, what we would like to do is, Mr. Franks and Ms. Stefanik, if each of you could ask a question and then they could get back for the record?

Mr. FRANKS. All right.

Mr. Shaffer, I guess I will start with you. And I thank you, again, for your great service.

What do you think the earliest we will be able to find an operational laser or high-powered microwave weapon, and especially as it relates to the laser and missile defense? And what additional resources would you need to either accelerate the development or to mitigate or down the technical risk?

Mr. WILSON. And you can get back for the record and—because we are in the midst of voting, and so thank you so much, Congressman Franks.

[The information referred to can be found in the Appendix on page 120.]

Mr. WILSON. And, Ms. Stefanik.

Ms. STEFANIK. Thank you, Mr. Chair.

My question is for Ms. Miller. I represent the Army 10th Mountain Division based at Fort Drum, and this division, as you know, has continuously served in Afghanistan from 9/11 until today.

Would you be able to discuss how the Army S&T enterprise is being utilized for the current mission in Afghanistan, and particularly in terms of the drawdown? Thank you.

[The information referred to can be found in the Appendix on page 121.]

Mr. WILSON. Thank you very much, Ms. Stefanik.

We have one final question from Mr. Langevin?

Mr. LANGEVIN. Thank you, Mr. Chairman.

And again, thanks to our panel for the discussion this morning.

So again, if you could get back to me on the record, just given the fact that time is tight. I was pleased to see Deputy Secretary Work's memo of March 17th creating the Electronic Warfare [EW] Executive Committee largely in response to the Defense Science Board's EW study, which pointed to lost focus on EW, particularly at the merge points of EW and cyber.

So I couldn't agree more with the need for more focus on these issues and the need for strong, intellectually vibrant and technologically superior electronic warfare community.

How do each of you see the creation of this organization changing how you conduct your business? Obviously with our adversaries using asymmetric threats and technologies and weapons to a greater extent than ever before that could overcome our both technological and numeric advantage, and perhaps even neutralizing it,

we obviously need to focus more on our EW and cyber capabilities to neutralize those asymmetric threats.

So I would like to hear your comments on that question. Thank you all.

And, Mr. Chairman, I yield back.

[The information referred to can be found in the Appendix on page 119.]

Mr. WILSON. And thank you very much, Mr. Langevin.

And indeed, as you can hear the bells and whistles, we are in the process of voting.

But thank you for being here, and you have received the requests for the final questions, and we appreciate, again, very much your service, and we look forward to working with you in the future.

And we wish Mr. Shaffer the best in his future career. God bless.

We are adjourned.

[Whereupon, at 11:46 a.m., the subcommittee was adjourned.]

# A P P E N D I X

March 26, 2015

## PREPARED STATEMENTS SUBMITTED FOR THE RECORD

MARCH 26, 2015

HOLD UNTIL RELEASED
BY THE COMMITTEE

STATEMENT TESTIMONY OF

MR. ALAN R. SHAFFER
PRINCIPAL DEPUTY, ASSISTANT SECRETARY OF DEFENSE FOR
DEFENSE RESEARCH AND ENGINEERING

BEFORE THE UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON ARMED SERVICES

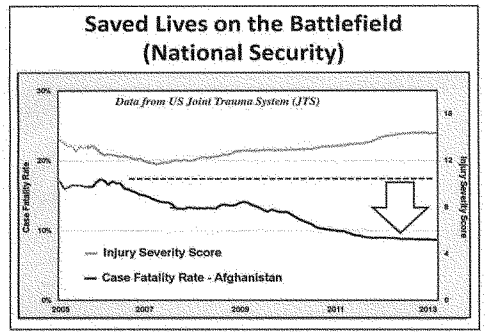
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES

MARCH 26, 2015

Introduction

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

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




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

**Macro scale Changes in the National Security Environment**

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

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

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

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

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

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

**Erosion of Technology Based Superiority**

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

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

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

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

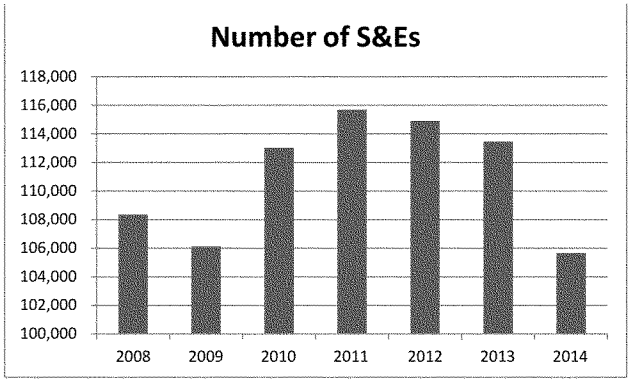
long-term, comprehensive military modernization program designed to improve the capacity of its armed forces to fight and win short-duration, high-intensity regional contingencies. Preparing for potential conflict in the Taiwan Strait, which includes deterring or defeating third-party intervention, remains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

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

Third, technological superiority relies on developing capabilities more rapidly than potential adversaries. Yet, over the last decade, the US and the West have been focusing on counter-insurgency. Other nations have had time to focus on developing their capabilities on countering US/allied systems. The ability of others to adopt and apply advanced commercial technologies (digital electronics, advanced data processing) is closing the capability gap. Simply, it is easier to close a gap than maintain the advantage. For example, other nations have fielded systems that negate US advantage in precision navigation and timing through denial of GPS by electromagnetic jamming; others have learned

how to use digital radio frequency memory jammers to reduce our capabilities in radar and air-to-air systems. Other nations are developing more complex, networked integrated air defense systems (IADS) operating throughout the electromagnetic spectrum to keep the US and allies from operating in international air space. There are other examples, but the point is the US focus was placed on counter-insurgency for the current fight, while other nations have not had the same focus. This has contributed to an erosion of our conventional military advantage.

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



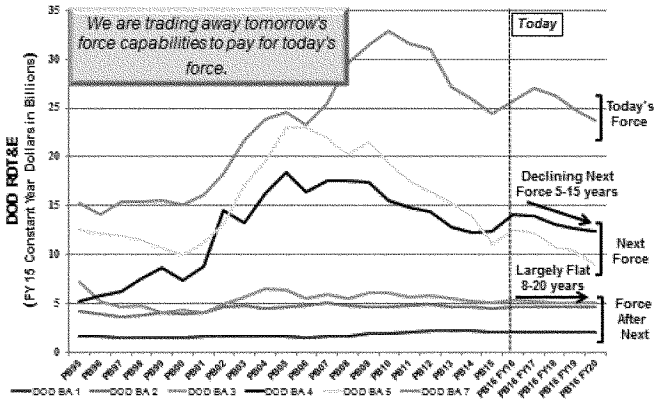

In short, the DoD has lost 10,000 scientists and engineers since 2011. Of greater concern is the loss of scientists and engineers coupled with the average age of DoD S&E. Beginning in 2013, the average age of DoD S&Es started to climb. A workforce that is simultaneously getting smaller and older is a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

Data from the Defense Manpower Data Center (DMDC) and the Office of Personnel and Management's FEDSCOPE indicates that the decrease in engineers was caused by retirement (50%), resignation (25%), or transfer to other government agencies. These numbers, by themselves, are not necessarily troubling given the recent federal budget challenges. An additional factor that we are concerned about is the age of the Department's technical workforce. Over

half of our technical acquisition workforce is retirement eligible within the next 10 years. We simply have to emphasize shaping our future workforce to continue to meet future challenges.

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

**DOD RDT&E – PBR1995-PBR2016**




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

innovative programs and validated methods, and that will attempt to ensure a workforce that is more technologically knowledgeable, capable, and representative than ever before.

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

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

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

**Department of Defense Fiscal Year 2016 Budget Request**

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

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

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

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

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

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

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

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

**Response to the Emergent Challenges to the DoD**

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

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

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

The LRRDPP is an effort to reach out to the broadest possible community to identify technologies that can shape future military systems and capabilities. The LRRDPP effort will help the RDT&E community prioritize its investments, protect the S&T investments with the highest potential impact, and increase the

return on our S&T investments. To initiate the LRRDP effort, a Request For Information was released in December 2014 to solicit the public's input on five focus areas: Space Technology, Undersea Technology, Air Dominance and Strike Technology, Air and Missile Defense Technology, and Other Technology-Driven Concepts; the first deadline for responses was mid-January but will remain open for new ideas and concepts. The LRRDPP will complete its initial review in Summer 2015.

**DoD Research and Engineering Strategy**

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

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

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

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

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

**Reliance 21**

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

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

**Specific Prototyping and Demonstration Efforts Supporting Innovation**

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

**Prototypes and demonstrations that support mitigating current and near future threat**

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

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

support an operational utility assessment for US SOUTHCOM. This capability will provide limited (spot beam) communications in a jammed environment.

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

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

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

The Navy has an Innovative Navy Prototype (INP), the Electromagnetic Rail Gun. This comprises a launcher, pulsed power system and battery energy storage system capable of firing a Hyper Velocity Projectile (HVP) 110 NM at a firing rate of 10 rounds per minute. The Electromagnetic Rail Gun is being jointly developed by the Office of Naval Research and Naval Warfare Center, Dahlgren, VA. This multi-mission system is designed to support integrated air and missile defense and provide Naval Surface Fire Support to troops ashore and to conduct

anti-surface warfare, both line-of-sight and over-the-horizon. We expect a sea demonstration aboard a Joint High Speed Vessel in the summer of 2016. The OSD Strategic Capability Office has partnered with the Navy to test the applicability of Rail Gun for point defense, with a demonstration expected in 2017.

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

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

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

My EC&P Office has developed a series of demonstrations that address directly affordability and performance by developing new technologies or modifying existing commercially available capabilities. I will mention a few. The first, Steel Tiger, is a commercially developed maritime radar which has been modified with Department of Defense capabilities to perform specific maritime surveillance missions. In testing, this system achieved all its intended performance objectives at a fraction of the cost of more traditional military systems. Specific details are classified but the system offers a low cost option for the maritime environment. The second is the development of the Accelerated Nuclear DNA Equipment (ANDE) which enables automated rapid DNA profiling while minimizing analytical complexity and user manipulations for employment in a field, rather than laboratory environment. About the size of a desktop printer,

ANDE enables fully automated analysis of a buccal (cheek) swab in about 90 minutes. Following successful evaluation of ANDE in late 2014, the capability is now deployed operationally with more systems to be procured by DoD. ANDE can replace a significant amount of the costly laboratory infrastructure required to perform forensic DNA analysis in a forward deployed field environment. The Departments of Homeland Security and Justice were both participants in the ANDE program and are evaluating the system's ability to support their unique mission requirements. Finally, the Stiletto is a maritime demonstration craft that assesses a wide variety of capabilities in a realistic environment. Manufactured of composite material with a significant amount of internal deck space and capable of high speeds (50 knots plus), Stiletto is easily configurable to support both government and commercial evaluation of technologies or concepts. The return on investment for DoD is early insight and risk reduction of systems, concepts and technologies developed under DoD sponsorship or by the commercial sector which have resulted in early transitions into programs of record or fielded prototypes.

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

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

the program. Additionally, developing two different engines will help sustain a healthy industrial base enabling the Air Force and the Department of Defense to have multiple vendors, including second and third tier vendors, to meet development and production needs for legacy and future platforms. We expect a demonstration engine ready to enter Engineering & Manufacturing Development phase in the early 2020's.

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

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

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

I would like to mention one additional effort we have initiated within the Deputy Assistant Secretary of Defense for Research and Engineering Developmental Test and Evaluation office. Again, this is not a prototype or demonstration but will enable getting more value out of the prototypes and demonstrations the Department conducts. A vital element of S&T and R&D is to develop an early test program to better build knowledge throughout the early cycles of prototypes and demonstrations. This knowledge informs critical

decisions along the way that guide the maturing technology or system, and steer it towards utility, manufacturability, availability, and affordability. This knowledge is built through experimentation, analysis (to include modeling and simulation), testing, assessment, and evaluation – all of which are elements of developmental test and evaluation (DT&E). Therefore, DT&E should start at the earliest stages of development (i.e. analysis of alternatives, assessment of technology maturity, early risk reduction) and mature from early experimentation and assessment to support research, to rigorous test and evaluation to inform the systems engineering and development process, to supporting continuous evaluation throughout the system's life cycle. The Department has launched a set of initiatives that we call Shift Left to indicate that DT&E is moving early in the research, development, and acquisition process to help build the essential knowledge base for each significant effort. DT&E is no longer just about verifying specifications or assessing readiness for operational test. It is about making sure that decision-makers at all levels have the right knowledge at the right time from when a development is a researcher's bright idea to when it is in the warfighter's hands and beyond.

**Prototypes and demonstrations that develop technology surprise**

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

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

The AII effort builds on the recently completed Air Dominance Initiative (ADI) study. In this effort, DARPA worked closely with the Air Force and Navy to convene leading warfighter and technology experts for a fresh look at what will be needed to extend U.S. air dominance in the face of fast-moving potential

adversary capabilities. This group determined that no single new technology or platform could deter and defeat the sophisticated and numerous adversary systems under development. Instead, future U.S. capabilities will build on an integrated system of ISR, weapons, communications, electronic warfare, cyber, and other advanced technologies. We are excited about the probability that AII offers in demonstrating new capabilities through prototypes.

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

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

Although not a prototype or demonstration, I would also like to highlight some of the exciting progress we are making in quantum technology-based applications to national security. This past year we have demonstrated a prototype compact gyroscope based on cold-atom technology. This is a new technology, and has the potential to bring high-accuracy navigation solutions to a

wide class of military platforms at a fraction of the cost of existing systems. It addresses the growing denial vulnerability of the GPS system. To more effectively pursue the broadest set of applications using advances in 21st century quantum technology, we have initiated a close partnership with the United Kingdom, as they have recently announced a £300 million quantum initiative that will span quantum sensing, to metrology, to simulation, to precise time keeping, and that holds promise of a new set of applications with both defense and economic benefits. We kicked off this collaboration with a jointly sponsored US-United Kingdom workshop in February 2015.

**DoD S&T Successful Transitions**

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

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

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

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

DARPA's Nexus 7 (N7) program applies forecasting, data extraction, and analysis methodologies to develop tools, techniques, and frameworks for the

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

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

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

**Prize Authority**

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

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

**Summary**

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

**Mr. Alan R. Shaffer**
**Principal Deputy, Assistant Secretary of Defense for Research and Engineering**

Mr. Shaffer serves as the Principal Deputy, Assistant Secretary of Defense for Research and Engineering. In this position, Mr. Shaffer is responsible for formulating, planning, and reviewing the DoD Research, Development, Test, and Evaluation (RDT&E) programs, plans, strategy, priorities, and execution of the DoD RDT&E budget. Specifically, this position reviews the maturity of technology as part of the acquisition cycle, as well as develops options to reduce the overall technology development risk to DoD programs.

Prior to entering the federal government, Mr. Shaffer served a 24-year United States Air Force career with assignments in weather, intelligence, science and technology management, acquisition oversight, and programming. His career included deployment to Honduras in support of Joint Task Force Bravo in the mid-1980s and direct support of the United States Army 3rd Armored Division at Hanau, Germany. During Operation DESERT STORM, he was responsible for deployment of the 500-person theater weather force. Other assignments included Wing Weather Officer supporting the 320th Bombardment Wing (Heavy) at Mather AFB, California; Intelligence Officer at Foreign Technology Division, Wright Patterson AFB, OH; Deputy Director of Weather for Air Combat Command, Langley AFB, VA, numerous staff assignments in the Air Staff and Office of the Secretary of Defense, in the Pentagon; and finally, the Air Force Weather Agency, Offutt AFB, Nebraska.

Upon retirement from the United States Air Force in 2000, Mr. Shaffer was appointed to the Senior Executive Service as the Director, Multi-disciplinary Systems, Office of the Deputy Under Secretary of Defense for Science and Technology. In 2001, he assumed the position as Director, Plans and Programs, Defense Research and Engineering. Mr. Shaffer continues to serve as the Director while serving as the Principal Deputy. As the Director for Plans and Programs, Mr. Shaffer is responsible for the oversight of the Department of Defense science and technology portfolio totaling over $10.5 billion. Mr. Shaffer has served as the Executive Director for several senior Task Forces. These included the Technical Joint Cross Service Group during the Base Realignment and Closure activity; DoD Energy Security Task Force in 2007and most recently the Executive Director of the Mine Resistant Ambush Protection Task Force. In addition he serves as the tri-chair to the Department of Defense Modeling and Simulation Steering Committee.

Mr. Shaffer earned a Bachelor of Science Degree in Mathematics from the University of Vermont in 1976. He earned a second Bachelor of Science in Meteorology from the University of Utah, a Master of Science in Meteorology from the Naval Postgraduate School, and a Master of Science in National Resource Strategy from the Industrial College of the Armed Forces. He has been awarded the Distinguished Executive Presidential Rank Award in 2007 and the Meritorious Executive Presidential Rank Award in 2004.

**STATEMENT BY**
**MS. MARY J. MILLER**

**DEPUTY ASSISTANT SECRETARY OF THE ARMY**

**FOR RESEARCH AND TECHNOLOGY**

**BEFORE THE**

**EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE**

**OF THE**

**HOUSE ARMED SERVICES COMMITTEE**

**ON**

**THE UNITED STATES ARMY'S SCIENCE AND TECHNOLOGY (S&T)**

**PROGRAM FOR FISCAL YEAR 2016**

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**BY THE COMMITTEE ON ARMED SERVICES**

**UNITED STATES HOUSE OF REPRESENTATIVES**

**STATEMENT BY**
**MS. MARY J. MILLER**

**DEPUTY ASSISTANT SECRETARY OF THE ARMY**

**FOR RESEARCH AND TECHNOLOGY**

Chairman Wilson, Ranking Member Langevin, and distinguished members of the Subcommittee, thank you for the opportunity to discuss the Army's Science and Technology (S&T) Program for fiscal year (FY) 2016.

> *"Now more than ever, in today's uncertain and dynamic security environment, we must be prepared to meet multiple, wide-ranging requirements across the globe simultaneously while retaining the ability to react to the unknown. The velocity of instability around the world has increased, and the Army is now operating on multiple continents simultaneously in ways unforeseen a year ago. In short, our Army is busy."*[1]
>
> *— Sec John W. McHugh, Gen Raymond T. Odierno*

The Army faces a continued challenge – balancing force structure, operational readiness and modernization in an increasingly complex environment. The Chief of Staff of the Army (CSA) has identified the velocity of instability – the realization that what used to take our enemies months and years to disrupt may now take only days – as a key concern. The Army has developed a new Army Operating Concept (AOC), "Win in a Complex World" to address this new environment. Acknowledging the changing world around us, the AOC envisions the Army of the future as expeditionary, tailorable, scalable and prepared to meet the challenges of an increasingly global environment. The AOC sets the foundation upon which Army leaders can focus our efforts and resources to maintain both strategic and operational flexibility – to prevent conflict, shape the security environment and win wars now and in the future.

The path to get there is the Force 2025 and Beyond (F2025B) initiative – the Army's comprehensive strategy to create the Army of the future and deliver landpower capabilities as a strategic piece of the future Joint Force. F2025B envisions a series of improvements implemented over time to create Army forces that can conduct expeditionary maneuver, operating in multiple regions simultaneously. These forces must routinely operate with the initiative, moving and executing operations more swiftly

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[1] The Posture of the United States Army, Senate Committee on Appropriations Subcommittee on Defense, United States Senate, March 11, 2015, pg i

than adversaries can fight or respond. To do this, we need forces that can be scaled and tailored to suit the terrain and enemy, and that our Joint Force can transport in quantities necessary to be decisive. These forces must possess the right combination of mobility, protection and lethality to defeat our adversaries and consolidate gains. Often this combination of capability will be specific to address the threats of the region of operations. The concept of Regionally Aligned Forces (RAF) is one that offers the ability to tailor equipment and Soldier expertise to a specific area of interest/deployment.

The Army S&T Enterprise[2] is postured to address these challenges and capitalize on opportunities by focusing not only on developing more capable and affordable systems, but also on understanding the complexity of the future environment. The timelines for science and technology innovation are long. The F2025B strategy looks at the Army of 2025 as a way point to the future and acknowledges that the needs of this force must be met with technologies that already exist within the S&T realm and are, in many cases, well into advanced development. The "Deep Future" Army (2040+) envisioned will exhibit dramatic new levels of capability, deployability and sustainability, while also being more affordable. The S&T investments the Army is making now will be relied upon to meet the critical requirements of the Army after 2025, many of which cannot be foreseen today.

> *"No one can predict where the next contingency will arise that calls for the use of Army forces. Despite our best efforts, there remains a high likelihood that the United States will once again find itself at war sometime during the next two decades. It is our job to be prepared for it."*
>
> *– 2014 Army Posture Statement*[3]

We are grateful to the members of this Committee for your sustained support of our Soldiers, your support of our laboratories and research, development and engineering centers and your continued commitment to ensure that funding is available to provide our current and future Soldiers with the technology that enables them to defend America's interests and those of our allies around the world.

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[2] The S&T Enterprise refers to ASA(ALT) and the Army S&T Executing Organizations, U.S. Army Materiel Command's Research Development and Engineering Command (RDECOM), U.S. Army Medical Command's Medical Research and Materiel Command (MRMC), U.S. Army Corps of Engineer (USACE) Engineering Research and Development Center (ERDC), U.S. Army Corps of Engineers (USACE), Space and Missile Defense Command/Army Forces Strategic Command (SMDC/ARSTRAT), Space and Missile Defense Command-Technical Center (SMDC-TC), and the Army G1's Army Research Institute for the Behavioral and Social Sciences (ARI).

[3] 2014 Army Posture Statement, March 2014, 32.

***Strategic Landscape***

The United States still faces a complex and growing array of security challenges across the globe as described in the 2014 Quadrennial Defense Report:

> *"Future conflicts could range from hybrid contingencies against proxy groups using asymmetric approaches, to a high-end conflict against a state power armed with WMD or technologically advanced anti-access and area-denial (A2/AD) capabilities. Reflecting this diverse range of challenges, the U.S. military will shift focus in terms of what kinds of conflicts it prepares for in the future, moving toward greater emphasis on the full spectrum of possible operations."*[4]

The future Army will be smaller and increasingly Continental United States (CONUS) based, yet must remain capable of conducting the full range of operations on land, including prompt and sustained land combat as part of large, multi-phase joint and multinational operations. The future operational environment is likely to have several characteristics that will have a significant impact on land force operations in the future, including increased momentum of human interaction and events, potential for overmatch, proliferation of weapons of mass destruction, increasing importance of the space and cyberspace domains, and demographics and operations among populations in complex terrains.[5] While the future force will become smaller and leaner, its great strength will lie in its increased agility, flexibility and ability to deploy quickly, while remaining technologically advanced.

While adversaries continue to invest in technology to counter or evade our strengths, resource reductions and insufficient force modernization place at risk our ability to overmatch opponents. To mitigate these risks, the Army must maintain high levels of readiness while also investing in future force modernization.[6] To maintain a decisive advantage over our enemies, the Army emphasizes the integration of advanced technologies with skilled Soldiers and well-trained teams.

You have heard from the Army leadership that decreases in the Army's budget have had a significant impact on modernization and threaten our ability to retain overmatch through the next decade. The fiscal challenge brought on by the Budget Control Act (BCA) continues to strain our ability to balance readiness, modernization and end strength – it puts at significant risk our ability to meet the Army's obligations within the Defense Strategic Guidance and fulfill its national security requirements.

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[4] 2014 Quadrennial Defense Review, March 2014, vii.
[5] TRADOC Pamphlet 525-3-1, *The U.S. Army Operating Concept: Win in a Complex World*, 7 October 2014, 9-10.
[6] FY2016 Budget Request and US Army Strategy, Readiness, and Equipment Modernization Testimony, 26 March 2015.

Despite these great pressures, the Army continues to protect its S&T investments critical to identifying, developing and demonstrating technology options that inform and enable affordable capabilities for the Soldier.[7]

***A Balanced Approach to Modernization***

It is the Army's responsibility to address both current and emerging threats to ensure every Soldier deployed is equipped to achieve decisive overmatch regardless of the situation. As is often stated, we never want to send our Soldiers into a fair fight. To ensure a balanced modernization strategy, even under these austere fiscal conditions, we created long-term investment road maps across our investment portfolios. I spoke to this activity, our Long-range Investment Requirements Analysis (LIRA), last year as an effort being used within the Army to facilitate more informed program planning and budget decisions. The LIRA has put additional rigor into the development of the Army's budget submission, creating an environment where the communities who invest in all phases of the materiel lifecycle work together to maximize the Army's capabilities over time and strengthen the ties between the S&T community and their Program Executive Office (PEO) and Requirements community partners. This process has formed the basis of a balanced modernization strategy which is being implemented within the Army and addresses five key areas: (1) protect S&T investments in key technologies that will enable next-generation capabilities when resources become available; (2) selectively invest in new capabilities for priority areas; (3) incrementally upgrade existing platforms; (4) reset equipment returning from current contingency operations; and (5) divest select platforms to reduce operations and sustainment costs.

***The FY16 Budget Request***

Over the next five years, we face a situation where decreases to the Army's overall budget are at odds with the increasingly uncertain and dynamic security environment. The Army has made difficult choices to maintain a minimum force level and operational readiness by slowing Army modernization. As a result, new programs will not be initiated as originally envisioned and the Army's S&T Enterprise will be challenged to better prepare for the programs and capabilities of the future. As part of this balanced modernization strategy, the Army has called upon S&T to focus on maturing technology, reducing program risk, developing prototypes that can be used to better define requirements and conducting experimentation with Soldiers to refine new operational concepts. The S&T community has been challenged to bring forward not only new capabilities, but capabilities that are affordable for the Army of the future.

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[7] The Posture of the United States Army, 2015 pg 2

Fortunately, senior Army and Department of Defense (DoD) leadership continue to recognize the importance of S&T efforts for bridging this gap in modernization, and our FY16 budget request holds steady at the level of our FY15 request of $2.3 billion. This includes $425 million in Basic Research (6.1), $880 million in Applied Research (6.2) and $896 million in Advanced Technology Development (6.3). This represents nearly 32 percent of Army Research, Development, Test and Evaluation (RDT&E) funds, and nearly 9.5 percent of overall Army Research, Development and Acquisition (RDA). Additionally, my office manages 6.4 funding for Technology Maturation Initiatives ($41 million in FY16) and 6.7 funding for Manufacturing Technology ($48 million in FY16). These funds allow for prototyping and experimentation in collaboration with our acquisition and requirements communities (6.4) and the development of new manufacturing processes and techniques to increase the affordability of existing and new Army systems.

However, the threat of sequestration continues to hang over all our heads. As Congress debates funding levels within the confines of the Budget Control Act, I urge you to keep in mind that without the fundamental work being done in S&T today, our forces are likely to face a future in which we can no longer claim technological superiority.

***S&T Strategy***

The Army depends on its S&T program to help prepare for the future, mitigate the possibility of technical surprise and ensure that we are able to remain dominant in any environment. **The Army's S&T mission is to identify, develop and demonstrate technology options that inform and enable effective and affordable capabilities for the Soldier.** In alignment with this mission, the **Army's S&T Vision** is to **provide Soldiers with the technology to Win.** The S&T Enterprise must attract the best and brightest minds to apply their expertise to creatively solve difficult national security challenges and provide the flexibility and agility to respond to the many challenges that the Army will face.

While the Army will become smaller and leaner, it will focus investments and develop concepts and technology to become more lethal, expeditionary, and agile, with greater capability to conduct decentralized, distributed, and integrated operations. The Army will also focus on decisions and priorities regarding current technology to maintain overmatch, while driving critical capability and technology needed for the future.[8]

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[8] TRADOC Pamphlet 525-3-1, "The US Army Operating Concept: Win in a Complex World," 7 October 2014, 9-10.

Innovation and technology continue to reshape the strategic environment, multiplying and intensifying the effects that even minor actors are able to achieve. Rapidly advancing technologies in many fields may become critical to military effectiveness; examples include autonomous systems, disruptive energetics, immersive training environments, quantum computing, synthetic biology, alternative power and energy solutions and unprecedented levels of networking capabilities. The Army will continue to develop countermeasures to future threat capabilities and pursue technological opportunities. However, enemies and adversaries will counter U.S. technological advantages through cover, concealment, camouflage, denial, deception, emulation, adaptation or evasion. Finally, understanding how humans apply technology to gain capabilities and train will become as important as the technologies themselves.

The technology playing field is changing. Important technology breakthroughs in many fields are now driven by commercial and international concerns. Our strategy acknowledges the imperative of a global, networked and full-spectrum joint force. It responds to the new fiscal environment and emphasizes new ways of operating and partnering. In a world where all have nearly equal access to open technology, innovation is a critical discriminator in assuring technology superiority.

The Army has identified enduring capability challenges that are necessary to conduct future operations to prevent, shape, and win conflicts, and are used to frame Army modernization. These challenges drive our S&T priorities, including the next generation rotorcraft and ground combat vehicles; modular and open architectures; directed energy weapons; materials research; the human dimension, including cognitive and physical loads, training and medical research; and securing information at the tactical edge. S&T develops these priorities within the context of the LIRA in order to develop a synchronized program that is nested within both the Army and National Military Strategies and balances across the near-, mid-, and far-term investments.

The nature of S&T is such that continuity and stability have great importance. Starting and stopping programs prevents momentum in research and lengthens the timelines for discovery and innovation. While the Army S&T portfolio gains valuable insight from the threat community, this only represents one input to the portfolio and likely describes the most probable future. To have a balanced outlook across all the possible futures requires that the portfolio also address the “possible” and “unthinkable.” The Army’s S&T portfolio is postured to address these possible futures across the eight technology portfolios identified Figure 1.

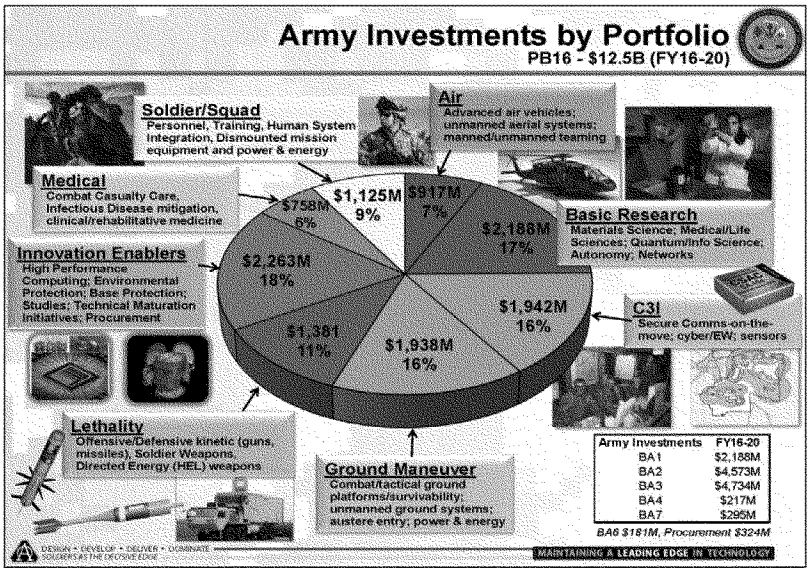


*Figure 1. Army S&T Investments by Portfolio*

The efforts of the S&T Enterprise are managed by portfolio to ensure maximum synergy of efforts and reduce unnecessary duplication. The S&T program is organized into eight investment portfolios that address challenges across six Army-wide capability areas (Soldier/Squad; Air; Ground Maneuver; Command, Control, Communications, and Intelligence (C3I); Lethality; and Medical) and two S&T enabling areas (Basic Research and Innovation Enablers). While we manage by technology portfolio, I will highlight our activities by the various roles we play in ensuring that the U.S. Army remains the dominant landpower in the world.

### *S&T Roles within the Army*

Often S&T is looked at with a singular focus - what have we done to develop the next materiel item that can transition into a Program of Record (PoR)? While that remains a critical aspect of our function within the Army, our contributions are much, much broader than that limited perspective. I'd like to take the opportunity to highlight some of these "other" roles - roles which provide critical capabilities for the Army of the future.

The S&T Enterprise is made up of over 11,500 Scientists and Engineers (S&Es) who understand the needs of the Army and the operational environment within which our Soldiers and equipment must operate. This wealth of expertise enables the many ways we support the Army through our S&T investments. Key roles for the S&T Enterprise include:

- **Solve current problems** –Operational Needs Statements (ONS)/Joint Urgent ONS (JUONS);
- **Improve current system capability** – Engineering Change Proposals (ECPs), product improvements;
- **Drive down technical risk** for Programs of Record (PoRs);
- **Inform affordable and achievable requirements**;
- **Investigate new technology/approaches** for potential Army applications;
- **Determine technology/system vulnerabilities** and identify mitigation approaches; and
- **Conduct "technology watch"** functions

I would like to take this opportunity to briefly describe some of our efforts and successes within each of these roles.

***Solving Current Problems***

As noted before, it is the expertise resident within our Army S&T Enterprise that enables our ability to respond to Warfighter urgent needs in a timely and effective manner. The familiarity of our S&T workforce to the Army operational environment helps them to quickly assess the ability for commercial solutions to meet the need (either with or without modifications) and/or identify developing capability that could address the immediate needs of the Warfighter. A great example of having the right technical expertise to solve an urgent problem is the work that was done by the Army's Edgewood Chemical and Biological Center (ECBC) (within the Army Materiel Command) to respond to an urgent need for the destruction of chemical agents and precursor materials found within Syria. ECBC developed and operated the Field Deployable Hydrolysis System (FDHS) in support of the Organisation for the Prohibition of Chemical Weapons (OPCW) and the United Nations. Working with the Joint Program Executive Office for Chemical and Biological Defense (JPEO-CBD) and in support of the Defense Threat Reduction Agency, ECBC enabled the chemical-biological defense enterprise to rapidly develop the capability needed to destroy 600

metric tons of Syria's declared chemical agent and precursor materials in an atypical operational environment.

From science and technology to advanced engineering, ECBC's proven chemistries, rapid prototyping capabilities and field operational experience were vital to the design and functionality of the FDHS onboard the MV Cape Ray. In less than six months, ECBC transitioned the technology to the JPEO-CBD on a fast-track acquisition process. During that time, ECBC scientists analyzed multiple reagents at varying concentrations and mixing ratios to determine the correct chemistries to achieve at least 99.9 percent destruction of the declared Syrian mustard and a sarin precursor in the sea-based hydrolysis reaction.

More typical responses to ONS/JUONS are a result of the acceleration of capabilities already under development within the DoD. Examples include an effort done in conjunction with Program Executive Office (PEO) Soldier to re-design the Improved Outer Tactical Vest (IOTV) to better fit female Soldiers. The standard issue IOTV was found to restrict movement of female Soldiers while they were getting in and out of vehicles or when they were placing a rifle up to their shoulder for firing. In addition, female Soldiers reported that the hard armor plates, as situated in the standard IOTV, caused abrasions on their hips and cut into their thighs when sitting. The female variant was designed, in response to requests from theater, to fit smaller torsos and is tailored to fit closer to women's chests. This solution is becoming the standard for female Soldiers. Another ONS response that resulted from the S&T Enterprise is the Video from Unmanned aircraft systems for Interoperability (VUIT-2), which addressed the request from theater for better reconnaissance capability. VUIT-2 is a capability that allows video feed from an unmanned system (in this case the Shadow Unmanned Aerial System (UAS)) to be viewed by the pilot of a manned aircraft (we assess VUIT-2 with both Kiowa and the Apache). This manned/unmanned teaming capability was successfully demonstrated in Afghanistan and is planned for insertion as part of the Apache Block 3 PoR.

***Improving Current Capabilities***

The Advanced Affordable Turbine Engine (AATE) program was a 3,000 shaft horsepower engine demonstrator S&T program designed to provide advanced propulsion capability for Army rotorcraft. AATE focused on developing a new centerline, turboshaft engine to support modernization requirements necessary to ensure the Apache and Black Hawk remain operationally effective well into the 21st century. In FY14, AATE transitioned two competing engine designs into a PEO Aviation PoR, the Improved Turbine Engine Program (ITEP), which will provide significantly more

capability and better fuel efficiency, including critically needed operational improvement in hot conditions at high altitudes (6,000 feet/95 degrees).

Another example of S&T improving current capability is the development of an under armor Auxiliary Power Unit (APU) for the Abrams M1 Main Battle Tank. The APU (9kW) provides electrical power for the combat vehicle without depending on the main engine, saving fuel, lowering vehicle maintenance costs, and reducing audible noise. The APU transitioned to PEO Ground Combat Systems as part of the M1A2 SEP V3 Abrams program, (being executed by General Dynamics Land Systems (GDLS)), which is currently in its Engineering and Manufacturing Development phase. It is estimated that the fielding of this APU within the Abrams SEP V3 to approximately 1600 vehicles would save 111,000 gallons of fuel per full battlefield day when calculated across the fleet, according to a 2009 Army Materiel Systems Analysis Activity (AMSAA) study.

***Driving Down Technical Risk***

In this time of decreased modernization funds, it is incumbent upon the S&T Enterprise to drive down the technical risks associated with developing new capabilities. As I mentioned last year, the Army has given us a great challenge – we have been asked to better prepare for new PoRs -- to bring forward not only new capabilities, but capabilities that are affordable for the Army of the future. The 3rd Generation Forward Looking InfraRed (FLIR) system is an example of where the S&T Enterprise has done just that. In the development of the 3rd Gen FLIR, S&T proved the viability and benefit of having a dual-band IR system. By combining the LongWave InfraRed (which provides search and track) and the MidWave InfraRed (which enables identification), we created an unprecedented all-weather capability which increased our performance range by 2.3 times that of the current 2nd Gen FLIR systems and extended our identification range beyond that of the detection capability of threat sensors. To ensure that this increase in capability was affordable, we also invested in the manufacturability of both the focal plane array (FPA) and the variable aperture dewar system which allows the system to perform both Wide Area Surveillance and Narrow Field of View ID. This technology transitioned to PEO Intelligence, Electronic Warfare & Sensors (IEW&S) in September 2013 as the Improved FLIR (I-FLIR) program and will help ensure our overmatch capability.

We know that future combat will require technologies that provide dismounted and mounted Soldiers trusted Position, Navigation and Timing (PNT) information, while operating in conditions that impede or deny access to the Global Positioning System (GPS). The S&T Enterprise is driving down the risk in four thrust areas: 1) Pseudolites (pseudo-satellites) that augment or replace military GPS signals by developing a terrestrial/aerial based transmission of a GPS-like signal, enabling signal acquisition/tracking, navigation and timing in degraded or denied environments; 2) a

PNT hub for vehicular applications that develops a robust system to support all PNT needs on the platform and maintain PNT assurance during operations in GPS-denied environments; 3) a PNT hub for dismounted Soldiers systems that has low Size, Weight, And Power (SWAP) and can provide assured PNT signals for all Soldier equipment; and 4) Anti-Jam Antennas that enable GPS signal acquisition and tracking in degraded or denied environments.

These PNT efforts are also part of our 6.4 Technology Maturation Initiatives and have a direct tie into the Assured PNT PoR. By developing these technologies to a relatively high maturity level, we are driving down the risk to the PoR, ensuring that when needed, our troops will be able to operate in a contested environment.

***Informing Affordable and Achievable Requirements***

One of our key current initiatives, the Joint Multi-Role Technology Demonstrator (JMR TD) program, is focused on addressing the Anti-Access/Area Denial (A2/AD) need for rotorcraft with longer range and more efficient combat profiles. The goal of the JMR TD effort is to inform affordable requirements and reduce risk for the Future Vertical Lift planned PoR, the DoD's next potential "clean sheet" design rotorcraft. The overall JMR TD effort will use integrated government/industry platform design teams and exercise agile prototyping approaches. In FY13, AVX Aircraft Company, Bell Helicopter, Karem Aircraft and Sikorksky/Boeing were awarded contracts for Phase 1 (concept design) of the JMR TD. In FY15, Sikorsky/Boeing and Bell Helicopter were selected to complete the design and fabricate and flight test demonstrator aircraft from FY17 to FY19. The Army is considering additional technology efforts with both AVX and Karem Aircraft.

We continue to develop modular and scalable technologies to enable current and future combat vehicles, which includes the Future Fighting Vehicle (FFV). In FY16, you will see the continuation of a focused initiative, done in collaboration with PEO GCS, to develop critical subsystem prototypes to inform the development and requirements of a future Infantry Fighting Vehicle (IFV) replacement program. These subsystem demonstrators focus on mobility (e.g., engine, transmission, suspension); survivability (e.g., ballistic protection, under-body blast mitigation, advanced materials); a medium caliber gun and turret; the Modular Active Protection Systems (APS); and open vehicle power and data architectures that will provide industry with standard interfaces for integrating communications and sensor components into ground vehicles. These activities are also part of our Technology Maturation Initiatives.

We are making a concerted effort to develop common architectures and Radio Frequency convergence (moving C4ISR/Electronic Warfare systems from separate boxes to cards in a common chassis) for a variety of platforms. By moving toward modular, open designs for architectures in this and other areas, we are creating

systems that are easily upgradeable as new threats emerge. We are also making it easier for small, innovative businesses to contribute their technologies.

***New and Game Changing Technologies***

We continue to develop solid state High Energy Lasers (HEL) to provide paradigm-shifting, low-cost defeat of rockets, artillery, mortars, unmanned aircraft systems and cruise missiles. We have demonstrated defeat of mortars and unmanned aircraft using an off-the-shelf 10kW laser integrated on a tactical platform and are continuing the development of technology to enable demonstration of tactical 50kW- and 100kW-class laser platforms. The Army has made great strides with these technologies and is well positioned to insert this capability into the Indirect Fire Protection Capability (IFPC) PoR around 2024. Additionally, this fall, we are bringing together industry for a HEL "rodeo." This is a chance for industry to show us their state-of-the-art capabilities beyond what they have developed for the Army or other Services, in a demonstration at White Sands Missile Range. Based on the outcome, there may be opportunities to provide some limited operational capabilities against specific threats in even sooner.

In our Basic Research portfolio we are pursuing a number of potentially game-changing technologies. Our "Materials on Demand and By Design" research will provide the capability to select and create material properties and responses, essentially building new materials from the atom up. This effort requires intensive computational capability and the research to establish (and validate) a model that accurately reflects the material properties across the various domains from the atom to the continuum. 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.

***Identifying and Mitigating System Vulnerabilities***

New theaters present new challenges – we will face future operations against technically savvy opponents who will challenge our military superiority. In FY14, building from the success of our Deployable Force Protection efforts, we began a new effort that aims to identify and understand potential vulnerabilities early in the materiel development lifecycle. This effort looks at vulnerabilities in both individual technologies and systems, providing timely feedback to technology and materiel developers in order to increase awareness of potential risks (in context of future scenarios and threats) and to identify opportunities for technology and/or employment improvements. These efforts have the potential for significant cost savings, as vulnerabilities are mitigated before system designs are finalized and/or systems are fielded. A key aspect of this initiative is red teaming, challenging the systems with an emulated enemy – one who can use innovative and adaptive methods to disrupt the planned capability. This has proven to

be an effective method to tease out inadvertent seams that result from the introduction of new technologies and systems into operational use.

One way we are accomplishing this is through our Adaptive Red Teaming activities, in which we provide technologists and systems developers with realistic and challenging multi-day experiments to employ and assess their solutions prior to acquisition. These collaborative, non-punitive experiments take emerging systems and prototypes out of the lab and into "messy" environments, incorporating varied operational and increasingly complex scenarios against capable adversaries, as well as experienced warfighters and security forces that provide real-time user feedback on design and performance. In these settings, technology solutions are examined from multiple perspectives – including systems integration, logistics, training and adaptability risks – in order to expose potential employment vulnerabilities and identify needed improvements early on.

***Understanding the Global Technology Environment***

Understanding the current and projected threat environment is essential as we develop future capabilities. As part of Better Buying Power 3.0, we are establishing tighter linkages between the intelligence, acquisition and requirements communities. To this end, we are engaging the National Ground Intelligence Center, the Army G2 and the Office of Technical Intelligence at OSD to remain aware of projected future threats and identify areas of interest for future assessment.

To foster greater innovation within the S&T enterprise, we have undertaken a new effort in technology wargaming. This is focused on identifying concepts and conducting technology-based assessments about what S&T will look like in the deep future (the 2030-2040 timeframe) and how this will affect both the Army and our adversaries. We are taking a multipronged approach that includes crowd-sourced brainstorming from Government, industry and academia, virtual workshops with Government subject matter experts, and red teaming of potential technology concepts. At the heart of this initiative lies a commitment to solid analysis and a focus on bringing fresh ideas from a wide community, including innovative thinkers who haven't traditionally been a part of the S&T planning process.

Our red teaming/vulnerability analysis activities and our technology wargaming are fostering closer ties between S&T and the intelligence community, a partnership that is increasingly important as we look beyond the recent wartime period into a more complex and unknown future.

***The S&T Enterprise Workforce and Outreach Initiatives***

The Army relies on its laboratories and centers (collectively referred to as "labs") to foster innovation; development and demonstrate new technologies; assess competing technology options; and help transition its basic research investments as they mature. Only with the support of a world-class cadre of Government civilian scientists and engineers – approximately 11,700 – complemented by a military and contracted workforce, in combination with an infrastructure that supports their work, can the labs fully support the needs of the Army. Scientists and engineers in the Army labs also provide scientific and engineering expertise to the Program Managers and Program Executive Offices. In recent military operations in Iraq and Afghanistan, the Army's labs have been a source of rapid technology transition of solutions to meet operational needs. Most recently, the military's response to the Ebola crisis has highlighted the importance of a strong, agile lab system. Ebola Virus Disease (EVD) research and development efforts executed at United States Army Medical Research and Materiel Command (USAMRMC) have contributed to the development of investigational EVD therapeutics, vaccines and diagnostic assays. In addition, USAMRMC overseas laboratories are providing technical support to their host nations' laboratory preparedness and EVD response planning efforts.

Critical to the development of the agile workforce is the ability to recruit new employees, the ability to develop existing employees, and the ability to retain these same employees. Recruiting, developing, and retaining the best science and engineering talent into the Army laboratories is becoming increasingly challenging because of the pay freeze instituted in 2010; conference restrictions implemented in 2012; furloughs related to sequestration in 2013; and the retirement eligibility for greater than 25% of the workforce. Despite these challenges, the labs continue to have an exceptional workforce. The authorities Congress has provided, such as the flexibility to enhance recruiting through direct hire mechanisms, allow the lab directors the management flexibility to shape their workforce and remain competitive with the private sector.

Last year, I described a new concept developed by the Army Research Laboratory (ARL), the Open Campus Initiative, meant to enhance innovation by leveraging the substantial intellectual resources represented by the global academic scientific research community, including industry and small business. Open Campus collaborations are anticipated to empower groundbreaking advances in fundamental science and technology research areas of mutual and strategic interest to the Army. In collaborations cultivated within the Open Campus business model, a value proposition exists for both ARL and the collaborator without a required exchange of funds and where collaborators and institutions are typically financially responsible for their arrangements. Since the introduction of the Open Campus, the ARL has initiated over

60 agreements with small businesses, industry, and academia. More than 200 researchers have come into and out of the laboratory to conduct side-by-side research in the critical S&T areas, including Human Sciences, Information Sciences, Computational Sciences, Sciences for Lethality and Protection, Maneuver, Materials Research, and Assessment and Analysis. An Open House held on December 9th and 10th, 2014, attracted over 500 college/university faculty and graduate students, science entrepreneurs, small business, contractors with enhanced-use lease aspirations, and other large industry participants. The majority of the external guests were from academia (65%), industry and small business (30%), with representation from 25 countries and 37 different states. An additional 572 remote participants joined via streaming. The interest level of high-quality leads is anticipated to result in 200 new collaborations by summer 2015.

In order to sustain the S&T Enterprise for the future, we need to develop the next generation of scientists and engineers. The Army has unique capabilities to assist in addressing the Science, Technology, Engineering and Math challenge. The Army provides access to its research facilities and STEM professionals through its Army Educational Outreach Program (AEOP). AEOP is supported through a cooperative agreement that brings together our Government, industry, and academic partners to provide students access to our laboratories and research centers for STEM enrichment activities, provide one-on-one mentorship opportunities through apprentice programs and reward student achievements in research through competitions, all while introducing students to the world of DoD research.

***Conclusion***

As the Army S&T program continues to identify and harvest technologies suitable for transition to our force, we aim to remain ever vigilant of potential and emerging threats. We are implementing a strategic approach to modernization that includes an awareness of existing and potential gaps; an understanding of emerging threats; knowledge of state-of-the-art commercial, academic, and government research; as well as a clear understanding of competing needs for limited resources. Army S&T will sharpen its research efforts to focus upon those core capabilities it needs to sustain while identifying promising or disruptive technologies able to change the existing paradigms of understanding. Ultimately, the focus remains upon Soldiers; Army S&T consistently seeks new avenues to increase the Soldier's capability and ensure their technological superiority today, tomorrow, and decades from now. The Army S&T mission is not complete until the right technologies provide superior, yet affordable, overmatch capability for our Soldiers.

> *"Innovation is the result of critical and creative thinking and the conversion of new ideas into valued outcomes. Innovation drives the development of new tools or methods that permit Army forces to anticipate future demands, stay ahead of determined enemies, and accomplish the mission."*
>
> -- *Army Operating Concept – Win in a Complex World, 31 October 2014*

All of the efforts described above would of course be impossible without the continued support of our partners in Congress. I would again like to thank the subcommittee for your long-standing support of the incredibly important work of the Army S&T Enterprise. I am extremely proud to represent the men and women who have dedicated their lives to provide our Soldiers with the capabilities to operate in any environment and situation. As we continue to navigate this difficult budget environment, I look forward to working with you to ensure the U.S. Army remains history's preeminent ground force. Thank you. I would be pleased to answer any questions you have.

**Ms. Mary Miller**
**Deputy Assistant Secretary for Research and Technology**

**Vision**
Provide technology enabling capabilities that empower, unburden and protect our Soldiers and Warfighters in an environment of persistent conflict.

**Mission**
Foster invention, innovation, maturation and demonstration of technologies to enable future force capabilities while exploiting opportunities to transition technology enabled capabilities to the current force.

**Challenge**
Deliver these technologies through effective partnerships in synchronization with Army Force Generation and fiscal processes.

**Our Strategy for Success**
- Understand Army current and future Warfighter capability needs.
- Identify opportunities to leverage emerging science and technology to address needs.
- Selectively invest to develop, adapt, mature, and demonstrate technologies to provide solutions to capability needs.
- Collaborate and leverage with other Services, agencies, international partners, academia, and the private sector to achieve efficiencies.
- Partner with Program Executive Office program managers and rapid acquisition agents to accelerate technology transition.
- Inform and provide technology readiness guidance to acquisition programs to help reduce program risk.
- Sustain an in-house, high quality workforce of scientists and engineers and a sound laboratory infrastructure.
- Communicate the vision and strategy to decision-makers, stakeholders, and our partners so they understand our value.

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HOUSE ARMED SERVICES COMMITTEE
EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

STATEMENT OF
REAR ADMIRAL MATHIAS W. WINTER, UNITED STATES NAVY
CHIEF OF NAVAL RESEARCH

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

MARCH 26, 2015

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HOUSE ARMED SERVICES COMMITTEE
INTELLIGENCE, EMERGING THREATS AND CAPABILITIES SUBCOMMITTEE

**Introduction**

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

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

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

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

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

**Naval Science and Technology Strategy**

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

**Executing the Strategy**

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

**Discovery and Invention**

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

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

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

**Leap Ahead Innovations (Innovative Naval Prototypes)**

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

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

**Technology Maturation (Future Naval Capabilities)**

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

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

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

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

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

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

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

**Quick Reaction S&T**

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

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

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

**S&T Highlights**

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

**Expeditionary Maneuver Warfare and Combating Terrorism**

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**Ocean Battlespace Sensing**

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

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

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

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

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

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

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

**Sea Warfare and Weapons**

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

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

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

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

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

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

**Warfighter Performance**

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

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

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

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

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

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

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

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

**Naval Air Warfare and Weapons**

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

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

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

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

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

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

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

**Science, Technology, Engineering and Mathematics (STEM)**

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

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

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

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

**Naval Research Laboratory (NRL)**

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

**ONR Global**

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

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

**How We Do Business**

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

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

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

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

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

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

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

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

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

**Conclusion**

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

**Rear Admiral Mathias W. Winter**
**Chief of Naval Research/Director, Innovation Technology Requirements, and Test & Evaluation (N84)**

Rear Adm. Mathias Winter, a 1984 graduate of the University of Notre Dame with a Bachelor of Science in Mechanical Engineering, received his commission through the Naval Reserve Officers Training Corps and was designated a naval flight officer in 1985.

Winter served operational tours as an A-6E Intruder Bombardier/Navigator with Attack Squadrons 42, 85 and 34 making multiple deployments aboard aircraft carriers USS Saratoga (CV 60), USS America (CV 66), USS Dwight D. Eisenhower (CVN 69) and USS George Washington (CVN 73).

Winter's acquisition tours include assistant deputy program manager (DPM) for the Joint Standoff Weapon System; executive assistant to the Joint Strike Fighter (JSF) program director; chief engineer for JSF Integrated Flight and Propulsion Control; DPM for the Tactical Tomahawk All-Up-Round development program; chief of staff to the Program Executive Officer (PEO) for Tactical Aircraft Programs; and his major acquisition command tour as the Precision Strike Weapons (PMA-201) program manager.

Winter has served flag tours as the commander, Naval Air Warfare Center Weapons Division, China Lake/Point Mugu, California, assistant commander for Test and Evaluation, Naval Air Systems Command and PEO for Unmanned Aviation and Strike Weapons. In December 2014, he became the 25th chief of Naval Research with concurrent flag responsibilities as director, Innovation Technology Requirements, and Test & Evaluation.

Winter holds a master's degree in computer science from the Naval Postgraduate School and another in national resource strategy from National Defense University's Industrial College of the Armed Forces; and a Level III certification in Program Management and Test & Evaluation from the Defense System Management College.

His personal awards include the Legion of Merit (3), Defense Meritorious Service Medal (2), Navy Meritorious Service Medal (2), Navy and Marine Corps Commendation Medal (4), Joint Service Achievement Medal (2), Navy and Marine Corps Achievement Medal, Air Force Acquisition Excellence Award, Southwest Asia Service Medal, Kuwait Liberation Medal, and various unit and sea service awards.

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BY THE ARMED SERVICES COMMITTEE,
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES
UNITED STATES HOUSE OF REPRESENTATIVES

DEPARTMENT OF THE AIR FORCE

PRESENTATION TO THE HOUSE ARMED SERVICES COMMITTEE
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES
U.S. HOUSE OF REPRESENTATIVES

SUBJECT: Fiscal Year 2016 Air Force Science and Technology

STATEMENT OF: Dr. David E. Walker, SES
Deputy Assistant Secretary
(Science, Technology and Engineering)

March 26, 2015

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BY THE ARMED SERVICES COMMITTEE,
SUBCOMMITTEE ON EMERGING THREATS AND CAPABILITIES
UNITED STATES HOUSE OF REPRESENTATIVES

Chairman Wilson, Ranking Member Langevin, Members of the Subcommittee and Staff, I am pleased to have the opportunity to provide testimony on the Fiscal Year 2016 Air Force Science and Technology Program.

This has been an exceptional year for Air Force science and technology. In the summer of 2014, the Secretary and Chief of Staff of the Air Force published *America's Air Force: A Call to the Future*, our 30 year strategy for the future of the Air Force. Science and technology was highlighted as foundational to achieving the strategy's goals.

The fiscal year 2016 President's Budget request for Air Force science and technology is $2.4 billion, a 14% increase from the previous fiscal year request. Air Force leadership recognizes the excellent work the S&T Program is accomplishing and clearly wants to see more. This request supports our continued pursuit of technology that is responsive, revolutionary, and relevant. We will continue to be responsive to urgent warfighter needs, revolutionary at inventing new concepts, and relevant to near- and mid-term military requirements.

Being responsive to a time-critical need, the Air Force S&T Program directly supported the warfighter through its' rapid innovation process. In support of the Combined Joint Special Operations Task Force in Afghanistan, the Air Force developed and deployed a sensor payload on a tactical remotely piloted vehicle that is credited with IED detection, weapons cache identification, and enemy captured or killed.

On the revolutionary front, adaptive engine technology work boasts a new engine architecture expected to reduce specific fuel consumption by 25 percent. This will improve how the next generation aircraft get to the fight, stay for the fight and survive the fight by producing greater range, higher speeds, and increased loiter. Ground testing of the Adaptive Versatile Engine Technology (ADVENT) project, which began in 2007, was completed last year and

demonstrated greater than 20 percent reduction in specific fuel consumption. Based on the huge successes of ADVENT, the FY16 President's Budget request includes support of a demonstration and validation program for adaptive engine technologies, the Adaptive Engine Transition Program. Nanotechnology is another revolutionary, game-changing, technology. An example of our work in nanotechnology is our development of nontraditional, flexible and wearable sensors that detect biomarkers signifying fatigue, cognition, and other human performance indicators. Applications of this technology are endless, but include medevac and trauma care, flight operations and special operations. The skin-like sensors are being developed using nanoparticle inks and printed with additive manufacturing technology to integrate microfluidics, power, and communications onto a small wearable sensor.

We are also addressing relevant warfighter near- and mid-term requirements, and I would like to highlight three of these technologies. The High Velocity Penetrating Weapon (HVPW) project was completed last year and enables smaller, boosted penetrators for defeating hard and deeply buried targets, an essential capability in our current threat environment. Additionally, in July, the Automated Navigation and Guidance Experiment for Local Space, or ANGELS program, was launched into geosynchronous earth orbit to conduct on-orbit proximity experiments. The technology being demonstrated will test our ability to detect, track and characterize space objects at geostationary orbit, allowing the Air Force to more expediently and efficiently evaluate events affecting military space assets. Lastly, I would like to highlight novel training and education approaches we are developing in a live, virtual, and constructive advanced training environment. This environment will prepare the warfighter for success in diverse and complex security situations, improving our combat readiness through realistic training.

Game-changing advances in technology cannot be accomplished without our talented workforce. Last year, our Secretary and Chief signed two documents that show our commitment and determination to improve our technical workforce. They signed an Air Force Engineering Enterprise Strategic Plan and an Air Force STEM Workforce Strategy. In these documents, Secretary James asks Airmen to seize every window of opportunity to improve their technical skills through training and education. The Chief encourages Airmen to embrace the innovation culture and continue to be "STEM ambassadors" in their communities. They both understand that attracting and developing technical talent in our workforce is critical to our continued innovation and ability to adapt to future threats.

In closing, the Air Force 2016 President's Budget request for science and technology ensures we continue to be responsive, revolutionary, and relevant to our mission. On behalf of the dedicated scientists and engineers of the Air Force S&T enterprise, thank you for the opportunity to testify today and for your continued support of the United States Air Force S&T Program. I look forward to answering any questions you may have.

**Dr. David E. Walker**
**Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering**
**Office of the Assistant Secretary of the Air Force for Acquisition**

Dr. David E. Walker, a member of the Senior Executive Service, is Deputy Assistant Secretary of the Air Force for Science, Technology, and Engineering, Office of the Assistant Secretary of the Air Force for Acquisition, Washington, D.C.

Dr. Walker is responsible for preparing policy, guidance, and advocacy for the Air Force's annual $2 billion science and technology program. He provides annual testimony to Congress, technical advice and counsel to the Air Force Acquisition Executive, and the Air Force's science and technology recommendations to the Office of the Secretary of Defense. In addition, Dr. Walker is responsible for overseeing a broad range of engineering and technical management policy spanning systems engineering; environmental safety and occupational health; industrial preparedness; and functional management of more than 14,000 military and civilian scientists and engineers.

Dr. Walker retired from an active-duty Air Force career as a colonel in 2006. As a master navigator, he has more than 2,700 hours in 65 different types of aircraft including the RF-4C and the F-15E. He served in a variety of assignments in operations, developmental test and evaluation, science and technology and the Air Staff.

Prior to his current position, Dr. Walker served as Associate Deputy Assistant Secretary of the Air Force (Acquisition Integration), Washington, DC.

**EDUCATION**
1979 Bachelor of Science degree in aerospace engineering, University of Texas at Austin
1980 Master of Science degree in aerospace engineering, University of Texas at Austin
1984 Squadron Officer School, Maxwell Air Force Base, Ala.
1991 Air Command and Staff College, Maxwell AFB, Ala.
1994 Doctor of Philosophy degree in Aeronautical Engineering, Air Force Institute of Technology, Wright-Patterson AFB, Ohio
1997 Air War College, Maxwell AFB, Ala.
1999 Advanced Program Manager Course, Defense Systems Management College, Fort Belvoir, Va.
2009 APEX Senior Executive Orientation Program, Washington, D.C.
2010 Air Force Enterprise Leadership Seminar, Darden School of Business, University of Virginia, Charlottesville
2011 CAPSTONE, National Defense University, Washington, DC
2012 Senior Managers in Government, Harvard Kennedy School, Cambridge, Mass.

**CAREER CHRONOLOGY**
1. February 1980 - October 1980, Student, undergraduate navigator training and Tactical Navigation Course, Mather AFB, Calif.
2. October 1980 - June 1981, Student, RF-4C Replacement Training Unit, 33rd Tactical Reconnaissance Training Squadron, Shaw AFB, S.C.
3. June 1981 - May 1984, RF-4C Weapon Systems Officer, 38th Tactical Reconnaissance Squadron, Zweibrucken Air Base, West Germany
4. June 1984 - July 1984, Student, Squadron Officer School, Maxwell AFB, Ala.

5. August 1984 - June 1985, Instructor Weapon Systems Officer, 16th Tactical Reconnaissance Squadron, Shaw AFB, S.C.
6. June 1985 - June 1986, Student, Air Force Test Pilot School, Edwards AFB, Calif.
7. June 1986 - January 1987, Experimental Test Navigator, 6512th Test Squadron, Edwards AFB, Calif.
8. February 1987 - November 1988, Experimental Test Weapon Systems Officer, F-15 Combined Test Force, Edwards AFB, Calif.
9. November 1987 - July 1990, Executive Officer to the Commander, Air Force Flight Test Center, Edwards AFB, Calif.
10. August 1990 - June 1991, Student, Air Command and Staff College, Maxwell AFB, Ala.
11. June 1991 - June 1994, Doctoral Student, Air Force Institute of Technology, Wright-Patterson AFB, Ohio
12. July 1994 - May 1995, Chief, Instructor Training, Curriculum Development, USAF Test Pilot School, Edwards AFB, Calif.
13. May 1995 - July 1996, Deputy Commandant, Air Force Test Pilot School, Edwards AFB, Calif.
14. July 1996 - June 1997, Student, Air War College, Maxwell AFB, Ala.
15. July 1997 - June 1998, Deputy Chief, Common Systems Division, Directorate of Global Power Programs, Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.
16. June 1998 - August 1999, Chief, Agile Combat Support Division, Directorate of Global Power Programs, Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.
17. August 1999 - June 2001, Director, Air Vehicles Directorate, Air Force Research Laboratory, Wright-Patterson AFB, Ohio
18. June 2001 - July 2003, Commander, 412th Operations Group, Edwards AFB, Calif.
19. July 2003 - July 2006, Vice Commander, Air Force Research Laboratory, Wright-Patterson AFB, Ohio
20. July 2006 - September 2008, Director, Material and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson AFB, Ohio
21. September 2008 - May 2011, Associate Director of Programs, Deputy Chief of Staff for Strategic Plans and Programs, Headquarters U.S. Air Force, Washington, D.C.
22. May 2011 - August 2012, Associate Deputy Assistant Secretary of the Air Force (Acquisition Integration), Office of the Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.
23. August 2012 - present, Deputy Assistant Secretary of the Air Force (Science, Technology and Engineering), Office of the Assistant Secretary of the Air Force for Acquisition, the Pentagon, Washington, D.C.

**AWARDS AND HONORS**

Meritorious Executive Presidential Rank Award
Associate Fellow, American Institute of Aeronautics and Astronautics
Legion of Merit with two oak leaf clusters
Meritorious Service Medal with two oak leaf clusters
Air Medal
Air Force Commendation Medal
Air Force Achievement Medal
Distinguished graduate, ATC Commander's Cup, and Ira Husek Flying Trophy, Undergraduate Navigator Training
Top Gun, Tactical Navigation Course
Distinguished Graduate, RF-4C RTU
Distinguished Graduate and Outstanding Contributor, Squadron Officer School Distinguished Graduate and Raymond L. Jones Award, USAF Test Pilot School Distinguished Graduate, Air Command and Staff College

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Subcommittee on Emerging Threats and Capabilities

Armed Services Committee

U.S. House of Representatives

Hearing:

"Department of Defense (DOD) Fiscal Year 2016 Science and Technology Programs: Laying the Groundwork to Maintain Technological Superiority"

March 26, 2015

**Statement by**

**Dr. Arati Prabhakar**

**Director**

**Defense Advanced Research Projects Agency (DARPA)**

NOT FOR PUBLICATION UNTIL RELEASED BY THE SUBCOMMITTEE

Chairman Wilson, Ranking Member Langevin and Members of the Subcommittee, thank you for the opportunity to testify before you today. I am Arati Prabhakar, Director of the Defense Advanced Research Projects Agency, better known as DARPA. It is a pleasure to be here with my colleagues from across the Department of Defense (DoD) Science and Technology (S&T) community, with whom we in DARPA work every day to advance our Nation's defense technologies. DARPA plays a particular role in this community, and in the broader U.S. technology ecosystem. That role is to anticipate, create and demonstrate breakthrough technologies that hold the potential for extraordinary advances in national security capability. It is a mission that dates to the launch of Sputnik in 1957 and a commitment by the United States that, from that time forward, it would be the initiator and not the victim of strategic technological surprises.

That mission, our current work and our plans for the coming years are the focus of my testimony today. But the short version of that story is that the people of DARPA come to work every day to extend the Agency's historic role by working with innovators inside and outside of government to transform revolutionary concepts—and even seeming impossibilities—into practical capabilities. Our record speaks volumes about our capacity to succeed. The ultimate results of past work by DARPA include not only game-changing military capabilities such as precision weapons and stealth technology but also such icons of modern society as the Internet, automated voice recognition and language translation, and Global Positioning System receivers small enough to embed in myriad consumer devices. Our work today aims to have similarly exceptional impact in the future.

I have noted that DARPA explicitly reaches for transformational change instead of incremental advances. Importantly, however, it does not perform its engineering alchemy in isolation. It works within an innovation ecosystem that includes academic, corporate and governmental partners, with a constant focus on the Nation's military Services, which work with DARPA to create new strategic opportunities and novel tactical options. For decades, this vibrant, interlocking ecosystem of diverse collaborators has proven to be a nurturing environment for the intense creativity that DARPA is designed to cultivate.

**OPERATING IN A GLOBAL CONTEXT**

I have emphasized that DARPA's mission and philosophy have held steady for decades, but it is equally important to note that the world around DARPA has changed dramatically—and the rate at which those changes have occurred has in many respects increased. Those changes include some remarkable and even astonishing scientific and technological advances that, if wisely and purposefully harnessed, have the potential not only to ensure ongoing U.S. military superiority and security but also to catalyze societal and economic advances. At the same time, the world is experiencing some deeply disturbing technical, economic and geopolitical shifts that pose potential threats to U.S. preeminence and stability. These dueling trends of unprecedented opportunity and simmering menace—and how they can be expected to affect U.S. national security needs a decade and more from now—deeply inform DARPA's most recent determination of its strategic priorities for the next several years.

To understand those priorities in context, it is important to start from the undeniable premise that America is in a very strong position today and is endowed with enormous advantages as it enters the last decade before its 250$^{th}$ birthday. But DARPA's mission is to look beyond the reality of today and to focus on futures we anticipate may emerge. And a number of current trends provide sobering reminders that continued U.S. global pre-eminence cannot be taken for granted.

On the technology front, for example, the Nation faces the growing challenge of maintaining domestic superiority even as sophisticated components and systems once available almost exclusively to U.S. forces become increasingly available on the global market. This reality is largely the result of otherwise beneficial economic forces that have made once-proprietary products less expensive and more accessible. But it points to the need for approaches other than technological exclusivity to maintain U.S. economic strength and military superiority.

Challenges relevant to DARPA's work also loom on the geopolitical front—including peer adversaries and other nation states that pose conventional- and nuclear-weapon threats as well as terrorist groups and other non-nation-state actors. These latter groups pose unique risks in part because they operate outside

the bounds of international conventions and so are less responsive to conventional approaches to deterrence.

Finally, DARPA and the Nation face the accelerating and overarching challenge of increasing pace—the fact that in virtually every security-relevant domain, change is coming quicker than ever, as is the need to be nimble and adaptive. Pace today matters on every scale, from the micro- and nanosecond time scales at which our information and radio frequency systems operate to the decades it currently takes to design, develop and deploy new complex weapons systems. And of course pace is central to success on the battlefield, where communications must be instant and accurate, intelligence must be current to the moment, and weapons must close on target before the adversary moves.

These are kinds of challenges and future perspectives that inform DARPA's priorities today.

**DARPA'S INVESTMENT PORTFOLIO**

DARPA's strategic priorities can be grouped within four areas, each one focused on developing and ensuring a family of key capabilities. The summaries below outline the focus areas within each of those four areas; further details about each are available in "Breakthrough Technologies for National Security" released today and available on DARPA's website, www.darpa.mil.

Rethink Complex Military Systems

Across many warfighting and security domains, U.S. capabilities are powerful today but neither sufficiently robust nor adequately scalable for the future the Nation faces. For example, modern weapons today are spectacularly complex, and the multipurpose platforms on which they reside only add to the enormity of this complexity. To be sure, these systems are formidable and have been overwhelmingly successful to date. But there is growing evidence that, under current practices, the benefits of these remarkably complex architectures are being undermined by inherent drawbacks. Today, many high-end weapons 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 harnessing complexity is outdated and inadequate, and risks leaving the Nation vulnerable to adversaries developing more nimble means of adopting the latest technologies.

To initiate new trajectories for military capabilities in this shifting landscape, DARPA is addressing the following challenges:

- Assuring dominance of the electromagnetic spectrum
- Improving position, navigation and timing (PNT) without GPS
- Maintaining air superiority in contested environments
- Leading the world in advanced hypersonics
- Asserting a robust capability in space
- Enhancing maritime agility
- Exerting control on the ground
- Augmenting defense against terrorism

Master the Information Explosion

Global digital data is in the midst of a seemingly boundless growth spurt. Every minute of every day, more than 300 hours of video is uploaded to YouTube and hundreds of new Web sites are launched. Nearly $5x10^{22}$ bytes of digital data are predicted to be generated by 2020—about ten times the current volume. And of the approximately $5x10^{21}$ bytes created as of 2014, an estimated 90 percent was generated in the previous two years alone. Adding to this widely available information is the deluge of bits generated by military and intelligence sensors.

This accelerating glut of information—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—virtually the same as the opportunity—is how to separate signal from noise to derive these insights, and how to know when to trust the information in hand.

DARPA is developing novel approaches to deriving insights from massive datasets, with the goal of enabling the operational user of information with powerful big data tools. The Agency is also developing technologies to ensure that the data and systems with which critical decisions are made are trustworthy. That includes, for example, automated cyber defense capabilities and methods to create fundamentally more secure systems.

Harness Biology as Technology

The recent maturation of genetic technologies and bioinformatics—in conjunction with recent breakthroughs in neuroscience, immunology and related biomedical fields—have begun to erase the longstanding gap between the life sciences, engineering and computing disciplines. This synthesis is catalyzing the creation of a new interdisciplinary domain rich with potential breakthroughs in areas as diverse as mental health and materials science.

Recognizing that this largely unexplored opportunity space is ripe for early, game-changing attention, DARPA in 2014 created its Biological Technologies Office, which has enabled a new level of momentum for DARPA's portfolio of innovative, bio-based programs. DARPA's work in this area includes programs to accelerate progress in synthetic biology, outpace the spread of infectious diseases and master new neurotechnologies.

Expand the Technological Frontier

From its earliest days, DARPA's core work has involved overcoming seemingly insurmountable physics and engineering barriers and, once showing those daunting problems to be tractable after all, applying new capabilities made possible by these breakthroughs directly to national security needs. That tradition holds true today.

Maintaining momentum in this core component of the agency, DARPA is working to achieve new capabilities by applying deep mathematics; inventing new chemistries, processes and materials; and harnessing quantum physics.

**MAKING A DIFFERENCE—FROM CONCEPT TO REALITY**

The four broad areas above describe DARPA's portfolio of programs today. Across that portfolio, DARPA's performers are achieving significant technical progress—the first important step in the journey to achieving our mission. In my testimony today, I would like to highlight what comes next from DARPA's programs: the transition of technical results into use.

DARPA's mission is to reveal new possibilities and enable groundbreaking capabilities by developing and demonstrating breakthrough technologies, but true success happens only when these technologies make significant, transformative improvements in the Nation's security. That's why, even before a program launches, DARPA starts developing strategies for transitioning anticipated results into the hands of those who can put them to work.

Transitions are rarely simple and can follow different paths. In fact, the successful transition of a technology to a military, commercial or other entity is, in itself, still but an intermediary step to the final goal of revolutionary impact, which can be a years-long process. DARPA pursues and catalyzes a wide range of transition pathways, each selected to maximize the ultimate impact of a given technology.

In some cases, a DARPA program that demonstrates a military systems capability will become a program of record in one or more of the Services. In other cases, new DARPA-enabled technologies will transition first to the civilian sector, where commercial forces and private capital may drive further advances and cost efficiencies that can facilitate incorporation into military systems. In still other cases, DARPA's role ends after proving at a fundamental level the potential for a new capability, after which a military or civilian organization will typically pick it up for further research and development.

Because DARPA focuses explicitly on game-changing, non-incremental goals, some DARPA efforts do not transition upon their conclusion—either because the technology itself failed or because the resulting capability promises to be so disruptive that, in the short term at least, it cannot be integrated into existing systems or strategies. In those cases, years may pass before a DARPA-supported advance gets the opportunity to make its mark, after related technologies mature or other contexts evolve in ways that make the advance more practicable.

In recognition of the essential importance of technology transition as well as the complexity and challenges inherent in transitions, DARPA has a support office—the Adaptive Execution Office—dedicated to transition alone. Staffed by a team of individuals with deep experience in the military Services and working in close collaboration with Service liaisons, the office is committed to finding and facilitating the most effective path from the research laboratory to operational impact for DARPA-supported technologies.

Notwithstanding the many inherent challenges to successful transition, technologies that had their genesis in DARPA programs can be found inside countless military capabilities today—and the Agency continues to make progress toward transition from its current and recent programs. Examples include:

Riding the Gallium Nitride Wave

For years, DARPA and its Service partners pursued the technically daunting task of developing high-power-density, wide-band-gap semiconductor components in the recognition that, whatever the end-state task, U.S. forces would need electronics that could operate and engage at increasing range. The result was a series of fundamental advances involving gallium-nitride-enabled arrays, which now are providing significant benefits in a wide range of applications in the national security domain. Today, three major systems under development are enabled by DARPA's advances in radio frequency (RF) component technology: Next Generation Jammer, designed to give the Navy the ability to jam adversary radars to protect U.S. assets; Air and Missile Defense Radar, which is designed to search for and track ballistic missiles and provide terminal illumination of targets; and Space Fence, to boost space domain awareness by providing vastly improved detection of small objects in orbit.

Creating Deep-Ocean "Satellites"

DARPA's Distributed Agile Submarine Hunting (DASH) program is creating fixed and mobile underwater observing systems that look up from the ocean floor. Just as satellites provide a wide-area view of the ground from space, these systems can see submarine threats passing overhead across vast volumes of ocean. This deep-ocean system has as a goal the ability to track a submarine until other platforms can arrive to track, trail or prosecute the threat. DARPA is working with Navy

operational commanders in the Pacific and the Atlantic to conduct at-sea prototype testing that will integrate these new capabilities with existing undersea surveillance operations—testing that will underpin Navy consideration of a potential program of record for undersea surveillance.

Delivering Long-Range Anti-Ship Capabilities

DARPA jumpstarted the development of the Long Range Anti-Ship Missile (LRASM), a precision-guided standoff missile that is on track to reduce dependence on intelligence, surveillance and reconnaissance (ISR) platforms while extending range significantly. After successful flight tests in August and December 2013, the Navy stepped up to work in close partnership with DARPA. With yet another successful test in February 2015, this time led by the Navy, the joint effort is speeding deployment of this system to deliver its unprecedented capabilities for the warfighter.

Gathering and Sharing Critical Information

Extending DARPA's longstanding commitment to provide the Services with the best available technologies for ISR, DARPA has signed a technology transfer agreement with the Joint Special Operations Command (JSOC) allowing the Command to receive and operate the Autonomous Real-time Ground Ubiquitous Surveillance-Imaging System (ARGUS-IS). This very-wide-area, high-resolution motion video sensor is enabled by advanced on-board processing and an integrated ground station that allows interactive designation and tracking of multiple targets simultaneously. This technology will provide warfighters unprecedented ability to see, understand and engage hostile networks and high-value targets. The JSOC is integrating this package onto a manned platform for further development to enable near-term combat deployment.

Exploiting Photo and Video Images

Burgeoning volumes of images collected in support of surveillance and reconnaissance efforts—such as photo and video albums stored on laptop computers confiscated from insurgents during DoD operations—are growing at such a rate that unassisted analysis cannot keep up with demand for interpretation. DARPA has developed and transitioned to relevant agencies several technologies

that are enhancing analysts' productivity, including technology that searches imagery and video archives for persons, objects, events and activities of interest; novel interfaces to support live video exploitation; and the capability to track all movers in a dynamic field of view.

Digitizing Close Air Support

When ground forces have identified the location of an adversary out of their reach, or are pinned down and in need of support from the air, they should not be dependent on paper maps and voice communications to convey essential information to pilots. Yet that has been the case, until recently. DARPA's Persistent Close Air Support (PCAS) system digitizes and greatly simplifies the mission-critical capability of air support. Today, DARPA is transitioning PCAS' air and ground technologies to Army Special Operations Command (USASOC), giving ground elements the capability to request air-delivered munitions from manned or unmanned platforms with unmatched accuracy and shared awareness. Specifically, USASOC has committed to integrate and deploy PCAS technology with its fleet of MQ-1C Gray Eagle unmanned platforms and related networking systems.

Searching the Deep Web

Today's web searches use a centralized, one-size-fits-all approach that uses the same set of tools for all queries. While that model has been successful commercially, it is inadequate for a number of national-security-relevant applications because it neither recognizes nor aggregates shared content across pages and misses information in the deep web—the web domains not indexed by standard commercial search engines. DARPA's Memex program has developed software that advances online search capabilities far beyond the current state of the art and is already revolutionizing the discovery, organization and presentation of domain-specific, deep-web content. DARPA's initial focus has been on fighting human trafficking, an illicit enterprise with implications for and connections to many types of military, law enforcement and intelligence investigations. With a number of initial successes in that domain—including arrests and a recent conviction—the program is now being expanded for use by DoD in the fight against the Islamic State of Iraq and the Levant, or ISIL.

Revolutionizing Prosthetics

Recognizing the particular debt our Nation owes to those seriously wounded in battle, DARPA several years ago launched a concerted effort to improve upper-limb prosthetic technology, which, reflecting the medical and engineering challenges posed by the complexities of the human arm and hand, had trailed far behind lower-limb technologies. In 2014, capping an intensive effort by DARPA's Revolutionizing Prosthetics program, the U.S. Food and Drug Administration gave marketing approval for a modular prosthetic arm and hand that provides unprecedented user dexterity. Users can once again perform everyday activities such as feeding themselves, shaking hands and offering a child a pat on the back or a hug.

**KEEPING DARPA VIGOROUS**

DARPA's leadership takes seriously its responsibility to maintain and encourage the agency's culture of innovation and its ability to execute rapidly and effectively.

At the center of DARPA's success is an abiding commitment to identify, recruit and support excellent program managers—extraordinary individuals who are at the top of their fields and who are hungry for the opportunity to push the limits of their disciplines during their limited terms at DARPA. I am most grateful for the critical support this Subcommittee provided last year for expanding DARPA's ability to use its 1101 hiring authority. That authority has proven invaluable to our ability to attract some of the finest scientists, engineers and mathematicians to the important work of public service and national security.

DARPA's technical staff is also supported by experts in security, legal and contracting issues, finance, human resources and communications. These are the people who make it possible for program managers to achieve big things during their relatively short tenures.

Having worked in several agencies in the public sector and several companies in the private sector, I am acutely aware that a humming, effective enterprise is never achieved by accident. Congress has played a vital role in DARPA's success over many years, providing through legislation the tools to recruit stellar people, work in new ways with companies outside the traditional defense contractor community,

and build communities around prize challenges—experimenting, learning and adapting all the while. Thank you for this important support.

**DARPA'S BUDGET**

The President's FY 2016 budget request for DARPA is $2.973 billion. This reflects an increase of $57 million compared to the $2.916 billion appropriated for FY 2015. To put these numbers in context, from FY 2009 to FY 2013 DARPA's budget declined steadily through a series of reductions, including the 8 percent across-the-board sequestration cut in FY 2013. The total reduction to DARPA's budget from FY 2009 to FY 2013 was 20 percent in real terms.

With modest increases in FY 2014 and 2015, the budget has now recovered slightly, gaining back about 7 of those 20 percentage points in real terms. I thank this Subcommittee, and Congress more broadly, for your support over the past two years to stabilize the budget. And I ask for your support of the President's budget request for FY 2016 so we can continue to deliver on our vital mission.

I will also note that the implementation of sequestration under the Budget Control Act will have real and negative impact on our work. We do not have to speculate about sequestration effects; unfortunately, we know from the experience of FY 2013 what will happen. Cuts will mean that some important new programs will be delayed. Some existing programs will end prematurely, before achieving their critical milestones. Demonstrations will be delayed, and because they typically involve our Service partners and test facilities, these projects will ultimately cost more to complete after multiple interlinked schedules are rebuilt. As in prior years, no single cut is a death blow. Rather, the cumulative effect is an erosion of our ability to execute our mission and an erosion of the confidence that the wider technology community has in government.

**CONCLUSION**

I have spoken today about many challenges facing our Nation, and we in DARPA take these threats very seriously, as do all our colleagues throughout the DoD and across government. But one of the wonderful things about working in a place like DARPA is that our day-to-day work is always about solutions—about creative ways to neutralize risk and rise above danger. In that sense, DARPA is a very

optimistic and even joyous place to work. So it is not just our responsibility but also our privilege and passion at DARPA to strive every day to cultivate and harness emerging technologies in the cause of U.S. national security.

I thank you for your trust, and I will be pleased to respond to your questions.

**Arati Prabhakar**
**Director, Defense Advanced Research Projects Agency**

Arati Prabhakar is the director of the Defense Advanced Research Projects Agency.

Dr. Prabhakar has spent her career investing in world-class engineers and scientists to create new technologies and businesses. Her first service to national security started in 1986 when she joined DARPA as a program manager. She initiated and managed programs in advanced semiconductor technology and flexible manufacturing, as well as demonstration projects to insert new semiconductor technologies into military systems. As the founding director of DARPA's Microelectronics Technology Office, she led a team of program managers whose efforts spanned these areas, as well as optoelectronics, infrared imaging and nanoelectronics.

In 1993, President William Clinton appointed Dr. Prabhakar director of the National Institute of Standards and Technology, where she led the 3,000-person organization in its work with companies across multiple industries.

Dr. Prabhakar moved to Silicon Valley in 1997, first as chief technology officer and senior vice president at Raychem, and later vice president and then president of Interval Research. From 2001 to 2011, she was a partner with U.S. Venture Partners, an early- stage venture capital firm. Dr. Prabhakar identified and served as a director for startup companies with the promise of significant growth. She worked with entrepreneurs in energy and efficiency technologies, components for consumer electronics, and semiconductor process and design technology.

Dr. Prabhakar received her Doctor of Philosophy in applied physics and Master of Science in electrical engineering from the California Institute of Technology. She received her Bachelor of Science in electrical engineering from Texas Tech University. She began her career as a Congressional Fellow at the Office of Technology Assessment.

Dr. Prabhakar has served in recent years on the National Academies' Science Technology and Economic Policy Board, the College of Engineering Advisory Board at the University of California, Berkeley, and the red team of DARPA's Defense Sciences Research Council. In addition, she chaired the Efficiency and Renewables Advisory Committee for the U.S. Department of Energy. Dr. Prabhakar is a Fellow of the Institute of Electrical and Electronics Engineers, a Texas Tech Distinguished Engineer, and a Caltech Distinguished Alumna.

**WITNESS RESPONSES TO QUESTIONS ASKED DURING THE HEARING**

MARCH 26, 2015

## RESPONSES TO QUESTIONS SUBMITTED BY MR. LANGEVIN

Mr. SHAFFER and Dr. PRABHAKAR. The Electronic Warfare Executive Committee (EW EXCOM) is co-chaired by the Under Secretary of Defense for Acquisition, Technology and Logistics and the Vice Chairman of the Joint Chiefs of Staff and includes the Service Vice Chiefs, Service Acquisition Executives, the commanders of USSTRATCOM and USCYBERCOM, Director, Operational Test & Evaluation, Director, Cost Assessment and Program Evaluation, Director, Defense Advanced Research Projects Agency and the DoD Chief Information Officer. This level of senior visibility and decision authority will necessarily focus attention and resources toward the challenges posed to our freedom of maneuver in the electromagnetic spectrum (EMS).

The EW EXCOM's initial focus is on ensuring that fielded weapon systems and those in earlier stages of development are designed and equipped to operate effectively in the EMS, notwithstanding the growing capabilities of potential adversaries. This means that weapon systems must have adequate electronic protection (EP) to withstand the growing electronic attack (EA) capabilities of our adversaries made possible by the worldwide proliferation of advanced devices for signal processing, and that continual expansion of EA capabilities is needed to maintain U.S. advantage. To do so, the Department requires closer coordination and cooperation among the Military Departments, the many acquisition programs of record, and both national and Military Department's research laboratories. This coordination and cooperation are an essential emphasis of the EW EXCOM. Effective operation in the EMS requires extensive knowledge of the spectrum and how the adversary is operating within it. Thus, efforts to collect signals, both at a strategic level with SIGINT and a tactical level with electronic warfare support (ES), require continued emphasis and support. Additionally, as operations in the EMS are increasingly connected and essential to both kinetic and non-kinetic operations across the range of military operations, electromagnetic battle management (EMBM) capabilities require development and thus attention by, and direction from, the EW EXCOM. Finally, the EXCOM will consider operational issues, including the quantity and expertise of EW personnel.

Specifically, through efforts in science and technology, the EW Science and Technology Community of Interest developed a roadmap for use by the service laboratories. The EW S&T roadmap was developed by Military Departments' input and approved by the ASD(R&E) to define a cross-cutting EW S&T investment strategy. The EW EXCOM's support to implement the roadmap capabilities, or to provide direction to amend it if required, is anticipated. The ASD(R&E) will submit an annual review of progress on the EW S&T Roadmap for EW EXCOM approval.

The ASD(R&E) will seek to inform the EW EXCOM, and be guided by it, on EW matters. The ASD(R&E) will provide input to the EW EXCOM on the technologies and capabilities we see relevant to EW, a process that has already begun. The EW EXCOM will provide and prioritize guidance to drive technology development to meet specific challenges. The EXCOM's authority will bolster the visibility and support of proposed EW capabilities relative to competing options and leverage the varied EW strengths of the Military Departments. In regard to EW and cyber, the EW EXCOM will address cyberspace operations as they relate to the EMS in coordination with the Cyber Investment Management Board (CIMB). [See page 24.]

Ms. MILLER. While it is too soon to say exactly how the newly-formed Electronic Warfare (EW) Executive Committee (ExCom) will impact our Science & Technology (S&T) programs, I would say that our EW and Cyber S&T efforts are already very well coordinated with the other Services and OSD through our involvement in the EW and Cyber Security Communities of Interest. We also coordinate extensively with our acquisition partners and the Training and Doctrine Command community during the development and execution of our programs to ensure we are addressing Warfighter needs. We will continue to collaborate across the DoD to address this important area and will participate in the EW ExCom as appropriate. [See page 24.]

Admiral WINTER. The Defense Science Board (DSB) recommendations regarding improving our Electronic Warfare (EW) capabilities spanned all phases of military

development, from science and technology (S&T) through acquisition and deployment. The March 17, 2015 memo from Deputy Defense Secretary Work established the Electronic Warfare Executive Committee and chartered this new group "to provide senior oversight, coordination, budget/capability harmonization, and advice on EW matters to the Secretary of Defense, Deputy Secretary of Defense and the Deputy's Management Action Group." Further, it states the initial focus areas of the group "will include EW strategy, acquisition, operational support, and security."

Missing from this list is EW science and technology (S&T), which is where Office of Naval Research (ONR), the other service S&T organizations and DARPA can contribute. Fortunately, Assistant Secretary of Defense (Research & Engineering) has already established a joint S&T oversight group, the EW Community of Interest (COI), which produced in 2014 a far term joint roadmap for EW research and development. This Joint EW COI S&T Roadmap independently identified many of the shortfalls in current EW capabilities highlighted by the DSB study. More importantly, this roadmap shows how past, current and planned EW S&T investments in developing technology enablers have put the DoD on a path toward realizing a future EW vision to mitigate and eliminate these shortfalls. A separate Cyber S&T COI has produced a similar long term Joint Cyber S&T Roadmap and both COIs are working "at the points where EW and cyber are converging." Our recommendation would be that the new EW Executive Committee adopt the EW COI and the Cyber COI as advisory bodies on S&T and endorse their respective roadmaps as the long term vision for future DoD EW/Cyber capability development. [See page 24.]

Dr. WALKER. The creation of the Electronic Warfare Executive Committee (EW EXCOM) will complement our existing efforts to harmonize the development of EW, Cyber, and integrated Cyber-EW capabilities across the Services and Agencies of the DoD. It will mesh well with the efforts and activities of the Assistant Secretary of Defense's (Research & Engineering) Reliance 21 Program in the Science & Technology (S&T) community.

The EW EXCOM will provide senior oversight, coordination, budget/capability harmonization, and advice on EW matters to the Secretary of Defense, Deputy Secretary of Defense, and the Deputy's Management Action Group. It will facilitate cohesion across requirements, science and technology (S&T), research, development, acquisition, test and evaluation (T&E), and sustainment to ensure that EW and joint electromagnetic spectrum operations (JEMSO) investments are effectively planned, executed, and coordinated across the DoD. The EW EXCOM will provide feedback to key senior level DoD decision-making bodies on the execution of EW requirements and acquisition processes.

Underpinning the science and technology (S&T) leadership is an ecosystem of technical groups known as Communities of Interest (COIs). The COIs provide a forum for coordinating S&T strategies across the Department, sharing new ideas, technical directions and technology opportunities, jointly planning programs, measuring technical progress, and reporting on the general state of health for specific technology areas. Separate COIs for Electronic Warfare and Cyber exist and have been successful in their endeavors. The EW EXCOM, in coordination with the Cyber Investment Management Board, should provide an avenue to increase technology transitions from the EW and Cyber S&T COIs, potentially streamline acquisition of the technologies, and aid in establishing more integration and synergy of the technologies. [See page 24.]

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## RESPONSE TO QUESTIONS SUBMITTED BY MR. FRANKS

Mr. SHAFFER. The Department has an integrated technology and systems development roadmap for both high-energy lasers and microwaves (HEL, HPM). It is unlikely that either system could be operationally fielded before the 2022–2025 timeframe. Additional resources are not likely to accelerate development, but they could potentially contribute to significant lower risk reduction in achieving the necessary milestones. Development of both HEL and HPM is really an engineering challenge. Adding more resources is not likely to accelerate the engineering process. What more resources might facilitate is the chance to work on competing designs simultaneously, which could reduce technical risk, leading to a program of record that would be more predictable in cost and schedule. [See page 23.]

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## RESPONSES TO QUESTIONS SUBMITTED BY MR. NUGENT

Dr. WALKER. The rocket propulsion system effort, as referred to in the fiscal year 2015 National Defense Authorizations Act (NDAA), is funded in the Evolved Expendable Launch Vehicle Program (SPACE)—EMD Program Element (PE)

0604853F. That effort is managed through the Air Force Program Executive Officer for Space (AFPEO/SP) in the Space and Missile Systems Center (SMC) at Los Angeles AFB, CA.

The Air Force has obligated about $50 million so far; $37 million in fiscal 2014 money, which was reprogrammed in the Omnibus, and about $13 million of the fiscal year 2015 money, which was appropriated in 2015. We intend to invest an additional $45 million to $50 million over about the next six months. We issued a draft Rocket Propulsion System (RPS) Request for Proposals (RFPs) in April and will award multiple contracts with propulsion system or launch system providers to partner with their ongoing investment in domestic propulsion systems as part of our plan to develop a domestic propulsion system by 2019, and to do so competitively. However, this will only give us an engine, and an engine alone will not launch us into space. Transitioning the engine to a fully integrated tested and certified capability will take longer than that. This is the consensus of experts across the space enterprise. [See page 20.]

Dr. WALKER. We do not have the ability to give the combatant commanders this capability right now for a fraction of the cost. One year and $10 million is not sufficient to provide a CHAMP-like capability to the warfighter. Raytheon, a CHAMP contractor, has estimated that the cost and schedule to provide 32 missiles is four years and $140 million. This estimate does not include the cost, resources and planning required by the Air Force and the combatant commands for the development and implementation of doctrine, organization, training, materiel, leadership and education, personnel and facilities (DOTMLPF) associated with a weapon system capability. Additionally, maintaining a very small number of CHAMP platforms, with the associated sophisticated hardware, in the inventory will be expensive. There are also concerns with the platform's survivability, ingress range, target engagement ranges, and guidance and navigation capabilities in a realistic scenario. Developing and producing any weapon system would not be funded within the Science and Technology portfolio. [See page 21.]

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## RESPONSE TO QUESTION SUBMITTED BY MS. STEFANIK

Ms. MILLER. One of the great strengths of Army Science & Technology (S&T) is our world-class cadre of nearly 12,000 scientists and engineers. For 30 years now, the Army has embedded scientists and technology experts in the field to ensure that the exchange of new technology and the feedback it yields moves efficiently between the researchers who develop it and the Soldiers who use it. In recent military operations in Iraq and Afghanistan, the Army's labs have been an important source of rapid technology transition of solutions to meet operational needs. Through the Research, Development and Engineering Command (RDECOM), our Field Assistance in Science and Technology (FAST) Activity brings Army labs and research and engineering centers into closer contact with their "customers"—the major Army commands throughout the world, providing the Soldier in the field with greater support and responsiveness to operational needs. This includes the Science and Technology Assistance Team (Afghanistan) (STAT–A), a rotating 3-person team that from 2007 to 2014 provided in-theater technical advice and quick reaction solutions to technical problems, as well as a direct connection back to our scientists and engineers back home. Today, RDECOM provides the lead Engineer in the Rapid Equipping Force (REF) Expeditionary Lab in Afghanistan on a 179 day rotation supporting Soldiers on the ground. Over the past years, the Army S&T Enterprise has made numerous other important contributions to our efforts in Afghanistan. For example, our Deployable Force Protection (DFP) program was established in response to the DoD's priority initiative to improve force protection at forward operating bases (FOBs). U.S. military units operating remotely at small bases are more vulnerable to enemy attacks, especially extra small FOBs, combat outposts, and patrol bases where 300 personnel or less occupy the base. Their vulnerabilities are greater because they have less manpower and organic equipment for construction of protective measures, weapon systems with shorter kinetic reach, significant bandwidth limitations, and are generally more remote making them difficult to reach with reinforcements or supplies. The DFP S&T Program was stood-up to help address these shortfalls and was geared toward accelerated development of technologies with spiral transitions to acquisition partners or related activities such as the Rapid Equipping Force. The DFP program concluded in FY14, having delivered a number of important capabilities to US Forces–Afghanistan, including Cerberus Lite and Low-logistics Modular Protective Systems Mortar Pit Kits. These small FOB force protection capabilities were especially useful during the drawdown when the bases' manpower and organic capabilities were being reduced. Army S&T has also developed several

Soldier power technologies that have transitioned through Program Executive Office Soldier and been provided specifically to the 10th Mountain Division. For example, the Conformal Wearable Battery (CWB) is a 2.3lb ergonomic Soldier-worn battery that bends to the curvature of the Soldier's chest and/or back and provides 150 watt-hours of power. The battery serves as the central source of power for multiple Soldier-worn devices, and increases Soldier mobility by better distributing weight around the Soldier's core. The Integrated Soldier Power/Data System (ISPDS) is an integrated Soldier worn power/data distribution system intended to manage power and data from Soldier worn devices and powered by the CWB. The system manages the distribution of power across all worn peripherals and aggregates peripheral data onto a common end-user device. Over a 72 hour period, ISPDS provides a 32 percent weight savings in batteries. Both these technologies were provided to the 1st, 3rd and 4th Brigades, 10th Mountain Division, between 2012 and 2014. [See page 23.]

## QUESTIONS SUBMITTED BY MEMBERS POST HEARING

MARCH 26, 2015

## QUESTIONS SUBMITTED BY MR. WILSON

Mr. WILSON. Could you give us an update on the status of the "Trusted Foundry" program for providing a secure source of microchips for sensitive defense systems? What is being done to respond to the recent announcement that IBM plans to sell its Foundry capabilities to a foreign controlled company?

Mr. SHAFFER. [The information referred to is for official use only and retained in the committee files.]

Mr. WILSON. Do you have enough visibility into industry-directed independent research and development (IR&D)? Are there additional legislative tools you need to be more effective in coordinating with those investments?

Mr. SHAFFER. IR&D conducted by defense contractors as an allowable overhead expense can be an important source of innovation for both industry and DoD. IR&D represents well over $4 billion in annual R&D spending. Reviews of IR&D spending indicate that a significant fraction of IR&D is being spent on near-term competitive opportunities and on de minimis investments principally intended to create intellectual property rights for a company. IR&D allowability should encourage contractors to engage in R&D activities of potential interest to DoD. We have established a database in which companies meeting certain dollar thresholds are required to report their IR&D projects. Because companies enter the information at the end of their Fiscal Year, our visibility is limited to looking in the past. We are working to increase visibility into IR&D without increasing administrative burdens or requiring legislation.

Mr. WILSON. What tools do you have to transition successful technologies developed by S&T, whether in the labs or from contractors, into programs of record?

Mr. SHAFFER. Prototyping and experimentation have become key transition tools. Prototypes are preliminary versions of a system or major sub-system assembled to resolve some area of risk and/or to explore operational potential. Experimentation puts prototypes into end users' hands in an operational context. Experimentation capabilities span ranges from field use by military personnel, wargaming, simulation, Service/Combatant Command exercises, and government/industry live, virtual and constructive environments.

Prototyping and experimentation aid in the transition of successful technologies by providing Warfighters with the opportunity to explore novel operational concepts. In addition, they provide a hedge against threat development and reduce the lead time to develop and field new capabilities.

Mr. WILSON. How important are programs like the Small Business Innovative Research program (SBIR), Small Business Technology Transfer program (STTR), or the Rapid Innovation Program (RIP) to your technology transition efforts?

Mr. SHAFFER. SBIR/STTR and RIP are key enablers for transitioning small business technologies into DoD products. Based on a recent DoD-wide survey of military and industry RIP participants, RIP remains one of the few programs available to acquisition managers to solicit competitively for technology refresh, providing small businesses an "on-ramp" into defense acquisition programs.

RIP stimulates U.S. manufacturing and supports small businesses. Eighty-eight percent of RIP contracts (321 of the 365 awards over a five year period) are awarded to small businesses, with over seventy-five percent awarded to businesses that participate or have participated in the SBIR program.

Mr. WILSON. Do you have enough visibility into industry-directed independent research and development (IR&D)? Are there additional legislative tools you need to be more effective in coordinating with those investments?

Ms. MILLER. The Army currently has sufficient visibility into industry-directed independent research and development (IR&D). In fact, quarterly IR&D updates are held at the OSD level between the heads of large defense companies and Defense and Service Acquisition and S&T leads and provide a regular opportunity to exchange dialogue and inform investment decisions in their R&D portfolios. The Defense Federal Acquisition Regulation Supplement (DFARS) rules provide for a major contractor's annual IR&D costs to be allowable only if the contractor reports its IR&D projects to the Department of Defense. Currently this reporting is done through the Defense Technical Information Center (DTIC) via an online form. Par-

ticipating companies are required to update their efforts annually and again upon project completion. While the DoD has visibility into IR&D projects, the DoD has only limited ability to impact the allowability of the projects and therefore may require statutory or regulatory changes to gain the ability to endorse or reject projects prior to their initiation.

Mr. WILSON. What tools do you have to transition successful technologies developed by S&T, whether in the labs or from contractors, into programs of record? How important are programs like the Small Business Innovative Research program (SBIR), Small Business Technology Transfer program (STTR), or the Rapid Innovation Program to your technology transition efforts?

Ms. MILLER. One example of the tools that exist within the Army to assist in the transition of technologies is the Army's Technology Maturation Initiative (TMI) (Program Element 0604115A), which aligns S&T and acquisition partners under a coordinated effort to assess emerging but needed capability improvements and facilitate their transition to Programs of Record. TMI matures high-payoff S&T products beyond traditional technology readiness levels in order to drive down program risks, inform affordable and achievable requirements and increase transition success. By engaging key stakeholders from the requirements, technology, acquisition and resourcing communities to select and oversee the TMI and other prototyping efforts, we are able to prioritize and coordinate efforts that best enable the integration of new capability into current and planned Acquisition programs.

The Army SBIR and STTR programs also aid in technology transition by providing acquisition Program Managers with visibility of innovative small business technologies. Army SBIR Phase I projects develop proof of concept solutions and Phase II further develops those technologies into prototypes. The Army SBIR program uses their Phase II Enhancement Program to facilitate transition of promising technologies into acquisition programs. Under the Phase II enhancement program, the acquisition program needs to make a tangible commitment to the transition, and SBIR will provide up to $500,000. Started in 2008, this program has led to many successful transitions into acquisition programs and industry.

The Army has also used the Rapid Innovation Funding (RIF) program to transition technologies. The RIF program provides the Army a useful mechanism to address Program Executive Office and the Research community near-term challenges. Of the 71 projects awarded in Fiscal Years 2011 and 2012, nine have transitioned to acquisition programs with committed outyear funding and an additional 58 are working transition agreements, with outyear funding not yet committed.

Mr. WILSON. Do you have enough visibility into industry-directed independent research and development (IR&D)? Are there additional legislative tools you need to be more effective in coordinating with those investments?

Admiral WINTER. As reflected in the recent guidance on Better Buying Power (BBP) 3.0 issued by USD/AT&L, there is clearly a need for increasing our visibility into industry IR&D. This is a valuable complement to the Services' RDT&E investments, but to ensure that it is being used productively, we need to increase communications between industry and Government on the subject. Under BBP 3.0, this is being done in two ways.

First, we have initiated a recurring series of Technology Interchange Meetings (TIMs), organized by the DoD technical Communities of Interest, which will provide a forum for the Government to communicate future strategies and program thrusts to industry and for industry to share relevant IR&D efforts with Government subject matter experts. The initial stages of these information exchanges will be accomplished virtually, via the DTIC hosted Defense Innovation Marketplace. Based upon reviews of these initial exchanges, face to face meetings and reviews of relevant projects will be conducted. The outcome of these TIMs will include both increased shared situational awareness and the identification of potential new areas for partnering between Government and industry.

Second, we are initiating a new process for review and endorsement of IR&D efforts prior to the Government making a determination regarding allowable IR&D expenses. Discussions with industry regarding this new process and specific mechanisms to accomplish it are ongoing. Depending on the outcome of these discussions, there may be a need for legislative action to support implementation of the new process. However, that is yet to be determined, so no action is requested at this time. The resulting process will increase Government visibility into industry strategy and focus of IR&D efforts, allowing the Government to more effectively inform industry of relevant RDT&E programs and shape those programs to better leverage industry investment.

Mr. WILSON. What tools do you have to transition successful technologies developed by S&T, whether in the labs or from contractors, into programs of record? How important are programs like the Small Business Innovative Research program

(SBIR), Small Business Technology Transfer program (STTR), or the Rapid Innovation Program to your technology transition efforts?

Admiral WINTER. GAO recently reported positively on DoN's approach and tools for technology transition. Technology Transition Programs Support Military Users, but Opportunities Exist to Improve Measurement of Outcomes GAO–13–286: Published: Mar 7, 2013. One of DoN's primary investments in late term transition focused research is the Future Naval Capability (FNC) program. This science and technology (S&T) investment portfolio utilizes nine (two-star level) mission-focused Department-wide Integrated Product Teams to collaborate to determine the naval need, product priority, and appropriate technology focus of any new FNC S&T investments. These FNCs are recommended at the two-star (IPT) level and forwarded to a naval technology oversight board at the three-star level for approval. Once approved at the three-star level, FNC S&T investments are tracked and enforced through negotiated Technology Transition Agreements (TTAs) agreed-to and signed by program managers across the three collaborating naval communities from S&T, Requirements and Acquisition. These agreements are reviewed and renewed annually to ensure appropriate leadership visibility and progress in delivering the capability to the warfighter. The SBIR/STTR Programs are very important as they are the largest source of early stage research and development funds for small businesses (over $300 million in the DoN). By utilizing agile small businesses, SBIR/STTR awardees develop innovative technologies that address DoN needs and enhance military capability, accelerate military development capability, and provide cost savings to acquisition programs and fielded systems. The Rapid Innovation Program is also very important and provides acquisition program managers with a tool to select and transition technology that addresses their priority needs. The goal of RIP is to accelerate the fielding of innovative technologies into military systems. The program achieves its goal utilizing source selection preference for small businesses, particularly those from SBIR/STTR, whose technology readiness levels are at the component and/or breadboard validation in a relevant environment or at the system/subsystem model or prototype demonstration in a relevant environment. A 2015 GAO report, DOD Rapid Innovation Program: Some Technologies Have Transitioned to Military Users, but Steps Can Be Taken to Improve Program Metrics and Outcomes, GAO–15–421, supported the Navy's approach to technology transition. "In addition, the Office of Naval Research's risk management team can provide support for small businesses to stay on track in fulfilling RIP contracts, including making sure companies can ramp up production if their projects are transitioned. We have previously reported that this office has a well-established technology transition focus which may contribute to project success. Because of this, the Navy may be better aware of the benefits and obstacles associated with a substantial portion of their S&T portfolio. This knowledge can better inform investment decisions made by Navy leadership."

Mr. WILSON. Do you have enough visibility into industry-directed independent research and development (IR&D)? Are there additional legislative tools you need to be more effective in coordinating with those investments?

Dr. WALKER. Yes, the Air Force has sufficient visibility into industry-directed independent research and development. The Air Force science and technology program frequently interacts with industry, academia, small businesses and international partners to enable research and development synergies. As a prime example, the Aerospace Systems Technology Directorate in the Air Force Research Laboratory participates in several consortiums such as the Rocket Propulsion for the 21st Century and the Versatile Affordable Advanced Turbine Engine, where both government and industry collaborate to achieve common goals and address national technology needs. At this time, the Air Force does not request additional legislative tools to be more effective in coordinating investments.

Mr. WILSON. What tools do you have to transition successful technologies developed by S&T, whether in the labs or from contractors, into programs of record? How important are programs like the Small Business Innovative Research program (SBIR), Small Business Technology Transfer program (STTR), or the Rapid Innovation Program to your technology transition efforts?

Dr. WALKER. There are two keys to the successful transition of technology developed from S&T. The first is that the technology must address a prioritized capability gap. The second is that the technology must be successfully demonstrated in a relevant environment. With today's budget constraints, only those technologies that address top capability gaps and are successfully demonstrated have a chance at transition to the warfighter. The involvement of Program Executive Offices (PEOs) and Centers is essential to successful transition of technology. PEOs and Centers are best positioned to understand the Major Command (MAJCOM) requirements, what the labs can deliver, and what vendors are working on. The Air Force

has been working hard to tighten the lines of communication between the S&T community, PEOs, Centers, and MAJCOMs. The Air Force has several programs that facilitate the transition of technology. The SBIR/STTR and Rapid Innovation programs are three such programs that are very important to Air Force technology transition efforts. SBIR/STTR programs identify small businesses that are engaged in developing technologies with the potential to address Air Force requirements. Funds provided through these programs empower small businesses' efforts to bring their innovative technologies to commercial readiness. As the technical readiness level matures during the period of support, the potential Air Force customer works closely with the company to ensure alignment of the capability with the requirement. As part of the SBIR/STTR programs, the Commercialization Readiness Program (CRP) identifies companies that have significantly advanced their technologies, but still require some additional support to move to enable insertion into programs of record. The Rapid Innovation Program has been an excellent means for the Air Force to communicate areas of critical need and solicit vendors to respond with innovative technology solutions. The Air Force is now in its fifth year of working with this program and has experienced very positive results in transitioning technology, primarily from small businesses, to address Air Force requirements. There are two other programs that also assist in the transition of technology: the Technology Transition program and the Technology Transfer program. The Technology Transition program provides funds to mature and demonstrate technologies to enable or accelerate their transition into programs of record. Currently, the primary focus in this program element is the follow-on maturation and demonstration/validation of next generation adaptive jet engines. The Technology Transfer program was created to promote the transfer and exchange of technology with state and local governments, academia and industry. The primary means for doing this is through Partnership Intermediary Agreements between the Air Force and nontraditional contractors such as a small business or university to facilitate technology transfer. This year the Office of the Secretary of Defense (OSD) is rolling out a new program to assist in transitioning technology to address hard problems. This program is through the Emerging Capabilities and Prototyping Directorate in OSD and offers the Services the opportunity to propose technology that addresses top priority challenges throughout the DoD. The Air Force Research Laboratory and PEOs, in partnership with other organizations such as national labs, university affiliated research centers, and Combatant Commanders, propose technologies that address OSD challenges and if successfully demonstrated will transition. The Air Force continues to focus on technology transition and is striving to ensure our MAJCOMs, PEOs, Centers, and AFRL are all working together to maximize results of our S&T efforts. We especially recognize small businesses areas are a major driver of innovation and we continue to explore and strengthen all avenues to encourage our partnership with them.

Mr. WILSON. Could you give us an update on the status of the "Trusted Foundry" program for providing a secure source of microchips for sensitive defense systems? What is being done to respond to the recent announcement that IBM plans to sell its Foundry capabilities to a foreign controlled company?

Dr. PRABHAKAR. [The information referred to is for official use only and retained in the committee files.]

Mr. WILSON. Do you have enough visibility into industry-directed independent research and development (IR&D)? Are there additional legislative tools you need to be more effective in coordinating with those investments?

Dr. PRABHAKAR. IR&D conducted by defense contractors as an allowable overhead expense can be an important source of innovation for both industry and DoD. IR&D represents well over $4 billion in annual R&D spending. Reviews of IR&D spending indicate that a significant fraction of IR&D is being spent on near-term competitive opportunities and on de minimis investments principally intended to create intellectual property rights for a company. IR&D allowability should encourage contractors to engage in R&D activities of potential interest to DoD. We have established a database in which companies meeting certain dollar thresholds are required to report their IR&D projects. Because companies enter the information at the end of their Fiscal Year, our visibility is limited to looking in the past. We are working to increase visibility into IR&D without increasing administrative burdens or requiring legislation.

Mr. WILSON. What tools do you have to transition successful technologies developed by S&T, whether in the labs or from contractors, into programs of record? How important are programs like the Small Business Innovative Research program (SBIR), Small Business Technology Transfer program (STTR), or the Rapid Innovation Program to your technology transition efforts?

Dr. PRABHAKAR. Tools: The primary means by which S&T-funded efforts performed in laboratories or contractor facilities are transitioned to programs of record is driven by acquisition program managers who competitively solicit proposals from industry to initiate a new program of record or to modify or enhance an existing program of record. Contractors who have demonstrated technical feasibility and developed components or prototypes on DARPA contracts and demonstrated a sufficiently high technology readiness level (TRL) typically respond to these competitive solicitations. The decision and the funding to incorporate the DARPA-developed technology into a program of record is determined and executed by the acquisition program. To facilitate the transition of DARPA-funded projects into programs of record, DARPA works with both the military operational community (COCOMs) and the acquisition community PEOs/PMs and Chiefs of Staff of the Military Departments to validate needs, understand concepts of operations, demonstrate prototypes and participate in operational exercises. The primary benefit of this aggressive and continuous interaction is that the acquisition professionals (those responsible for programs of record) not only learn about the benefits of DARPA programs but become active participants in the development process and advocates for technology transition in their Service.

SBIR/STTR: The DARPA Technology Offices leverage the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs to address significant technical problems that are considered high risk, but high payoff; to explore alternative technology approaches to mitigate risk for a DARPA program; to explore the feasibility of a new start; or to investigate a disruptive technology. DARPA frequently uses the SBIR/STTR programs to explore new ideas from novel and sometimes unconventional small businesses rather than as a technology transition tool.

However, the Small Business Programs Office places high emphasis on helping small businesses to transition their technology and offers transition and commercialization planning and implementation assistance for active DARPA-funded SBIR/STTR Phase II projects during the contract period of performance (typically 24 months). The goal is to increase the potential for these companies to move their developed technologies, solutions or products beyond Phase II and into the DoD military services, other federal agencies, and/or the commercial market. Entry into the program is voluntary and services are provided at no cost to participants, which is consistent with added congressional and DoD priorities over the past several years.

The DARPA Transition and Commercialization Support Program (TCSP) offers a range of assistance, including consulting and collaborating with small companies in developing and executing their project-focused transition and commercialization strategies. More than half of all qualified companies take advantage of the program's offerings:

- review and provide feedback to the company on their transition and commercialization plans
- identify experiment and demonstration opportunities and sources of potential funding and collaborators
- facilitate introductions to potential funders, collaborators, and partners
- provide business planning and technology readiness assessment tools
- provide routine alerts about opportunities

Support includes targeted outreach and training events to promote transition successes and share best practices and lessons learned. Participants' progress is tracked as they move on to Phase III awards and beyond.

In FY15 the DARPA SBIR/STTR program is funded by placing 3.3% of the DARPA top line appropriated budget into the SBIR/STTR account. DARPA does not receive external funding for this program.

Rapid Innovation Fund (RIF): DARPA does not directly participate in RIF. This program is administered by the ASD(R&E) and is intended to reach out to small business that may have technology products available at a technology readiness level 6–9 (low risk) that can be rapidly adapted to meet a Military Department acquisition program or operational need. DARPA typically funds projects that are high risk (lower TRL) with large payoff. The DoD RIF program participants are typically organizations that have an operational mission where a minimal, short-term investment in a mature small business technology can impact near-term operations. DARPA does not have an operational mission and is not a customer for or consumer of these products. However, performers on DARPA programs are made aware of the RIF program and they can independently respond to the competitive RIF solicitation if their technology products satisfy the appropriate criteria. From an SBIR standpoint, the firms in our SBIR Phase 2 portfolio are informed of RIF funding opportunities.

## QUESTIONS SUBMITTED BY MR. NUGENT

Mr. NUGENT. Last year, the 113th Congress appropriated $220 million dollars for the sole purpose of accelerating the development of a domestic rocket propulsion system. However thus far, neither the Air Force nor the Department of Defense has moved expeditiously to accomplish this task.

Since the passage of last year's Appropriations act, what has the Air Force specifically done to develop an advanced liquid rocket booster engine to replace the RD–180?

Dr. WALKER. The rocket propulsion system effort, as referred to in the fiscal year 2015 National Defense Authorizations Act (NDAA), is funded in the Evolved Expendable Launch Vehicle Program (SPACE)—EMD Program Element (PE) 0604853F. That effort is managed through the Air Force Program Executive Officer for Space (AFPEO/SP) in the Space and Missile Systems Center (SMC) at Los Angeles AFB, CA.

The Air Force has obligated about $50 million so far; $37 million in fiscal 2014 money, which was reprogrammed in the Omnibus, and about $13 million of the fiscal year 2015 money, which was appropriated in 2015. We intend to invest an additional $45 million to $50 million over about the next six months. We issued a draft Rocket Propulsion System (RPS) Request for Proposals (RFPs) in April and will award multiple contracts with propulsion system or launch system providers to partner with their ongoing investment in domestic propulsion systems as part of our plan to develop a domestic propulsion system by 2019, and to do so competitively. However, this will only give us an engine, and an engine alone will not launch us into space. Transitioning the engine to a fully integrated tested and certified capability will take longer than that. This is the consensus of experts across the space enterprise.

Mr. NUGENT. Last year, Congress directed the Air Force to deliver the CHAMP system on the cruise missile.

Congress also set aside an extra $10 million dollars for the specific purpose of getting this particular technology out of the lab and to our warfighters on the non-reusable platform. Why has this not been completed?

Dr. WALKER. Gen Welsh stated, concerning CHAMP, during the HASC Fiscal Year 2016 National Defense Authorization Budget Request from the Military Departments hearing that took place on Mar 17 2015 "Do we plan to produce this weapon by F.Y. '16? No, sir, we can't get there from here." We do not have the ability to give the combatant commanders this capability right now for a fraction of the cost. One year and $10 million is not sufficient to provide a CHAMP-like capability to the warfighter. Raytheon, a CHAMP contractor, has estimated that the cost and schedule to provide 32 missiles is four years and $140 million. This estimate does not include the cost, resources and planning required by the Air Force and the combatant commands for the development and implementation of doctrine, organization, training, materiel, leadership and education, personnel and facilities (DOTMLPF) associated with a weapon system capability. Additionally, maintaining a very small number of CHAMP platforms, with the associated sophisticated hardware, in the inventory will be expensive. There are also concerns with the platform's survivability, ingress range, target engagement ranges, and guidance and navigation capabilities in a realistic scenario. Developing and producing any weapon system would not be funded within the Science and Technology portfolio.

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