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Statement by Dr. Arati Prabhakar

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Submitted to the

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Chairwoman Mikulski, Ranking Member Shelby and Members of the Committee, thank you for the opportunity to testify before you today. I am Arati Prabhakar, Director of the Defense Advanced Research Projects Agency, or DARPA. It is a pleasure to be here today—along with my colleagues from other parts of the Administration's science and technology leadership team.

As you know, our nation enjoys unparalleled prowess in the domain of science and technology—the result of a vibrant research and development (R&D) ecosystem that includes federal agencies, academic centers, and industrial partners. But the United States is not alone today in recognizing the importance of R&D for economic and military strength; indeed, others around the world are working aggressively to match or exceed our abilities. So like any ecosystem in a changing environment, it is essential that the U.S. R&D enterprise constantly adapt and evolve to maintain its position of global preeminence.

DARPA's part in America's R&D ecosystem is relatively small in dollars but substantial in impact. DARPA is part of a Department of Defense (DoD) R&D investment of $63.5 billion in its Science and Technology accounts in the President's FY 2015 budget. That is about half of the federal R&D budget over all. Most of DoD's R&D investment is devoted to the "D" for development of military systems. Of the remaining $11.5 billion that DoD proposes to invest in basic and applied research and advanced technology development in FY 2015, DARPA represents just under $3 billion. That is less than $1/20^{th}$ of DoD's total R&D budget.

Yet DARPA's goal—indeed, its very mission—is to accomplish much more than those numbers might suggest. Working closely with others—in universities, in government and private laboratories, and in companies large and small, from giant aerospace firms to high-tech startups—DARPA has a specific responsibility to anticipate, create, and demonstrate breakthrough technologies that are outside and beyond conventional approaches, and that hold the potential for extraordinary advances in national security capability. It is a role we have played for decades, and one that has led not only to fundamental advances in defense capabilities but also to a leading-edge technology base that the commercial sector has built on to enhance our lives and change how we work. My testimony today will focus on DARPA's mission, some of our current work, and our operating model for high-impact technology research.

DARPA's Mission in Today's World

In the fall of 1957, a polished metal sphere, 23 inches in diameter and launched from Soviet soil, began its orbit around the Earth, passing over American skies approximately every 96 minutes and initiating the space age, a space race, and a new era in the long struggle to maintain American military and technological superiority. The decision to create DARPA was one of the pivotal choices our Nation made in the wake of Sputnik. As a result of this and many other wise and strategic investments, America today enjoys a hard-earned and privileged position, with tremendous military might, unrivaled economic strength, and a degree of social and political freedom that is the envy of the world.

Yet, as this Committee knows well, risk is ever evolving—and that is true more than ever in today's exceedingly complex and dynamic world. Regional instability, shifting military and economic positions, social and demographic trends and evolving natural resource needs – these

forces drive constant change in our national security environment. The very nature of our adversaries has changed to include not only nation states but also smaller, less well-defined bad actors and an increasingly networked terror threat, posing both acute and chronic national security challenges.

Compounding these challenges is the fact that technology and its accessibility have changed so significantly in recent decades. Startlingly powerful technologies—semiconductors, information systems, and nuclear and biological technologies among them—are now available to a much wider swath of society and the world, for good and for evil. At the same time, while the U.S. capacity for research, innovation, and entrepreneurship remain unmatched, other nations are accelerating their efforts in these domains—expanding universities, building new laboratories, and launching ambitious companies.

This technological revolution is bringing a spectacular array of once-aspirational advances plainly into the realm of the possible. New capacities for harnessing light are opening the door to a revolution across a range of military components, including sensors, radars, and clocks. Remarkable progress in robotics and prosthetics are helping us work in inhospitable environments and overcome physical disabilities. And groundbreaking research in the domain of mathematical algorithms is enabling the unprecedented detection of hidden patterns within the information-rich world we have created, allowing us to extract meaning and value from data arrays that were once inscrutable. And these are only a few examples.

DARPA was designed and built for just this kind of shifting, dynamic environment. Through more than five decades of tumultuous geopolitical and technological change, we have stayed focused on our crystal-clear mission of cultivating breakthrough technologies for national security. We imagine groundbreaking new technology advances with the potential for defense applications; we bring the best of those ideas to fruition by providing the right mix of research support, intellectual freedom, and responsible oversight to outstanding performers in industry, academia, and other government organizations; and we facilitate the transition and operationalization of these new, paradigm-shifting capabilities.

Of course, none of this would be possible without the other elements of our nation's R&D enterprise, including federal agencies like those being led by my fellow witnesses here today as well as large and small partners in the private sector with a range of innovative capacities both to advance the basic work and to transition results to use. Working within that ecosystem, we address national security challenges through a portfolio approach that encompasses hundreds of programs—each of them reaching for high payoff, and each willing to undertake high risk in pursuit of that high payoff. The value of this model is evident in the many breakthrough technologies for national security that DARPA has helped bring forth. I am including for the record with this testimony a summary document describing some of these achievements. They include stealth aircraft; seminal advances in computing and information technology—not least of which was the creation of ARPANET, the predecessor to today's Internet; and miniaturized Global Positioning System (GPS) components, which made this navigation technology practical for a wide range of applications—advances that have significantly changed warfare in recent decades while in many instances changing civilian life as well.

But DARPA is not an institution that spends much time looking backward. Those of us who have the privilege of serving at DARPA come to work each day in pursuit of new opportunities to

achieve outsized impacts in the future. Our strategy for achieving this goal is to overcome complexity by harnessing it, and our programs reflect that approach of relentlessly playing offense.

A few examples of current programs in three realms illustrate this approach.

DARPA's Programs: Harnessing Complexity to Create Exceptional New Capabilities

Rethinking Complex Military Systems

Today more than ever, our military relies upon the interaction of multiple complex systems, each featuring its own array of electronic, optical, software, and mechanical components with varying degrees of interdependency. Moreover, these platforms and mission systems must operate in environments that will be increasingly contested by others with access to ever-improving global technologies. All these factors contribute to the high cost, long development times, and inflexibility of today's most advanced systems. This situation demands that we rethink – sometimes in fundamental ways – how we approach the next generation of defense systems.

DARPA programs pursuing fresh approaches to military systems include efforts to:

- dynamically control the electromagnetic spectrum;
- create options for robust space operations, including space domain awareness; flexible, low-cost launch; and lower risk and cost geosynchronous satellites;
- use the undersea environment to observe and access regions around the world;
- rapidly bring advances in commercial technology to the battlefield;
- develop hypersonic technologies for advanced speed and range; and
- create new distributed, cooperative systems and architectures for the contested environments of the future.

Information at Massive Scale

The sheer scale and complexity of data generated by the information revolution presents not just a challenge to national security but also an array of major opportunities. For example, sensor and communications technologies have advanced to the point today where these technologies can provide significant advantages to our warfighters—indeed, to the point where warfighters today are in many respects dependent upon a virtual sensory net for battlefield awareness and decision-making. However, current defense systems for processing this ocean of information struggle to handle the volume and parse the characteristics of these elaborate data environments. The XDATA program is one of several in the DARPA portfolio that aim to tackle this problem for various applications—in this case through the development of a new generation of software with unprecedented capacities to fuse, analyze and disseminate the massive volumes of data these networks produce to provide practical and actionable information for use on planning tables and under battle conditions. In February 2014, DARPA released an Open Catalog that includes software toolkits and peer-reviewed publications from the XDATA program. The toolkits are designed to encourage flexible development of software to help users analyze and visualize large volumes of data. Multiple partnering organizations have performed successful early testing and have begun to adopt relevant components.

Another DARPA program wrangles a related challenge in the enormous data volumes online: how to transcend current web-search methods, which today use a centralized, one-size-fits-all approach that searches the Internet with the same set of tools for all queries. While this model has been wildly successful commercially, it does not work adequately for many government use cases—often missing, for example, potentially critical information ensconced in the deep web and ignoring shared content across pages. To help overcome these shortcomings, DARPA launched the Memory and Exploration of the Internet for Defense, or MEMEX, program. This ambitious effort has as its goals the development of domain-specific search technologies and revolutionary approaches to discovering, organizing and presenting the types of search results needed for national security concerns. MEMEX's initial focus will be human trafficking, which is a factor in many types of military, law enforcement and intelligence investigations and which takes advantage of the Web to attract customers and conduct its illicit and dehumanizing business.

Biology as Technology

Biology is nature's ultimate innovator, and any agency that hangs its hat on innovation would be foolish not to look to this master of networked complexity for inspiration and solutions. DARPA is doing exactly that in a number of programs.

First, DARPA is tackling that most complex of biological systems, the brain. DARPA's interest starts with our desire to protect and assist our Warfighters, whether it means preventing or treating traumatic brain injury, easing the effects of post-traumatic stress disorder, or learning to operate sophisticated prosthetic limbs with thoughts alone, as is now increasingly possible with our new and exciting technologies. These advances also open the door to a much deeper understanding of how humans interact with the world around them—new insights that may fuel the next revolution in how we work with complex technologies and systems. Over the past year, we launched several new brain-function-related programs that are now getting underway as part of the President's initiative in brain research—technology programs that build on the research foundation laid by our federal partners in this initiative, the National Institutes of Health and the National Science Foundation.

But DARPA's biology-related investments reach well beyond neuroscience. They include critical efforts to make game-changing advances in our ability to rapidly and accurately diagnose biological threats; novel diagnostics and prophylaxes to outpace the spread of infectious diseases; and new methods to accelerate the testing of critical therapeutics, including those that can be effective even against newly emerging agents that are increasingly resistant to conventional antibiotics.

Finally, to achieve a number of these goals and to facilitate the availability of other breakthrough technologies in the biological arena, DARPA is focused on synthetic biology—the hybrid discipline of biology and engineering—through its Living Foundries program. This promising approach to engineering has enormous potential to enhance protections in a fast-evolving biological environment. This field has already proven itself capable of harnessing customized bacteria to produce new classes of medicines, and is allowing us to enlist other microbes to perform entirely new chemistries that can be used to create new materials with novel mechanical, optical, or bioactive properties. Our Living Foundries program seeks to compress the biological

design-build-test cycle in both time and cost, and has already demonstrated the ability to generate a suite of novel bioproducts in weeks rather than years.

DARPA's Operating Model

DARPA represents less than one percent of the nation's R&D investment and less than 5 percent of the Defense Department's budget for research, development, test, and evaluation. But our impact has been outsized over many decades. Our unique mission—focused on Defense science and technology, but enlisting and empowering the broad community of innovators—drives all our work and lays the foundation for our disproportional effect.

As a projects agency, we accomplish our objectives through deep engagement with companies, universities, and DoD and other labs. Our success hinges on having a healthy U.S. R&D ecosystem. Within the DoD S&T efforts, our role is to invest in high-payoff opportunities that often require taking significant risk. We work closely with our colleagues in the Service S&T organizations, sometimes building on their early research and drawing on their technical expertise, and often relying on them to help us transition successful results to military use.

DARPA's operations center on stellar program managers. They come to DARPA with inspirations about achieving breakthroughs in technologies that stand conventional wisdom on its head, mindful of the rare opportunity to bring about rock-the-boat changes that will contribute to our national security. We keep these program managers onboard typically for 3 to 5 years; that helps to infuse new people with fresh views into the Agency continuously.

Vigorous pursuit of mission is equally engrained in DARPA support functions, creating a productive environment around our program managers that enables them to take bold technology leaps despite their short tenures. Security and legal staff ensure we have a solid foundation, and contracting, finance, and human resources operate with the speed and flexibility that our diverse portfolio demands. Statutes providing specialized hiring authorities and alternative contracting vehicles have proven critically important.

DARPA's work is executed in programs with defined start and end dates. When a program ends, we may move to another area that is more fruitful, or we may continue with a new project in the same field if we see high potential. But in every case, this is a conscious and deliberate decision, not an automatic default to perpetuate work in any one area.

Within each program, the DARPA program manager sets clear milestones according to the objectives for that effort. For a systems demonstration program, typical milestones include design reviews and tests at increasing levels of maturity. For a more research-oriented program, appropriate milestones are often first-of-a-kind lab experiments or meeting increasingly challenging performance criteria. As programs unfold, program managers work closely with their performer communities. They assess results and then redirect or eliminate less productive work and accelerate efforts that are making great progress.

We balance the need to give our programs and performers the time and resources necessary to make progress toward our extremely challenging objectives with the need to curtail or redirect efforts that are not productive. These are judgment calls informed by data and direct interactions

with the people doing the work. Our overall success lies in striking this balance across the broad portfolio of DARPA programs.

The President's FY 2015 Budget Request

The President's FY 2015 budget request for DARPA is $2.915 billion. This compares with $2.779 billion appropriated for FY 2014, an increase of $136 million. Before describing our FY 2015 plan, let me put this number in context.

From FY 2009 to FY 2013, DARPA's budget declined through a series of small reductions followed by a 9 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.

This pernicious trend turned around last year. I thank this Committee, and Congress more broadly, for your support in helping us to begin to address this issue in FY 2014 by restoring an initial $199 million. The President's FY 2015 request continues restoration, almost returning the Agency's budget to its pre-sequestration level in real terms.

Let me outline what these budget changes mean in terms of our ability to execute DARPA's vital mission. As budgets eroded over the last few years, one effect was a reduction in our major demonstration programs. In some cases, we have been unable to advance our work to the point of actually demonstrating that a totally new approach is workable. In other cases, we had to rely on a single approach to solving a particularly challenging problem because we could fund only one performing organization. That is especially problematic since we are trying to do something that has never been achieved before. Reduced funds also meant fewer early-stage investments to explore new research frontiers. Sequestration further affected our programs, with many being delayed or reduced.

In the current fiscal year, the partial restoration of funds is making a real difference in DARPA's ability to attack the thorny problems the nation faces in today's military and national security environment. As a projects agency, DARPA is always beginning new programs as old ones end. But the new efforts in FY 2014 are stronger because of the healthier budget level. In some areas, we are now able to plan for the real-world prototyping and field testing needed for new concepts to be fully evaluated. And our new programs include the important exploratory projects that will expand future national security opportunities. The FY 2015 request before you today will allow us to continue to restore and strengthen our portfolio of investments. With this funding level, we will be on the right track.

Let me close by saying that I am mindful of the challenges that our nation faces and the increasingly difficult environment in which we work, including severe constraints on resources. But I also am excited about what lies ahead and confident that – with your support – DARPA will continue to make a real and outsized difference in redefining the national security landscape with breakthrough technologies.

Again, thank you for your support – past, present, and future. I look forward to working with you, and will be pleased to respond to your questions.

-end-

Breakthrough Technologies: What DARPA Has Done for U.S. National Security

By making pivotal, early investments in technologies that ultimately create and prevent decisive surprise for our nation, the Defense Advanced Research Projects Agency (DARPA) has helped to change military and national security outcomes and deliver outsized benefits. Transforming these DARPA concepts into breakthroughs has depended upon performers in industry, academia, and military and other government agencies, often including their large follow-on investments, with DARPA serving as the initial catalyst to innovation. For example:

Stealth: DARPA turned the concept of stealth—low observability—into a reality for otherwise vulnerable U.S. combat aircraft deployed against enemy targets. That helped to change the shape and prospects of wars in Iraq, Afghanistan, and Libya.

Computing and, Communications: DARPA research played a central role in launching the Information Revolution. That includes developing or furthering much of the conceptual basis for and then launching the ARPANET, which led directly to the Internet. DARPA also is responsible for multiple additional future-defining advances underlying today's computers and communications systems, with smartphones and tablets among them. Since the early 1960s, DARPA has led the development of artificial intelligence/machine intelligence. Initially DARPA machine intelligence R&D focused on military operations, especially military command and control. The commercial sector adopted many of the results and developed wide-spread applications.

Microelectronics: DARPA's many fundamental advances and breakthroughs in microelectronics have been integral to computing and communications developments that could not have been achieved otherwise. These have greatly enhanced military command and control operations as well as intelligence, surveillance, and reconnaissance—in addition to leading the revolution in commercial electronics that has fed back into benefits for national security.

Satellite Navigation Systems, GPS, and Precision Guided Munitions: Revolutionary DARPA electronics advances shrank GPS receivers dramatically so that they could be carried easily by troops for location information, as well as added to "dumb" bombs to inexpensively turn them into precision-guided munitions. Their use has contributed to the U.S. military's ability to attack and eliminate more difficult targets from greater distances with increasing probability of success. These weapons have been instrumental in fundamentally changing strategy during the Cold War, the Gulf War, and in more recent conflicts as the U.S. has had to contend with dispersed and elusive foes.
Beyond military applications, GPS devices now seem ubiquitous in our daily lives, with enormous commercial and consumer value.

Intelligence, Surveillance and Reconnaissance: DARPA introduced multiple new concepts and technologies for advanced radar, data links, and electro-optical and infrared sensors used in conflicts from the 1990s to today. Resulting improvements significantly upgraded U.S. forces' ability to detect, identify, and track foes and to guide weapons in flight.

Infrared Night Imaging: DARPA developed—and continues to invest in—enabling technologies that improve our air and ground forces' and weapons' capabilities to "see" in the dark with higher sensitivities and at longer standoff distances. That has allowed U.S. warfighters to "own the night."

Unmanned Aerial Vehicles (UAVs): Since DARPA's 1970s investments in UAV development, the agency has advanced UAVs far beyond their earlier capabilities and military uses and delivered major impacts in Afghanistan, Iraq, and Pakistan.

Today's challenges are even greater in many respects. We face multiple real and potential adversaries, and not all are nation states. Risks increasingly involve cyber and biological concerns. Systems are much more complex. U.S. resources are more constrained. Here are some of the things that DARPA has been achieving and working on lately to strengthen military and national security:

Ground War:

- ***TransApps:*** To overcome reliance on outdated paper maps, notes, and voice radio transmissions, DARPA employed a new, agile development process using Android smartphones for enhanced situational awareness—getting mobile devices with regularly updated information to every Army maneuver squad in Afghanistan in short order.
- ***Persistent Close Air Support*****:** DARPA-developed software on Android tablets was provided to units in Afghanistan, drastically improving ground forces' ability to quickly and safely coordinate air engagements to improve accuracy and reduce collateral damage and friendly fire losses.
- ***Blast Gauge*****:** A low-cost, disposable, wearable DARPA blast exposure warning system that quantifies and ranks explosive events from Improvised Explosive Devices, rocket-propelled grenades, or training is being adopted widely by Special Operations Forces and the U.S. Army. Device cost: under $50.

Seas:

- ***Long-Range Anti-Ship Missile:*** With U.S. warfighters needing to penetrate sophisticated enemy air defense systems from long range, DARPA has had very promising results on a precision-guided anti-ship standoff that would reduce dependence on intelligence, surveillance and reconnaissance platforms. DARPA is collaborating with the Navy, helping them to quickly deploy this capability.
- ***Finding, Tracking and Trailing Subs***: Several affordable, unmanned submarine tracking and trailing alternatives are being developed that could transform today's reliance solely on more resource-intensive manned systems while greatly increasing the number of submarines tracked.

Space:

- ***Avoiding Collisions in Space*:** With satellite traffic and risk of space collisions growing, DoD has made space situational awareness a top priority to maintain communication, Earth observation, and other critical capabilities upon which military, civilian, and commercial functions rely. DARPA's new Space Surveillance Telescope being deployed soon to Australia seeks to enable much faster discovery and tracking of previously unseen, hard-to-find objects in geosynchronous orbits.
- ***Lowering the Risk and Cost for Satellites in Space*:** DARPA's Phoenix program strives to develop and demonstrate technology to robotically service, maintain and construct satellites in the harsh environment of geosynchronous orbit.

Information at Massive Scale:

- ***High-Assurance Cyber Military Systems:*** Embedded systems form a pervasive network underlying much of modern technological society. They range from large systems that manage physical infrastructure, to medical devices such as pacemakers and insulin pumps, to computer printers and routers, to cell phones and radios, and to vehicles like autos and airplanes. These networked devices are vulnerable to remote attack that can cause physical damage while hiding the effects from monitors. DARPA aims to create technology to construct high assurance cyberphysical systems using a fundamentally different approach that would produce publicly available tools to be distributed to the defense and commercial software sectors.
- ***Breaking through the Language Barrier*:** Multiple DARPA language translation devices and systems have been deployed in conflict zones over the past decade. These have supported warfighter interaction with local populations and generated regional intelligence from broadcast media and other sources. Past and ongoing development also helps to combat transnational crime and piracy and enable international cooperation, including humanitarian assistance.

Biology as Technology:

- ***Brain Function Research:*** Dramatically improving our knowledge of the dynamic functions of the brain and demonstrating breakthrough applications based on these insights—those are the ambitious goal of DARPA's brain research. It may inspire the design of a new generation of information processing systems, lead to insights into brain injury and recovery—and enable new diagnostics, therapies, and devices to repair traumatic injury. An example: DARPA has developed advanced prosthetic arm systems and methods to restore near-natural movement and control.