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Science and Technology Programs:
Maintaining a Robust Ecosystem for Our Technological Edge

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DARPA plays a unique role in the DoD R&D 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 and timelines – technologies that hold the potential for extraordinary advances in national security capabilities. This mission, our current work, and future plans are the focus DARPA's Fiscal Year 2020 budget request and are reflected in my testimony today.

Introduction

DARPA's mission and philosophy have held steady and yielded breakthrough technologies and capabilities for more than 6 decades, even as the world has changed dramatically – because the Agency always targets the future. The rate at which those changes are arriving and affecting national security has accelerated. What had been a fairly well-defined global order punctuated by occasional surprises has transformed into an ever-shifting, complex, and less certain security picture. Troubling technological, social, economic, and geopolitical movements threaten U.S. preeminence and stability. These trends inform DARPA's strategic priorities and investments into the next decade and beyond. As those threats change, so too will the Agency's focus.

Daunting challenges are on the national security landscape. On the technology front, the nation must maintain domestic superiority even as sophisticated components and systems once available almost exclusively to U.S. forces now are available on the global market. This new reality is largely the result of economic forces that have made once proprietary products less expensive and more accessible. The still nascent synthetic biology and biotechnology fields are prime examples. While they remain specialized domains requiring well-equipped laboratories and skilled researchers, these areas show early signs of a future in which off-the-shelf gene-editing kits will make the tools of genetic engineering accessible to many, justifiably stoking biodefense concerns.

DARPA's role has never been more vital, and we have made important strides forward. The following details the current threat environment and our plans for the next several years that will create new national security capabilities by conceiving and delivering breakthrough technologies.

Strategic Priorities in a Global Context

DARPA's strategy aligns with the National Defense Strategy (NDS) and the National Security Strategy (NSS). As the NDS states, "The drive to develop new technologies is relentless, expanding to more actors with lower barriers of entry, and moving at accelerating speed."

The common theme in the NSS, NDS, and DARPA's strategy is a focus on threat-based mission scenarios. With myriad threats to national security, DARPA is working to achieve new, revolutionary capabilities in the following four focus areas:

- ***Defending the homeland*** from varied threats requires the development of cyber deterrence capabilities, biosurveillance and biodefense techniques, and the ability to sense and defend against weapons of mass terror/destruction.
- ***Deterring and prevailing against peer adversaries*** requires the development of new capabilities across the land, sea, and air domains, in addition to enabling new capabilities in space and the electromagnetic spectrum.
- ***Prosecuting stabilization efforts across the globe*** for more lethal fighting in varied environments, including capabilities to address gray-zone conflict and 3D city-scale warfare, along with the development of rigorous and reliable models to predict adversarial moves prior to engagement, are critical investment areas.
- ***Pursuing foundational research*** in science and technology is what makes never-before-seen capabilities possible. The goal of the Agency's fundamental R&D investments is to ensure U.S. warfighters have access to the most cutting-edge technologies. Research funded by DARPA in the near term explores science and technology that will lead to "leap ahead" solutions for current as well as future challenges to military readiness across multiple operational domains.

Defend the Homeland

DARPA’s mission is to conceive, develop, and demonstrate innovative technologies for national security. Our mission is complete only when those technologies have transitioned into capabilities that will protect our nation from existential threats.

The following highlights recent DARPA developments at various stages of transition that promise to keep the nation secure.

Stopping Pandemics in 60 Days or Less

Preventing pandemic outbreaks and mitigating the impact of a potential high-threat biological agent release are national security priorities. The U.S. military supports U.S. Government responses to public health emergencies such as Ebola, which can cause regional destabilization and spread through global travel.

Warfighters must also operate in regions where diseases like chikungunya and dengue are endemic, and even seemingly mild challenges like seasonal influenza affect force readiness. In addition to these naturally occurring threats, terrorists and other adversaries possess a growing palette of biological tools to engineer new biological threats. The threat of natural or engineered infectious agents on U.S. and global national security will be mitigated if the Department of Defense (DoD) can rapidly deploy near-immediate countermeasures for military personnel and civilian populations for known and newly emerging pathogens.

Previous DARPA investments in gene encoded antibody technology demonstrated the ability to protect animal models from a variety of pathogens, including those with pandemic potential—this technology has advanced to human clinical safety trials. Based on this foundational effort, in 2017, DARPA launched the Pandemic Prevention Platform (P3) program, which made significant progress in the last year. Researchers made two major advances, demonstrating the antibody discovery component of the 60-day response platform in less than 4 days. Additionally, research teams developed technology that will protect against the seasonal influenza pathogen within 3 days after administration in relevant animal models. These two programs are important steps in creating a fully-integrated end-to-end platform that can stop pandemics early and more rapidly provide countermeasures to our warfighters, first responders, and vulnerable populations.

Cybersecurity

The cyber domain is of critical national importance and must be protected against adversary cyberattacks. DARPA is working to develop technologies to enhance cyber domain defense and is collaborating with DoD cyber stakeholders to improve cyber deterrence capabilities. This includes a variety of efforts with USCYBERCOM and the Military Services to participate in exercises, develop concepts of operation, evolve prototype systems, mature the technology base, and transition cyber-deterrence technologies to operations. In addition, DARPA is developing technologies to create software systems that are secure by design, reducing constant patching in response to newly discovered vulnerabilities, providing greater visibility into network operations for enterprises and service providers, and enabling cyber response capabilities that are accurate, robust, and safe.

An example of DARPA research efforts that are significantly improving the way DoD and the Intelligence Community conduct cyber threat intelligence is our Enhanced Attribution program, which identifies and tracks malicious cyber actors at scale and in real-time. The program provides high-fidelity visibility into all aspects of malicious cyber operator actions and increases the Government's ability to reveal the actions of individual malicious cyber operators without damaging sources and methods.

<u>Deter and Prevail Against Peer Adversaries</u>

The innovations highlighted below will play critical roles in the years ahead against growing threats posed by peer adversaries. DARPA is leading the way in developing kinetic and non-kinetic strike options, battle management command and control technologies, and new warfighting constructs to deter peer adversaries from initiating offensive actions.

<u>Hypersonics</u>

Hypersonic vehicles fly through the atmosphere at incredibly high speeds, creating intense friction with the surrounding air as they travel at Mach 5 or above – that is, at least five times faster than sound travels. Developing structures that can withstand furnace-like temperatures at such high speeds is a substantial technical challenge.

In 2018, DARPA addressed several outstanding technical challenges in two of its key hypersonics development programs: Tactical Boost Glide (TBG) and Hypersonic Air-breathing Weapon Concept (HAWC). On TBG, DARPA has been able to retire major technical risks following successful replicated tests of a new design and leading-edge material testing. On the HAWC program, the Agency also conducted successful risk reduction testing, which places the program on path to demonstrate hypersonic cruise missile technologies.

Supplementing TBG and HAWC efforts is the combined DARPA and U.S. Army ground-based Operational Fires (OpFires) program. OpFires will provide operational/theater-level commanders with flexible capabilities to strike time-sensitive targets while providing persistent standoff from unpredictable land-launch positions. This flexibility would restore combatant commander options in force deployment and employment, enabling adaptable engagement at extended ranges. OpFires is exploring the use of hypersonic payloads to provide a ground-launched weapon system for persistent standoff.

On a more fundamental level, DARPA is aggressively researching novel materials to help cool hypersonic vehicles as they cut through the atmosphere. In December 2018, DARPA announced its Materials Architectures and Characterization for Hypersonics (MACH) program, which seeks to develop and demonstrate new design and material solutions for sharp, shape-stable, cooled leading edges for hypersonic vehicles.

Directed Energy

High-powered lasers hold the potential to rapidly and effectively counter surface-to-air threats, unmanned air vehicles, and armed swarms. Laser weapons also promise an offensive capability featuring precise delivery to reduce the probability of collateral damage. Over the next few months, DARPA will demonstrate a fiber laser array that offers significant size and weight savings compared to previous, chemical-based laser technology. Fiber lasers are modular and, ultimately, scalable and feature near-perfect beam quality and improved electrical efficiency.

Autonomy and Collaboration with Minimal Human Command

In a recent test series, DARPA's Collaborative Operations in Denied Environment (CODE) program demonstrated the ability of CODE-equipped unmanned aerial systems (UASs) to adapt and respond to unexpected threats in an anti-access area denial (A2AD) environment. The UASs efficiently shared information, cooperatively planned and allocated mission objectives, made coordinated tactical decisions, and collaboratively reacted to a dynamic, high-threat environment with minimal communication.

The DARPA team also advanced the infrastructure necessary to support further development, integration, and testing of CODE as it transitions to future autonomous systems. CODE's scalable capabilities could greatly enhance the survivability, flexibility, and effectiveness of existing air platforms, as well as reduce the development times and costs of future systems. Further development of CODE and associated infrastructure will continue under DARPA until the conclusion of the program, followed by full transition of the CODE software repository to Naval Air Systems Command.

Responsive Space Operations

The growing importance of space for national security is transforming this domain, with technology advancing to the point where U.S. military success may depend upon our ability to place very capable small satellites in low-earth orbit (LEO) and in larger constellations. Right now, satellites critical to our national security and warfighting capabilities traditionally are custom-designed and placed in geosynchronous orbit (GEO) to deliver persistent overhead access to any point on the globe. In a contested space environment, these exquisite yet costly and monolithic systems have become vulnerable targets that would take years to replace if degraded or destroyed; their long development schedules preclude orbital systems that are responsive to new threats.

The evolution of commercial space has led to the design and manufacturing of LEO constellations intended for broadband Internet service that could offer previously unavailable economies of scale. DARPA is interested in leveraging these advances and driving them forward in order to demonstrate military utility. A new program launched with the Air Force in 2017, Blackjack, consists of collaborating with the commercial sector to achieve that goal and meet needs ranging from command and control to intelligence, surveillance, and reconnaissance (ISR). Blackjack aims to develop and demonstrate many of the critical technical elements of a global high-speed network backbone in LEO. This network would enable highly-connected, resilient, and persistent DoD payloads that provide over-the-horizon sensing, signals, and communication, and hold the ground, surface, and air domains in constant global custody.

Networking Undersea Platforms

No matter how capable, the most advanced vessel can only be in one place at a time, yet U.S. Navy assets must cover vast regions around the globe. DARPA initiated the Hydra program to help address this challenge. Hydra is bringing the U.S. Navy much closer to developing a distributed undersea network of unmanned payloads and platforms to supplement manned vessels. The system innovatively integrates existing and emerging technologies to deliver capabilities above, on, and below the ocean’s surface. By separating capabilities from the traditional platforms that deliver them, Hydra’s communications features would serve as a force multiplier, allowing asset deployment wherever needed, faster, at the needed scale, and more cost effectively.

Hydra intends to enable other new capabilities not currently performed by manned platforms, such as allowing for forward-deployed airborne ISR platforms or recharging hubs for undersea vehicles. Separating capabilities from the platforms that deliver them, Hydra would equip naval forces to deliver those capabilities much faster and more cost effectively, wherever needed.

Mosaic Warfare Construct

Part of imagining future national security technologies and capabilities is the ability to conceive and develop new constructs for operations in never-before-seen theaters of engagement. U.S. military power has historically relied upon monolithic military systems where one type of aircraft, for example, is designed to provide a single end-to-end capability, comprising all elements of a kill chain. These traditional systems, tailored to a very specific warfighting context, offer powerful warfighting capabilities but also provide an adversary with a single high-value target. In contrast, DARPA is developing a concept that seeks to rapidly compose kill chains from a mix of available sense, decide and act elements to provide a mosaic-like flexibility for any threat scenario. By using less expensive systems brought together on demand as a conflict unfolds, this mosaic construct would enable diverse, agile applications – from kinetic engagement in a remote desert setting, to multiple small strike teams operating in a bustling megacity, or an information operation to counter an adversary spreading false information in a population threatening friendly forces and strategic objectives.

DARPA's mosaic strategy stands to enhance the effectiveness of existing military capabilities across all domains — maritime, ground, air, space, and cyberspace — and enable new, low-cost unmanned systems that the Services, DARPA, and the commercial sector anticipate building in the future. The mosaic strategy will change the way the military thinks about designing and buying future systems.

Our SoSite program, one of several efforts that fall under the mosaic portfolio of programs, is moving this new warfare concept from theory to practice. Late last year, DARPA researchers successfully demonstrated rapid integration of three different command and control systems to pass mission planning, threat, and strike tasking data in real time. Integration of these systems was completed in 2 days and further modified in just hours using DARPA's automated integration tools. Conventional, manual methods would have taken more than a year to complete the same tasks.

Assault Breaker II

The Assault Breaker II (ABII) program addresses challenges posed by our near peer competitors. Patterned after the original Assault Breaker program in the late '70s, a memorandum of agreement was signed by DARPA and the vice chiefs of all four Services to establish a DARPA-led, joint Service team creating technology solutions to these critical challenges. Interacting closely with the intelligence, military operator, and technology communities, the team's first objective is to architect new warfighting operational constructs based on new and emerging technologies and capabilities. The program's second objective is developing an advanced modelling and simulation environment to support analysis of true cross-domain (seafloor to space) cross-Service, warfighting constructs. Finally, the program is tying the advanced modelling and simulation environment into an interactive experiment environment to support exploration of highly complex, highly interdependent warfighting approaches that characterize the future of warfighting.

As described earlier in the Mosaic Warfare discussion, modern warfare is becoming less about singular platform and weapon capabilities, and more about combinations of systems that can be rapidly developed and composed into more effective warfighting constructs. ABII helps organize this evolution and acts as a conduit to both communicate technology solutions to the Services in a warfighting context as well as articulate critical challenges to the technology development community in a manner in which they can appreciate the larger warfighting picture. ABII will serve as the technical baseline for multidomain operations moving forward.

Prosecute Stabilization Efforts

Our world is certainly becoming a competition among nation-states, and DARPA is addressing this competition as seen above. However, the United States has been fighting for 20+ years now to counter terrorist and insurgency movements, and we need to become more effective at doing so. Ground troops are often at the frontline in these efforts and need new technologies to help them fight at stand-off, understand gray zone operations, and better operate in large urban areas.

Squad X Experimentation

DARPA’s Squad X Experimentation (SXE) program is designed to provide more stand-off capabilities to our Army and Marine Corps squads and has conducted several live experiments that have fostered the evolution of both new technologies and tactics. In August 2018, the Marines supported several weeks of training and testing that demonstrated autonomous systems working within dismounted formations to achieve objectives within urban environments. These experiments also demonstrated the capability of dispersed, collaborative radio frequency (RF) sensing systems to provide significantly improved situational awareness when coupled with airborne and ground robotics assets.

Making Gray-Zone Activity More Black and White

As “gray-zone activity” around the world becomes more sophisticated, the United States needs to leverage artificial intelligence (AI) and other technologies to help commanders make effective decisions to thwart an enemy’s disruptive activity. Gray zone conflicts sit in a nebulous area between peace and conventional warfare. An action and its intent are not openly declared or defined, and it is slower and prosecuted more subtly – using social, psychological, religious, information, cyber, and other means to achieve objectives with or without violence. The lack of clear intent, the grayness, makes it challenging to detect, characterize, and counter an enemy fighting this way.

DARPA's Media Forensics (MediFor) program is developing automated, scalable tools for detecting the type of forged or manipulated visual media assets (VMAs) that are increasingly used in information operations. Nation states have had the capability to manipulate media for decades and, today, due to the shift from analog to digital media and the profusion of simple editing tools, it is now easy to manipulate and distribute content. The ability to quickly detect compelling manipulations has not kept pace. Currently, this type of analysis is performed by human experts using complex tools and methods. MediFor is delivering new tools that measure the digital, physical, and semantic aspects of VMA integrity and integrate that information to produce a single, quantitative integrity score. DARPA is designing a cloud-based system to enable computation at scale and to support transition to Government and commercial partners.

Subterranean Challenge: Make the Inaccessible Accessible

Underground settings are increasingly relevant to global security and safety. Rising populations and urbanization are requiring military and civilian first responders to perform their duties below ground in human-made tunnels, underground urban spaces, and natural cave networks. However, one of the main limitations is a lack of situational awareness. Recognizing that innovative, enhanced technologies could accelerate development of critical lifesaving capabilities, DARPA is running the Subterranean or "SubT" Challenge, which aims to explore new approaches to rapidly map, navigate, and search underground environments.

Advances in robotics, autonomy, and even biological systems could permit us to explore and exploit underground environments too dangerous for humans. Instead of avoiding caves and tunnels, we can use surrogates to map and assess their suitability for use – coming up with new technologies and concepts to make the inaccessible accessible.

Pursue Foundational Research and Technologies

DARPA's core work has always involved discovering new physics and overcoming seemingly insurmountable engineering barriers to change what is possible. By showing those daunting problems to be tractable after all, DARPA breakthroughs in foundational research and technology open new pathways to addressing the most pressing national security challenges. Maintaining momentum in this essential specialty, DARPA is working to achieve new capabilities by applying deep mathematics; inventing new chemistries, processes and materials; and harnessing quantum physics.

Since its inception, DARPA has relied frequently on an open research model that involves pairing with non-defense-oriented partners. Rather than relying on secrecy, which often is required in military research, the investments the Agency has made in the fundamental sciences have allowed the country to take the lead in pioneering several technologies. Nowhere is this more evident than in the field of semiconductors and information technology. Thanks to DARPA's long history of investment in these spaces, we have helped build communities that allow ideas to be rigorously developed, and then perfected and manufactured by industry – generating advancements that have brought both economic and defense gains.

Electronics Resurgence Initiative

As Moore's Inflection approaches, the U.S. Government has decided to take large-scale action by investing $1.5 billion over the next 5 years in the DARPA-led Electronics Resurgence Initiative (ERI). This effort seeks to build a specialized, secure, and heavily automated innovation cycle that will enable the U.S. electronics community to move from an era of generalized hardware to specialized systems. Building on DARPA's legacy of electronics invention, ERI aims to foster forward-looking collaborations and novel approaches to usher in this new era of circuit specialization. The large-scale initiative will apply DARPA's open research model to the future of microelectronics and bring together Government, academia, industry, the defense industrial base, and DoD to create the environment needed for continued advancement.

In November 2018, DARPA expanded the program with the announcement of ERI Phase II, which will further connect the technology needs and capabilities of the defense enterprise with commercial and manufacturing realities of the electronics industry. ERI Phase II builds on existing ERI programs with the goal of supporting domestic semiconductor manufacturers that can implement specialized circuits. This effort aims to ensure those circuits can be trusted through the supply chain and are built with security in mind, making certain that technological advances are ultimately available to and applied to national security objectives.

Artificial Intelligence/Machine Learning

For more than 5 decades, DARPA has been a leader in generating groundbreaking research and development that has facilitated the advancement and application of rule-based, so-called "first wave" artificial intelligence (AI) technologies. The past few years have seen an explosion of interest in a sub-field of AI dubbed "machine learning" that applies statistical and probabilistic methods to large data sets to create generalized representations that can be applied to similar data , also known as "second wave" AI technologies. Today, DARPA continues to lead innovation in AI technologies research as it funds a broad portfolio of R&D programs, ranging from basic research to advanced technology development. DARPA envisions a future in which machines are more than just tools that execute human-programmed rules or generalize from human-curated data sets. Rather, the AI-enabled machines DARPA envisions will function more as colleagues than as tools. Towards this end, DARPA is focusing its investments on a "third wave" of AI technologies that brings forth machines that can reason in context.

DARPA announced in September 2018 a multi-year investment of more than $2 billion in new and existing programs called the "AI Next" campaign. Key areas include providing robust foundations for second wave technologies, aggressively applying second wave AI technologies into appropriate systems, and exploring and creating third wave AI science and technologies.

In addition to new and existing DARPA research, a key component of the AI Next Campaign will be DARPA's Artificial Intelligence Exploration (AIE) program, first announced in July 2018. AIE constitutes a series of high-risk, high-payoff projects where researchers will work to establish the feasibility of new AI concepts within 18 months of award. Leveraging streamlined contracting procedures and funding mechanisms is enabling these efforts to move from proposal to project kick-off within 3 months of an opportunity announcement. Already, DARPA has made 44 awards, including 26 to universities and 10 to small businesses, all in under 90 days from posting the request for research proposals, and there is a strong, almost overwhelming, interest on the part of the research community to participate in these opportunities.

Conclusion

The ultimate objective of the Agency's work is the achievement of major, unexpected advances in national security capabilities. DARPA's record in this regard is unrivaled. Precision-guided munitions, stealth technology, unmanned systems, advanced ISR, and infrared night vision produced remarkable changes in how U.S. forces fight and win.

At the same time, the enabling technologies behind these military capabilities – new materials, navigation and timing devices, specialized microelectronics, advanced networking and artificial intelligence technologies, among others — helped lay a foundation for private-sector investments that extends far beyond the battlefield.

I look forward to working with this subcommittee and others in Government to see that DARPA remains true to its mission and continually delivers game-changing national security capabilities.