

**ARTIFICIAL INTELLIGENCE INITIATIVES WITHIN
THE DEPARTMENT OF DEFENSE**

HEARING

BEFORE THE

SUBCOMMITTEE ON
EMERGING THREATS AND CAPABILITIES

OF THE

COMMITTEE ON ARMED SERVICES
UNITED STATES SENATE

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

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MARCH 12, 2019
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Printed for the use of the Committee on Armed Services



Available via: <http://www.govinfo.gov>

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U.S. GOVERNMENT PUBLISHING OFFICE

WASHINGTON : 2021

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CONTENTS

MARCH 12, 2019

	Page
ARTIFICIAL INTELLIGENCE INITIATIVES WITHIN THE DEPARTMENT OF DEFENSE ..	1
STATEMENTS OF MEMBERS OF THE SUBCOMMITTEE	
Statement of Senator Joni Ernst	1
Statement of Senator Gary C. Peters	2
WITNESS STATEMENTS	
Highnam, Peter T., Deputy Director, Defense Advanced Research Projects Agency	3
Brown, Michael A., Director, Defense Innovation Unit	9
Shanahan, Lieutenant General John N.T., USAF, Director, Joint Artificial Intelligence Center, Office of the Department of Defense Chief Information Officer	15
Questions for the Record	36

ARTIFICIAL INTELLIGENCE INITIATIVES WITHIN THE DEPARTMENT OF DEFENSE

TUESDAY, MARCH 12, 2019

UNITED STATES SENATE,
SUBCOMMITTEE ON EMERGING
THREATS AND CAPABILITIES,
COMMITTEE ON ARMED SERVICES,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:37 p.m. in room SR-232A, Russell Senate Office Building, Senator Joni Ernst (Chairman of the Subcommittee) presiding.

Members present: Senators Ernst, Shaheen, Heinrich, and Peters.

OPENING STATEMENT OF SENATOR JONI ERNST

Senator ERNST. The Subcommittee on Emerging Threats and Capabilities meets today to receive testimony on Department of Defense artificial intelligence (AI) initiatives.

I want to thank you, gentlemen, for being here today.

I do apologize. We have a vote series going on right now, so, at some point, Senator Peters and I may have to switch on and off. We'll run down and vote accordingly.

But, I do want to thank you for being here. I'd love to welcome you. We have a very distinguished panel joining us today, ladies and gentlemen.

As highlighted in the NDS [National Defense Strategy] Commission Report, the U.S. must stay ahead in several emerging technologies in order to maintain or regain a warfighting advantage. These technologies include hypersonics, directed energy, artificial intelligence, 5G, and quantum computing. Russia and China are aggressively developing these capabilities and, in some cases, have already surpassed, or will soon surpass, our technologies. Without action, the U.S. may find itself at a technological disadvantage in future conflicts.

Over the next few months, this Subcommittee will focus our efforts to ensure the Department is well positioned to outpace our adversaries and maintain a strategic advantage in these key technologies. Today, we will focus on one technology of particular importance, which is artificial intelligence.

The recently released Department of Defense Artificial Intelligence Strategy makes clear AI is poised to transform every industry and is expected to impact every corner of the Department, spanning operations, training, sustainment, force protection, recruiting, healthcare, and many others. AI has the ability to provide

powerful new capabilities to our warfighters that we are only beginning to imagine. When applied to back-office functions and operations within the Department, AI will be critical in boosting efficiency and increasing the effectiveness of limited resources. With such broad potential impacts, it is important that the Department move quickly to adopt these capabilities so that we don't lose the technological edge.

Our adversaries understand the critical importance of AI. Last year, the Chinese government released a strategy detailing its plan to take the lead in AI by 2030. Less than 2 months later, Vladimir Putin publicly announced Russia's intent to pursue AI technologies, stating, "Whoever becomes the leader in this field will rule the world." Both of these countries are investing heavily in military applications of AI to achieve a warfighting advantage.

The United States is also investing heavily in AI applications. Over the last year, the Department has initiated several important efforts to accelerate the adoption of AI, including the establishment of the Joint AI Center, or JAIC, the development of a DARPA [Defense Advanced Research Projects Agency] AI Next Campaign, and the release of the DOD [Department of Defense] AI Strategy. These efforts demonstrate the extent of the AI transformation already underway within the Department of Defense and the priority that is being placed on growing these capabilities. However, with these important efforts comes the challenge of coordinating hundreds of disparate AI efforts across multiple offices and organizations. I look to our witnesses to help the committee better understand how AI can be adopted more rapidly, how coordinating the initiatives already underway within the Department can help us harness this powerful technology, and where we must invest in future research to ensure we maintain a long-term advantage.

Again, I thank our witnesses for being with us today. I look forward to their testimony.

I would turn to my Ranking Member, Mr. Peters. Senator Peters, thank you. New Ranking Member joining us. This is our first subcommittee hearing of the Congress. Senator Peters, I welcome you onboard. Thank you very much.

STATEMENT OF SENATOR GARY C. PETERS

Senator PETERS. Well, Madam Chairwoman, thank you. It's an honor to be with you. I've enjoyed working with you over the years, and we'll continue to do that in the next 2 years in this Congress.

Also, I'd like to thank the gentlemen for you being here today, for your testimony.

You know, artificial intelligence is already impacting our daily lives through commercial products and services, from applications as simple as Alexa to very complex systems, like self-driving automobiles. AI has huge implications for our national security, as well. For example, it'll enable new capabilities in intelligence analysis, autonomous systems, as well as cybersecurity. At the same time, AI can create new threats in these and other areas that can be exploited by our adversaries. I hope, in this hearing, that we can hear from our witnesses on the Pentagon's efforts to position itself in the rapidly changing world of AI, from the more near-term activities of

the Joint AI Center to the long-term, high-risk, high-payoff research efforts of DARPA and the Defense Innovation Unit (DIU).

The current AI systems that exist today only exist because of decades of research in computer science, control systems, microelectronics, and other fields. There are many amazing commercial capabilities available today, yet AI is still relatively primitive to what we all think it can be. We need to continue to invest in fields like computer science and electronics, but also research in areas such as our understanding of how machines and people learn and can work together to make sure that that promise becomes a reality.

I would like to understand how the DOD is working to move AI capabilities quickly into fielded systems, as well as how the Pentagon is developing a long-range strategy on R&D [research and development] of new capabilities.

I hope we can discuss how we are engaging with the best minds in defense and the commercial industry, Silicon Valley, government labs, and universities to address many of these challenges.

I would also like to learn about efforts to ensure that the DOD and the Nation has the expert workforce that we will need within government to stay at the leading edge of this technology.

Finally, I'd like to recognize—General Shanahan is a distinguished graduate of the University of Michigan, earning his commission there through the ROTC [Reserve Officer Training Corps]. The University of Michigan is one of many academic institutions in Michigan that prioritizes artificial intelligence research, particularly for the development and testing of autonomous vehicle systems.

General Shanahan, I know that U of M [University of Michigan] would love to host you back on campus to see the work that they're doing on AI and on autonomy and its relevance to your work. I hope that you and—as well as our other members of the panel, are able to take a trip to Michigan sometime soon.

I thank the Chair again for holding this hearing. I certainly look forward to our discussion.

Senator ERNST. Yes. Thank you very much, Senator Peters.

We will start with Dr. Peter T. Highnam. Dr. Highnam became the Deputy Director of the Defense Advanced Research Projects Agency, what we know of as DARPA, in February of 2018. Prior to coming to DARPA, Dr. Highnam was the Director of Research at the National Geospatial-Intelligence Agency, on assignment from the Office of the Director of National Intelligence (ODNI). Prior to that assignment, he also served 6 years at ODNI's Intelligence Advanced Research Projects Activity, initially as an Office Director and then as Director.

Dr. Highnam, we welcome you. You may start your opening remarks. Thank you very much.

**STATEMENT OF PETER T. HIGHNAM, DEPUTY DIRECTOR,
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY**

Dr. HIGHNAM. Thank you, Chairwoman Ernst, Ranking Member Peters. I'm pleased to be here to represent the Defense Advanced Research Projects Agency and share with the Subcommittee DARPA's work to advance AI technologies.

I'm going to begin with a little bit about DARPA's history in this field. In 1960, shortly after DARPA was created, ARPA [Advanced Research Projects Agency] was created. One of the first information technology offices that we had gave this quote, "It seems reasonable to envision bringing computing machines effectively into processes of thinking that must go on in realtime, time that moves too fast to permit using computers in conventional ways. To think in interaction with a computer in the same way that you think with a colleague whose competence supplements your own will require much tighter coupling between man and machine than is possible today."

Back then, when computers were large, were room-size, when they were being used for computing missile trajectories and so on, this man saw what was possible, saw the insights that were becoming available, and saw the push that we're still working on, which is changing computers from tools to partners. That actually is the history of AI investments by DARPA for the last 60 years.

That is also quintessential DARPA. This man had, you know, one foot in defense, seeing the mission and seeing what was needed, and one foot in the technology side, and framed the problem using use cases, knew what had to be done, and started driving. It's unlikely that he thought that there would be 6 decades of investments and hard work that followed that to get to where we are today.

I'd like to say that, after 60 years of pushing, AI is an overnight success.

[Laughter.]

Dr. HIGHNAM. Really, within the last 10 years, when you think about the kind of technologies. A lot of transitions and successes over the decades, much accomplished, and much still to do.

DARPA describes the investments in AI using a waves construct. The first wave at the beginning, for the first 20 years or so, are normally known as describe. This is where knowledge was encoded in rules, "If A, then B." If you look inside the tax—if you do personal taxes today, there's a rule-based system inside there that was what, 40 years ago, would have been called AI technologies, now is just computer science, or IT [information technology]. That's the price of success. It's no longer AI. It's just commonplace.

Then, beginning in the mid-1970s, the technology—science had put in place to begin what became machine learning. The theory was put down, but it—only in the last 10–15 years, we now have the compute cycles, we have the data availability. That's when the current wave, the second wave, of machine learning really took place and really came into being.

Now we're looking past that, at DARPA, into what comes next. We have two waves of technology. One was descriptive, one was recognizing situations, classifying, and so on. Now we have to be able to explain, to really build the trust between these systems and the people who are using them and working with them in realtime, in difficult, stressful situations, but building the trust so that they really can become partners. This is the role of explanation.

It's a great time to be at DARPA, because we're now on the brink of a lot of really exciting things. That's the genesis of the current initiative, the \$2 billion investment that we've said we're now making in AI technologies.

That said, there's a brittleness to the current technologies. The tools are immature, still. We don't have an engineering discipline behind AI technologies. There are issues, that I'm sure everyone will talk to you about, about missing data volume, missing data quality, provenance, and so on, the training, second-wave systems. These systems tend to have unexpected failure modes.

In front of you, there should be an example of the brittleness of AI. These are drawn from the academia mixture. You may have seen these before. In the first picture, on the left, there's a panda, which you and I look at with all the history that we have of looking at these critters. On the right is also a picture that looks like a panda, as well, to us. The difference is that, in the digital representation, a certain amount of "noise" represented by the middle picture was laid on top of it, and a highly trained second-wave classification system, machine-learning system, went from classifying that picture as a panda to now as a gibbon, with high certainty. The fragility of these methods—these are very literal methods. There is no semantics, there is no intelligence.

The second example is perhaps of more concern. This shows a stop sign in a physical situation. Think autonomous vehicles. To you and I, again, it's a stop sign. It has a certain shape. To a trained system, to a highly trained system, it's no longer—when you put that little white sticker—or that yellow sticker onto the stop sign, it's now classified as a speed limit sign. You can think in terms of autonomous vehicles, the brittleness and fragility of the systems. You can also think in terms of adversarial endeavors. It takes new level.

Very important to point those things out.

Today we have autonomy. We have a lot of work successes in cyber, from first- and second-wave technologies. We have novel hardware, high-performance hardware, low-energy hardware coming into place. Yes, then we have a lot of tools, and hundreds of thousands of people are being trained and really wanting to use machine learning. We have to go to the next step, this common-sense reasoning, being able to explain where this inference came from. We have to get there. Otherwise, trust won't come into place.

What we've done is to talk about, in our new initiative, robust AI, dealing with adversarial AI, both unintentional and intentional, high-performance, in terms of compute cycles and minimizing energy, and delivering radically new capabilities. This is the genesis of the AI Next Campaign, creating systems capable of reasoning, regenerative, contextual, and explanatory models. We already have over 20 programs running in AI, new programs—research programs started. We have over 80 programs in the agency. About one-third of the programs in the entire agency now are either creating AI technologies or aggressive users of those technologies.

Last, to your point about workforce, we really had to get more people engaged. Typically, we put out a call for proposals—research proposals, people apply, and, 6 to 9 months later, if selected, they're on contract. We have something called AI Exploration, by which we are driving the research community to explore this—the space of the third wave aggressively. We post a topic, and we award contracts within 90 days of posting the topic. We've now done this six times. We've invested, so far, on the order of \$45 mil-

lion in this. There's tremendous uptake from the research community, these opportunities. All unclassified, all fundamental work.

From 60 years ago to now, I don't think Mr. Licklider, at the time, would have anticipated that the Department of Defense would have an AI strategy, such a huge success in recognition, and that the President would sign an AI executive order. Who would have thought?

Game-changing capabilities for the Defense Department and the world, from 60 years of investment, much accomplished, and much to do.

Thank you.

[The prepared statement of Dr. Peter Highnam follows:]

PREPARED STATEMENT BY DR. PETER HIGHNAM

DARPA'S SEMINAL ROLE IN THE FIELD OF ARTIFICIAL INTELLIGENCE

Seventy years ago, when early electronic computers ran on vacuum tubes and filled entire rooms, researchers already were striving to enable machines to think as people do. Only a few years after its start in 1958, DARPA began playing a central role in realizing this ambition by laying some of the groundwork for the field of artificial intelligence (AI). Early work in AI emphasized handcrafted knowledge, and computer scientists constructed so-called expert systems that captured the rules that the system could then apply to situations of interest. Such "first wave" AI technologies were quite successful—tax preparation software is a good example of an expert system—but the need to handcraft rules is costly and time-consuming and therefore limits the applicability of rules-based 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 future samples. Foremost among these approaches are deep learning (artificial) neural networks trained to perform a variety of classification and prediction tasks when adequate historical data is available. Therein lies the rub, however, as the task of collecting, labelling, and vetting data on which to train such "second wave" AI techniques is prohibitively costly and time-consuming.

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 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. Incorporating these technologies in military systems that collaborate with warfighters will facilitate better decisions in complex, time-critical, battlefield environments; enable a shared understanding of massive, incomplete, and contradictory information; and empower unmanned systems to perform critical missions safely and with high degrees of autonomy.

Today, DARPA is funding more than 24 programs exploring ways to advance the state of the art in AI, pushing beyond second wave machine learning towards contextual reasoning capabilities. This is in addition to more than 55 active programs that are leveraging machine learning or AI technologies in some capacity—from managing the electromagnetic spectrum to detecting and patching cyber vulnerabilities.

This level of investment has been years in the making and will define scientific and technical exploration, as well as resulting military capabilities, for decades to come.

CURRENT PROGRAMS

DARPA's Lifelong Learning Machines (L2M) program is exploring ways to enable machines to learn while doing without catastrophic forgetting. Such a capability would enable systems to improve on the fly, recover from surprises, and keep them from drifting out of sync with the world. First announced in 2017, L2M research teams are developing complete systems and their components, as well as exploring learning mechanisms in biological organisms with the goal of translating them into computational processes. Discoveries in both technical areas are expected to generate new methodologies that will allow AI systems to learn and improve during tasks, apply previous skills and knowledge to new situations, incorporate innate system limits, and enhance safety in automated assignments. While the program is still

in its early stages, L2M researchers already have identified and solved challenges associated with building and training a self-reproducing neural network.

DARPA is also currently running a program called Explainable AI or XAI to develop new machine-learning architectures that can produce accurate explanations of their decisions in a form that makes sense to humans. As AI algorithms become more widely used, reasonable self-explanation will help users understand how these systems work, and how much to trust them in various situations. XAI specifically aims to create a suite of machine learning techniques that produce explainable models—while maintaining a high level of prediction accuracy so human users understand, appropriately trust, and effectively manage the emerging generation of artificially intelligent partners. Enabling computing systems in this manner is critical because sensor, information, and communication systems generate data at rates beyond what humans can assimilate, understand, and act upon.

The real breakthrough for artificial intelligence, however, will not come until researchers figure out a way for machines to learn or otherwise acquire common sense. Without common sense, AI systems will be powerful but limited tools that require human inputs to function. With common sense, an AI could become a partner in problem solving. Common sense knowledge is so pervasive in our lives that it can be hard to recognize. For example, in conflict and warzone situations, people tend to make snap decisions about the cause of the problem and ignore evidence that does not support their point of view. To act as a valued partner in such situations, the AI system will need sufficient common sense to know when to speak and what to say, which will require that it have a good idea of what each person knows. Interrupting to state the obvious would quickly result in its deactivation, particularly under stressful conditions.

In order to find answers to the common sense problem, DARPA launched in October of last year the Machine Common Sense (MCS) program, which will explore recent advances in cognitive understanding, natural language processing, deep learning, and other areas of AI research. MCS is pursuing two approaches for developing and evaluating different machine common sense services. The first approach seeks to create computational models that learn from experience and mimic the core domains of cognition as defined by developmental psychology. This includes the domains of objects (intuitive physics), places (spatial navigation), and agents (intentional actors). Researchers will develop systems that think and learn as humans do in the very early stages of development, leveraging advances in the field of cognitive development to provide empirical and theoretical guidance.

To assess the progress and success of the first strategy's computational models, researchers will explore developmental psychology research studies and literature to create evaluation criteria. DARPA will use the resulting set of cognitive development milestones to determine how well the models are able to learn against three levels of performance: prediction/expectation, experience learning, and problem solving.

The second MCS approach will construct a common sense knowledge repository capable of answering natural language and image-based queries about common sense phenomena by reading from the Web. DARPA expects that researchers will use a combination of manual construction, information extraction, machine learning, crowdsourcing techniques, and other computational approaches to develop the repository. The resulting capability will be measured against the Allen Institute for Artificial Intelligence (AI2) Common sense benchmark tests, which are constructed through an extensive crowdsourcing process to represent and measure the broad common sense knowledge of an average adult.

AI NEXT CAMPAIGN

DARPA announced in September 2018, a multi-year investment of more than \$2 billion in new and existing programs called the "AI Next" campaign. 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.

AI Next builds on DARPA's five decades of AI technology creation to define and to shape the future, always with the Department's hardest problems in mind. Accordingly, DARPA will create powerful capabilities for the DoD by attending specifically to the following areas:

New Capabilities: AI technologies are applied routinely to enable DARPA R&D projects, including more than 60 ongoing programs, such as the Electronic Resurgence Initiative, and other programs related to real-time analysis of sophisticated cyber attacks, detection of fraudulent imagery, construction of dynamic kill-chains for all-domain warfare, human language technologies, multi-modality automatic tar-

get recognition, biomedical advances, and control of prosthetic limbs. DARPA will advance AI technologies to enable automation of critical Department business processes. One such process is the lengthy accreditation of software systems prior to operational deployment. Automating this accreditation process with known AI and other technologies now appears possible.

Robust AI: AI technologies have demonstrated great value to missions as diverse as space-based imagery analysis, cyber attack warning, supply chain logistics and analysis of microbiologic systems. At the same time, the failure modes of AI technologies are poorly understood. DARPA is working to address this shortfall, with focused R&D, both analytic and empirical. DARPA's success is essential for the Department to deploy AI technologies, particularly to the tactical edge, where reliable performance is required.

Adversarial AI: The most powerful AI tool today is machine learning. Machine learning systems are easily duped by changes to inputs that would never fool a human. The data used to train such systems can be corrupted, and the software itself is vulnerable to cyber attack. These areas, and more, must be addressed at scale as more AI-enabled systems are operationally deployed.

High Performance AI: Computer performance increases over the last decade have enabled the success of machine learning, in combination with large data sets, and software libraries. More performance at lower electrical power is essential to allow both data center and tactical deployments. DARPA has demonstrated analog processing of AI algorithms with 1000 times speedup and 1000 times power efficiency over state-of-the-art digital processors, and is researching AI-specific hardware designs. DARPA is also attacking the current inefficiency of machine learning, by researching methods to drastically reduce requirements for labeled training data.

Next Generation AI: The machine learning algorithms that enable face recognition and self-driving vehicles were invented over 20 years ago. DARPA has taken the lead in pioneering research to develop the next generation of AI algorithms, which will transform computers from tools into problem-solving partners. DARPA research aims to enable AI systems to explain their actions, and to acquire and reason with common sense knowledge. DARPA R&D produced the first AI successes, such as expert systems and search, and more recently has advanced machine learning tools and hardware.

In addition to new and ongoing 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 work to establish the feasibility of new AI concepts within 18 months of award. Leveraging streamlined contracting procedures and funding mechanisms enables these efforts to move from proposal to project kick-off within 3 months of an opportunity announcement.

CONCLUSION

Over its 60-year history, DARPA has made significant investments in the creation and advancement of artificial intelligence technologies that have produced game-changing capabilities for the Department of Defense and beyond. DARPA's AI Next effort is simply a continuing part of its historic investment in the exploration and advancement of AI technologies.

Current R&D investment around the world is largely focused on second wave AI or machine learning, which is very good in finding patterns in voice and imagery and has many commercial applications. The difference is, in the United States, DARPA is aggressively pursuing programs that will make second wave AI more robust for defense and security applications, all while helping realize the third wave of AI, or contextual reasoning. DARPA has unique access to the United States' world-class science and technology community, comprised of leading universities, government labs, and industry partners—this mix cannot be found or replicated anywhere else in the world. Marshalling those unique resources, the Agency's third wave research efforts will forge new theories and methods that will make it possible for machines to adapt contextually to changing situations, advancing computers from tools to true collaborative partners. Going forward, the agency will be fearless about exploring these new technologies and their capabilities—DARPA's core function—pushing critical frontiers ahead of our nation's adversaries.

Senator ERNST. Very good. Thank you so much.

Mr. Michael Brown is the Director of the Defense Innovation Unit, DIU, at the U.S. Department of Defense. DIU fields leading-edge capability to the military, using commercial technologies faster and more cost-effectively than traditional acquisition methods.

Prior to that, Mr. Brown served as a White House Presidential Innovation Fellow at the Defense Department. He has also worked as CEO [Chief Executive Officer] of Semantec Corporation and as CEO of Quantum Corporation.

Thank you, Mr. Brown, for joining us today. It's good to have you here again. If you would, please go ahead with your opening statements.

**STATEMENT OF MICHAEL A. BROWN, DIRECTOR, DEFENSE
INNOVATION UNIT**

Mr. BROWN. Thank you, Chairman Ernst, Ranking Member Peters, and Members of the Subcommittee. Thank you for inviting me here today to discuss DIU's efforts in AI.

As you said, about 6 months ago, I joined DIU as the Director, and, having led a number of technology companies, most recently Semantec, I've witnessed how new technology like AI can fundamentally redefine how we live and work, and how we fight wars.

Before joining DIU as the Director, as you mentioned, I worked as a Fellow, responding to the Secretary of Defense's request to understand China's investments in early-stage technology firms, many of which were AI-focused, and its technology transfer implications for national security.

As you mentioned in opening remarks, China and Russia have already recognized the enormous commercial and military potential of AI, and are investing heavily, with aims to become dominant. By 2025, China aims to achieve major breakthroughs in AI and increase its domestic market to reach \$60 billion. To achieve this target, the Chinese government leverages civil-military fusion, where, by law, every commercial AI innovation is immediately transferred to the Chinese military. China also leverages United States talent and resources by establishing research institutes in the United States, investing in AI-related startups in the United States, recruiting talent in the United States, and building academic partnerships.

Russia, as you mentioned, with Vladimir Putin's comments, is similarly focused on building its AI capacity, but is behind the United States and China, in terms of overall investment, research, and startups.

In the face of great-power competition, DIU is working alongside—with the rest of DOD to maintain our technological edge, not only in AI, but other dual-use technologies, as well. Accessing mature AI-driven technologies from the commercial sector is an essential component of the Defense Department's Artificial Intelligence Strategy and a paradigm shift from defense industrial base to a national security innovation base prescribed by the National Defense Strategy.

DIU's AI portfolio focuses on understanding, tracking, and vetting commercial companies' abilities to solve high-impact problems identified by our military leadership. AI projects today include work with the Air Force, Army, Navy, and components, as well as Joint Chiefs of Staff.

As a foundational technology, the DIU AI portfolio specifically prioritizes projects that address three major impact areas where AI has proven to excel commercially. Here are three examples:

First, computer vision. Adding automation to object recognition and infrastructure assessment, DIU is prototyping computer-vision algorithms in humanitarian assistance and disaster recovery use cases.

Second, large dataset analytics and predictions, making sense of massive datasets and patterns more efficiently and cost-effectively than human analysts. For example, DIU is prototyping predictive maintenance applications for Air Force and Army platforms, with the potential to save the Department billions of dollars.

Third, strategic reasoning, mapping probabilistic chains of events and developing alternative strategies to inform top-down planning in environments characterized by uncertainty, missing information, and speculation. DIU is prototyping an application that leverages AI to provide insights to high-level strategic questions.

With these projects, DIU engages across the Department on AI and makes its commercial knowledge and relationships with potential vendors available to any of the services, service labs, and components. We already have in place a strategic partnership with JAIC, which we've agreed upon with General Shanahan. Simply stated, DIU will prototype commercially successful AI applications and measure their relevance to mission imperatives. If successful, we transition those to JAIC so they can be scaled and integrated into their national mission initiatives. We look forward to working closely together with JAIC.

DIU also works with the Defense Innovation Board and will work with the newly established Congressional National Security Commission on AI to leverage the best practices and learnings from the commercial software industry executives who participate on that board.

Cultural divides and ethical differences are often blamed for the lack of closer cooperation between DOD and Silicon Valley, but, more often than not, the true deterrent is misaligned economics. Enabling DOD to be a better customer for early-stage companies will not only help DOD acquire the best commercial technology faster and cheaper, but will also provide access to the ideas of sought-after AI talent that DOD may not be able to attract. The more we collaborate with the private sector on mutually-beneficial projects, the more opportunities we'll have to engage in an open dialogue about the applications and principles for the use of AI.

DIU plans to continue its focus on AI as a key technology portfolio, solving DOD problems with commercial AI solutions to bring the Department new capabilities and encourage nontraditional technology firms to work with DOD as part of the national security innovation base, will be a priority.

Thank you.

[The prepared statement of Mr. Brown follows:]

PREPARED STATEMENT BY MICHAEL BROWN

INTRODUCTION

Chairman Ernst, Ranking Member Peters, and distinguished Members of the Subcommittee on Emerging Technologies and Threats, thank you for inviting me to appear before you today to discuss the Defense Innovation Unit (DIU) and our efforts in artificial intelligence (AI) alongside my colleagues at the Defense Advanced Re-

search Projects Agency (DARPA) and the newly formed Joint Artificial Intelligence Center (JAIC).

AI is fundamentally redefining how we live, work, and fight wars. Within the Department of Defense (DOD), AI has the potential to transform how the Department operates at all levels, from business to the battlefield. In the face of competition from China and Russia, DOD aims to maintain its technological edge through establishing a more decentralized, experimental procurement approach: cultivating a leading AI workforce, engaging academic, commercial, and international allies and partners, and developing ethical and lawful guidelines for AI use.¹

China and Russia have recognized the enormous commercial and military potential of AI and are investing heavily to become dominant in the field. In its *13th Five-Year Plan (2016–2020)* and subsequent industrial plans, the Chinese Government has outlined a comprehensive, whole-of-government strategy to become the global leader in AI.² In July 2017, the State Council released the *Next-Generation Artificial Intelligence Development Plan* that laid out a 2020 target for Chinese AI technology and applications to match international developments and create a \$22.3 billion (Renminbi [RMB] 150 billion)³ domestic market.⁴ By 2025, China will aim to achieve major breakthroughs in AI and increase its domestic market to reach \$59.6 billion (RMB 400 billion).⁵ To achieve these targets, China’s National Development and Reform Commission (China’s industrial policy-making agency) funded the creation of a national AI laboratory, and Chinese local governments have pledged more than \$7 billion in AI funding.⁶ In addition, Chinese firms and the Chinese Government are leveraging United States talent and ecosystems through the establishment of research institutes in the United States, investment in U.S. AI-related startups and firms, recruitment of U.S.-based talent, and commercial and academic partnerships.⁷ Russia is similarly focused on building its AI capacity but is behind the United States and China in terms of overall AI investment, research, and startups.⁸

Underscoring the potential magnitude of AI’s impact on the whole of society, the breadth of its applications, and the urgency of this emerging technology race, President Trump signed the executive order, *Maintaining American Leadership in Artificial Intelligence*, on February 11, 2019, launching the American AI Initiative. This was immediately followed by the release of DOD’s first-ever AI strategy.⁹ These documents emphasize the essential role of research and development (R&D) across the Federal Government, business, and academia to maintain U.S. leadership in AI, bolster national security, and safeguard the values shared by the United States, its allies, and partners.

To increase intergovernmental coordination, DIU will engage with DARPA and JAIC, among other DOD entities focused on AI, as well as make its commercial knowledge and relationships with potential vendors available to any of the Services and Service Labs. For example, DIU will be working with the Services and Defense Agencies as DOD customers for the projects it undertakes. AI projects today include work with the Air Force, Army, Navy, and components as well as the Joint Chiefs of Staff. DIU also works with the Defense Innovation Board and the newly estab-

¹United States Department of Defense, *Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity*, (February 12, 2019), <https://media.defense.gov/2019/Feb/12/2002088963/-1/-1/1/SUMMARY-OF-DOD-AI-STRATEGY.PDF>.

²Central Committee of the Communist Party of China Central Compilation and Translation Press, *The 13th Five-Year Plan for Economic and Social Development of the People’s Republic of China (2016–2020)*, (March 17, 2016), 64.

³For this testimony, the exchange rate is: \$1 = 6.72 RMB.

⁴PRC State Council, *Xinyidai rengongzhieng fazhan guihua de tongzhi [Next-Generation Artificial Intelligence Development Plan]*, PRC State Council-2017–35 (July 20, 2017).

⁵Ibid.

⁶“2017 Annual Report to Congress,” (United States-China Economic and Security Review Commission, November 15, 2017), 525–527; Michael Brown and Pavneet Singh, “China’s Technology Transfer Strategy: How Chinese Investments in Emerging Technology Enable a Strategic Competitor to Access the Crown Jewels of United States Innovation,” (Defense Innovation Unit, January 2018).

⁷Ibid.

⁸Alina Polyakova, “Weapons of the Weak: Russia and AI-driven Asymmetric Warfare,” (Brookings Institution, November 14, 2018); “Artificial Intelligence -A Strategy for European Startups: Recommendations for Policymakers,” (Asgard and Roland Berger, May 14, 2018).

⁹Maintaining American Leadership in Artificial Intelligence, Exec. Order No. 13859, 84 Fed. Reg. 3967 (February 11, 2019). U.S. Department of Defense, *Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity*.

lished Congressional Commission on AI to leverage the best practices and learnings from the commercial software industry executives who participate on the Board.

In particular, we anticipate a close partnership with JAIC, the outlines of which DIU has already agreed upon with Lieutenant General Jack Shanahan. As JAIC matures, we anticipate that DIU will be at the leading edge of the Department's National Mission Initiatives (NMIs), proving that commercial technology can be applied to critical national security challenges via accelerated prototypes that lay the groundwork for future scaling through JAIC. DIU looks to bring in key elements of AI development pursued by the commercial sector, which relies heavily on continuous feedback loops, vigorous experimentation using data, and iterative development, all to achieve the measurable outcome, mission impact.

REINVIGORATING OUTREACH TO COMMERCIAL TECHNOLOGY COMPANIES: DEFENSE INNOVATION UNIT

DIU is focused on accelerating commercial technology into the hands of men and women in uniform. Its staff is comprised of Active Duty military from every service, civilians, and individuals with extensive private sector experience and deep ties into venture capital and startup communities. DIU partners with the Services, Combatant Commands, and component organizations to seek out and rapidly prototype advanced commercial solutions—spanning AI, autonomy, cyber, human systems, and space—to address military challenges ranging from the tactical level to the defense enterprise. Within OUSD(R&E) and the broader DOD, DIU is unique in its focus on developing and fielding commercial hardware, software, and methodologies within an approximately 24-month timeframe.

Accessing R&D and mature AI-driven technologies advanced by the commercial sector is an essential component of the strategic approach defined by the *2018 Department of Defense Artificial Intelligence Strategy* and the paradigm shift from “defense industrial base” to “national security innovation base” prescribed by the *2018 National Defense Strategy*. Senior leaders in the Department understand that DOD no longer holds a monopoly on emerging technologies like AI that will sway strategic, deterrent, and battlefield advantage in future wars.¹⁰ U.S. businesses began outspending the Federal Government in R&D in the 1980s, and now, industry-funded R&D represents approximately 67 percent of total U.S. investments.¹¹

Moreover, venture capital funding for AI-related companies reached record highs in 2018, increasing 72 percent from 2017 totaling \$9.3 billion.¹² With offices in Silicon Valley, Boston, Austin, and Washington, D.C., DIU is embedded in the core innovation ecosystems where these deals are taking place, AI startups are thriving, and top tech companies and universities are conducting groundbreaking research.¹³ DIU's location not only facilitates deeper ties with leading edge companies but allows the Department to establish a closer relationship with venture firms as they scout the horizon for their next big bets and take into consideration clear demand signals from DOD.

DIU seeks to lower barriers to entry into the defense market by more closely matching commercial terms and contracting speeds via its Commercial Solutions Opening (CSO) solicitation process, which leverages Other Transaction (OT) authority. Traditional acquisition pathways overburden technology companies operating with little or no prior DOD contracting experience and runways that are often shorter than the typical time to award a contract under the Federal Acquisition Regulation. Shaping the DOD into a better customer through new processes allows the De-

¹⁰ Ben FitzGerald, Alexandra Sander, Jacqueline Parziale, “Future Foundry: A New Strategic Approach to Military-Technical Advantage,” (Center for a New American Security, December 2016).

¹¹ DIU exists, in part, in response to the growing disparity between federal and commercial R&D, leading to a global technology landscape in which commercial companies are leading the development of some of the world's most advanced technologies: “In 1960, the United States accounted for 69 percent of global R&D, with U.S. defense-related R&D alone accounting for more than one-third of global R&D. The Federal Government funded approximately twice as much R&D as U.S. business. However, from 1960 to 2016, the U.S. share of global R&D fell to 28 percent, and the Federal Government's share of total U.S. R&D fell from 65 percent to 24 percent, while business's share more than doubled from 33 percent to 67 percent. As a result of these global, national, and federal trends, federal defense R&D's share of total global R&D fell to 3.7 percent in 2016.” Moshe Schwartz and Heidi M. Peters, “Department of Defense Use of Other Transaction Authority: Background, Analysis, and Issues for Congress,” Report no. R45521 (Congressional Research Service), 43.

¹² “MoneyTree Report: Q4 2018,” (PricewaterhouseCoopers and CB Insights, 2019), <https://www.pwc.com/us/en/moneytree-report/moneytree-report-q4-2018.pdf>.

¹³ The top five states for AI investment in 2018, in order, were California, Massachusetts, New York, Texas, and Washington. Ibid.

partment to acquire the best commercial technology faster and cheaper than the traditional system. Furthermore, new acquisition pathways create more opportunities for national security service, making DOD a more competitive employer of AI and other sought-after tech talent through commercial contracts.

While cultural divides and ethical differences are often blamed for the lack of closer cooperation between DOD and Silicon Valley, more often than not, the true deterrent is misaligned economics.¹⁴ Since DIU opened its first competitive solicitation using the CSO process in June 2016, there has been no shortage of top-performing companies interested in working alongside our DOD partners to solve some of the toughest military challenges. DIU has awarded contracts to 103 of these companies, 43 of which are first-time, non-traditional DOD contractors.¹⁵

DIU'S AI STRATEGY & PROJECTS

Commercial AI companies are active across a wide range of sectors and the opportunities for dual-use applications within DOD are vast. The DIU AI portfolio focuses on understanding, tracking, and vetting these commercial companies' ability to solve high-impact problems identified by our military leadership and DOD partners. The portfolio team combines depth of commercial AI, machine learning, and data science experience from the commercial sector with military operators. As a foundational technology, AI-driven solutions appear across a number of DIU projects administered by other portfolio teams, however, the AI portfolio specifically prioritizes projects that address three major impact areas where AI is proven to excel:

1. Computer vision: AI and machine learning adds automation to object recognition and infrastructure assessment; for example, DIU is prototyping computer vision algorithms in humanitarian assistance and disaster recovery scenarios.
2. Large dataset analytics and predictions: AI and machine learning can help make sense of massive datasets and patterns more efficiently and cost-effectively than human analysts; for example, DIU is prototyping predictive maintenance applications for Air Force and Army platforms.
3. Strategic reasoning: AI and machine learning has the capacity to inform top-down planning in environments characterized by uncertainty, missing information, and speculation; for example, DIU is prototyping an application that leverages AI to reason about high-level strategic questions, map probabilistic chains of events, and develop alternative strategies.

Furthermore, DIU has a strategic partnership with JAIC wherein DIU's prototype AI applications "pull" on commercial capabilities, prove and measure their applicability to mission imperatives, and (if successful) are transitioned to JAIC to be scaled and integrated into their NMI. In previous testimony before the House Armed Services Subcommittee on Emerging Threats and Capabilities, Dr. Lisa Porter, Deputy Under Secretary of Defense for Research and Engineering, discussed the need to rigorously assess AI performance against quantitative metrics tied to specific mission needs.¹⁶ DIU's partnership with JAIC aims to institutionalize the rigor Dr. Porter spoke of—the AI portfolio's prototype projects are designed to drive metrics, establish benchmarks, and contribute infrastructure towards a common foundation as described by the *2018 Department of Defense Artificial Intelligence Strategy*.¹⁷

Following are three specific use cases and projects which employ AI technology:

Applying Computer Vision to Humanitarian Assistance and Disaster Relief

In 2018, DIU hosted the xView Challenge to test computer vision and the use of algorithms to automatically identify objects from images. The competition attracted

¹⁴Rachel Olney, "The Rift Between Silicon Valley and the Pentagon is Economic, not Moral," War on the Rocks, January 28, 2019, <https://warontherocks.com/2019/01/the-rift-between-silicon-valley-and-the-pentagon-iseconomic-not-moral/>.

¹⁵The 2018 OT Guide defines non-traditional defense contractor as "an entity that is not currently performing and has not performed, for at least the one-year period preceding the solicitation of sources by DOD for the procurement or transaction, any contract or subcontract for the DOD that is subject to full coverage under the cost accounting standards prescribed pursuant to section 1502 of title 41 and the regulations implementing such section (see 10 U.S.C. 2302(9))." *Defense Acquisition University, Other Transactions (OT) Guide*, (November 2018), <https://aaf.dau.mil/ot-guide/>.

¹⁶Dr. Lisa Porter, Deputy Under Secretary of Defense for Research and Engineering, testimony to the Subcommittee on Emerging Threats and Technologies, House Armed Services Committee, December 11, 2018, <https://docs.house.gov/meetings/AS/AS26/20181211/108795/HHRG-115-AS26-Wstate-PorterL-20181211.pdf>.

¹⁷U.S. Department of Defense, *Summary of the 2018 Department of Defense Artificial Intelligence Strategy: Harnessing AI to Advance Our Security and Prosperity*.

more than 4,000 submissions from 100 participants from around the world including companies, universities, and individuals. The top performing algorithms were 300 percent more accurate than the government produced baseline, which helps advance computer vision proficiency across four core elements of overhead imagery analysis. The winning algorithm was then used to automate post-disaster assessments in the wake of Hurricane Florence, assisting emergency personnel to quickly identify flooded areas and impassable roads. This use of AI holds the potential to automate post-disaster assessments and accelerate search and rescue efforts on a global scale.

Scaling Predictive Maintenance to Improve Readiness and Cut Costs

DIU's predictive maintenance prototype project provides a specific example of the synergy that we plan to foster between OUSD(R&E) and JAIC. DIU identified a leading commercial airline industry supplier of predictive maintenance solutions and launched a six-month prototype for E-3 Sentry aircraft maintenance. The prototype began with testing predictions at the part and sub-part level against historical actuals to establish the robustness of the AI and its relevance to operational decision-making. This methodology effectively assesses the accuracy of the AI predictions, how much they matter, and in which areas the most impact can be expected (as defined by cost and/or platform availability). Early results of Air Force applications indicate a potential 28 percent decrease in unscheduled maintenance on the E-3 across six sub-systems and more than 32 percent reduction on the C-5 across ten sub-systems. DIU is partnering with JAIC to scale this solution across multiple aircraft platforms, as well as ground vehicles beginning with DIU's complementary predictive maintenance project focusing on the Army's Bradley Fighting Vehicle. This is one of DIU's highest priority projects for fiscal year 2019 given its enormous potential for impact on readiness and reducing costs.

Automating Cyber Vulnerability Detection & Remediation

DOD's current vulnerability discovery process for weapons systems software lacks the capability to scale because it relies on time and labor-intensive human search and analysis. According to an October 2018 GAO report, \$1.66 trillion of weapon system development is at risk due to the scale of unmitigated cyber vulnerabilities.¹⁸ One of the tools to address these vulnerabilities is DIU's Project VOLTRON, which is an active prototype project that has demonstrated artificially intelligent detection of previously unknown vulnerabilities in classified weapons systems. The project seeks to demonstrate autonomous exploitation and patching; development of an application programming interface (API) for extensibility; and integration into DOD software development environments. This would give the DOD an end-to-end capability that goes from writing software free of vulnerabilities to remediating vulnerabilities in compiled mission software for which source code is not available. The products from Project VOLTRON help make DOD owned systems more resilient to cyber attacks and inform program offices of configuration errors faster and with less errors than humans. An initial capability demonstration of the commercial technologies leveraged by VOLTRON yielded previously undiscovered bugs within the first few minutes of testing against representative aircraft software provided by a defense contractor. In addition, previously unknown vulnerabilities have already been discovered in currently fielded aircraft systems. Integration into software development pipelines will ensure that most vulnerabilities can be found and remediated before future systems go into production and/or deployment.

Tremendous Opportunity for DOD/Commercial Collaboration

Commercial industry is breaking ground on AI applications supporting a wide range of business areas and there is a tremendous opportunity to re-establish and grow the ties between the user communities in DOD, commercial entrepreneurs, and partners in universities and labs dedicated to performing the basic research that provides a foundation for future advances. While DIU has found the vast majority of high-tech companies focused on AI to be willing and enthusiastic partners, there is work yet to be done to provide and encourage an open dialogue with the private sector and researchers about applications and principles of use for this powerful tool. DIU will continue to solve DOD problems with commercial AI solutions to bring the Department new capabilities and encourage non-traditional technology firms to work with DOD to grow the national security innovation base.

Senator ERNST. Thank you very much, Mr. Brown.

¹⁸United States Government Accountability Office, *Weapon Systems Cybersecurity: DOD Just Beginning to Grapple with Scale of Vulnerabilities*, GAO-19-128 (October 2018), <https://www.gao.gov/assets/700/694913.pdf>.

Last, certainly not least, we have Lieutenant General John N.T. “Jack” Shanahan. General Shanahan is the Director, Joint Artificial Intelligence Center, Office of the Department of Defense Chief Information Officer (CIO) at the Pentagon. General Shanahan is responsible for accelerating the delivery of AI-enabled capabilities, scaling the departmentwide impact of AI, and synchronizing AI activities to expand joint force advantages.

General, please go ahead.

STATEMENT LIEUTENANT GENERAL JOHN N.T. SHANAHAN, USAF, DIRECTOR, JOINT ARTIFICIAL INTELLIGENCE CENTER, OFFICE OF THE DEPARTMENT OF DEFENSE CHIEF INFORMATION OFFICER

General SHANAHAN. Good afternoon, Madam Chairwoman, Ranking Member, distinguished Members of the Subcommittee. Thank you for the opportunity to testify before the Subcommittee today on the Department’s artificial intelligence committees.

I’m honored to serve as the first Director of DOD’s Joint AI Center, or the JAIC. I’ve been in this position for just over 2 months. Previously, I served in the Under Secretary of Defense for Intelligence, where, for 2 years, I was the Director of the Algorithmic Warfare Cross-functional Team, also known as Project Maven.

Artificial intelligence, or AI, is rapidly changing an ever-expanding range of businesses and industries. It offers the opportunity to transform every corner of the Department from multidomain operations at the edge to back-office business functions. As described in the 2019 National Defense Strategy, or NDS, it is also poised to change the character of warfare. Thoughtful, responsible, and human-centered adoption of AI in the DOD will strengthen our national security and transform the speed and agility of our operations.

Last June, then-Deputy Secretary of Defense Shanahan directed the DOD Chief Information Officer, Mr. Dana Deasy, to establish the Joint AI Center to accelerate the delivery and adoption of AI-enabled capabilities, scale the departmentwide impact of AI, and synchronize the Department’s AI activities. In parallel, DOD submitted its first AI Strategy to the Congress as an annex to the NDS. Last month, the Department released an unclassified summary of DOD’s AI Strategy, doing so on the heels of the President’s signature of the executive order on AI. The JAIC’s missions and functions nest well under the principles and objectives outlined in the AI executive order.

JAIC’s formation also dovetails section 238 of the fiscal year 2019 NDAA. Additionally, JAIC will benefit from, and help bring to fruition, recommendations of the new National Security Commission (NSC) on AI. I was privileged to talk with the members of the Commission yesterday, when they met for the first time. I know Senator Heinrich was also there.

The JAIC is the focal point of the DOD AI Strategy and was established to provide a common vision, mission, and focus to drive departmentwide AI capability delivery. I want to highlight three primary themes for our approach:

First, delivering AI-enabled capabilities at speed. JAIC is collaborating with teams across DOD to identify, prioritize, and select

mission needs, and then execute a series of cross-functional use cases to demonstrate value and spur momentum. We need early demonstrable wins to show practical results and the art of the possible, followed by scaling across the enterprise. Projects fall into two main categories: national mission initiatives, or NMIs, and component mission initiatives, or CMIs. NMIs are driven and executed by the JAIC as broad, joint, crosscutting AI challenges; whereas, CMIs are component-led, but are able to make use of JAIC's common tools, libraries, best practices, and more.

Our emphasis on rapid, iterative delivery of AI complements the Department's ongoing work at the other end of the AI spectrum, in fundamental research and development, as you heard from Dr. Highnam. Our first two NMIs are predictive maintenance with the Special Operations Command and U.S. Army H-60 helicopter use case and humanitarian assistance and disaster relief, in which we will field AI capabilities in support of natural events, such as wildfires and hurricanes. We are also getting a headstart on a planned fiscal year 2020 cyberspace NMI designed to use AI-enabled capabilities to improve event detection, network mapping, and compromised-account identification.

At the same time, we are now in the early problem-framing stage for another proposed NMI in fiscal year 2020 that will be more oriented on the NDS, National Defense Strategy, in operations against peer competitors. We are also in initial discussions with the Military Services, components, and combatant commands on the applicability of AI to help with solutions in areas as diverse as talent management, suicide prevention, preventive medicine, and information operations, among others.

The second theme is scale. As I know firsthand from Project Maven, scaling AI across the enterprise is hard, but it's also the only way we will realize the full benefits of AI in the Department. JAIC's early projects serve a dual purpose, to deliver new capabilities to end users as well as to incrementally develop the common foundation that is essential for scaling AI's impact across DOD. We will put this foundation in place in a way that aligns with DOD enterprise cloud adoption.

The third theme is talent. We built the initial JAIC team with representatives detailed from across each of the services and other components. Today, we have 30 people, growing to over 50 within the next 5 months. We do not receive our permanent manpower until fiscal year 2020.

For the JAIC to succeed, we must attract and cultivate a select group of mission-driven, world-class AI talent, to include enticing experts from the tech industry to serve with us. The success of human-centered AI and human-machine teaming within DOD requires growing and sustaining an AI-ready force, one that is conversant in the language of AI, willing and able to operate with a new kind of speed and agility.

In closing, the JAIC is now up and running, and we're open for business. Thank you for your strong support in driving momentum in this critical area. I look forward to continuing to work with Congress as we advance the adoption of AI across the Department and use the JAIC to accelerate our progress.

Thank you for the opportunity to testify this afternoon. I look forward to your questions.

[The prepared statement of General Shanahan follows:]

PREPARED STATEMENT BY LIEUTENANT GENERAL JOHN "JACK" N.T. SHANAHAN

INTRODUCTION

Good afternoon Madam Chairwoman, Ranking Member, and distinguished Members of the Subcommittee. Thank you for this opportunity to testify before the Subcommittee today on the Department's Artificial Intelligence (AI) Initiatives.

I am Lieutenant General Jack Shanahan, the Director of the Joint Artificial Intelligence Center or JAIC. I have been in my current position for a little over two months. Previously, I served in the Under Secretary of Defense for Intelligence as the Director of the Algorithmic Warfare Cross-Functional Team or Project Maven, the Department's pathfinder project to integrate AI capabilities to augment, accelerate, and automate collection from a variety of manned and unmanned intelligence platforms and sensors.

AI is rapidly changing an ever-expanding range of business and industry. As described in the 2018 National Defense Strategy (NDS), AI is also poised to change the character of warfare. Structurally, we know AI has the potential to be an enabling layer across nearly everything—meaning countless applications in industry and everyday life, while offering the opportunity to positively transform every corner of the Department. We envision innovative concepts that change the way we plan and fight, including improvements in the way we perceive our environment, maintain our equipment, train our men and women, defend our networks, operate our back offices, provide humanitarian aid and respond to disasters; and more. By harnessing the power of AI in defense, we will better support and protect American servicemembers, safeguard our citizens, defend our allies, and improve the effectiveness, affordability, and speed of our operations.

Other nations, particularly strategic competitors such as China and Russia, are making significant investments in AI for military purposes. These investments threaten to erode our technological and operational advantages and destabilize the free and open international order. The Department of Defense, together with our allies and partners, must adopt AI to maintain its strategic position, prevail on future battlefields, and safeguard this order.

Per the NDS, the Department will accelerate the delivery and adoption of AI to expand our military advantages and create a force fit for our time. AI will enhance operational effectiveness, improve readiness, and increase efficiency in the general business practices of the Department. We will make a concerted effort to move AI technologies in a direction that improves our odds of long-term security, peace, and stability through vigorous dialogue and multilateral cooperation on the ethical, safe, and lawful use of AI for national security and establishing new norms for responsible behavior, consistent with the law. The Department's AI transformation will ensure that we maintain the ability to execute our vital mission of protecting the security of our nation, deterring war, and preserving peace.

ESTABLISHMENT OF JAIC

Last June, then-Deputy Secretary of Defense Patrick Shanahan directed Mr. Dana Deasy, the Department's Chief Information Officer, to establish the Joint AI Center. This new organization is tasked to accelerate the delivery of AI-enabled capabilities, scale the Department-wide impact of AI, and synchronize the Department's AI activities. In parallel, the Department submitted its first AI Strategy to Congress, an annex to the NDS that captures the integrated set of decisions we are making now to harness AI to advance our security and prosperity. Last month, the Department released an unclassified summary of the classified DOD AI strategy, in support of the President's Executive Order on AI (Maintaining American Leadership in Artificial Intelligence) that calls for greater AI investment, harmonization of standards, and training and workforce development initiatives. The JAIC's missions and functions nest well under the principles and objectives outlined in the AI Executive Order.

The founding of JAIC supports implementation of section 238 of the fiscal year 2019 National Defense Authorization Act, this provision directed a joint approach to coordinate the efforts of the Department to develop, mature, and transition AI technologies into operational use. The Department views the requirements of section 238 as a strategic opportunity to improve its posture for AI. In fact, we used elements from the language in section 238 to help frame the JAIC's roles, missions,

and functions. In December 2018, JAIC commissioned a team from the RAND Corporation to support our analysis. The RAND team built its analytical framework, completed initial DOD-wide data collection, and is currently building interview protocols and contact lists for engaging with industry.

As part of this, I will now touch on how we are partnering with the Under Secretary of Defense (USD) Research & Engineering (R&E), the role of the Military Services, the Department's initial focus areas for AI delivery, and how JAIC is supporting whole-of-government efforts in AI.

As the focal point of the DOD AI Strategy, the JAIC was established to provide a common vision, mission, and focus to drive Department-wide AI capability delivery. JAIC will operate across the full AI delivery lifecycle, emphasizing near-term prototyping, execution, and operational adoption to meet current needs. JAIC's work will complement the AI efforts of USD(R&E), which are focused on foundational research, longer-term technology creation, and innovative concepts. Both JAIC and USD(R&E) will need to collaborate effectively and succeed individually for the DOD to implement its ambitious AI strategy.

The JAIC communicates a consistent message about transforming DOD through AI. This refers to the transformation that happens when you field technology on operationally-relevant timelines, enable frontline men and women to experiment with it based on their own creativity, and ultimately generate new ways of working that solve our most critical challenges and enhance our military strength. As we move to rapidly incorporate AI, those men and women in America's military will remain our enduring source of strength. We will use AI-enabled information, tools, and systems to empower and augment, not replace, those who serve.

To derive maximum value from AI application throughout the Department, JAIC will operate across an end-to-end lifecycle of problem identification, prototyping, integration, scaling, transition, and sustainment. Emphasizing commerciality to the maximum extent practicable, JAIC will partner with the Services and other components across the Joint Force to systematically identify, prioritize, and select new AI mission initiatives. Then JAIC will stand up cross-functional teams that will rapidly execute a sequence of use cases that demonstrate value and spur momentum. We need early, demonstrable wins that show practical results and the art of the possible. Then, we must scale these capabilities across the enterprise. To do this, JAIC is engaging with leading commercial and academic partners for prototypes, and employing standardized processes with respect to areas such as data management, testing and evaluation, assessment of delivered capabilities, and program protection and cybersecurity. Our approach has been directly informed by the Department's AI pathfinder activity, Project Maven, which successfully identified and is beginning to address key challenges with integrating AI into operations. This program put in place an initial set of data, tools, and infrastructure for AI delivery, as well as initial templates for contracting and acquisition, testing and evaluation, operational assessment, and program protection.

JAIC's early projects serve a dual purpose: to deliver new AI-enabled capabilities to end users, and to help incrementally develop a common foundation that is essential for scaling AI's impact across DOD. This foundation includes shared data, reusable tools, frameworks, libraries, and standards, and AI cloud and edge services. JAIC will work with teams throughout the Department to ensure that they can leverage this foundation to accelerate their progress in a manner that aligns with DOD enterprise cloud adoption. Our enterprise approach for AI and enterprise cloud adoption as outlined in the DOD-wide Cloud Strategy are mutually reinforcing, mutually dependent undertakings. Finally, JAIC will provide ongoing support to the efforts of the Services and other organizations to ensure continuous improvement, assessment, and sustainment of AI systems and solutions across the enterprise.

The AI capability delivery efforts that will go through this lifecycle will fall into two categories: National Mission Initiatives (NMI) and Component Mission Initiatives (CMI). As outlined in the DOD AI Strategy, a NMI is a pressing operational or business reform joint challenge, typically identified from the National Defense Strategy's key operational problems or nominated by a mission owner, and requiring multi-service innovation, coordination, and the parallel introduction of new technology and new operating concepts. NMIs are typically driven by JAIC and are executed by cross-functional teams that comprise both JAIC personnel as well as subject matter specialists from across the Department on a rotational basis. Execution of these projects will be essential for putting in place our initial common foundation.

The second project category is a Component Mission Initiative (CMI), which is a component-level challenge that can be solved through AI. JAIC will work closely with individual components on CMIs to help identify, shape, and accelerate their Component-specific AI deployments through funding support; usage of common foundational tools, libraries, cloud infrastructure; application of best practices; part-

nerships with industry and academia; and so on. The Component will be responsible for identifying and implementing the organizational structure required to accomplish its project in coordination and partnership with the JAIC.

We will form teams to work with the Services, Components, and Combatant Commands on potential CMIs. Based on initial conversations with all of these stakeholders, I fully expect that we will see rapid growth in the number of CMIs in Fiscal Year 2020. We are in early discussions with the Services, Components, and Combatant Commands on the applicability of AI to help with solutions in areas as diverse as talent management, suicide prevention, preventive medicine, installation and force protection, information operations, operational war planning, and modeling and simulation. Additionally, we intend to identify smart automation initiatives that could provide near-term dividends in terms of increased effectiveness and efficiency for back-office functions.

All of the Services are increasing their levels of investment in AI-related capabilities in near term. The JAIC is already forming strong partnerships with the Services and key Components. For example, the Army established a new AI Task Force that is working closely with the JAIC on predictive maintenance. We are actively engaged in an effort to apply data-driven insights to equipment availability at U.S. Special Operations Command and in the U.S. Air Force in partnership with Defense Innovation Unit (DIU). We are partnering with U.S. Cyber Command and the National Security Agency to shape a new cyberspace-related mission initiative. These early efforts will better define how we make use of common approaches to data, tools, libraries, architectures, development approaches, and more.

JAIC's focus on near-term AI implementation and adoption complements efforts within the USD (R&E). Organizations such as the Defense Advanced Research Projects Agency (DARPA) are focused on the future or next wave of AI research and longer-term technology creation. When it comes to research for the future versus the ability to apply it now at scale, DOD needs the best of both, and they feed one another—USD(R&E) will feed JAIC with updates on leading-edge AI technologies and concepts, and JAIC will provide R&E insights from operational fielding, user feedback, and data. There is a distinct and shared vision of an enterprise approach promulgated by USD(R&E) and DOD CIO. JAIC is already working with DIU, DARPA, and the Strategic Capabilities Office to improve integration and enhance unity of effort on current and future AI projects.

Further examples of early NMI's include:

- *Perception*. Improve the speed, completeness, and accuracy of Intelligence, Surveillance, Reconnaissance (ISR) Processing, Exploitation, and Dissemination (PED). Project Maven's efforts are included here. -Predictive Maintenance (PMx). Provide computational tools to decision makers to help them better forecast, diagnose, and manage maintenance issues to increase availability, improve operational effectiveness, and ensure safety, at reduced cost.
- *Humanitarian Assistance/Disaster Relief (HA/DR)*. Reduce the time associated with search and discovery, resource allocation decisions, and executing rescue and relief operations to save lives and livelihood during disaster operations.
- *Cyber Sensemaking*. Detect and deter advanced adversarial cyber actors who infiltrate and operate within the DOD Information Network (DODIN) to increase DODIN security, safeguard sensitive information, and allow warfighters and engineers to focus on strategic analysis and response.

We selected these initiatives to deliver mission impact at speed, demonstrate the proof of concept for the JAIC operational model, enable rapid learning and iterative process refinement, and build out our library of reusable tools while validating our enterprise cloud architecture. These efforts will benefit us by growing more AI credibility and expertise within the JAIC that will return to the Services and Components to help accelerate and sustain their own AI projects.

For the predictive/preventive maintenance NMI, we are starting with Army and Army Special Operations helicopters (H-60s). There is sufficient data available to train algorithms, there will be defined return on investment criteria, and this project helps address the Secretary's direction to the Services to improve their maintenance readiness rates. We anticipate moving to other airframes and vehicles, to include working with DIU to scale the promising results they have demonstrated using AI for predictive maintenance on other Air Force and Army platforms.

For the humanitarian assistance and disaster relief (HA/DR) NMI, we are already applying lessons learned and reusable tools from Project Maven to field AI capabilities in support of federal responses to events such as wildfires and hurricanes—where DOD plays a supporting role. One of the most important benefits of this NMI is that it is an inspiring, societally-beneficial, life-saving mission that is not only whole-of-government but whole-of-society. It brings in interagency, state and local

governments, non-governmental organizations, allied and partner nations, and more. It offers a unique opportunity to combine DOD efforts with industry and academia in a new type of public-private endeavor to operationalize AI to solve our most challenging problems. Doing this at scale to address disasters on an integrated basis creates the potential to both save lives and livelihood as well as advance common tools, lessons, and partnerships for the benefit of many DOD missions.

We are also in the early problem-framing stage for another substantial NMI in Fiscal Year 2020 that will be much more oriented on the National Defense Strategy and operations against peer and near-peer competitors. At the same time we will be seeking cutting-edge technologies within commercial industry and in DOD organizations such as DARPA that are ready for operational fielding across the Department.

While its primary focus is delivery initiatives such as these, JAIC has an important role in synchronizing DOD AI activities. This avoids duplication and excess cost, fosters sharing of lessons, and establishes a new enterprise approach for translating AI into decisions and impact at scale across the Joint Force. Under the DOD CIO's authorities and as delineated in the JAIC establishment memo, JAIC will coordinate all DOD AI-related projects above \$15 million annually. This does not mean that JAIC will control the execution of these projects or the funding for Service- and Component-level AI initiatives. It does mean that we will start to ensure, for example, that they begin to leverage common tools and libraries, manage data using best practices, reflect a common governance framework, adhere to rigorous testing and evaluation methodologies, share lessons learned, and comply with architectural principles and standards that enable scale. Over time, when properly resourced, JAIC will assume a greater role with regard to Component AI programs.

JAIC will be a key resource for whole-of-government efforts in AI, particularly as we explore as a nation the opportunities and challenges associated not merely with fundamental AI research, but also with translating the technology into decisions and impact in operations. To underscore our focus on ethics, humanitarian considerations, and both short-term and long-term AI safety, JAIC is working closely with the Defense Innovation Board (DIB) to foster a broad dialogue and provide input into the development of AI principles for defense. We are offering our perspective on crucial policy and research and development associated with operationalizing AI today in our engagements with the important work of the National Security Council Staff and the National Science and Technology Council Select Committee on AI. This remains a larger Administration priority. On February 11, 2019, President Trump signed an executive order launching the American AI Initiative, a whole of government strategy for ensuring American leadership in this important field. I want to emphasize the importance of our partnerships with Congress in all areas, but with a particular focus on AI. The establishment of the National Security Commission on Artificial Intelligence in the National Defense Authorization Act for Fiscal Year 2019 is one key example of this partnership, to which JAIC will serve as the DOD liaison element.

The ingredients for JAIC's success include: enterprise cloud adoption; world-class AI talent, particularly in areas that are scarce within DOD today such as data science and data engineering, machine and reinforcement learning, and product management; a workforce that is taking steps to become broadly AI-ready; strong partnerships with the Services, Combatant Commands, and other key components; a tight two-way integration with the critical work of USD(R&E); and energetic, combined problem-solving enabled by bonds of trust with AI leaders in industry and academia. The final ingredient for success in cultivating and sustaining an "AI Ready" force for the future is culture: specifically, the need to become a more data-centric, computer science-literate, force conversant in the language of AI, and willing and able to operate with a new kind of speed and agility. Finally, an unwavering commitment to ethics and principles. These are the table stakes in AI.

DOD's legacy culture and processes are particularly apparent in the challenges we encounter launching what can only be described as a startup within the Department of Defense. As we do so, we are incorporating lessons learned from other Department activities that resembled startups in how they responded to urgent, compelling requirements across the Department—such as the Intelligence, Surveillance and Reconnaissance Task Force, Joint Improvised Explosive Device Defeat Organization, and Project Maven. As we learned with Project Maven, there is no substitute for simply embarking on an AI project to gain critical hands-on experience, but we also acknowledge the importance of implementing more systemic AI education and training programs across the entire Department, at all levels. The Defense Innovation Board has been particularly helpful in charting a path forward in this area.

All of this requires striking the right balance between top-down pressure and bottom-up innovation. Adding funding and people will not by themselves spark the nec-

essary level of institutional change, at least not until we have a broader and deeper foundation of people—especially within all of the military Services—who understand how to operationalize and accelerate the AI pipeline.

AI will change the character of warfare, which in turn will drive the need for wholesale changes to doctrine, concept development, and tactics, techniques, and procedures. There will be a need for much more experimentation, at every level and in every domain. New operating concepts will depend on a greater understanding of what AI can (and cannot) help achieve. We need to accelerate fielding AI capabilities across the joint force, and as we do so, we must validate, refine, and adapt operating concepts. This includes thinking about entirely new concepts centered on human-machine teaming, as well as the cognitive consequences of the widespread fielding of AI capabilities.

The Joint AI Center will play a critical role in transforming the Department by delivering capability at speed to address key missions; establishing a common foundation for scaling AI's impact across the Joint Force; and facilitating AI plans, policies, and standards, including those that ensure we lead the world in the development of AI solutions that are robust, resilient, ethical, and secure. We will attract and cultivate the expertise of a world-class AI team and an AI-ready workforce.

The speed and scale of technological change required is daunting. However, the Department must embrace it if we are to reap the benefits of continued security and prosperity for the future. Our sustained, systemic approach accompanies a palpable sense of urgency. Ultimately, this needs to extend across our entire department, government, and society.

I look forward to continuing to work with Congress in an ongoing dialogue on our progress in AI adoption, and the ways in which JAIC is being used to accelerate that progress. Thank you for the opportunity to testify this afternoon, and I look forward to your questions.

Senator ERNST. Absolutely.

Again, thank you, to our witnesses, for being here today.

I'll go ahead and start with the questioning here, and then, when Senator Peters—oh, here he comes—when he returns—I'll go ahead and start with my questions, and then, Senator, I'll turn it over to you.

Again, thank you very much. This is a very interesting topic, and I think we can learn a lot from the discussion today.

To all of our witnesses here, if you could share, how are the AI efforts in R&D coordinated among DARPA, JAIC, and the services? General Shanahan, you had mentioned the synchronization of AI activities, and you had mentioned R&D. If you could all share, how do you synchronize that information? How do you share that information? What are the best techniques in doing that?

Dr. Highnam, if we could start with you, please.

Dr. HIGHNAM. Whenever DARPA starts a research program, there's a development of use cases. We seek to understand: If we succeed in that program, who cares, who benefits? That means that our program managers are out, talking inside the services all the time; in fact, across the national defense establishment, writ large. There's the natural inbuilt connection before we even start, before we even agree to start a high-risk activity. That's true whether it's hypersonics or quantum or AI. This is normal business.

Now, in fields like AI technologies, which are software tools with a lot of tail to them—sustainment, deployment tails—I personally, as an R&D guy, am really happy to now have the JAIC sent up as a partner to take on that 6-4 and on, that engineering, deployment, sustainment tail, because I expect it will make transitions into practice a lot—not simpler, but more straightforward. I fully recognize just how much hard work General Shanahan and his team are going to have to do to make that end of the business happen.

Senator ERNST. Absolutely. Thank you.

Mr. BROWN. Senator Ernst, the most important area for us to collaborate with is JAIC. As I'm sure you recognize, DARPA has a different timeframe in mind that we all benefit from, being longer term. DIU's timeframe is 24 months or less, so we aim to get commercial companies on contract within 60 days, and then a prototype fielded within 2 years. In software, we're trying to go faster than that, a year to 18 months.

In coordinating projects, our strategy with JAIC, which I'm very pleased to be in partnership with General Shanahan, is, we'll go out and look at what's successful commercially, including vendors, and then, if we prototype something successfully, we're the trial, and we want to scale it. Then we start working with JAIC for what's the infrastructure we need and how would we make that available to all of the services. For example, we're working together now to get a vendor that we have worked with on prototype to get a production contract that will be with JAIC so any of the services can take advantage of that.

For our project-base work, we also coordinate with the Vice Chairman of the Joint Chiefs. We have a quarterly meeting with General Selva, not just on AI, but our other projects, to make sure we're doing things that make sense to joint forces. Then we have monthly meetings with each of the Assistant Secretaries for Acquisition—so Army, Navy, Air Force, Dr. Jette, Dr. Roper, Hondo Geurts—to make sure that what we're working on makes sense with their priorities. The last thing we want to be doing is a lot of independent projects that don't have leverage—

Senator ERNST. Right.

Mr. BROWN.—across the—

Senator ERNST. Correct.

Mr. BROWN.—Department.

Senator ERNST. Correct. Thank you.

General SHANAHAN. Senator, while the number may vary depending on who wrote it, I think, in fiscal year 2018, the number was 511 projects that had AI as their primary focus across the Department. The question is, Are all those 511 projects towards a common end, in support of the National Defense Strategy? This question of synchronization is essential to where we're going in the JAIC, and it comes down to governance and oversight. In section 238 of the NDA [National Defense Authorization Act] actually directs governance and oversight, for this very reason.

We have a lot of work to do in this area. I would like to start by just getting our arms around all of the projects that will come out in fiscal year 2020, to understand the amount of funding, what the projects are for, not to threaten somebody's budget. That is not the intent of the JAIC. But, we owe it to the Department and to the Hill and to the public to be able to account for all of those projects and the money that's being spent.

I take that very seriously. We're still in the building phase right now for the JAIC, but we are in early discussions about what governance looks like for the JAIC and, How do we bring all of us together to understand what are the projects going towards? A \$200,000 research project at University of Michigan may be exactly what we need for a long-term insight into a particular part of au-

tonomous vehicles. The question is, Do we know about it at a central level so that the Secretary and the Deputy Secretary of Defense are comfortable about what the Department is doing in artificial intelligence?

We take this very seriously. As Dr. Highnam said, we're also in discussions, just between DARPA and us, on, Where is that transition from DARPA, ready to field, over to the JAIC? We are in early conversations of that. We don't have programs identified yet.

Senator ERNST. Very good. Well, I appreciate that.

Going back to what Dr. Highnam said is, of course, Who cares and who benefits? I think, bottom line, that is a great way to put it. If you're not sharing information and going through that synchronization, who cares and who benefits? We don't really know. I appreciate that very much.

Thank you. I will step out. Ranking Member will take over the meeting.

Thank you.

Dr. HIGHNAM. If I may, one go-back on that. In all of our research programs, we also seek transition of the technologies that come out. We don't just do the research. This is Defense. We're pushing it. We seek transition agreements with the end users, wherever they may be, in the services or in the IC [intelligence community].

Senator ERNST. Thank you.

Senator PETERS [presiding]. Thank you, Madam Chairwoman.

I think I want to—I'd like to pick up a little bit, Mr. Brown, on—you were discussing the commercial sector and how we're reaching out to the commercial sector to be bringing in a lot of this technology. Certainly, that's what we're seeing—probably some of the most exciting advances are happening outside of the DOD, in the commercial space, and, because of all the applications from the financial industry, to banking to insurance to automobiles—I mean, all of that is going to be transformed in significant ways from artificial intelligence.

But, it's important for the DOD to be able to bring that in and use it effectively. There are a number of factors that usually, I think, stand in the way of that happening, from our very cumbersome procurement process, to say the least, that we have, that scares companies away from being involved with the Federal Government, to a slow and often late budget process that we have here. There are enhanced security reviews. I mean, there's a long list of challenges. That's what I'd like you to elaborate on, as to, What challenges do you envision, as we try to adapt some of these commercial applications into military use? Then, General Shanahan, if you'd follow up on Mr. Brown's comments. Dr. Highnam, too.

Mr. BROWN. So, Senator Peters, you're exactly right. I am benefiting from the wisdom of folks who came before me in setting up the Defense Innovation Unit, because we largely address, by how we were formed, some of those constraints that you talked about.

First, procurement process. We have set up a special solicitation process. It's open—anyone can respond—where we do not start with a list of detailed requirements assuming we know how industry should solve a problem we might have in DOD. But, we start

with something very simple—sentence or paragraph, saying, “This is the problem we’re trying to solve. What can you offer us that will help address that?” That gets us away from, again, very detailed requirements to seeing, What does the commercial sector offer?

Then we try and move at commercial speed and commercial terms, meaning we don’t have onerous requirements for IP [intellectual property], and we don’t take companies through something that is unfamiliar to them. We’d like them to view DOD and government as just another vertical as they look at other commercial segments they want to pursue. Again, commercial terms and speed are important for us there. Because our mission is, How do we expand the national security innovation base? How do we get more vendors working with us?

Then, as it relates to the budget process, that’s something that we are looking at now. How do we ensure that there’s a transition if we successfully prototype a use case? How can we move quickly to get that fielded? We have to use a variety of techniques. Some of them you’ve helped establish, like the Rapid Innovation Fund. Fortunately, in the AI sector, that’s made much more easy with the partnership with JAIC, because now we’ve got infrastructure, folks who can help make this available to the rest of the services. We’ve talked about the contract that we’re working right now, production contract being one we’ll be able to draw from.

As it relates to security, we try and move away from classified use cases and translate those to a commercial problem. We try and work almost exclusively in an unclassified realm. We’re conscious of those constraints, and we have ways to make it easier for commercial vendors to work with us.

I think another benefit is being able to work and access the talent, the ideas that come from the folks in the commercial sector, because we may not be able to track all the talent—it’s likely we will not be able to—in the AI fields within the Department of Defense.

Senator PETERS. All right. Thank you.

General?

General SHANAHAN. Senator, the legislation is clear: commerciality, first and foremost. For the 2 years that I worked in Project Maven, we took that approach. Now, there are always going to be some unique problem sets within the Department that require some in-house developments and in-house solutions, but we went with commerciality every time. I would say I was fortunate, fortunate in the form of a Marine Corps colonel who was an operator, an intelligence professional, but also a level-3 certified acquisition pro, and he was able to work within the confine of the DFAR [Defense Federal Acquisition Regulations Supplement]. People are surprised that we use the DFAR to that effect. There are additional authorities we’ve been granted. I haven’t had to use them yet in the JAIC because we’re so new in the standup of the process. But, there are ways to work the system, thanks to—as Michael Brown just said, the existing solutions are already out there in commercial industry. As I get further into standing up the JAIC, what I’m looking for, as many arrows as possible in the quiver of acquisition and contracting, able to pull for a different situation on any given day, whether it’s an other transaction authority, commercial serv-

ice, or just using straight-up DFAR. But, it's not easy to do it, but there are ways to work within the system, and we do put commerciality at the beginning of every project.

Senator PETERS. You say that it's not easy, but there are ways. You believe that you have the authorities that you need, at least at this moment? Or is there more that this committee—

General SHANAHAN. I do believe, at this moment, we have the authorities we need.

Senator PETERS. Okay.

General SHANAHAN. I reserve the right, 1 year into this, to come back and make a different case.

[Laughter.]

Senator PETERS. Yeah. Duly noted, General.

Dr. Highnam, did you have anything to add?

Dr. HIGHNAM. Yes. From the research aspect, looking at our investments in fiscal year 2018, about 50 percent of our AI research investments were industry, about 14 percent were small business. We have a very large coverage of picking up and driving the development of the best ideas. About one-third went to universities. Those are the sources.

For us, as we look ahead to technologies coming onboard, maturing them, and, to the examples they gave earlier, reducing the brittleness and just catering towards the engineering front needed for large-scale military deployments, we're addressing rigor, making sure they work, robustness. Second-wave technology is applied aggressively to defense applications. Then creating and proving out the third wave of technologies—of AI technologies—again, creating them not from whole cloth, but from working with the companies and working with the schools to do that.

Senator PETERS. Great.

Thank you.

Senator Shaheen.

Senator SHAHEEN. Thank you all very much. I'm sorry I missed your testimony earlier.

In 2017, China laid out plans to become the leader in AI by 2030. What's our strategy to make sure, (a) that doesn't happen, and (b) that we are the leader, as opposed to China?

Mr. BROWN. I'll take a crack at that. This is obviously much broader than a Department of Defense strategy. I think we know well how to win a tech race, because we did it quite effectively the last time we were involved in one with the Soviets in the Cold War and afterwards. It starts with, What are doing to invest in ourselves? All the breakthroughs that Silicon Valley is benefiting from, even today in our economy, as we look at some of these software IPOs [initial public offerings]—Uber, Lyft, AirBNB—have come from federally funded research. I credit DARPA and the other parts of the Federal Government that create those breakthroughs—Internet, GPS [global positioning system], miniaturized electronics, et cetera. I think it starts with what we do in federally funded research, education. What we did to focus on engineering and science after Sputnik, need to do that again. Then the national purpose. What we have now with the executive order, how do we build on that to create a common purpose about this being important? My concern would be that—How many Americans know about the na-

tional order on artificial intelligence, and how many young people are we reaching to inspire that this needs to be their mission? Because this technology race, especially on AI, is going to be multigenerational. It's not going to be lasting one administration, or two. We've got to get the national purpose behind this to support, then, what we can do to leverage that in the Defense Department.

Senator SHAHEEN. Well, that raises the next question, which is, Are we doing that?

Mr. BROWN. Well, I think you could always say we could be doing more.

Senator SHAHEEN. Okay. What more should—

Mr. BROWN. There's no—

Senator SHAHEEN.—we be doing?

Mr. BROWN. There's no time to waste in this race with China. They have—

Senator SHAHEEN. So, what—

Mr. BROWN.—some advantages, in terms of, today, probably more patents that they've—there's more startup activity, in terms of dollars invested. But, the U.S. still has a lot of critical advantages, in terms of our education system, what we're doing to actually pioneer things, in terms of hardware technology to advance AI, the tensor processing units, et cetera, the activities like DARPA is working on, with very long-term research in mind. I feel like the U.S. still has a lead there. We've just got to take more advantage of that. What makes us special in this race?

Senator SHAHEEN. How concerned are we that, not only is China making this commitment, but that they're stealing our intellectual property, which includes AI, and that we have not figured out how to adequately respond to that, I would say? You all may not agree with that, but that's certainly my view. I don't know who would like to answer that? General Shanahan?

General SHANAHAN. Yes, Senator. To just carry on to what Mr. Brown was talking about earlier, it—this is not just a DOD question—whole of DOD—it's not just whole of government, it's whole of society, it's multigeneration to be able to build. If I look at bringing in talent—AI talent into the JAIC, I can ask the services to, "Give me your best AI talent." There's just not enough to go around. It will take decades to build this. This is, one, for the executive order on AI. It's a start, but there has to be an implementation plan, which I know is coming. But, also, the National Security Commission on AI will lay out some of these very factors about, How do we do this as a society, everything from grade-school education to military courses bringing in concepts of coding all the way from the very beginning?

Now, to your other point, Senator, about intellectual property theft, every one of us has a concern about that. It's been taken much more seriously in the past 2 years than I would have said 5 years ago, beginning to understand the scope of the problem. Just using Huawei as an example, having a whole-of-government approach to convince people not to use that technology, because it has an entry point into places in China. This is something we're working very hard at protecting our own systems, protecting our data. Without getting into any details in the project I worked on the

Under Secretary of Defense for Intelligence Project Maven, but also as we stand up the JAIC, is protecting our data, doing everything we can to make sure somebody doesn't understand what that data is, how we built our algorithms. There is so much more than this. But, I believe the sounding board of what China is doing, just within the past 2 years, is now making a difference. Much more to do, but we are taking a different approach than we were in the past.

Senator SHAHEEN. Well, thank you. I appreciate that.

I would argue that, as we look at the education system, that one of the things we should recognize is the importance of immigration to that, and that, as we look back over the last 30 or 40 years, that one of the things that has been so important to our system of higher education are those people from around the world, the best and the brightest. When we have a system that says, "We don't want you to come here to college, and we want you to go home as soon as you're done," that's not in our interest. I would argue that that needs to be part of our strategy, as well.

Thank you.

Senator ERNST [presiding]. Thank you, Senator Shaheen.

Senator Heinrich.

Senator HEINRICH. I want to start by thanking our Chair and Ranking Member for hosting this hearing. This is an incredibly important topic, and one which we all need to be, educating our peers about, because, as our guests today know, this is going to be a bigger and bigger piece of what we focus on in the next few years.

I'm really pleased to announce that this week we are officially launching the Artificial Intelligence Caucus in the U.S. Senate. Along with Senators Portman and Schatz, Gardner, and our Chair and Ranking Member, we're looking forward to trying to work together to strike that right balance in developing the technology and the policy so that academia or labs, private industry, and Federal entities like the ones we have testifying here today, can harness this to the benefit of the American people.

AI is, as you said, really going to impact every sector of our economy, our society, not just the Department of Defense. I want to start with Lieutenant General Shanahan and thank you for your participation yesterday with the AI Commission. It's my understanding that the services and other components in the Pentagon right now have been directed to coordinate with the JAIC, with the Joint Artificial Intelligence Center, regarding any AI initiatives that cost more than 15 million annually. Is that coordination happening?

General SHANAHAN. Senator, it's not fully in place yet. It is—

Senator HEINRICH. Okay.

General SHANAHAN.—my intent, through governance and oversight within the JAIC, to put that structure in place, for the very reason that you said. We have to know what they're spending it on.

Senator HEINRICH. It all starts with knowing what we're doing—

General SHANAHAN. Yes.

Senator HEINRICH.—and then building off of that. Do you have the authorities that you need to be able to do this part of your job effectively?

General SHANAHAN. I'd say section 238 will grant those authorities. If I feel like we need any other authorities, we'll go back through the Department. But, I believe I have those authorities right now.

Senator HEINRICH. As we look at this over the course of the next couple budget years, what should we be measuring the JAIC against, in terms of metrics, and by what timeline?

General SHANAHAN. When we talk about the JAIC, in capability delivery, I'll divide it up into product delivery and then the rest of the JAIC. Product delivery is, Are we delivering on the national mission initiatives and component mission initiatives? On the national mission initiatives, have we put results in place that are making a difference, with a return on investment? That won't be an instantaneous measure, even with Project Maven, which has been going for almost 2 full years right now. The return on investment takes a while to measure in AI. As we talked about yesterday at the National Security Commission, this is transformational. When you feel the first sprint 1 algorithms, they are not game-changing, they're designed for the operator to say, "They're not good enough. Here's what I need to do and get to sprint 2, and we'll get to transformation." But, we need to show that we are delivering capabilities.

For the component initiatives, I need to give an incentive for the services and components to come to the JAIC. How do I do that? One, funding. Two, joint common foundation, or a JAIC common foundation. "I have data for you to use. I have tools. I have frameworks. I have some cloud and edge services. I have a—I'm a place that—one-stop shopping," which is a term that doesn't always work as well as it sounds on paper. But, I need to give people an incentive to come in to the JAIC, to help them accelerate their own AI initiatives.

Yes, sir.

Senator HEINRICH. Yesterday at the AI Commission meeting, I thought it was really helpful, what you said about the cultural nature of this, and the multigenerational aspect of this. Talk about how we manage that. Because the people who manage it, yourself included, we're not going to have the same intuitive access to this world that the people getting out of coding schools right now have today. How, as the Pentagon, do you manage this cultural transition within such a large organization?

General SHANAHAN. Well, I would put culture and talent management at the top two of my priorities in trying to change the Department in bringing artificial intelligence into it. As I said yesterday, there is a combination of top-down pressure and bottom-up innovation. For the most part, I believe the bottom-up innovation exists. We have to give it an outlet, a vehicle to give people room to go out and try things new and different, allow them to fail, and just show that they have a different way of doing business, that we can listen to them. There are now new programs in some of the departments, like Kessel Run with the Air Force. There is more and more of a culture change beginning to happen, but it's not part of the institution yet. What we have to do is institutionalize it. We have to give the top cover, in forms of resources, authorities, and policies, as well as going out and giving capabilities to people in the field.

One of the things I say is that, absent somebody getting to play with AI, it's science fiction. They need—

Senator HEINRICH. Right,

General SHANAHAN.—to see it, to smell it, to touch it and really see what it can and cannot do. And part of that is experimentation. It's almost like a war period between World War I and World War II, where we can go out and actually experiment with these capabilities. But, to do that, we have to develop the capabilities. It's a little bit of a vicious cycle. We have to get capabilities in the hand of operators and analysts, try them out, wargame with them, try new operating concepts, and then figuring out what works and doesn't work. That cycle is a little slow in getting going right now. When you ask about timeframe, I would say a year, in some respects, in terms of delivering capabilities; 2 years to begin to say, "Are we changing the Department?" As you heard from Colonel Cukor yesterday, we're 2 years into this, and I would say not everybody accepts the change—

Senator HEINRICH. Yeah.

General SHANAHAN.—that's coming.

Senator HEINRICH. Great. Thank you, General. Appreciate it.

Senator ERNST. Thank you, Senator Heinrich.

I think we'll go ahead and do a second round of questions. I will reserve my questions until the end so we can make sure that the rest of our Senators have an opportunity.

Senator Peters, please go ahead.

Senator PETERS. Thank you, Madam Chair.

General Shanahan, there is a concern out there by many about the possibility that AI-enabled systems and autonomous systems will cross some ethical lines, especially in operational settings. I know that the DOD AI Strategy includes efforts to think about AI ethics and safety issues as you're developing the systems. As you just said, you've got to get them out in the field, you've got to work them, but it probably makes sense to be thinking about this on the front end, as well, as we go forward.

For the panel, here, if you could highlight for us what your biggest ethics-related concerns are for the possible use of AI systems by the military, and how you're working to address them.

General SHANAHAN. Yes, Senator. Every technology introduced in the Department comes with a question of the lawful, safe, and ethical use of that technology. AI is not different in that respect. It has some differences, in terms of what you would call "explainable AI." Is an AI making decisions based on data now instead of algorithms—rules-based algorithms that have been programmed into it? We are thinking about this from the very beginning.

Based on my work in Project Maven, I can tell you the algorithms fielded are light years away from SKYNET and full autonomous weapon systems. But, we know we have to start thinking about the policy implications of that. If you were to ask where the highest temperature is outside the Department, it's on the question of lethal autonomous weapons. Autonomy in weapon systems is governed by DOD policy today, and we are partnered, and the JAIC is partnered, with the Defense Innovation Board, who has a year-long project underway about AI principles for defense, doing open hearings, being able to hear from anybody that wants to come

in and talk about their concerns about the ethical, safe, and lawful use of artificial intelligence in DOD. I will tell you, it's something we take extremely seriously. We will go at this, as we have done with other technologies, through a very rigorous and disciplined test and evaluation, validation, and verification process. We have not fielded an algorithm in Project Maven without having gone through that rigorous and disciplined process. As early as we are, and as brittle as those algorithms are, we put them through that process. If we start talking about full autonomous systems, that level of rigor and discipline will only continue to increase.

But, in terms of what we are most concerned about is its performance of algorithms. As Dr. Highnam said earlier, some of the algorithms have failure modes that we have to take into account. That DOD directive that I referred to, has several sections on what we have to go through in the Department to be ready to test and field technology that involves autonomy.

But, autonomous weapon systems with artificial and general intelligence is what people seem to think is the worst case. I think of artificial narrow intelligence. Anything we field will be fielded in accordance with the Law of War, international humanitarian law, rules of engagement, and commanders' judgment. I mean, these are things that we take into account for every technology, even more so because people don't know all about the implications of artificial intelligence in a weapon system.

Senator PETERS. Yeah. As you go through that process, you know, certainly, that's encouraging, that that thought process is occurring within your organization, but I think we have to also realize that some of our adversaries may not be constrained by some of the same kinds of processes that we go through, and could present unacceptable risk to us, from a national security perspective, as well as the men and women who go in harm's way facing autonomous systems that operate under a completely—set of rules than what we would think is appropriate here in the United States.

I think that leads to my last point, and that's thinking of some of these higher-level concerns and policy concerns of what we should be thinking about globally, in terms of these technologies. I know, when we were talking about AI, we often turn to technical experts and engineers. Often technical experts and engineers make comments about ethics. But, I have found that's a somewhat narrow approach, and we've made those kinds of mistakes in the past. My sense is—are you and Dr. Highnam—are you also working with philosophers and ethicists and folks who think deeply about some of the moral questions associated with these technologies? Or should we be doing more?

Dr. HIGHNAM. One, there's always more to do. We had an AI colloquium last week, a DARPA colloquium. About 700 people there. One of the most interesting panels that we had was on ethics, led by Richard Danzig, who used to be the Secretary of the Navy. Fascinating discussion. It's very much a part of the technical discussions that are going on. We are looking at that.

Now, within—wearing a slightly more technical hat, there are some issues, at the moment, that we are very concerned about, with a technical solution. One is the implicit bias. The field of data science and machine learning or machine training have significant

overlap. There's a tendency among people who are human, as they build these systems, to pick datasets, to cull datasets, to unintentionally put leads or, again, bias into how they're doing things, which means a system could preferentially recognize Joe or Jane, based on—just because of the way it was trained. That's a piece of the puzzle. We have research programs going directly against that. A large one underway now is understanding group biases. But, again, this is common to data science and machine training.

The second area is about the deployment of technology when we don't fully understand its failure modes, back to the point I made earlier. One of our programs, short autonomy, has a very interesting premise, an important one. We have an autonomous vehicle, a flight vehicle, a ground vehicle. You can make it a lot more flexible in how it deals with unexpected conditions by adding some second-wave AI technologies to the puzzle. A condition shows up, it adapts and makes changes. But, it's—again, if you don't really understand the failure modes, if you don't have that assurance and sense, almost, of a cyber assurance that this is going to behave itself and operate within safe limits, then you put something on the street or in the air that's—you really have to take a little—you have to think hard about before you do that. A lot of our research, again, is going into making technologies robust in that sense, as well. We have multiple programs—research programs addressing different aspects of this problem. It's a very important problem.

Senator PETERS. Great. Thank you.

Senator ERNST. Senator Shaheen.

Senator SHAHEEN. Thank you.

Dr. Highnam, did I understand you correctly when you said: As we look at where AI is currently being developed in this country, about 50 percent of it is in large businesses; 14 percent, small businesses; and a third from universities? Was that—

Dr. HIGHNAM. It's 50 percent in business, of which 14—so, 14 percent, overall—

Senator SHAHEEN. Ah. Okay.

Dr. HIGHNAM.—then 36 percent, larger businesses; 34 percent universities; and the rest in service labs, energy labs, and so on.

Senator SHAHEEN. The rest is from the public sector—

Dr. HIGHNAM. Yes.

Senator SHAHEEN.—then.

Dr. HIGHNAM. Yeah.

Senator SHAHEEN. If you think about past circumstances in our history, whether it was the Manhattan Project or putting a man on the Moon, can we analyze the sectors that provided that technological innovation, and figure out whether this is the right breakdown, in terms of where AI is coming from?

Dr. HIGHNAM. The answer is certainly yes. It's not something I've done. But, to comment on that, if I may, the—this is the research phase. We're finding—these investments are not on systems that are in any sense deployable.

Senator SHAHEEN. Sure.

Dr. HIGHNAM. But, these are people—I'm finding them in industry, with really good ideas, who propose to our research programs. Then, as much of this technology evolves, they publish some, they don't publish some, depending on—

Senator SHAHEEN. Right.

Dr. HIGHNAM.—classification, and so on. But, a lot of the time, we want industry to make these technologies, as they are proven to work, to be commercial, to be incorporated into——

Senator SHAHEEN. Right.

Dr. HIGHNAM.—other products that then the Department can buy back. I think that the days are gone when we can think about corraling hundreds of thousands or very large numbers of experts in such a hot technology area. We—this is normal—DARPA's normal business mode, but I'm certainly going to take your question back for a look.

Senator SHAHEEN. Well, I was just thinking about, How do we encourage more experimentation, more research? Thinking about small businesses. Small businesses create 16 times more patents than large businesses.

Dr. HIGHNAM. Yep.

Senator SHAHEEN. You know, two out of every three jobs are created from small business. Are there ways we can incentivize small business to do more of that research and innovation that we're looking at to provide the AI that we need? I would argue that one program that is there that helps do that is the SBIR program——

Dr. HIGHNAM. Yeah.

Senator SHAHEEN.—Small Business Innovation Research program.

Dr. HIGHNAM. Two answers. One—I'm sorry, it was part of my preamble—one of the things we've done in our AI campaign is to set up something called AI Exploration. In that, we post a topic of interest. Anybody is given 30 days to respond. It's typically schools and small businesses who do that. Then we award within 60 days after that. Ninety days from posting to award, up to a million dollars per award, up to about 18 months in duration. We've invested about 45 million so far, since September, in this activity. Because, you're right, this is a lot of the innovation, and this is us exploring in a space and giving them the grounds to do that. We've also recently revamped our small business approach to align it directly with our research programs. We're also encouraging moving directly to phase two. We also have an innovation accelerator, as well, to advise small businesses on how to take things commercial after they discover it, not just in AI, but across the board.

Senator SHAHEEN. Are there other policy changes that we should be thinking about to promote—should we be encouraging more set-aside for SBIR programs? Are there other ways in which we can promote AI that we're not currently doing?

For any of you?

Dr. HIGHNAM. We're seeing an awful lot of smart small businesses come forward, teaming with schools, teaming with big companies sometimes. Certainly those in the larger DARPA ecosystem understand how to work us.

Mr. BROWN. I think this just emphasizes what you've heard from all of us, the need to work with commercial innovators in ?

Senator SHAHEEN. Right.

Mr. BROWN.—AI. I saw an interesting statistic that came from Congressional Research Service recently, that, in the 1960s, a third of the global R&D was U.S. defense-related, and now that number

is 3.7 percent. It just speaks to the need to look outside. I think what you've heard from all of us—DIU, that's our mission, so of course you'd expect me to say that, but we heard it from Dr. Highnam, General Shanahan, that we want to work with these successful innovators outside, and bring that technology in, because, unlike the Manhattan Project working on one specific goal, AI is a horizontal technology that is infused in everything, or will be. That really speaks to the beauty of the U.S. capitalistic free-market system so that we can benefit from all that innovation happening across. I think our challenge is, Where do we pull that in, from a talent perspective, technology perspective, and proven use cases? How do those apply to the Defense Department?

General SHANAHAN. Senator, it's about messaging that—as been said, AI, unlike any other technology in the past, is been—the equation has been completely turned around as commercial and not government. The message of—the United States Government, not just the Department of Defense, has an interest in promoting AI from the smallest company up to the biggest company. With Project Maven, we had no favorites. Everybody was a player, smallest startup all to the biggest companies in the United States. But, getting the message that we want the business, and if they have their intellectual property to work with the government on, we want to take that.

What I don't want to see is some of the best companies in the United States, some of the best intellectual talent we have out there being funded with VC [venture capital] money from places like China. But, if they have to go somewhere, and we're not giving them an opportunity, that's what's going to happen.

We have a role, I think. It's a very serious role, is to communicate that we're serious about artificial intelligence, we need the capabilities you bring to the table, and the three of us represented here from AI now to AI next, and Mr. Brown in between, sort of going out and doing the pilots and finding the right companies out there, that is a message we need to communicate. I think part of that, through the executive order on AI, but also the National Security Commission on AI that will come out with, I expect, some very weighty recommendations about a societal change in how we're looking at artificial intelligence.

Senator SHAHEEN. Well, thank you. I appreciate all of those responses.

If we're going to continue to be competitive in the rest of the world, then this needs to be part of our strategy. If you're correct, Mr. Brown, that in our system that unleashes all of this innovation in the private sector, then we should be able to win that competition. But, I think that there are policies that we need to put in place to encourage that, and we ought to think about which ones make sense to get where we want to go.

Thank you all very much.

Thank you, Madam Chair.

Senator ERNST. Thank you. Absolutely.

I will wrap up with just a couple questions. I do want to thank you for the discussion. We've covered a lot of territory, a lot of very interesting territory. I appreciate the discussion on ethics, as well,

with lethal autonomous weapons. I think that's something that we need to fully vet and explore even more.

But, what I'd like to do is turn back to the more mundane, everyday uses of AI, if we can. General Shanahan, you had—I think, had mentioned some of those uses. Of course, we have companies, like Amazon and UPS and Walmart, and they do use AI for those back-office types of tasks that you had mentioned earlier. Can you walk us through some of those tasks and where we might be able to utilize AI? Not big, sexy topics, but certainly if we can streamline the way we do business within the DOD, I think this would be helpful.

General SHANAHAN. Yes, Senator. When you talk about smart automation, or, in the vernacular of the industry, “robotic process automation,” it's not headline-grabbing, in terms of big AI projects, but it may be where some of the most efficiencies can be found. That's the case if you read the dailies in industry, whether it's in medicine or in finance. This is where early gains are being realized in AI. Some of the other projects we take on in the Department are probably years in the making of return on investment. These other areas, I think, will be much shorter-term return on investment.

What we're trying to do in the JAIC—when I looked at this just a couple of months ago, we weren't even concentrating on this smart automation. I'm now trying to figure out how I stand up a small office just focused on that. I don't see us leading that, but it's leading others to find out how to incorporate these technologies into their back-office functions.

I've already met with the Chief Management Officer of the Department, as well as the Chief Data Officer of the Department, to have these early discussions. I'm convinced there will be lots of opportunities in back-office functions, finance being, I'd say, the first one to take on, to help augment people. I think people get very concerned, right off the bat, about being replaced. There's not enough people to go around, for the most part, so this is about augmenting people and being able to do much more work than they were able to do with the tools, which, in some cases, are far too old, manual, laborious. These are about how to—if you see the demonstrations of a bot versus a human doing the same sort of manual task, there's no question who gets to the finish line first.

Senator ERNST. Absolutely.

General SHANAHAN. We're early in this process right now. But, that's one I'm very interested in taking.

Senator ERNST. No, I think that's really important. One of the big discussions that we've had, just in the last year, was the DOD audit, and how do we arrive at a clean audit through such a large—what I describe as a large, you know, animal. Is it practical to look at an application like that? Would it be helpful to guide us towards a clean audit?

General SHANAHAN. I'd say the answer to that is yes. Scoping it will be the challenge, is finding out how big this is to go after the audit. But, I know the Chief Data Officer, Michael Conlin, is looking at applications like this. There are big decisions made in the Department with data done in a very manually intensive way. If those decisions can be made faster and better, that, of course, is something that the leadership of the Department is interested in.

The answer to your question is yes. It's a question of understanding the scope and the scale of doing it.

Senator ERNST. Very good.

Of course, the inventory purposes, acquisition, program spending, you name it, I think that AI can help in those areas. It has been mentioned, maintenance, as well—predictive maintenance on equipment and aircraft, so forth, would be very helpful, as well.

General SHANAHAN. Senator, if I may just add on to the point. Whether it's smart automation or predictive maintenance—as we're finding very early, the problems themselves are not massive, but the lessons learned are what we're really catching on to.

Just one use case of a helicopter, seemingly simple. But, everything we're learning about data management, which would be no surprise to anybody in industry who's dealing with artificial intelligence and machine learning. But, those are what we're trying to collate and bring up to a higher level for the Department about understanding what different standards, policies, authorities need to be in place to make this happen against all the different aircraft in the Department of Defense.

To your other point about—I call it a flywheel effect. Once a few people begin to understand what smart automation does, it will catch on. But, nobody believes it yet, because they haven't the benefit of actually seeing it work.

Senator ERNST. Absolutely.

General SHANAHAN. But, that's what we have to do, is—we have to show—it's the show-me piece. We have to have people believe it's real, and not just science fiction.

Senator ERNST. Absolutely.

With that, I will go ahead and wrap up this hearing today. I do want to thank the members of our panel for being here. The flywheel effect, it starts here, as well, in Congress, and making sure that we are educating others on artificial intelligence and the applications for our DOD.

Thank you, again, to the witnesses for being here and for educating us on what your jobs entail and how we can better use artificial intelligence. Thank you, gentlemen, very much.

This concludes the hearing of Emerging Threats and Capabilities.

[Whereupon, at 3:53 p.m., the Subcommittee adjourned.]

[Questions for the record with answers supplied follow:]

QUESTIONS SUBMITTED BY SENATOR JONI K. ERNST

AI TO IMPROVE PROCESSES

1. Senator ERNST. Dr. Highnam and Mr. Brown, how can DOD [Department of Defense] use AI to improve its business and back office processes to save money for readiness missions?

Dr. HIGHNAM. There are many commercial companies offering AI-based solutions for business and back office processes. However, the implementation, customization and deployment effort for such a project is complex and subject to schedule and performance risks. Back-office operations have been studied in-depth for decades, and many sophisticated computer algorithms are routinely used in currently deployed enterprise solutions. Nonetheless, an AI technology system requires a software layer that captures user actions and business processes in a computer-readable form. To be successful, AI methods must access disjoint databases and combine financial reports with computer-interpretable information about human decision processes. A graduated approach to adopting AI techniques would first automate repeatable processes while also capturing human responses to nonstandard situations. Computer-readable information about human responses would then provide the data required to test if and when AI methods might further improve business processes. Offerings claiming to provide value through the application of AI technologies should be vetted thoroughly and their life-cycle-costs analyzed and compared to best practice in the commercial world and to current solutions. Superior solutions would both enable end users to automate repeatable processes and learn from user behavior to recommend courses of action for non-standard situations.

Mr. BROWN. Based on routinely collected data, artificial intelligence (AI), data analytics and machine learning technologies are well-suited to make predictions to improve back office processes. For example, commercially available software for robotic process automation is the use of software with AI and machine learning capabilities to handle high-volume, repeatable tasks that previously required humans to perform. These tasks can include queries, calculations, and maintenance of records and transactions.

2. Senator ERNST. Dr. Highnam and Mr. Brown, for example, can AI-enabled systems help DOD achieve a clean audit, better track inventory and acquisition program spending, or assist in the personnel assignment process?

Dr. HIGHNAM. The goal of an audit is to ensure compliance with a complex set of regulations. To achieve this goal requires extensive common-sense and organization-specific knowledge. For example, a financial auditor must be deeply familiar with the Generally Accepted Accounting Principles (GAAP) and understand they should be applied to the organization in question. For the DOD, a thorough knowledge of the Defense Federal Acquisition Regulation Supplement (DFARs) would also be essential. The application of such knowledge is well beyond current AI capabilities. AI tools can assist auditors by enabling more rapid analysis of data relevant to the audit. For example, machine-learning systems can be trained to detect fraudulent transactions. However, the use of such tools requires years of training and experience. The DOD may be able to achieve cost savings in audits through judicious incorporation of automated processes and AI technologies. Nonetheless, the DOD faces unique challenges related to scale, expiration of funds, and operational diversity. It is unlikely that common commercial products will fully address DOD use cases without extensions or modifications. Graduated solutions should first advance the level of automation while providing a software foundation for future AI deployments. Finally, decades of research have produced well-established procedures and mathematical concepts for managing inventory, such as logistic regression for demand forecasting and Economic Order Quantity estimation. Machine learning techniques may potentially improve demand forecasts, but DOD should undertake a careful analysis of any AI-based solution to ensure that its lifecycle costs and complexity do not exceed current solutions, without substantial increase in accuracy and timeliness. Similar caveats apply to other areas of business process automation, such as personnel assignment.

Mr. BROWN. Although not a focus area of DIU at the moment, there are a number of commercially available data analytics platforms that make this information more visible.

3. Senator ERNST. Dr. Highnam and Mr. Brown, what specifically have your organizations done to support AI for back-office functions at DOD?

Dr. HIGHNAM. DARPA creates foundational AI components that generalize to a variety of application areas. DARPA recently engaged in a knowledge exchange with

DFAS and DISA to explore whether DARPA AI components might support back-office functions within the DOD. Several near term investments would need to be made to lay the foundation for future pilot testing and deployment of AI technologies from DARPA and other organizations. Specifically, the DOD would need to invest in a software layer that enables users to automate routine business processes and stores the actions taken by humans to address non-standard situations. Ideally, the software layer would connect disjoint databases and software tools in a manner that builds on users' current workflows, captures an ontology of user actions, and stores relevant data in a computer-readable form. The software layer would provide a foundation for pilot tests, extensions, and rapid deployment of AI components from DARPA and other organizations. There will be a follow-up meeting between DARPA, DFAS, and DISA.

Mr. BROWN. DIU has been working with a commercial solution on AF strategic planning choices to predict necessary POM inputs for given decisions. The use cases center around using integrated data (current and historical: budget; financial execution; manpower; personnel; and logistics/equipment) to identify 3rd, 4th and 5th order effects of a given planning choice. The intent is to improve fidelity in the strategic planning process, and understand quantitatively the likely outcomes on readiness, manning, equipment needs, training impacts, and other weapon systems. There is both a quality and speed component to decision making. Using a tool increases the throughput of decisions through the budgeting process, and provides more fidelity so senior leaders and analysts can ask the questions that will help them improve decisions.

DOD TECHNOLOGY ACQUISITION

4. Senator ERNST. Dr. Highnam, Mr. Brown, and Lt. General Shanahan, how does the DOD acquisition process delay the development and implementation of AI and other emerging technologies and what efforts have you taken to address this problem?

Dr. HIGHNAM. DOD acquisition is often process driven, rather than mission driven like DARPA. The state of the art of emerging technology like AI evolves much faster than DOD acquisition timelines. For this reason, DARPA uses streamlined or rapid acquisition authorities to connect with the best people and technology at the speed of innovation. For example, DARPA has used "Other Transaction" authorities for decades because they allow flexibility and often faster results than traditional government contracting. Recently, DARPA launched the Artificial Intelligence Exploration (AIE) program to execute forty-eight (48) separate Other Transaction awards totaling \$45 million, for rapid feasibility studies of AI concepts lasting eighteen (18) months. To keep pace with industry changes, DARPA's AIE awards had an average timeline of less than ninety (90) days from announcement to award.

Mr. BROWN. DIU's mission is to look beyond traditional DOD vendors and focus on the commercial technology community. To attract these commercial solutions, DIU developed the Commercial Solutions Opening (CSO) process in 2016, a three-phase, competitive merit-based business model leveraging prototype Other Transaction authority. This process has enabled DIU to focus on balancing speed, flexibility, and collaboration to award prototype projects to leading-edge, dual-use technology companies that might otherwise not do business with DOD. A potential future problem would be the length of time to get new vendors cleared to solve some of our problems.

Lt. Gen. SHANAHAN. The Department of Defense's acquisition process is still oriented primarily towards materiel weapon systems rather than software development. Modern software development requires a different process, with end-users providing feedback at every stage and developers continually refining the model after deployment. In pursuit of our mission needs, the JAIC is taking advantage of current regulations and policies wherever possible to implement proven iterative development strategies for software and emerging technologies such as AI. Based on my previous experience with Project Maven, there is often sufficient flexibility within the Defense Federal Acquisition Regulation Supplement (DFARS), but to navigate the DFARS successfully requires government personnel with a commensurate level of experience and deep understanding of DOD acquisition and contracting regulations. Further simplification of existing regulations will be helpful. The JAIC is seeking to hire people with the requisite agile acquisition expertise while also reviewing a wide range of acquisition and contracting options designed to allow maximum flexibility and agility when pursuing commercial AI solutions. The JAIC will work closely with USD (Research and Engineering) and USD (Acquisition and Sustainment) on improving AI-related acquisition and contracting policies and au-

thorities. Congress has been especially helpful in crafting legislation designed to expedite fielding commercial AI technologies.

5. Senator ERNST. Dr. Highnam, Mr. Brown, and Lt. General Shanahan, have you faced any roadblocks in the Department to speeding up acquisition of these technologies?

Dr. HIGHNAM. DARPA has not faced any roadblocks. DARPA consistently uses a wide variety of existing acquisition flexibilities granted by Congress, such as the “Other Transaction authority”, which we have used for decades. The Artificial Intelligence Exploration (AIE) program was an example of DARPA using “Other Transaction authorities” to make forty-eight (48) awards with an average timeline of less than ninety (90) days from announcement to award. DARPA greatly appreciates the acquisition autonomy and flexibility that Congress and the Department grants us due to our unique R&D mission of pursuing breakthrough technology and avoiding strategic surprise. DARPA’s success so far has resulted from this autonomy and flexibility, and our future success depends on our ability to use a variety of special acquisition authorities to pursue innovative R&D.

Mr. BROWN. DIU has had a beneficial partnership with Army Contracting Command—New Jersey (ACC–NJ) for contract execution, but reliance on contracting organizations with other primary missions has been unable to meet DIU’s capacity needs and higher DOD demand. In November 2018, the Office of the Under Secretary of Defense for Acquisition and Sustainment (OUSD (A&S)) granted DIU authority to execute “Other Transaction agreements.” In April 2019, DIU utilized this new authority to release its first solicitation, the initial step in awarding a prototype contract.

Lt. Gen. SHANAHAN. Not at this point, although we acknowledge the risks inherent in not taking full advantage of a wide range of acquisition and contracting practices that support agile development, fielding, and sustainment. During the JAIC’s initial standup in fiscal year 2019, to avoid incurring delays in each of our three primary projects, the JAIC has primarily taken advantage of existing contract vehicles. As we prepare to scale operations in fiscal year 2020, we are using lessons learned from other DOD-wide AI projects such as Maven to create and combine a wide variety of new and existing contract vehicles, respectively, that will provide the JAIC and others in DOD with access to state-of-the-art AI technology and services, at the necessary speed and with the required agility. We will be prepared to request new or modified policies, authorities, and legislation as necessary.

QUESTIONS SUBMITTED BY SENATOR MAZIE K. HIRONO

ETHICAL CHALLENGES

6. Senator HIRONO. General Shanahan, the ethical use of AI is an issue that must be adequately addressed before AI can be deployed in a widespread and meaningful way. Who within DOD is responsible for issues regarding the ethical use of AI within DOD?

Lt. Gen. SHANAHAN. Leadership in values and ethics is at the core of everything we do in the JAIC. The responsibility for the ethical use of AI will be widely shared across the Department, spanning system developers, trainers, leaders, end users, and more. The breadth of this shared responsibility is a recognition that many different communities within DOD have a critical role to play in getting this right. The JAIC will play a central role in helping craft policies, guidelines, and authorities related to the ethical, safe, and lawful use of AI technologies. This includes working with allies, partners, and international organizations on questions of international norms for AI, while precluding unnecessary restrictions on our development and fielding of AI capabilities. The Department is fully committed to the ethical use of AI from concept through deployment and sustainment. This includes ensuring sufficient rigor and discipline throughout test and evaluation as well as validation and verification processes and procedures.

7. Senator HIRONO. General Shanahan, are there separate efforts to address ethical issues related to the uses of AI and the issues related to AI systems potentially generating errors or unwanted outcomes?

Lt. Gen. SHANAHAN. The Defense Innovation Board (DIB) is developing principles to guide current and future AI research, applications, and activities as part of the AI Principles for Defense project. Upon completion of the project, the DIB will make a recommendation to the Secretary of Defense on proposed AI principles for defense, at which point the Department will conduct an internal review process on adopting

such principles. Additionally, a major component of DARPA’s ‘AI Next’ campaign, titled Explainable AI, focuses on enabling AI systems to explain their actions. Progress in “explainable AI” will help users understand, appropriately trust, and use AI systems in an ethical and safe manner. Prior to fielding any AI capabilities, the Department will ensure sufficient rigor and discipline in test and evaluation processes and procedures with particular attention to independent evaluations and assessments, errors, biases, and unwanted outcomes. This will include establishing dynamic feedback loops that take into account feedback from operational users on algorithm or model performance on deployed systems.

PREDICTIVE MAINTENANCE

8. Senator HIRONO. General Shanahan, one of the areas of focus for JAIC [Joint Artificial Intelligence Center] that seems particularly promising is predictive maintenance. The ability to improve readiness by limiting downtime with predictive maintenance could have a tremendous positive effect on maintenance efforts across DOD. What are the major hurdles to widespread deployment of predictive maintenance AI within DOD?

Lt. Gen. SHANAHAN. I agree that machine learning (ML) looks particularly promising in terms of augmenting, accelerating, and automating current maintenance practices. The JAIC funded predictive maintenance as one of its initial National Mission Initiatives because of the near-term opportunity to increase aircraft readiness, aligning with the Secretary of Defense’s direction to improve aircraft readiness across the Department. However, one of the earliest identified challenges, which matches lessons learned from Project Maven and other previous DOD AI/ML projects, centers on data: its quality, accessibility, and relationship to ground truth. Existing maintenance data is often not at the level necessary for AI systems development. Critical data elements are often missing, incorrect, or at too low resolution. Additionally, data inconsistencies exist across the Services for related systems. One of the JAIC’s roles will be to help develop and implement DOD-wide policies, authorities, and governance designed to improve data readiness across the entire Department. This will include supporting efforts to digitize end-to-end processes, from the back office to the tactical edge.

9. Senator HIRONO. General Shanahan, where does DOD need to invest to widely deploy predictive maintenance?

Lt. Gen. SHANAHAN. Predictive maintenance should be employed widely across the Department. AI-enabling investments in data generation, curation, data access, and maintenance are necessary precursors to enable predictive maintenance AI to be successful at scale. Data curation is one of the most important investments, along with needed requirements to improve data quality at the point of use. In the interim, the JAIC is relying on AI and domain experts to conduct standardized post-processing of inaccurate and missing data. While our initial H-60 helicopter use case is relatively small, the lessons we are identifying in this project—particularly as they relate to data management—will be applicable to every future project in DOD. Investments in ontology, component standards, and use of a common infrastructure are addressing challenges with data access. Shared ontology ensures a common data lexicon across the Joint Force—an important step toward scaling new AI-capabilities. The JAIC is supporting a number of ongoing standards-related efforts including those led by the National Institute for Standards and Technology. If such data standards are established and uniformly adopted, then it will help DOD ensure future equipment procurements include government ownership of data needed to efficiently apply AI analysis.

10. Senator HIRONO. General Shanahan, will predictive maintenance AI be deployable at sea, where ships have traditionally been limited in computing power and communications bandwidth?

Lt. Gen. SHANAHAN. The JAIC’s Predictive Maintenance National Mission Initiative uses historical H-60 helicopter data. However, the Navy maintenance community has already raised the challenge of limited communication bandwidth as partially explaining missing data that is necessary for AI analysis. The Navy is working through the connectivity requirement between the Integrated Mechanical Diagnostics System (IMDS) and TRIAD shipboard servers to ensure maximum use of AI technology at the point of use. This is an area where the JAIC will work closely with the Navy and Marine Corps to identify and address specific challenges related to deploying AI-enabled predictive maintenance solutions at sea or in any degraded, disconnected, intermittent, or bandwidth-limited environment.

QUESTIONS SUBMITTED BY SENATOR MARTIN HEINRICH

COMMERCIAL INDUSTRY ENGAGEMENT

11. Senator HEINRICH. Mr. Brown, I am aware that you have DIU [Defense Innovation Unit] offices set up in Silicon Valley, Boston, and Austin. I'd like to make sure that AI startup companies, say in Albuquerque, Santa Fe, Des Moines, or Detroit have the same opportunities to present their AI solutions for your problem sets. How should they go about doing so?

Mr. BROWN. DIU is interested in getting the best commercial solutions from around the country and growing the national security innovation base. To date, we have received submissions from over 800 companies in 42 states and the District of Columbia. We post an Area of Interest (AOI) solicitation on our website, www.diu.mil, to which companies across the country can submit proposals.

12. Senator HEINRICH. Mr. Brown, is New Mexico within your upcoming outreach efforts? If not, I would like to extend a personal invitation to visit New Mexico and meet with several cutting-edge AI companies.

Mr. BROWN. Thank you for the invitation. We have recently met with your congressional lead about our processes and opportunities to work with DIU. We have a number of companies that have responded to our AOIs. We will definitely look to visit New Mexico in upcoming travels nearby.

THE CLOUD AND AI

13. Senator HEINRICH. Mr. Brown and Lt. Gen. Shanahan, as you know, the cloud contract and process itself, JEDI, has received significant attention. In general, how important is the establishment of a cloud to supporting the deployment of future AI capabilities?

Mr. BROWN. The establishment of a cloud solution to support the deployment of future AI capabilities is very important. Most vendors in the AI/ML space are moving toward cloud services to provide their most advanced capabilities, so it is a high priority to establish and migrate to cloud infrastructure to stay current with the vendor base. Large training data sets and substantial/scalable computational resources are two core capabilities that enable effective artificial intelligence applications. Cloud solutions enable those datasets to be shared across geographically separated commands, pooling together larger datasets. Cloud computing allows a far more efficient allocation of DOD capital, as the precise amount of computational resources are spun up to solve the specific problem and no idle capacity is being paid for.

Lt. Gen. SHANAHAN. Achieving the most effective results possible from AI-enabled technologies will depend on a future of enterprise cloud. The cloud provides massive and elastic compute power, lower latency, unlimited storage, and scalability. It will also enable local and global dynamic algorithm and model updates at the required speeds that will be essential to future multi-domain operations. The JAIC's objective is to use AI to solve large and complex problems to ensure that the Services and Components have real-time access to ever-improving libraries of data sets, reusable tools, frameworks, and standards. This cannot be achieved without the foundational framework established by a hybrid solution of general purpose and fit-for-purpose enterprise clouds, in accordance with DOD's enterprise cloud strategy

14. Senator HEINRICH. Mr. Brown and Lt. Gen. Shanahan, is it possible to deploy AI capabilities without cloud or clouds in place?

Mr. BROWN. Yes. Many of our prototypes are either "on premises" (non-cloud) deployments, or hybrids that have both on premise and cloud elements. It is possible to deploy trained algorithms at the edge with a "train in cloud, deploy at edge" concept of operations. Furthermore, it is also possible to deploy additional processing power at the edge with some of the more advanced hardware available from vendors. However, the core benefits of AI/ML solutions come into play when we pool together many data sources in a common operating environment.

Lt. Gen. SHANAHAN. It is possible to develop and field AI-enabled capabilities without a cloud. However, such "one-off" solutions will limit the overall effectiveness of deployed capabilities—everything from training through inference at the tactical edge and dynamic updates to deployed algorithms/models. It is possible to deploy limited AI capabilities in traditional data centers and on-premise infrastructures; data centers are generally cost prohibitive and suffer from a number of other limitations lowering the ability to achieve maximum effectiveness from AI technologies. AI deployment at scale requires the elasticity of compute and storage that is afforded by cloud computing, while also accounting for compute hosted on platforms

and sensors at the tactical edge. The full potential of an AI-enabled future depends on enterprise cloud that is optimized for AI, with sufficient backup measures in place to account for operations in degraded, disconnected, intermittent, or bandwidth-limited environments.

ETHICS AND SAFETY

15. Senator HEINRICH. Dr. Highnam and Lt Gen Shanahan, how is the Department of Defense addressing ethics and safety concerns surrounding military applications of AI?

Dr. HIGHNAM. The safe use of AI technologies by the military and others is an important concern of AI researchers and practitioners. DARPA is addressing this concern in multiple research programs, including its Assured Autonomy program. The Assured Autonomy program is developing rigorous design and analysis technologies for continual assurance of learning-enabled autonomous systems to guarantee safety properties in uncertain environments. These include new techniques for modeling and system design, formal verification, simulation-based testing, machine learning, and safety-assured learning. The technologies being developed in the Assured Autonomy program will enable the DOD to more rapidly and efficiently deploy learning-enabled autonomous systems that can be trusted to operate safely in uncertain environments. DARPA's recent AI Colloquium featured an ethics panel with in-depth discussion of ethical issues relevant to AI in military contexts: <https://youtu.be/jSxCWLJt0wY>.

Lt. Gen. SHANAHAN. The Department continues its full commitment to the ethical, safe, and lawful use of AI. Leadership in values and ethics is at the core of everything we do in the JAIC. One of the key pillars of DOD's AI Strategy is leading in military ethics and AI safety. JAIC will support ethical implementation of AI by consulting with leaders across academia, industry, and the international community; investing in resilient, robust, reliable, secure, and explainable AI systems; developing and improving policies that consider technical strengths and limitations of AI; and pioneering approaches for AI test, evaluation, verification, and validation. Concurrently, the JAIC will implement AI as required to maintain battlefield overmatch in alignment with the national defense strategy. There is no inherent contradiction between the ethical and safe integration of artificial intelligence across the range of military operations, and meeting the Department's enduring mission to deter war and protect the security of our nation. Artificial intelligence is a critical capability to ensure we field a lethal, resilient, and rapidly adapting Joint Force. The responsibility for the ethical use of AI will be widely shared across the Department, spanning system developers, trainers, leaders, end users, and more. The breadth of this shared responsibility is a recognition that many different communities within DOD have a critical role to play in getting this right, although the JAIC will play a central role in helping craft policies, guidelines, and authorities related to the ethical, safe, and lawful use of AI technologies. The Department is fully committed to the ethical use of AI from concept through deployment and sustainment. This includes ensuring sufficient rigor and discipline in test and evaluation as well as validation and verification. Prior to fielding any AI capabilities, the Department will ensure sufficient rigor and discipline in test and evaluation processes and procedures. This will include dynamic feedback loops that take into account feedback from operational users on deployed algorithms or models.

COMPONENT MISSION INITIATIVES

16. Senator HEINRICH. Lt Gen Shanahan, you stated that you expect to see a rapid growth of Component Mission Initiatives, or CMI's in fiscal year 2020. Can you talk more about why and what those new CMI's will look like?

Lt. Gen. SHANAHAN. Since the establishment of the JAIC, we have been interacting closely with the military Services and other DOD Components to explore how the JAIC can support their requests for AI-enabled solutions to a wide variety of potential challenges. This includes working with them on potential future CMIs. At present, these range from operational planning through predictive medicine, identifying individuals at risk of harming themselves, force protection, and information operations. We are further developing our internal JAIC governance framework to shape, prioritize, and recommend CMIs to ensure there are no duplicative efforts and to ascertain proper levels of support, from personnel resourcing to funding. Additionally, the establishment of the JAIC Common Foundation (JCF) will enable us to better support CMIs in the coming fiscal year.

17. Senator HEINRICH. Lt Gen Shanahan, does the budget request reflect the rapid growth of CMI's you anticipate?

Lt. Gen. SHANAHAN. Yes. We anticipate allocating about \$30 million to support six to ten CMIs in fiscal year 2020. Dedicated funding for CMIs will incentivize the services and components to rely on the JAIC while supporting the maturity of the JAIC Common Foundation (JCF), a crucial enabling capability for CMIs and National Mission Initiatives (NMI). As the JCF matures it will become a repository of tools, frameworks, processes, and data to accelerate new CMIs throughout the DOD. We expect a growing demand for CMI support through fiscal year 2020 and beyond; the current fiscal year 2020 budget request is currently projected to accommodate all expected CMI support through the end of fiscal year 2020.

COMPUTER SCIENCE AND RECRUITMENT

18. Senator HEINRICH. Lt Gen Shanahan, you stated that in terms of AI, adding funding and people will not by themselves spark the necessary level of institutional change we need, and that we need a deeper foundation of people who understand the technology and computer sciences. Do you believe the Department currently prioritizes recruitment for computer sciences?

Lt. Gen. SHANAHAN. There is more work to do in this area. Similar to the lessons learned across DOD over the past decade with the rapid growth of cyberspace, there is awareness the Department needs to accelerate efforts to grow, recruit, retain, and promote people with the kinds of skills necessary to thrive in an AI-enabled future. This is a multi-generational challenge, though there are a number of different near- and medium-term efforts that can begin to improve current shortfalls. These include targeted recruiting; recruiting incentives; introducing AI and coding principles in grade schools, high schools, and military entry-level education and training programs; retention bonuses; intermediate and advanced training throughout a career; exchanges with industry; and relying on commercial companies to accelerate the breadth and depth of AI experience across the DOD. The Services' Reserve Officer Training Corps and Service Academies remain committed to producing future officers with strong academic foundations in computer science. Moreover, the Services collaborate with industry leaders to advance the essential skills needed by these officers in many technical fields. For the enlisted force, the Services primarily select individuals with related qualifications and train them internally for AI-oriented positions. Specialized tests are administered by the Services to identify individuals with an aptitude for assignment into computer career fields. Our civilian workforce also helps to meet the needs of the Department not fulfilled by military personnel. Concomitant with efforts across DOD to close significant gaps in AI knowledge and expertise, we need a whole-of-society approach to further develop a cadre of people with the requisite skills in AI and AI-associated fields. Absent such an approach, the DOD will continue to compete with industry, academia, and other government agencies for an extremely limited pool of AI expertise. It is vital to grow the entire base of expertise across society, rather than focus only on the very small pool of AI talent that already exists within DOD.

19. Senator HEINRICH. Lt Gen Shanahan, what are your thoughts on establishing "computer sciences" as a core competency within the military? (i.e., career tracks, mission specialties)

Lt. Gen. SHANAHAN. Under Title 10 of the United States Codes the responsibility for training falls within the Services. Each Service reviews and updates their core competencies to best reflect the national defense strategy, changes in the operational environment, and available technology. Given the immediate need for substantially more expertise in AI and AI-related skills—from computer scientists to data architects, data engineers, system engineers and more—I am the strongest possible proponent for an approach in which the Services consider how best to represent this need in their core competencies. The JAIC will work closely with the Services, OSD, and DOD Components to propose and advance necessary authorities, policies, and legislation designed to grow a more qualified AI force.

20. Senator HEINRICH. Lt Gen Shanahan, given how important STEM [Science, Technology, Engineering, and Math] is to your efforts, should there be someone in the Department entrusted with recruiting individuals specifically for that type of skill set?

Lt. Gen. SHANAHAN. Each Service is best positioned to determine the optimum approach to meet their recruiting mission and training requirements. As the recruiting environment has become more challenging, I am confident, if deemed appropriate, each Service will consider other initiatives, including specialty recruiting, that will enable them to achieve their recruiting missions. I view one of the JAIC's key responsibilities as helping the Services and other Components assess their AI work-

force strengths, limitations, and shortfalls, and helping them craft strategies centered on AI talent recruiting, retention, and promotion.

BREAKOUT OF DOD AI FUNDING

21. Senator HEINRICH. Lt Gen Shanahan, the fiscal year 2020 budget request includes a \$927 million investment in Artificial Intelligence, with money directed toward the Joint Artificial Intelligence Center and Advanced Image Recognition (Project Maven). Can you please provide the breakdown on how the \$927 million will be allocated?

Lt. Gen. SHANAHAN. The \$927 million is allocated among three major AI programs in DOD: Joint Artificial Intelligence Center (\$268 million), Project Maven (\$250 million), and Defense Advanced Research Projects Agency (DARPA) (\$409 million). (The overall budget for all DOD AI programs is classified and can be provided separately upon request.) The Joint Artificial Intelligence Center was established in June 2018 to accelerate the delivery of AI-enabled capabilities. Project Maven's efforts are focused on ISR full motion video and expanding to other areas that include high altitude still imagery and captured enemy materials. Through its "AI Next" campaign, DARPA is developing advanced AI theory and applications making it possible for machines to adapt contextually to changing situations.

22. Senator HEINRICH. Lt Gen Shanahan, one impediment to accurately evaluating funding levels for AI is the lack of a stand-alone AI Program Element (PE) in DOD funding tables. As a result, AI R&D [Research and development] appropriations are spread throughout generally titled PEs and incorporated into funding for larger systems with AI components. As the lead coordinating entity for AI, do you have visibility on the Department of Defense's total investment in AI, including Services and components, and can you provide that breakdown to the Committee by PE and amounts?

Lt. Gen. SHANAHAN. I agree that we need better visibility on the entire range of spending on AI and AI-related projects across DOD. The Department of Defense's total AI funding was classified Secret by the Acting Secretary of Defense and can be provided separately upon request. Current procedures require the military Services and DOD Components to coordinate with the JAIC on all AI-related projects over \$15 million. For fiscal year 2020, we are relying on data calls by OSD-CAPE and USD-Comptroller to gather all AI-related funding information. DOD CIO will capture AI investments in the IT Budget starting in fiscal year 2021. Through updates in policy and institution of DOD AI governance, Components will be mandated to enter their AI projects in the DOD portal to be reflected in the Select & Native Programming Data Input System for Information Technology SNaP-IT exhibit. These are necessary first steps towards gaining a more comprehensive understanding of all AI-related spending across the Department. As part of our evolving JAIC governance framework, we will propose new processes and procedures to ensure greater oversight of DOD-wide AI spending; this will include spending by the DOD components of the intelligence community.

QUESTIONS SUBMITTED BY SENATOR GARY C. PETERS

GOOGLE WORKFORCE OBJECTIONS TO MAVEN

23. Senator PETERS. Lt. Gen. Shanahan, the decision by Google to pull out the Maven program raises many concerns. What is your assessment of why Google pulled out of the Maven project and what steps are you taking and what steps are these companies taking to ensure that we can work with the best minds in Silicon Valley on these important efforts?

Lt. Gen. SHANAHAN. Google's contribution to Project Maven was as a subcontractor to a prime contractor. They were one of many subcontractors associated with the project and they had no direct contractual relationship with Project Maven or the JAIC. They completed their statement of work as subcontracted and publicly withdrew from future consideration of a potential subcontract renewal or extension. The decision was based on entirely internal factors and Google only provided to the government limited information as to the private business considerations of that decision. It would be inappropriate for the Department to speculate as to the underlying rationale for that decision as private industry has the right to engage in contracts as they see fit. Nonetheless, the Google/Maven issue underscores that the DOD needs to improve its efforts to acquire, configure, and deploy commercial artificial intelligence technology, which requires adapting to the culture and business practices of a new, more diverse group of industry partners. The vast majority of

current AI companies do not rely on DOD as a substantial part of their AI business model. Their employees may have different motivations and ethical concerns about engaging in national security work. Continued engagement and two-way transparency with these companies are vital to maintaining our competitive military edge and ensuring the Department has access to the nation's top technology and talent. We need to continue to message that the United States military is the most important global institution for the preservation and expansion of widely-shared values, including privacy, liberty, and equality. Communicating the key messages that the benefits of AI-enabled technologies include enhancing protection of U.S. and allied forces, reducing the potential for civilian casualties and collateral damage, and saving lives. One of our key missions in the JAIC is to build and strengthen relationships across U.S. AI technology hubs. The Department wants to work with those companies who will support the full range of DOD missions, while acknowledging that every company has an inherent right to rely on its own internal review mechanisms to decide on whether and how to work with DOD on AI-related projects.

24. Senator PETERS. Mr. Brown, I know DIU is trying to forge relationships with the private sector as well—do you see a way for us to work with private sector companies who at the corporate or employee level has expressed concern about working with the Department of Defense on our toughest military challenges?

Mr. BROWN. Transparent, open and frequent communications with industry, academia and the public will be critical to our success. DIU was designed to rebuild some of these bridges, develop new relationships and facilitate conversations that would have commercial solutions providers engage with the Department of Defense.

VALUE OF LONG TERM RESEARCH

25. Senator PETERS. Dr. Highnam and Mr. Brown, there is a lot of understandable and deserved interest in the great advances that the commercial sector is making in AI. I know that the automotive industry is making great strides in developing new AI-enabled systems to support driverless cars and intelligent systems in traditional passenger cars. But I think that the Federal Government and this committee can play an important role in creating the environment and funding the research for that commercial innovation to thrive. Can you describe the role that federally-funded and university research plays in supporting commercial sector and Silicon Valley innovation, and what more should we be doing at the federal level to continue that support?

Dr. HIGHNAM. In terms of fostering commercial innovations in AI-enabled systems, DARPA has historically played the role of making pivotal early technology investments in high risk, high payoff technologies. For example, DARPA's early investments in computer vision, machine learning, and autonomous control in the Grand Challenge and Urban Challenge programs spurred the development of technologies that led to the self-driving car technologies being pursued in the commercial sector today. (DARPA's earlier investments in the same technical areas in the early 1980s created the basis for the Challenges.) Given the growing role and importance of AI technologies in our daily life, fostering an even broader, more robust AI research ecosystem is an area where the Federal Government, including DARPA, can continue to play an important role by: 1) funding early stage research that inspires commercial application development; 2) funding academia to ensure a talent pipeline for commercial AI organizations; and 3) funding programs that address new or previously unrecognized research issues that often arise when technology meets real world deployments.

Mr. BROWN. Galvanizing a generational investment in science and technology is one of the most important proactive steps we can take in a technology race to ensure we reinforce the best aspects of U.S. innovation and entrepreneurial behavior. This requires a foundation of leading science and technology development and a return to the technology prominence the U.S. enjoyed in the 1960s—developed as a response to the previous tech race that we won. The nation, including the commercial technology ecosystems around the country, are still benefiting from the technology breakthroughs that came from this investment in basic science and research in the 1960s and 1970s (internet, GPS, semiconductors, etc.). The field of AI and Deep Learning in particular has advanced through public challenges such as ImageNet, which was hosted by Stanford University and got teams to compete on building algorithms to identify various images. DIU is building on this legacy with xView, a series of competitions that challenge participants to build algorithms applicable to human assistance and disaster response. The upcoming iteration of xView will challenge participants to build algorithms to do automated building damage assessment, which is critical in post-disaster environments. These challenges not only deliver

cutting edge capabilities to the department, but also spur research interest in areas critical to DOD.

AI WORKFORCE

26. Senator PETERS. Lt. Gen. Shanahan, for us to move forward in AI we are going to need a workforce, both in uniform and on the civilian side, that is capable of being a smart user, buyer, regulator, and researcher of AI systems. What steps are you taking to build that workforce and do you need any special hiring, pay authorities or other authorities in order to compete for AI talent with the private sector?

Lt. Gen. SHANAHAN. The JAIC is challenged with the hyper-competitive market for top talent, specifically our difficulty in offering more competitive compensation packages. One of the key attributes of the Cyber Excepted Service (CES) is the Departments ability to offer more competitive market based compensation packages. While CES resolves many of the key issues, CES does not resolve all the concerns. To that end, the JAIC would benefit from Congressional assistance in the following two areas: Relief for the current federal pay cap (\$166,500; Executive Level IV). Authorities to offer retention incentives internally to DOD employees. Specifically, we would benefit from the ability to offer incentives for DOD employees moving internally to the Department. Current authorities only allow for retention incentives to be given if the employee is leaving Government.

NEED FOR GOOD DATA FOR AI SYSTEMS:

27. Senator PETERS. Lt. Gen. Shanahan, AI and machine learning systems require data sets to learn from, and DOD often struggles in collecting, clean and useful data sets related to their challenges. AI and machine learning systems can only learn and be more useful if they are given raw material, namely data to process and work on to begin to better answer questions and perform required processes. But the government in general and DOD specifically has a reputation for not having good data on either its operational or back office systems and processes, and especially for not sharing that data with others. How is the JAIC working to create policies on the generation and sharing of data for AI systems to learn from and get better?

Lt. Gen. SHANAHAN. Data is the fuel of AI. The Department recognizes that bad, dirty, or unshared data is a major impediment to implementing AI at scale. We need to move from a software-based to a data-first paradigm, refocusing on data as the product and establishing data-oriented architectures. With particular attention to designing AI-ready data-driven workflows. Over the past year, the Office of the Chief Management Officer and OUSD (Comptroller) have been collaborating to extract, standardize, and curate data from the Department's operational and back office systems and processes. This data is now resident in the Defense Repository of Common Enterprise Data (DRCED) soon to be known as ADVANA. DRCED includes a detailed cost baseline of the Department's Reform Lines of Business, comprising 75 percent of the Department's unclassified budget. In addition to this catchment of data, DRCED provides users with a selection of tools for data wrangling, data analysis, and data visualization, and machine learning. As Project Maven demonstrated, and as we learned immediately with our initial two National Mission Initiatives (NMI), data management is one of the most resource-intensive and time-consuming aspects of the AI delivery pipeline. Success in any DOD AI project will rest on a foundation of good data management. We acknowledge the level of effort involved in improving DOD-wide data management; one of our key responsibilities within the JAIC will be to work closely with CMO and all other stakeholders to address and solve data management problems, and to serve as a central hub for helping the Services and Components do the same. This will include establishing standards, setting new policies, and providing the necessary authorities to begin to shift the Department in the right direction for future data management. For some systems, the processes are not yet ready for AI since they are not data-driven. We will work with our mission partners to design workflows that are data driven—where users visualize data to perform their tasks and record information during tasks. These systems can perform many task with many users across the operation units—aggregating information for each task level. We are adopting a user-based design principal for all of our systems—where end-users are engaged in designing, testing, and providing feedback so that the best AI-enabled delivery is possible. Once the user workflows are data driven, then AI can be added to augment the workflow. The JAIC will use tools, libraries, and framework resources provided by the JAIC Common Foundation (JCF) to build AI/ML to enhance the data driven workflows through our NMIs and CMIs. In addition, each NMI/CMI contributes to

the data, models, libraries, and services in the JCF to be shared to the community at large

RESEARCH COMMUNITY DATA

28. Senator PETERS. Dr. Highnam and Mr. Brown, I imagine the research community has challenges with accessing, maintaining, and sharing useful datasets, especially with respect to classified data. How do your research teams get the data they need to develop new AI systems and concepts and do we need to make any policy adjustments to make that more streamlined?

Dr. HIGHNAM. DARPA AI research programs often need data that may be unclassified or classified. In some cases, it may be possible for a new program to re-use existing data from other on-going or completed programs, and in some cases the new program may need to create new data. A special case arises when we need to generate unclassified synthetic data as a surrogate for classified real-world data in order to permit participation by researchers at universities. Separately, we anticipate that the recently established DOD Joint Artificial Intelligence Center (JAIC), with part of its mission to establish a common set of AI standards, tools, shared data, reusable technology, etc. will be a step towards improving accessibility of datasets to the AI research community. DARPA has a long history of working data issues and does not seek specific policy adjustments at this time.

Mr. BROWN. For machine learning efforts to be successful, large volumes of data are necessary to train algorithms. Large datasets do exist, but there are challenges leveraging them for a variety of reasons—some of which are cultural, some of which are regulatory. While we have the obligation to safeguard unauthorized disclosure of data, we also have an urgent need to bring machine learning capabilities into the Defense Department. We would welcome more comprehensive data-sharing agreements across DOD organizations to streamline data access challenges that often slow the development of critical technology. In addition, clearances pose a barrier to getting some of the best companies and people working on DOD's most important problems. Efforts to streamline and accelerate the clearance process would be beneficial.

