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Committee on Appropriations, U.S. Senate

Statement by Dr. Arati Prabhakar

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Dr. Arati Prabhakar

**Director
Defense Advanced Research Projects Agency**

Submitted to the

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Chairman Durbin, Vice Chairman Cochran 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, DARPA. It is a pleasure to be here with my colleagues across the Department of Defense (DoD) Science and Technology (S&T) community. Our organizations work together 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 are outside and beyond conventional approaches – technologies that hold the potential for extraordinary advances in national security capability. This mission and our current work and plans are the focus of my testimony today.

DARPA's Mission and the Diverse Threats Facing our Nation

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. Starting DARPA was one of the pivotal choices our Nation made in the wake of Sputnik. America today enjoys a hard-earned, privileged position, with tremendous military might, economic strength, and social and political freedom. Yet, as this Subcommittee knows well, risk is ever evolving in our complex and dynamic world. Regional instability, shifting military and economic positions, demographic and natural resource trends – these forces drive constant change in our national security environment. Today and in the years ahead, our potential adversaries will still include nation states, but also smaller, less well defined bad actors and an increasingly networked terror threat. National security challenges will continue to range from the acute to the chronic. This is the threat environment that shapes our technology investments today at DARPA.

Adding to the security challenges we face is the fact that technology and its accessibility have changed so significantly. Startlingly powerful technologies – semiconductors, information systems, and nuclear and biological technologies among them – are now globally available to a much wider swath of society, for good and for evil. And while the cost of some technologies has dropped precipitously, other technology and non-technology related costs have risen steeply, leading DoD to make difficult choices about our operational capabilities. That means our assumptions about the cost of military systems must change. These factors will also continue to shape our investments at DARPA.

DARPA was designed and built for just this kind of shifting, challenging threat environment. Through more than 5 decades of tumultuous geopolitical and technological change, we have delivered outsized impact by focusing on our mission of 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.

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

Like most truly great problems that confront us, today's diverse threats can either be viewed as an imposing barrier or as an opportunity to overcome a difficult challenge. Either way, I believe our national security will depend upon how we deal with complexity. DARPA chooses to tackle complexity by harnessing it, and our programs reflect that approach of playing offense. We do that with game-changing new capabilities and with layered, adaptable, multi-technology systems. We do that by catalyzing major new national technology advances and by rapidly exploiting commercially available technologies. And at a time when systems cost is the difference between building operational capability or just building PowerPoint, we do that by striving to invert the cost equation for our military.

DARPA has made important strides forward in delivering key breakthrough technologies. In discussing how we are tackling various aspects of technological complexity, I will update you on several new programs that we have launched, results we have achieved, and transitions that have been accomplished or are in process.

Rethinking Complex Military Systems

Much of DARPA's work rethinks complex military systems, recasting today's approach with the intention of achieving far greater capabilities at lower cost. Today, our military relies upon the meshing of electronic, optical, software, and mechanical components to create satellites and the vehicles, aircraft, and ships that carry our Warfighters into battle. We also depend upon this integration of components in designing and producing the weapons these men and women must be prepared to use. That is not new. But today, these technology components are becoming ever more complex. Consider: radar systems have thousands of antenna elements, platforms run millions of lines of code, and integrated circuits are made of billions of transistors. These many components are also now interdependent and interacting to an unprecedented degree. And, of course, these platforms and mission systems must operate in an environment 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 demands that we rethink – sometimes in fundamental ways – how we approach the next generation of defense systems.

Let me give you a few examples of how DARPA is tackling this challenge from our portfolio of programs.

Robust Space

In times of conflict, our Nation's leaders count on our military to wage precise, overpowering war. This type of highly effective warfighting is critically dependent on space – for imaging and sensing, for communications, for navigation, even for keeping time. As never before, we require ready access to space and strategic control over our assets in space. But while space is becoming increasingly important, it's also becoming increasingly crowded and contested, and DoD's ability to access and operate in space has become less nimble and more expensive over many years. DARPA has several programs underway to change that equation.

Rapid Launch: Experimental Space Plane (XS-1) and Airborne Launch Assisted Space Access (ALASA)

Imagine a world in which getting a satellite into orbit can be as quick and reliable as an aircraft takeoff. Our new Experimental Spaceplane is designed to take a 3,000- to 5,000-pound payload into orbit using an expendable upper stage, all for under \$5 million; that is one-tenth the cost of a comparable launch today. Our ALASA program focuses on 100-pound payloads for less than \$1 million. Even more striking is our goal of providing satellite launches for these payloads with just 24 hours' notice.

Avoiding Collisions in Space: Space Surveillance Telescope (SST)

In space, one major challenge is simply a lack of knowledge of what is around you. With satellite traffic and the risk of space collisions growing, space domain awareness is a top priority. DARPA's SST enables much faster discovery and tracking of previously unseen, hard-to-find objects in geosynchronous orbits. We expect it to be ready for operations within 2 years in Australia as a result of a memorandum of understanding signed last November by Secretary of Defense Hagel with his counterpart. Once operational on the Northwest Cape of Australia, SST will provide detection and tracking of satellites and space debris at and near geosynchronous orbits within the Asia-Pacific region, information U.S. space operators can use to better protect critical U.S. and Allied space-based capabilities.

Lowering the Risk and Cost for Satellites

Communications satellites in geosynchronous orbit, approximately 36,000 kilometers above the Earth, provide vital communication capabilities to Warfighters and others. Today, when a satellite fails, we usually face the expensive prospect of having to launch a brand new replacement. Our Phoenix program strives to develop and demonstrate technology to robotically service, maintain, and construct satellites in the harsh environment of geosynchronous orbit. Phoenix is also exploring a paradigm change to satellite design that would enable ground and on-orbit assemble-able platforms to potentially lower the cost of next-generation space systems by a factor of 10 compared to what is possible today.

Winning in Contested Environments

Space is not the only environment that is growing more crowded and dangerous. We must always anticipate an actively contested environment as we look ahead to potential challenges from future adversaries. Today, we are dependent on centralized command and control, and the fragile lines of communications linking tactical assets to decision makers. While DARPA has multiple programs addressing these challenges for the air, ground and sea, a common thread is the development of technologies to shift and distribute capability at the forward edge of the battle and to adapt quickly to a changing technology landscape.

Long-Range Anti-Ship Missile (LRASM)

Today's anti-ship missiles face challenges penetrating sophisticated air defense systems from long range. As a result, Warfighters may require multiple missile launches and overhead targeting assets to engage specific enemy warships from beyond the reach of counter-fire systems. In important progress to overcome these challenges, the DARPA-Navy LRASM program has had a series of successful flight tests on a precision-guided anti-ship standoff missile. That will reduce dependence on intelligence, surveillance and reconnaissance platforms, network links, and Global Positioning System (GPS) navigation in electronic warfare environments. DARPA is collaborating with the Navy via a new joint program office, helping to move this leap-ahead capability to deployment very quickly.

Distributed Battle Management (DBM) and Communications in Contested Environments (C2E)

Under our Air Dominance Initiative, DARPA, the Air Force and the Navy together have been exploring systems-of-systems concepts in which networks of manned and unmanned platforms, weapons, sensors and electronic warfare systems interact to succeed in a contested battlespace. These approaches could offer flexible and powerful options to the Warfighter, but the complexity introduced by the increase in the number of employment alternatives – particularly in a dynamic situation – creates a battle management challenge. Further complicating matters, in future conflicts U.S. forces may face degradation or denial of critical communications capabilities essential for coordination and shared situational understanding.

We recently launched two programs that address these challenges. The Distributed Battle Management (DBM) program seeks to develop control algorithms and demonstrate robust decision-aid software for air battle management at the tactical edge. Our new Communications in Contested Environments (C2E) program is, at the same time, exploring the use of reference architectures to enable robust, scalable and rapidly evolvable airborne communications networks.

Dominating the Electromagnetic Spectrum

The challenge of the threat environment extends to the airwaves as well, a reality that also is beginning to affect commercial and civil activity as demand continues to grow for access to the electromagnetic spectrum. The United States and our Allies learned an important lesson in World War II, when we became the first to control and take advantage of one small part of the spectrum – the range occupied by radar. By many assessments, Allied dominance in radar technology was pivotal to our winning that crucial war. Today we can say that the next war may be won by the nation that controls the electromagnetic spectrum over the full range of wavelengths – a degree of control that can ensure dominance in communications and in the important linked domains of timing, location and navigation. It also can ensure dominance in seeing what our adversaries are doing, and in controlling what they see of us – both our capacity to hide things from their sensors and our capacity to make “visible” an array of things that are not really there.

Spectrum Challenge

One approach to dominating the spectrum is simply to be more nimble, both in sensing and using whatever portions of the spectrum are available. Radios, for example, lack agility, despite the fact that they are used for the most mundane to the most critical of communications, from garage door openers to first responders to military operations. Wireless devices often inadvertently

interfere with and disrupt radio communications, and, in battlefield environments, adversaries may intentionally jam friendly communications. To stimulate the development of radio techniques that can overcome these impediments, DARPA launched its Spectrum Challenge, a national competition to develop advanced radio technology capable of communicating in congested and contested electromagnetic environments without direct coordination or spectrum preplanning. We saw a massive increase in innovation when the teams returned for the final part of the Challenge with promising results for future applications.

Moving to New Frequency Domains: Terahertz Electronics (THz)

Another way to control the spectrum is to move to new frequency domains, where hardware limitations currently prevent us from operating effectively. The submillimeter wave, or terahertz, part of the electromagnetic spectrum falls between the frequencies of 0.3 and 3 terahertz, between microwaves and infrared light. Unlocking this band's potential may benefit military applications such as high-data-rate communications, improved radar, and new methods of sensing. But access to these applications has been limited due to physics and our limited understanding.

Researchers under DARPA's Terahertz Electronics (THz) program have designed and demonstrated a 0.85 terahertz power amplifier using a micromachined vacuum tube; we believe it to be a world first. The vacuum tube power amplifier is one achievement of the broader THz program, which seeks to develop a variety of breakthrough component and integration technologies necessary to one day build complex terahertz circuits for communications and sensing.

Many more DARPA programs also rethink complex military systems. These include efforts to use the undersea environment to observe and access regions around the world; to rapidly bring advances in commercial technology to the battlefield; to develop hypersonic technologies for advanced speed, reach and range; and to create new distributed architectures for the contested environments of the future.

Information at Scale

Let's consider a different aspect of complexity. As the information revolution continues, the sheer scale and variety of data seems immensely, and perhaps overwhelmingly, complex – but this challenge also presents major opportunities.

Insight to Enhance Analysts' Capabilities and Performance

Military intelligence analysts face the monumental and escalating task of analyzing massive volumes of complex data from multiple, diverse sources such as physical sensors, human contacts, and contextual databases. DARPA's Insight program addresses the need for new tools and automation to enhance analyst capabilities and performance. The program seeks to enable analysts to make sense of the huge volumes of intelligence-rich information available to them from existing sensors and data sources. Automated behavioral learning and prediction algorithms help analysts discover and identify potential threats, as well as make and confirm hypotheses about those threats' potential behavior. The goal is a comprehensive operating picture in which expedient delivery of fused actionable intelligence improves support of time-sensitive operations

on the battlefield. We are working closely with the Army and the Air Force to transition operational capabilities to programs of record.

MEMEX: A Different Approach to Search

Despite the vast amounts of data available, today's Web searches use a centralized, one-size-fits-all approach that searches the Internet with the same set of tools for all queries. While that model has been wildly successful commercially, it does not work well for many government use cases. Current search practices miss information in the deep Web – the parts of the Web not indexed by standard commercial search engines – and ignore shared content across pages.

To help overcome these challenges, DARPA launched the Memory and Exploration of the Internet for Defense (MEMEX) program. This ambitious effort seeks to develop domain-specific search technologies and revolutionize the discovery, organization and presentation of 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 has a significant Web presence to attract customers.

Mining and Understanding Software Enclaves (MUSE)

Information at scale includes not just data, but software code as well. Within the last few years, there has been a tremendous explosion in the number of open source projects and the size of codebases these projects contain. Software repositories today are estimated to contain more than 100 billion lines of code, and the number continues to grow. Open source software is widely used in mission-critical DoD systems as well as in the commercial world. DARPA's new Mining and Understanding Software Enclaves (MUSE) program aims to harness the scale and complexity of this array of software to instigate a fundamental shift in the way we conceive, design, implement, and maintain software. If successful, MUSE could lead to a new programming methodology, leading to automated mechanisms for improving resilience, reducing vulnerabilities, and simplifying the construction of software systems.

High-Assurance Cyber Military Systems (HACMS)

Embedded systems form a pervasive network that underlies much of modern technological society. Such systems range from large supervisory control and data acquisition (SCADA) systems that manage physical infrastructure to medical devices such as pacemakers and insulin pumps, to computer peripherals such as printers and routers, to communication devices such as cell phones and radios, to vehicles such as automobiles and airplanes. These devices have been networked for a variety of reasons, including the ability to conveniently access diagnostic information, perform software updates, provide innovative features, lower costs, and improve ease of use. But researchers and hackers have shown that these kinds of networked embedded systems are vulnerable to remote attack, and such attacks can cause physical damage while hiding the effects from monitors. DARPA launched the High-Assurance Cyber Military Systems (HACMS) program to create technology to construct high-assurance cyberphysical systems. Achieving this goal requires a fundamentally different approach from what the software community has taken to date. If successful, HACMS will produce a set of publicly available tools integrated into a high-assurance software workbench, which will be widely distributed for use in both the commercial and defense software sectors. For the defense sector, HACMS will

enable high-assurance military systems ranging from unmanned vehicles to weapons systems, satellites and command and control devices. In an early demonstration of the program, we are running first-of-its-kind provably correct software on a commercially available automobile.

These programs are examples from DARPA's broader portfolio in cyber and information at scale. Other efforts are developing new technologies to enable distributed computer systems to work through attacks; permit trustworthy Internet communications in untrusted environments; automate the discovery, identification and characterization of new malware; provide DoD with military cyber capabilities; and automatically process text information to discover meanings and connections that might otherwise not be readily apparent to analysts.

Biology as Technology

A third area of complexity of growing interest and importance to DARPA – and among the most promising for future major capabilities – is the idea of 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.

Living Foundries

Synthetic biology – a hybrid discipline of biology and engineering – has already proven itself capable of using customized bacteria to produce medicines, and now it is heading toward even more interesting applications as we harness it to create entirely new chemistries. Our Living Foundries program seeks to develop the next-generation tools and technologies for engineering biological systems, compressing the biological design-build-test cycle in both time and cost. For example, the program has demonstrated the ability to generate a suite of novel bioproducts in weeks rather than years. The program is also producing new classes of materials with novel properties that can enable a new generation of mechanical, optical and electrical products.

Rapid Threat Assessment (RTA)

Even as we develop new materials and tools for engineering biological systems, we understand that we must also be prepared to react quickly to how our adversaries may seek to use similar capabilities. This concern is not new: novel chemical and biological weapons have historically been mass-produced within a year of discovery. Using current methods and technologies, researchers would require decades of study to gain a cellular-level understanding of how new threat agents affect humans. This gap between threat emergence, mechanistic understanding and potential treatment leaves U.S. forces and populations here and around the world vulnerable.

DARPA launched the Rapid Threat Assessment (RTA) program with an aggressive goal: develop methods and technologies that can, within 30 days of exposure to a human cell, map the complete molecular mechanism through which a threat agent alters cellular processes. This would give researchers the framework with which to develop medical countermeasures and mitigate threats. If successful, RTA could shift the cost-benefit trade space of using chemical or biological weapons against U.S. forces and could also apply to drug development to combat emerging diseases.

Brain Function Research

In an era when harnessing complexity will be the *sine qua non* of success, it should not be surprising that DARPA has a particular interest in tackling 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. These efforts are part of the President's initiative in brain research. Recently, we have made unprecedented advances in developing advanced prosthetic arm systems and methods to restore near-natural movement and control, as demonstrated by the DEKA Arm System approved by the Food and Drug Administration last week.

DARPA's biology-related investments also include diagnostics and novel prophylaxes to outpace the spread of infectious disease and new methods to accelerate the testing of critical therapeutics.

New Frontiers

Consistent with our mission to prevent technological surprise by creating it, DARPA continues to invest across a wide range of fields where we see promising research that could lead to powerful technology capability. These investments are the seeds of what my successors, perhaps 5, 10, or 15 years from now, will be describing to you as technology revolutions.

I described earlier our work in developing new algorithms, software and architectures that allow us to better mesh our electronic, optical and mechanical components together. What about those components themselves? We are pushing the frontiers of physics to make them dramatically smaller, or more capable, or both.

iPhod, COUGAR, and ORCHID

Consider the many ways we are developing to harness light, which will directly affect the size, weight, cost and performance of military components ranging from small navigation sensors to phased array radars and communication antennas. One recently concluded program (iPhod) successfully miniaturized tools for creating delays in light transmission, while another (COUGAR) demonstrated unique designs in hollow-core fibers, which guide light within a device much more efficiently than conventional optical fibers. Yet another (ORCHID) successfully demonstrated the "squeezing" of light, a concept in quantum optics that can ultimately lead to dramatic performance gains in microsystems. These programs challenge the assumption that highly specialized, high-precision systems must be large and expensive.

Miniaturization with National Security Implications

Other advances in miniaturization include a recent demonstration by DARPA-funded researchers of the world's smallest vacuum pumps. This breakthrough technology may create new national security applications for electronics and sensors that require a vacuum: highly sensitive gas analyzers that can detect chemical or biological attack, for instance, or extremely accurate laser-

cooled chip-scale atomic clocks and microscale vacuum tubes. As part of another program (QuASAR), one which seeks to exploit the extreme precision and control of atomic physics for new sensor technology, researchers have developed methods for measuring magnetic fields at scales smaller than the size of a single cell. Applications include critical advances in position, timing and navigation – all critical to military situational awareness and operations.

Ground Robotics

Some advances seem much closer to our doorstep than they really are – thanks to science fiction and the amazing special effects of creative individuals and teams who lead our entertainment industry. Ground robotics is one such domain. At the DARPA Robotics Challenge trials a few months ago, we drove robotics technology forward by engaging teams of creative specialists at companies, universities and other government agencies. These world-leading experts were charged with advancing the capabilities of robots to perform basic skills that would be required in carrying out humanitarian and disaster relief missions. The Robotics Challenge – which is still underway – is showing how robotics capabilities can advance. It is also demonstrating just how far these kinds of robots are from serious battlefield application. That, too, is part of DARPA’s mission: push the research frontiers of what is possible and inform our military decision makers where those limits are and the prospects for the future.

Algorithms Opening New Horizons

Research in mathematical algorithms is also creating important new technological opportunities. Clustering algorithms can detect common activity patterns across a vast data set. A combination of vector mathematics, time integration, and power law distributions enables the analysis of ensemble behaviors – patterns that only become visible when correlated across large numbers of points. Time series analysis can find previously unknown outliers in a data set for anomaly detection. Our programs apply these mathematical techniques to immense data sets with hundreds of millions or even many billions of elements. Individually or in combination, these new algorithmic approaches enable rapid analysis of data volumes that finally begins to scale with the complexity of the national security challenges that we face today.

I have cited several examples of DARPA technologies that made significant progress in the last year. There are many more in that same category. Additional examples of successes in the making are attached to my testimony.

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 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.

This pernicious trend turned around last year. I thank this Subcommittee, 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 things that have 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 for the President's FY 2015 budget request – DARPA will continue to make a real and outsized difference in redefining the national security landscape and our Nation's security.

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-

Addendum

DARPA Transitions

Many technologies from earlier DARPA investments are now moving forward with a wide variety of our partners and customers. These summaries provide snapshots of progress for some programs from recent years.

Leap Ahead in Surface Warfare Capabilities by Reducing Dependence on ISR Platforms, Network Links, and GPS: Long Range Anti-Ship Missile (LRASM)

Technology Description and Program Goal

- Our current anti-ship missiles must penetrate sophisticated enemy air defense systems from long range. As a result, Warfighters may require multiple missile launches and overhead targeting assets to engage specific enemy warships from beyond the reach of counter-fire systems. To overcome these challenges, the DARPA-Navy Long Range Anti-Ship Missile (LRASM) program is investing in advanced technologies to provide a leap ahead in U.S. surface warfare capability.
- LRASM aims to reduce dependence on intelligence, surveillance and reconnaissance (ISR) platforms, network links, and GPS navigation in electronic warfare environments. Autonomous guidance algorithms should allow LRASM to use less-precise target cueing data to pinpoint specific targets in the contested domain. The program also focuses on innovative terminal survivability approaches and precision lethality in the face of advanced countermeasures.
- LRASM began in 2009. Now in its final DARPA phase, this program leverages the state-of-the-art Joint Air to Surface Standoff Missile Extended Range (JASSM-ER) airframe and incorporates additional sensors and systems to achieve a stealthy and survivable subsonic cruise missile.
- ***In 2013, DARPA conducted two flight demonstrations, each with resounding success.*** The LRASM was dropped from an Air Force B-1, successfully separated from the aircraft, navigated through a series of preplanned waypoints, and then transitioned to an autonomous mode while seeking the target it had been instructed to attack. ***The missile detected, identified, and tracked the mobile ship target at extended range; transitioned to guidance on the terminal sensor; and impacted the target*** with a miss distance well within acceptable error probabilities. Other flight achievements include weapon data link updates, transmission of weapon in-flight tracks, and increased flight range.

Transition Plan and Status

- The program is on track to deliver an advanced prototype weapon to the Navy and Air Force with capability for challenging future operational environments, while being sufficiently mature to transition rapidly to an acquisition program to address near-term operational challenges.
- DARPA is engaged with the U.S. Navy NAVAIR's Program Executive Office for Unmanned Aviation and Strike Weapons (PEO U&W) to provide an innovative management approach for rapid acquisition of LRASM for Air Force and Navy air launch platforms to meet offensive anti-surface warfare missions. This approach leverages DARPA investment, program security, contracts, and infrastructure. Ultimately, it will leverage DARPA's technology development and risk reduction efforts to expeditiously field LRASM. In FY 2014, DARPA and Navy efforts

include continued technology development, integration risk reduction, and pre-Milestone B activities.

- ***DARPA has transitioned the technology to a new DARPA/Navy/Air Force co-staffed office chartered by USD(AT&L) to rapidly deploy this dramatically enhanced new capability.***

Reducing Drag and Fuel Usage: Formation Flight for Aerodynamic Benefit

Technology Description and Program Goal

- With the Air Force consuming more than 2.5 billion gallons of aviation fuel in 2010, DARPA launched the Formation Flight for Aerodynamic Benefit program to seek creative ways to reduce drag and fuel usage in the C-17 fleet.
- C-17s are the largest single user of aviation fuel, consuming 650 million gallons (26 percent) in 2010. DARPA's goal was to achieve a 10 percent reduction in fuel flow.
- The approach taken was motivated by large flocks of migratory birds that fly in a "V" formation.
- All aircraft produce wingtip vortices when flying, which are a drag byproduct of producing aerodynamic lift. After analyzing C-17 wingtip vortices, DARPA predicted optimum formation positions.
- The DARPA program created new software that innovatively enabled precise autopilot and auto-throttle formation flight operations with existing C-17 hardware.
- DARPA simulation, modeling, and lab testing projected success in reaching the target reduction in fuel flow using this software modification.

Transition Plan and Status

- DARPA transitioned the software to the Air Force Research Laboratory (AFRL) in July 2012 as the Surfing Aircraft Vortices for Energy (\$AVE) program.
- AFRL conducted 30 hours of flight testing in C-17 formation flight, including 12 hours on operational flight routes over the Pacific in 2013.
- ***That testing validated a 10 percent fuel flow reduction with the DARPA software modification. Moreover, the changes were safe, aircrew friendly, and aircraft friendly – and made business sense.***
- The Applied Technology Council approved funding for an Advanced Technology Demonstration (ATD) of the DARPA C-17 software-only modification. The ATD will enable the Air Mobility Command to develop CONOPS for rapid fielding this DARPA energy efficiency advancement.
- ***AFRL is examining use of this technology to obtain fuel savings on C-130s and other DoD platforms.***
- Commercial carriers, the Federal Aviation Administration, and the National Aeronautics and Space Administration (NASA) expressed interest in civilian applications of this DARPA technology.
- This DARPA program success reflects significant contributions from the Air Mobility Command, AFRL, 412th Test Wing, Air Force Life Cycle Management Center, Boeing Company, and NASA Neil A. Armstrong Flight Research Center.

New Approaches to Tackling DoD's Language Challenges: BOLT, RATS, and MADCAT

Technology Description & Program Goal

- DARPA has invested in solutions for DoD to recognize, classify, and help digest written and spoken foreign languages.
- Technology from the Broad Operational Language Translation (BOLT) program provides automated translation and linguistic analysis that can be applied to informal genres of text and speech as well as multilingual search capability and unrestricted multi-turn bilingual conversation.
- The Robust Automatic Transcription of Speech (RATS) program creates algorithms and software to perform the following tasks on potentially speech-containing signals received over channels that are extremely noisy and/or highly distorted: speech activity detection, language identification, speaker identification, and keyword spotting in foreign languages.
- The Multilingual Automatic Document Classification Analysis and Translation (MADCAT) program automatically converts foreign language text images into English transcripts, eliminating the need for linguists and analysts while automatically providing relevant, distilled actionable information to military command and personnel in a timely fashion.

BOLT Transition Plan and Status

- The Combating Terrorism Technical Support Office (CTTSO), under the Assistant Secretary of Defense for Special Operations/Low-Intensity Conflict, ***successfully transitioned to military users a tool for translation of and topic spotting and data exploitation in social media***. Initial implementation is with a military user with plans to extend use to multiple government, military, and academic media monitoring system users.

RATS Transition Plan and Status

- The Air Force has provided lab facilities to test RATS capability using operational data. ***Initial evaluations show RATS technology superior to any other system***, and plans are underway for integrating the speech activity detection portion of the RATS technology into systems that provide noisy speech signal processing capabilities. Other interested DoD elements are awaiting the results of operational field trials before pursuing acquisition.

MADCAT Transition Plan and Status

- MADCAT optical character recognition has been coupled with machine translation and deployed in 11 languages to enable English-speaking government and military personnel to read hardcopy foreign language documents. A project also is underway to further develop Korean optical character recognition and machine translation to support user requirements.
- MADCAT offline handwriting recognition system was delivered to a government user in 2011 and is in ***operational use***. ***The CTTSO is supporting the MADCAT transition to various other DoD and intelligence community users.***

Achieving Dramatically Faster Mapping: High-Altitude LIDAR Operations Experiment (HALOE)

Technology Description and Program Goal

- Leveraging past DARPA developments in Light Detection and Ranging (LIDAR) systems, a sensor pod for rapid collect, wide area, long range, high-resolution 3D datasets was developed for the HALOE system. In 2010 and 2011, DARPA invested funds to harden the sensor system in preparation for a prolonged operational trial in Afghanistan.
- ***HALOE provided forces in Afghanistan with unprecedented access to high-resolution 3D data, and it collected orders of magnitude faster and from much longer ranges than conventional methods.*** At full operational capacity, HALOE could enable mapping of 50 percent of Afghanistan in 90 days. State-of-the-art deployed systems would have required 3 years to accomplish that task, and more conventional systems would have required 30 years.
- This increased performance is enabled by advances in shortwave infrared sensitive material properties that permitted photon-counting detector arrays so sensitive that it is now possible to make range measurements with fewer than 10 photons received, versus tens of thousands of photons. As is true with any camera, increased sensitivity means an image can be captured more quickly since the shutter has to be open for less time – and less light is required to capture an image. Less time and less power translate to higher collection rates at greater standoff. HALOE can collect data at a rate more than 10 times faster than state-of-the-art systems or 100 times faster than conventional systems.
- HALOE was one of several DARPA advances directly supporting the Warfighter that earned the agency the Joint Meritorious Unit Award from the Secretary of Defense late in 2012.

Transition Plan and Status

- The HALOE sensor pod was initially integrated onto a WB-57 aircraft and deployed to Afghanistan from November 2010 through August 2011 in a ***joint effort with the Army Geospatial Center (AGC)***. During this time, over 70,000 square kilometers of terrain data (about 10 percent of Afghanistan) were collected, reflecting the priorities of operational units.
- In March 2012, **with AGC funding**, the HALOE sensor pod was integrated onto a BD700 aircraft, a highly customized, longer-range flight platform.
- In July 2013 the HALOE system was deployed to the AFRICOM Area Of Responsibility (AOR). The system collected data in Africa during eight flight sorties through August.
- In September 2013, HALOE was transferred to Afghanistan in September 2013.
- ***HALOE performed exceedingly well in its several deployments in Afghanistan***, collecting more than 83 percent of all tasked regions with a cumulative mission area of greater than 74,000 square kilometers. The collected data have been in response to multiple RFIs in support of operational units. The HALOE system has transitioned out of theater, with the last sortie flown in December 2013.
- Plans call for a 6-month period in CONUS for maintenance and training followed by ***redeployment in June 2014*** for the remainder of FY 2014. Potential locations include AOR of USCENTCOM (not Afghanistan), USAFRICOM, and USPACOM.

Blast Monitoring Tool Also Will Improve Future Understanding of Injuries: Blast Gauge

Technology Description and Program Goal

- Blast Gauge is a low-cost, disposable, individually wearable sensor system that records the environment during an explosive event – for example, an attack from an improvised explosive

device (IED) or a rocket-propelled grenade (RPG), or the firing of a missile or rocket during training.

- ***The goal was to rapidly develop and field a system to quantify blast exposure, assist commanders in finding injured Service Members who would otherwise not report, and record data to understand blast injuries, including traumatic brain injury (TBI).***
- DARPA recognized that blast overpressure and linear acceleration must be recorded – and at multiple points on the body– to understand blast-related injuries and that the needed technology could be built completely out of common commercial components.
- The device was developed in just 11 months; Special Operations Forces (SOF) fielded Blast Gauge in Afghanistan in July 2011 and Rochester Institute of Technology researchers who developed the dosimeter quickly formed a small business to commercialize and manufacture the gauges.
- ***Costing less than \$50 per device***, the gauge includes a simple three-light system (red, yellow, green) to indicate condition and magnitude immediately following a blast. Service Members wear three gauges: on the back of the helmet, shoulder, and chest. This allows a blast to be captured regardless of its relative location.
- Information is transmitted to medical staff and researchers; doctors and medics report that the lights are a valuable feature for augmenting triage following a blast.
- DARPA also developed a system to capture the data, contributing to better understanding of the effects of blasts on the brain.

Transition Plan and Status

- DARPA completed development with release of the latest generation gauge in June 2013. It can be purchased directly from the manufacturer or from Defense Logistics Agency stock.
- DARPA initially provided field support to train Soldiers on the gauges and to distribute gauges and collect exposure data. More than 150,000 gauges (50,000 sets) have been distributed to all Services.
- ***As a result of the DARPA-funded field trials, Blast Gauge technology has been adopted by SOF and the Army:***
 - The Combined Joint Special Operations Task Force Afghanistan (CJSOTF-A) mandated that all special operators in its task forces use blast gauges. They are purchasing 60,000 gauges for deployed forces and stateside training.
 - Other SOF units are purchasing and using gauges throughout training and operations. In these cases, Blast Gauge has become a key component of their strategy for managing TBI.
 - The Army has selected Blast Gauge as one of three components of its Integrated Soldier Sensor System (ISSS) requirement. DARPA is supporting the Army in designing and evaluating the ISSS.
 - While the Army is developing its objective solution (ISSS), it selected the Blast Gauge to be fielded to 18,000 Soldiers in OEF.
- Other services (including the Marine Corps Warfighting Laboratory), NATO partners, and Australia have independently evaluated the gauges and are deciding on next steps.
- Blast Gauge was cited as a DARPA advance directly supporting the Warfighter that contributed to the agency being awarded the Joint Meritorious Unit Award from the Secretary of Defense in 2012.
- Military officials have shown interest in examining the data and post-event analyses to ***gain insights into potential issues with brain injuries resulting from improper techniques and procedures for using equipment, including during training when most exposures occur.***

Revolutionizing Prosthetics (RP): Restoring Near-Natural Movement and Control of Upper Limbs

Technology Description and Program Goal

- When DARPA launched the Revolutionizing Prosthetics (RP) program in 2006, the state of upper-limb prosthetic technology was far behind lower-limb technology and was judged to be a more difficult medical and engineering challenge.
- The concept of a new system design may open the option for Service Members and others with upper-limb loss the chance to return to more fully active lives.
- The two research teams selected for the program, DEKA Integrated Solutions Corporation and the Johns Hopkins University Applied Physics Lab (APL), were tasked to:
 - Design and build anthropomorphic electromechanical upper extremity prostheses that mimic the capabilities of a natural arm for people with loss of an upper-limb.
 - Develop near-natural control modalities including exploration of direct neural control from peripheral nerves or the brain.
 - Investigate the ability to provide sensory feedback from sensors on the prosthesis through peripheral nerves or directly to the brain.
- Collaboration with Veterans Affairs, National Institutes of Health, Army Medical Research and Materiel Command, and Walter Reed National Military Medical Center has given more than 75 users (amputees and tetraplegics) an opportunity to provide input to the design of both arm systems and supported regulatory submissions. In addition, Revolutionizing Prosthetics became the pilot program of the Food and Drug Administration's *Innovation Initiative* in 2011, providing a new pathway for novel medical technologies.

Transition Plan and Status

- Since February 2012, the University of Pittsburgh Medical Center, a subcontractor to the Applied Physics Lab (APL), has conducted a *successful clinical study* in which research participants living with tetraplegia were able to use neural signals from their brain to directly control the Modular Prosthetic Limb (MPL). *This work has demonstrated that advanced prosthetics and direct neural interfaces can enable restoration of near-natural arm control to improve the quality of life for military personnel and civilians living with amputation or paralysis.*
- Veterans Affairs is conducting an independent 3-year home study of the DEKA Arm System. The Food and Drug Administration's May 2014 approval allows DEKA to pursue manufacturing and commercial opportunities to bring the arm to market. Their transition plan includes development of advanced manufacturing and distribution to medical practitioners.
- The APL's MPL serves as a research platform and some MPL *technology has transitioned to small robotic systems used in manipulating unexploded ordnance and suspicious objects.*

Smartphone Apps for the Dismounted Warfighter: Transformative Apps (TransApps)

Technology Description and Program Goal

- Today's Warfighters perform increasingly complex tasks but are still using outdated tools to access and share information on the battlefield. From a ground Soldier's perspective, little has changed in the last 20 years. They rely on inferior paper maps, written notes and reference materials, and voice radio transmissions to carry out their missions. Many technology advances that consumers take for granted have not made their way to the battlefield for a variety of reasons, especially security concerns and lack of robust high-bandwidth networks.

- With the TransApps program, DARPA aims *to put today's commercial smartphone-grade capabilities in the hands of the Soldiers who most need them* – those on daily patrols in theater – making their work much more effective and their lives easier and safer. In the field, the devices are providing Soldiers with an integrated ecosystem for situational awareness.
- Soldiers on patrol can keep up with fast-paced missions and changing environments by sharing and managing information in real time. That allows Warfighters and decision makers up and down the ranks and in various functions to share a common operating picture.
- They do this by using features and apps designed for their unique requirements: for example taking note of changes in the field – such as new bridges, structures, or civilians in an area – and sharing that information immediately with others who will direct and carry out future operations in that area.
- TransApps created a new agile development process, integration framework, and customized test cycles to allow rapid development of new applications, with new features and enhancements deployed quickly based on Soldiers' evolving requirements. ***When Soldiers need new apps, they can get them quickly – sometimes the very next day. This is a radical departure from how they have been operating.*** The TransApps ecosystem bridges old and new, allowing future technologies to work seamlessly with legacy radios and information systems. By endowing commercial off-the-shelf (COTS) smartphones with custom multilayered security and agile development processes modified for the tactical community, TransApps is creating a scalable and sustainable infrastructure template.

Transition Plan and Status

- A 4-year program that concludes in FY 2014, ***TransApps was first fielded to Afghanistan in 2011; within 18 months, more than 3,000 systems were deployed to the battlefield, supporting all Army maneuver operations theater-wide.***
- In FY 2014, DARPA is working with the Army Nett Warrior Program to fully transition TransApps capabilities into the enduring Program of Record, as part of the Army's efforts to get new technologies into the hands of the Soldier.
- Other organizations and agencies are preparing to transition program components. These include the Application Testing Portal for streamlined security and performance analysis of mobile applications, as well as TransApps' custom imagery processing and configuration tools, which empower Soldiers to manage their own maps based on mission requirements.

Persistent Close Air Support: Faster and There When Troops Need It

Technology Description and Program Goal

- To maintain a decisive tactical advantage in 21st-century combat, Warfighters need to safely, rapidly, and collaboratively deploy ordnance against elusive mobile targets. Unfortunately, air-ground fire coordination, referred to as Close Air Support, or CAS, has changed little since World War I.
- Pilots and dismounted ground agents can focus on only one target at a time and often must ensure they hit it using just voice directions and a paper map. In complex environments, it can take up to an hour to confer, get in position and strike – time in which targets can attack first or move out of reach.
- DARPA created the Persistent Close Air Support (PCAS) program to enable dismounted ground agents and combat aircrews to share real-time situational awareness and weapons systems data.
- The system DARPA developed and tested ***enables ground agents to quickly and positively identify multiple targets simultaneously.*** Ground and air forces would jointly select precision-guided ordnance that best fits each target and minimizes collateral damage and friendly fire.

Finally, both parties would authorize weapons deployment.

- Benefits would include reduction in time from calling in a strike to target hits reduced from as much as 60 minutes to just 6 minutes; direct coordination of airstrikes by a ground agent from manned or unmanned air vehicles; improved speed and survivability of ground forces engaged with enemy forces; and use of smaller, more precise munitions against smaller and moving targets in degraded visual environments. Another benefit is graceful degradation; if one piece of the system fails, Warfighters still retain capability of more basic functionality.

Transition Plan and Status

- In early 2013, DARPA deployed 500 Android tablets equipped with PCAS-Ground situational awareness software to units stationed in Afghanistan. An operator on the ground – with a tablet and voice radio – communicated with a pilot who had a tablet in the cockpit about imagery they both share on their tablets. (The program also developed a networked solution that allows even more rapid information sharing.)
- ***Field reports show that PCAS-Ground replaced those units' legacy paper maps, dramatically improving ground forces' ability to quickly and safely coordinate air engagements.***
- The program, which began in FY 2010 and concludes in early 2015, is in the flight-testing phase, which concludes with live fire demonstrations.
- Elements of PCAS, particularly the JTAC ground software, are seeing traction among various JTAC-related programs of record across the Services.