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Statement by Ms. Barbara McQuiston

Performing the Duties of the Under Secretary of Defense for Research and Engineering

Submitted to the
U.S. Senate Appropriations Committee
Subcommittee on Defense

Defense Innovation and Research

April 13, 2021

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Chairman Tester, Ranking Member Shelby and Members of the Subcommittee, thank you for the opportunity to testify before you today. It is an honor to be here alongside my friend and colleague Dr. Stefanie Tompkins, the Director of the Defense Advanced Research Projects Agency, DARPA. And more importantly, I am honored to represent the men and women of the Office of the Under Secretary of Defense for Research and Engineering (OUSD(R&E)). In addition to DARPA, OUSD(R&E) is home to diverse group of engineers, scientists, researchers, and staff officers who work in three separate agencies and in offices, laboratories, and universities across our nation. OUSD(R&E)'s mission is to maintain DoD's technological edge and to lead technological change and innovation throughout the DoD.

In the three years since Congress directed the creation of OUSD(R&E), and gave the office a mandate to advance technology and innovation across the Department, OUSD(R&E) has developed and begun implementing modernization roadmaps in key technology areas. OUSD(R&E) has also strengthened lab and university partnerships for basic research and worked closely with the services to improve prototyping efforts in order to bridge the "valley of death" from prototype to program of record.

Recently, Deputy Secretary Hicks assigned OUSD(R&E) the additional role of chairing a new Innovation Steering Group (ISG). This group will provide OUSD(R&E) with a mechanism for collaborating with leaders across the Department, for synchronizing innovation efforts and sharing lessons learned, and for driving initiatives to innovate at speed and scale. We convened this group for the first time last week, and the Deputy Secretary will hold her first Defense Management Action Group meeting on the subject of innovation and joint experimentation later this week. By creating the ISG, Sec. Hicks has signaled the importance of innovation and the attention it deserves. Simply put, it is a good time to be an innovator in the Department of Defense.

OUSD(R&E) consists of three core organizations and a number of subordinate agencies and activities. The office of Research and Technology (R&T) is responsible for overseeing DoD's labs, Federally Funded Research and Development Centers (FFRDCs), University Affiliated Research Centers (UARCs), academic and basic research, manufacturing institutes, and Small Business Innovation Research (SBIR). R&T's support for basic science provides the fuel that will power DoD's innovation and modernization efforts well into the future.

OUSD(R&E)'s Modernization office (MOD) connects technologies developed in laboratories with future warfighting capabilities. MOD has developed roadmaps for DoD's 11 modernization priorities – that will be addressed later in detail—to guide these key technologies from early-stage science through capability fielding.

The office of Advanced Capabilities (AC) focuses on technology transition. By conducting war games, mission engineering analysis, prototyping, and demonstrations, AC converts technologies into warfighting capabilities and gets those capabilities ready to field.

In addition to these headquarters organizations, OUSD(R&E) also houses the Missile Defense Agency (MDA), the Space Development Agency (SDA), the Defense Innovation Unit (DIU), and DARPA. DIU connects DoD with private sector innovators who use commercial technology

to address some of the Department's hardest problems. MDA develops and fields advanced capabilities to defend against rogue regime missile threats. SDA is rapidly developing a new space architecture that is capable of tracking advanced missile threats. Finally, of course, I am honored to have the DARPA director speaking alongside me today.

FACILITATING TRANSITIONS

The "valley of death" is the chasm between a technology and warfighting capability. Countless technologies fail to transition into warfighting capabilities and fall victim to this valley of death. To shepherd new technologies across the valley of death instead, OUSD(R&E)'s Advanced Capabilities (AC) directorate executes nine programs that are dedicated to technology transition. By focusing on different sources of innovation, technology readiness levels (TRLs), and customer groups, these programs form a balanced portfolio that transitions capabilities to the Services, Combatant Commands, or other operational user groups, at an average rate of approximately 80%. This 80% "sweet spot" offers a responsible balance between using taxpayer dollars wisely, while also taking measured risks to maintain DoD's competitive edge.

Transition rate is an important measure of success because the Joint Staff, Services, Combatant Commands, and warfighters will not accept capabilities that do not meet their mission needs. By working closely with these partners early in the prototyping process, AC maximizes its transition rate by ensuring that partners are ready to accept and field new capabilities when prototyping completes. Beginning this year, AC added Mission Engineering to its toolbox; this process rigorously evaluates Joint Staff and Combatant Command priority missions and identifies new opportunities to transition capabilities and deliver even greater impact to the Department.

PROTOTYPING PATHWAYS TO DELIVER INNOVATION TO USERS

Results from OUSD(R&E)'s prototyping programs illustrate how, when combined with experiments and demonstrations, prototyping is an effective tool for bridging the valley of death. For example, the Quick Reaction Special Projects (QRSP) program seeks out prototyping ideas from across the innovation space, including small businesses, non-traditional performers, and academia. By discovering innovative but raw ideas and creating prototyping programs to further their development, QRSP serves as a vehicle for "technology push" and offers the warfighter capabilities that they did not realize were possible.

To ensure that DoD quickly transitions these new capabilities, QRSP awards contracts throughout the budget year of execution. For example, QRSP awarded a contract to the start-up Adronos which enabled it to compete in a "shoot off" demonstration. During this demonstration, Adranos achieved 15% better performance than other solid fuel formulations: a potential game-changer for hypersonics and long-range precision fires. QRSP's near real-time award enabled this small business to quickly refine their novel fuel and to demonstrate its utility to DoD.

Speed is a critical enabler of technology transition, especially for emerging technologies. For this reason, the Emerging Capabilities Technology Development (ECTD) program identifies promising technologies when they first appear on the horizon. ECTD then quickly assesses the potential utility of these technologies and creates a prototype for a Service partner to rapidly

evaluate. For example, in 2017, ECTD initiated a multi-Service project to prototype a cognitive software-defined radar capable of operating in congested and contested electromagnetic environments. In less than three years, the SDRadar prototype transitioned to U.S. Army and U.S. Air Force programs of record.

Finally, OUSD(R&E) maintains low-cost demonstration and experimentation venues to specifically support small business and non-traditional performers. These venues enable DoD to access cutting edge capabilities and ideas from across the innovation base. They also enable small businesses and non-traditional performers to interact with DoD users, to learn about DoD's mission, to gain experience that can be leveraged to meet future DoD needs. Two such venues, Thunderstorm and Stiletto, demonstrated technologies from 60 small businesses in FY20.

TECHNOLOGY TRANSITIONED BY OUSD(R&E) THAT IS MAKING A DIFFERNCE FOR THE WARFIGHTER

Not only do OUSD(R&E)'s prototyping programs enjoy an ~80% transition rate, they also deliver cutting-edge capabilities that make a different for the warfighter. For example:

- **Low Cost "Attritable" Strike Demonstration (LCASD) or XQ-58A Valkyrie, Joint Capability Technology Demonstration (JCTD):** Facing potential adversaries with increasingly complex air defenses, INDOPACOM issued a call for an ultra-low cost, long-range aircraft to conduct strike or reconnaissance missions. OUSD(R&E) answered the call with the LCASD JCTD. This aircraft, also known as the USAF XQ-58A Valkyrie, allows the United States to avoid placing our pilots and high value aircraft at risk during the early stages of a confrontation. The project also demonstrated agile automated manufacturing processes, gathered performance data (e.g., weight, strength, stiffness), evaluated cost model data (e.g., cost, schedule lead time), and developed in-house prototyping capability for low cost attritable aircraft technology. LCASD also proved that it is possible to rapidly manufacture a low cost, combat relevant aircraft. This accomplishment has tremendous implications for a future fleet of loss tolerant aircraft which could change the nature and conduct of warfare itself. These capabilities transitioned to the USAF Skyborg program and would not have been possible without the strong support of Congress.

- **More Situational Awareness for Industrial Control Systems (MOSAICS) Joint Capability Technology Demonstration (JCTD)**: MOSAICS demonstrated a semi-autonomous solution to enhance the cyber defenses of industrial control systems associated with DoD critical infrastructure (e.g., fuel depots and electric grids). MOSAICS provides warfighters with tools to quickly identify, respond, and recover from cyber-enabled attacks on critical power, water, communication, and transportation systems. Naval Facilities Engineering Command is already planning to transition and sustain the first MOSAICS leave-behind prototype at Naval Base San Diego and is evaluating other opportunities to deploy MOSAICS capabilities at facilities in the INDOPACOM area of responsibility. Additionally, the Department is looking to use of MOSAICS to improve the cybersecurity of other critical DoD systems, including offensive cyber, long-range strike, and nuclear deterrent systems.

- **Hack-A-Sat:** Borrowing a common practice for testing system security in the commercial sector, the Hack-A-Sat project invited hackers from around the world to attempt to hack actual DoD satellites. By watching the world's best hackers at work, DoD identified new, cutting-edge hacking strategies and is developing new offensive and defensive approaches for space and cyber protection. In Q2FY21, space and cyber experts from across DoD met to apply lessons learned from Hack-A-Sat to develop new concepts for space and cyber operations. I welcome the opportunity to share additional details about this effort in an appropriate setting.

DEFENSE INNOVATION UNIT TRANSITIONS COMMERCIAL TECHNOLOGIES TO THE WARFIGHTER

In addition to prototyping to bridge the valley of death, DoD's investments must cultivate new workforce talent, attract first-time DoD vendors, and identify novel solutions from across the national security innovation base: together, the Defense Innovation Unit (DIU), the National Security Innovation Network (NSIN), and National Security Innovation Capital (NSIC) partner with industry and academia to do just that. As Chinese investments aim to compete with U.S.'s technological lead in key sectors, DoD's investments can play an important role laying the foundation for a successful startup ecosystem and for ensuring national and economic security.

DIU, for example, rapidly prototypes, fields, and scales state-of-the-art commercial solutions. Leveraging the innovation, cost-savings, and economies of scale of the commercial sector, DIU has awarded contracts to 189 unique companies, of which 143 are small businesses and 61 are first-time vendors to DoD. DIU has transitioned 19 solutions to the warfighter, including small drones, automated cyber vulnerability detection and remediation, mobile endpoint security, advanced data management and analytics, air threat response, predictive mission configuration, rapid analysis of threat exposure, and space situational awareness. DIU's predictive maintenance solution scaled from one aircraft to fielding across the Air Force and Army and its small drone solutions scaled from the Army to all levels of the U.S. government. At DIU, there is also an opportunity for larger defense contractors to integrate the innovative commercial technology of smaller firms to provide ready-made solutions to the warfighter.

Like DIU, NSIN works to redefine what national security service means for academics, technologists, and entrepreneurs. NSIN runs problem-solving programs such as Hacking for Defense (H4D) to produce new concepts and capabilities for DoD end users. NSIN also works to commercialize dual-use technology developed at DoD laboratories and to support company formation and the scale-up of dual-use hardware manufacturing capabilities, including those in autonomy, communications, power, sensors, and space. NSIN partners with 66 universities in 46 states and has placed 175 people in DoD STEM positions, of which 47% were women or minorities.

MISSION ENGINEERING

Mission Engineering (ME) is an analytical approach for evaluating potential capabilities in the context of real-world missions and threats. Rigorous and data-driven, ME can help inform DoD's requirements definition and technology investment processes and can support the development

of government reference architectures. In December 2020, OUSD(R&E), in collaboration with the Services, Joint Staff and the OSD engineering community, codified the ME process by releasing the first edition of the Mission Engineering Guide. This guide disseminates best practices, invokes critical thinking, and provides a consistent methodology for practitioners to use when performing ME analysis.

In FY21, OUSD(R&E)'s Mission Engineering team initiated four analyses to answer priority questions for the Department; analysis topics include: high energy lasers for base defense, position, navigation, and timing in highly contested environments, electromagnetic spectrum maneuver and mission data integration, and rapid precision strike-next. These topics were identified through a OUSD(R&E)-led workshop which included participants from the Joint Staff, Combatant Commands, and other OSD organizations. The topics were subsequently approved by the Vice Chairman of the Joint Chiefs of Staff.

To perform these and other analyses, ME requires a technical database capable of managing a large amount of data and models. OUSD(R&E)'s new Mission Engineering Digital Environment (MEDE) serves as one such database, providing analysts with a collaborative, agile, secure, interoperable, and responsive digital environment in which to conduct ME activities. OUSD(R&E) is also standing up a mission integration / mission engineering war room to facilitate collaboration across all classification levels and to meet the technical demands of multiple concurrent analyses.

To further analyze the potential mission impacts of emerging technologies, OUSD(R&E)'s Strategic Intelligence and Analysis Cell (SIAC) established an Emerging Disruptive Technology (EDT) wargame series. Wargaming is an analytical approach that enables DoD to jump-start the innovation process by grappling with the implications of emerging technologies well in advance of their maturation. EDT wargames holistically examine emerging technologies' technical capabilities and policy considerations, as well as their potential impact on operational requirements and threats. EDT wargames have examined topics such as: autonomy in undersea warfare, AI's applications to command and control, directed energy weapons, and emerging technology considerations for the Joint Warfighting Concept (JWC). Wargame outputs help inform future concept and capability development, mission engineering studies, prototyping and experimentation, threat forecasting, and S&T investments.

EDT wargames also provide a unique opportunity to integrate a diverse set of subject matter experts across program office, technology, and Service stovepipes. EDT wargames include members of the technology, operational, and intelligence communities from OSD, the Joint Staff, the Services, Combatant Commands, and intelligence agencies. This inclusive approach creates a mutually beneficial feedback loop among the organizations and individual participants. For instance, the operational community gains a better understanding of the opportunities and risks of emerging technology and the technology community gains an appreciation for future concepts and capability requirements. Both communities further benefit by learning from the intelligence community's depiction of future threats.

These feedback loops were readily apparent in 2020, during EDT Wargame 4. By assessing the 2030 technology landscape and identifying technical opportunities for the S&T community to

align with the JWC, EDT 4 informed JWC's Supporting Concept capability requirements. Additionally, within OUSD(R&E), wargames are designed to inform prototyping activities, to shape modernization roadmaps, and to integrate across technology portfolios, thus enabling OUSD(R&E) to deliver the next generation of integrated capabilities to the warfighter.

TRMC DELIVERS CAPABIITY FOR TEST AND EVALUATION

The Test Resource Management Center (TRMC) ensures the readiness of the test and evaluation (T&E) infrastructure and workforce. TRMC also supports DoD modernization by forecasting future test infrastructure needs, assessing current test ranges and facilities, and developing critical test technologies and capabilities for use across the DoD T&E enterprise. TRMC, of course, also supports DoD-wide modernization by facilitating testing of key capabilities. Recent examples include:

- Improved aeroshell testing by developing an arc heater that more accurately produces hypersonic flight conditions and can evaluate thermal protection system materials;

- Upgraded a wind tunnel by developing a nozzle that provides air flow up to Mach 18 and that enables the measurement of hypersonic aerodynamics and weapon system stability;

- Enhanced the realism of nuclear survivability testing by prototyping a test capability that produces ultra-short, pulsed neutron radiation and can be used to assess the survivability of microelectronics and critical control circuits; and

- Improved 5th/6th generation aircraft testing against modern air defense systems by fielding sixteen threat-representative radar signal to assess detectability, survivability, and system performance.

In addition to strategic modernization investments, TRMC also makes foundational investments to improve test capabilities and lower the cost of testing across the Department. For instance, TRMC fielded a common range instrumentation system at eight open-air ranges. This system tracks aircraft under test with sub-meter accuracy and securely transmits highly classified flight test data down to the ground at four times the rate of previous systems.

WHERE INNOVATION RESEARCH AND TECHNOLOGY BEGINS

The Deputy Director for Research and Technology champions the Department's relationships with academia, is piloting efforts to attract a new and more diverse talent pool to the Department's science, technology, engineering, and mathematics (STEM) workforce, is promoting the use of new hiring authorities and flexibilities, and through the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) is working to bring small and innovative businesses into the Department.

GROWING THE PIPELINE OF SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS (STEM) TALENT

The Science, Mathematics, and Research for Transformation (SMART) Scholarship Program provides scholarships to U.S. citizens to pursue bachelors, masters, or doctoral degrees, and in doing so, helps build a future workforce capable of addressing the Department's most challenging problems.

Upon graduation, recipients work in a civilian position in a lab or agency of the Army, Navy, Air Force, or other DoD entity and have a one-year service requirement for each tuition year. In 2019, DoD targeted scholars with academic backgrounds that aligned with DoD's modernization priorities, including: quantum science, microelectronics, biotechnology, and artificial intelligence. Continuing to recruit stellar candidates into the SMART program will enable DoD to build a workforce that is capable of addressing even the most challenging science and technology problems in the future.

OUR COMMITMENT TO DIVERSITY

To attract and advance an inclusive DoD STEM workforce, the Department's STEM Education and Outreach efforts are working to increase women's and other underrepresented groups' involvement. For example, OUSD(R&E) conducts SMART Scholarship program outreach at Historically Black Colleges and Universities and Minority-Serving Institutions (HBCU/MI). DoD's long-standing partnership with HBCUs/MIs not only contributes to a diverse STEM workforce, it also focuses research grants on core DoD modernization priorities. Furthermore, although the DoD's HBCU/MI program research focuses specifically on defense, program investments also contribute to commercial innovation.

The HBCU/MI Program also manages nine centers of excellence that provide leadership, research, and education in DoD priority areas. The newest centers focus on quantum sensing, artificial intelligence/machine learning, networks, aerospace education, research, and innovation. The program is also working to establish to new centers focused on biotechnology and materials science. Finally, two other centers of excellence have a STEM workforce focus, and are cultivating a cohort of students through an education program that is coupled with exposure to the DoD's research and development enterprise. Many of these students also participate in DoD internships; after completing internships, 57 STEM scholars who also participated in the DoD HBCU/MI Program have accepted job placements with defense laboratories since FY 2018.

LEVERAGING INTERNATIONAL TALENT

To stay ahead of our competitors, both economically and militarily, the U.S. must continue developing and attracting world-class scientists and engineers. The Department employs more than 130,000 scientists and engineers, and nearly half of this number work in one of the Department's laboratories or engineering centers. Despite challenges in recruiting and retaining technical talent, the Department maintains an exceptional workforce.

Many of the U.S.'s top researchers and entrepreneurs have come here from other countries. To take advantage of this fact, in just the last year, OUSD(R&E) re-invigorated the Department's J-1 Visa waiver program. This effort will reduce barriers for foreign nationals who want to stay in the country to work in STEM fields.

Today's U.S. universities welcome a high percentage of international students, scientists, professors, and industry collaborators, and our adversaries compete with the U.S. to recruit from this same talent pool. Immigrants have been awarded 38% of the Nobel Prizes won by Americans in Chemistry, Medicine, and Physics since 2000 and immigrants or their children founded 45% of the 2019 Fortune 500 companies. We want these individuals to come here, stay here, and choose to work with us no matter where they were born. It is our strategic imperative to continue recruiting the best, highly-skilled individuals—regardless of national origin—to work within the U.S. research enterprise.

UTILIZING HIRING FLEXIBILITIES

The Department continues to make extensive use of recruitment and retention authorities to enhance its science and technology workforce. These authorities give Service laboratories the ability to conduct direct hiring in particular fields, such as cybersecurity, to support continuing education, provide recruitment bonuses, and reward employees with performance-based pay.

These tools allow DoD laboratories to recruit and retain top S&T talent and remain competitive with the private sector. For instance, the Air Force Research Laboratory (AFRL) has used the Enhanced Pay Authority to hire subject matter experts in the areas of autonomous systems, data analytics, and communications and networking, which directly enhances their ability to support the Department's modernization priorities.

THE ROLE OF SMALL BUSINESS

The Department invests nearly $2 billion annually in innovative small businesses, entrepreneurs, and academic research institutions through the Small Business Innovation Research (SBIR)/ Small Business Technology Transfer (STTR) programs. These programs provide the DoD access to the small business community, reaching experts and academics that may not otherwise be engaged.

Small businesses that begin working with DoD through the SBIR/STTR programs have the option of partnering with existing contractors or larger businesses that may already be working on Programs of Record or fielded services. For many small businesses this is a "foot in the door" providing experience working with the DoD and providing DoD with access to new perspective and talent from the small business community. Moreover, SBIR/STTR projects are often dual-use, and are both transitioned to the military and commercialized for private-sector benefit. The Department facilitates both military transition and private sector commercialization opportunities through Component SBIR/STTR Commercialization Readiness Programs (CRP) and the OSD Transitions SBIR/STTR Technologies (OTST) Program. The Department also held its first Virtual Symposium on transition in October 2020 with over 1,000 participants from small businesses, primes, and academia.

DoD has focused the SBIR and STTR investment programs on the Department's modernization priorities. Additionally, DoD has streamlined and modernized the SBIR and STTR proposal submission process, with the goal of making these programs more accessible to small, domestic firms.

In order to promote small business within the defense contracting space, the DoD facilitates licensing opportunities through our national partnership intermediary, TechLink. Partnership with TechLink offers licensing support to small businesses working with the DoD, which is mutually beneficial, delivering value to the small business and enabling further innovation.

Additionally, the Department encourages larger defense contractors to work with small businesses, including SBIR/STTR performers, through specific subcontracting requirements and through the Mentor Protégé program managed by the Office of Small Business Programs within the Office of the Under Secretary of Defense for Acquisition and Sustainment. These mechanisms further assist small businesses to contribute to Defense innovation, while also making it easier to do business with the DoD.

HOW SMALL BUSINESS INNOVATION IN DOD HELPS AMERICA BROADLY

DoD reaps tremendous benefits from partnering with small businesses. A recent study of the SBIR/STTR programs found the Department achieved a 22-to-1 return on investment in small business research and development over the past 23 years, resulting in $347 billion in total economic output. An economic impact study conducted in 2018 on the DoD license agreements active during the 2000-2017 period revealed $27 billion in sales of new products and services, including at least $5 billion in confirmed sales to the U.S. military. Overall, these agreements generated over $58 billion in total economic impact and created approximately 215,000 jobs. In this study, small businesses accounted for approximately 80% of the licenses.

THE DEFENSE MANUFACTURING BASE

Manufacturing is critical to the advancement of our technology modernization objectives. The DoD Manufacturing Technology program (ManTech) executes a portfolio of project investments across OSD, the Services, and Agencies, focusing on advanced manufacturing technologies. The ManTech program also serves as a lead Federal strategic investment partner to 9 of the 16 Manufacturing USA innovation institutes (MIIs).

These MIIs promote domain-focused manufacturing ecosystems in areas of value to the Department and identify emerging areas of importance to the U.S. manufacturing base. The MIIs employ pre-competitive technology advancement and investment, and facilitate community building and workforce development. They bring together industry, academia, and federal partners to increase U.S. manufacturing competitiveness and promote a robust and sustainable national manufacturing R&D infrastructure.

For example, the Manufacturing times Digital (MxD) Institute recently welcomed 5G on its Future Factory Floor to serve as a testbed for demonstrating the opportunities 5G, artificial

intelligence, and machine learning bring to manufacturing. The ManTech team has also begun to accelerate advanced manufacturing technologies through public-private partnerships in cybersecurity, photonics, and regenerative medicine.

Solar power and our most advanced medical diagnostic machines both depend on advanced photonics. The American Institute for Manufacturing Integrated Photonics (AIM Photonics) is an engineering technology consortium that has established a U.S.-based Photonic Integrated Chip (PIC) manufacturing ecosystem. This ecosystem is leading efforts in the prototyping, validation, and final packaging of advanced node microelectronics and photonic chip fabrication, and the development of test, assembly, and packaging facilities.

Last year the Department established its ninth DoD-lead Manufacturing Innovation Institute – BIOMADE, to specifically focus on bio-industrial manufacturing. This institute leverages emerging biotechnologies, including modern engineering biology techniques, to foster domestic leadership in bio-manufacturing. BIOMADE is already building partnerships across the U.S. bio-economy and strengthening linkages between defense needs and industry and academic partners.

Hypersonic weapons depend on the manufacturability of carbon-carbon materials. Working to address this need, ManTech is sponsoring the manufacture of carbon-carbon composite for the Hypersonics Applications (MOC3HA) initiative. This effort works directly with domestic manufacturers of carbon-carbon material to streamline processes and improve quality and reliability volume and size, reduce cost and cycle time, and increase yield.

The department has convened a DoD-wide Manufacturing Council to coordinate activities addressing defense-wide challenges as well as human capital investments and strategies, and to serve as a touchpoint for industry. Through this Council, we align the funds in the ManTech program, Industrial Base Analysis and Sustainment effort, and Defense Production Act Title III authorities to achieve our modernization goals and to maintain our technical advantage.

SUPPORTING DOD'S MIIS RESPONSE TO THE COVID-19 PANDEMIC

America Makes, the DoD-sponsored institute for additive manufacturing, rapidly partnered with the Food and Drug Administration (FDA), HHS/Assistant Secretary for Preparedness and Response (ASPR), National Institutes of Health (NIH), and Veterans Affairs (VA) to efficiently and safely match health care provider needs for PPE. This project also developed a rapid method for design submission and approval of 3D PPE designs under DoD funding.

As of February 25, 2021, more than 624 published designs were available on the Exchange, with 34 designs optimized for clinical use and 28 designs optimized for community use. These designs have been downloaded over 200,000 times with more than 2.5 million views. Through the effort, America Makes assisted front line workers in obtaining hundreds of thousands of pieces of critical PPE supplies from qualified manufacturing across the U.S.

The NextFlex Manufacturing Innovation Institute facilitated a project that uses novel RNA sequencing technology to prove the environmental contamination and transmission pathway, then refined and expanded production capacity of antimicrobial mats called "clean surfaces" to

address surface contact infections. Virus and bacteria surface contact infections are frequent, and pathogens often remain viable and contagious between surface cleanings even if proper episodic procedures are followed.

For this novel "clean surface" technology, any time microbes contact the mat surface, an embedded circuit board sends a micro-electric impulse along printed conductive traces to that location to activate antimicrobial silver and copper ions that quickly eradicate the contaminants. The flexibility of these mats allows them to be placed around the side rails of hospital beds, on tables, or doorknobs. The application of this innovation to public, medical and retail infrastructure in the long-term could impact how future viral outbreaks are controlled, especially during flu seasons. The mats went through validation testing throughout the University of Pittsburgh Medical Center hospital system and are now being installed in six hospital ICUs for a six-month experiment to measure pre- and post-infection rates.

The Advanced Functional Fabrics of America (AFFOA) is a DoD-sponsored advanced fabrics institute and was selected to participate on the Commonwealth of Massachusetts' Manufacturing Emergency Response Team. Alongside the Massachusetts Technology Collaborative, AFFOA helped administer $5.6 million in funds for PPE through the Massachusetts MII program for domestic manufacturers pivoting to manufacture PPE, identified opportunities to rapidly optimize the PPE supply chain, matched PPE manufacturers with producers of raw materials, and connected hospitals to manufacturers to quickly produce needed products. AFFOA also built a distributed PPE material-testing network to assist hospitals, state emergency management agencies, first responder organizations, and domestic manufacturers to test their materials and PPE products and ensure product performance and regulatory compliance.

STRENGTHENING OUR DEFENSE RESEARCH BASE

Scientific discoveries occurring at universities and laboratories supported by the DoD, have led to dramatic commercial and national security advances and have significantly improved citizens' lives around the world. DoD's relationship with academia is an incredibly valuable force multiplier for the basic research enterprise.

In addition to our Defense Laboratories, the Department's FFRDCs and UARCs are a critical element of our innovation base, providing the independent and objective scientific and technical expertise that the Department relies on to create technical superiority. Last year, we undertook a concerted effort to ensure the Department employs our FFRDCs for maximum strategic impact.

In FY19, the FFRDCs and UARCs made numerous contributions to enhance the capabilities of the Joint Force. For example, the Aerospace Corporation was an integral part of the Government and contractor team that successfully launched a GPS III on a Falcon 9 rocket. This was the first flight of a competitively awarded National Security Space Launch mission in nearly 20 years. In another instance, the Johns Hopkins Applied Physics Laboratory developed a technically rigorous "space game" that enabled participants to grapple with realistic and technically informed timelines, authorities, questions, and rules of engagement, and the operational implications of pursuing different space architectures. Playing out these scenarios has informed the department's investment decisions.

INTERNATIONAL PARTNERSHIPS

Our Allies are essential to our national security. This is true in research as it is in warfighting. We continue to develop our international partnerships through the SMART program. Two examples from the SMART program to highlight are the Alan Turing Institute in the U.K., where SMART scholars can perform research on artificial intelligence and machine learning, and the von Karman Institute for Fluid Dynamics in Belgium, where SMART scholars can perform research on hypersonics. Through these efforts, scholars work with their peers overseas improving our S&T community and contributing to the Department's international partnerships.

TECHNOLOGY PROTECTION

Our military's technological edge is at risk. Competitor nations are acquiring intellectual property and sensitive technologies from our academic research system and industry through illicit and legal means. The department is taking a multipronged approach to address this issue. We are applying protections for critical technologies and programs that prevent technologies from falling into the wrong hands. We are establishing procedures to reinforce the integrity of our research enterprise. We are also engaging the broader S&T community and our stakeholders to provide improved threat awareness, inform necessary controls, and develop best practices that can be institutionalized across the DoD S&T enterprise.

We continue to look for new methods to secure our technology. Technology Area Protections Plans (TAPPS) are new initiatives we are using to provide a common understanding of what needs to be protected and a strategy to establish protections. TAPPs will help S&T organizations get information regarding emerging and disruptive research that can be used to apply safeguards through Program Plans. The TAPPs in development align with the 2019 DoD list of critical programs and technologies mandated by Section 1049 of the FY2019 NDAA.

We have also taken other steps to protect open research at U.S. institutions. R&E is currently working with other federal research funding agencies to develop common standards for identifying and adjudicating conflicts of interest and conflicts of commitment. We are fully engaged with the White House Office of Science and Technology Policy to develop Federal guidance for Research Security and Integrity.

In March 2019, we issued instructions to our partners in academia, requiring that key research personnel funded by DoD grants, cooperative agreements, Technology Investment Agreements, and other non-procurement transactions disclose all current and pending projects and funding sources. We are also revising research grant and cooperative agreement procedures to exclude research funding for individuals posing an unacceptable risk to national security or participating in foreign talent recruitment programs. Moreover, DoD encourages academic institutions, associations, and councils to develop training modules for faculty to clearly explain the landscape of threats to research integrity.

Technology protection requires a nuanced and multifaceted approach as well as partnerships with other government agencies, industry, academia, and allies. An uncoordinated, broad-brush

approach to technology protection can result in damaging consequences that inhibit leading-edge research. At the same time as we work to protect our technological edge, we recognize that the free exchange of ideas and collaboration are critical to our continued success. We must preserve the long-standing norms that have benefited our research institutions while at the same time punishing bad actors who break the law. While we must guard against espionage and the theft of intellectual property, we must also nurture an open, pioneering and collaborative culture that has historically served our country so well.

CREATING AND PROMOTING NEW TECHNOLOGIES

The office of the Director of Defense Research and Engineering for Modernization develops and coordinates Department-wide science and technology strategies to guide and drive technology development and inform requirements. By developing S&T roadmaps, we prioritize resourcing, support future technology insertion, and provide opportunities for investments to accelerate development efforts. Our current efforts are focused on 11 modernization areas; 5G, Hypersonics, Directed Energy, AI, Biotechnology, Microelectronics, Cyber, Quantum Science, Autonomous Systems, Fully Networked Command and Control, and Space.

Microelectronics

Microelectronics is a critical focus area for DoD Modernization. Advanced capability microelectronics technology development directly influences success in fielding disruptive technologies, including Artificial Intelligence, Hypersonics, and 5G. The US is struggling to maintain global competitiveness in leading edge fabrication and design innovation, despite supporting a diverse infrastructure of research, design, intellectual property (IP) rights, and physical plants that should enable the US to be an attractive market for the semiconductor industry. Additionally, aggressive investments and actions by peer competitor nations threaten U.S. leadership. Russia and China have publicly stated that advanced microelectronics and AI are the keys to economic and military dominance. Nearly 90 percent of the world's semiconductor foundry market share belongs to companies with foundries in Taiwan, South Korea and China. This imbalance is prompting calls to boost domestic capacity.

R&E's Trusted and Assured Microelectronics (T&AM) Program is executing the development of key technologies in accordance with the DoD Microelectronics roadmap. The broad goals of the T&AM program are to secure U.S. microelectronics interests, reverse the erosion of domestic innovation and supply, and establish a strong leadership foundation for the next-generation of microelectronics technology for DoD applications. We are involved in three lines of effort to reach these goals:

1. Assurance of the integrity of microelectronic products as they move through the supply chain through the development and application of enhanced assurance technologies, services, and standards.

2. Availability of critical and common IP, manufacturing capabilities, and assurance tools and services required for DoD research, development and acquisition programs.

3. Access to design modules, design capabilities, manufacturing, and verification and validation services at commercial sources with lowered barriers and integrity/confidentiality protection measures.

We plan to continue investing in advanced capability microelectronics, ensuring access to State of the Art microelectronics, advanced packaging and test, and to radiation hardened microelectronics. We are also moving forward with the establishment of the Joint Federated Assurance Center, and continuing to investment in the DARPA led Electronics Resurgence Initiative (ERI). ERI is intended to ensure U.S. microelectronics technology leadership well into the 21st century. ERI will pursue electronics performance advancements by leveraging circuit specialization, to include materials, architectures and designs.

Artificial Intelligence

We are in a global arms race in artificial intelligence technology and applications, most notably with China, who has set a goal to lead in AI technology by 2030. To maintain US dominance in AI, we will:

1. Continue to invest in cutting-edge AI research through organizations such as DARPA and Office of Naval Research (ONR).
2. Democratize DoD AI innovation by developing modern data and software development processes providing end-users and warfighters the ability to engage with AI development directly.
3. Accelerate AI adoption by supporting a rapid development pipeline, from research to our engineering centers to the service software factories and program offices.

This three-prong approach will lead to: trusted AI capability that has high utility to the warfighter, decreased development timelines, lowered cost-structures and reduced maintenance; increased understanding and availability of DoD data which is so vital to AI development; and improved talent development and retention within the civilian and service member community. Although this revolution is in its early phase, the capability is currently being tested in such areas as predictive maintenance, business operations, and automated target recognition. More generally, AI will enable a myriad of capabilities across the force, including intelligence fusion and analysis, planning and prediction, and longer-term autonomy.

Just as the second wave of AI research performed within the Department 20 years ago led to the explosion of commercial activity in the US today, R&E is heavily involved in a third wave of advanced AI techniques and capability that will further strengthen the American AI ecosystem and have future commercial impacts.

Cyber

Our adversaries are engaged in wide-ranging and highly impactful malicious activities in cyberspace, often with near-impunity. Fortunately, through the implementation of the 2018 DoD Cyber Strategy, which embraces a defend-forward and persistent engagement approach, US Cyber Command and the Service Cyber Components are now blunting and disrupting many of our adversaries' malicious cyberspace activities. Through this approach, and by leveraging new capabilities made possible through significant and long-term DoD S&T investments, our cyber forces are now exacting far greater costs on our adversaries.

To build on this momentum and ensure increasing dominance, our cyber strategy calls for increased investments to accelerate the development and rapid transition of technologies that provide the basis for 1) vastly enhanced resilience of DoD systems and critical infrastructure 2) substantially increased capacity and unrivaled capabilities for the conduct of cyber and cyber-enabled operations, 3) overmatching skills and expertise within the Cyber Mission Forces, and the Cybersecurity and Cyber S&T workforces.

Further, thanks to Congress' support of FY20 and FY21 appropriations totaling $20M, OUSD(R&E) is awarding the first three academic Cyber Institute consortiums in April 2021. Known as VICEROY (Virtual Institutes for Cyber and Electromagnetic Research and Employ), they will prepare future ROTC and DoD-minded civilians for challenging cyber and electromagnetic spectrum operations and research careers through experiential learning. These increased investments in both technology and human capital will compound the dividends of the now decade-long increased focus, by DARPA and the Services, on the development of innovative and increasingly sophisticated cyber technologies.

5G

Technology to *secure* 5G communications is paramount to *leveraging* 5G for operations and communications superiority. As an investor in and significant consumer of technological innovation, the Department drives a cycle that parallels civilian industry and leads to new capabilities and services that would otherwise not be available. The technologies being developed and tested in the 5G Initiative will drive U.S. technology and innovation. Further, the dual-use applications being developed will help U.S. industry get 5G-enabled products to the commercial market more quickly while also providing DoD with new operational capabilities.

Security is often "bolted on" after a system has been developed. 5G networks, prototypes, and operating procedures are being developed now, and the 5G Initiative is actively working with industry to address security early by engaging both large integrators and non-traditional performers in experiments at over a dozen DoD facilities around the country. Examples include new 5G techniques for device authentication, using network slices (virtual networks on top of the underlying network) for threat detection and protection, and using multiple network paths for added resilience. We are working with industry and the standards community to build security into the design from the start, so security is viewed as a key metric, comparable to factors like network speed and latency.

Our 5G Initiative emphasizes Zero Trust principles, that is, moving away from defenses based on perimeters to defense in depth. Perimeter-based defenses are ineffective in dynamic environments that include multiple mobile devices, potentially untrusted supply chain components, and massive scale – all of which are anticipated under 5G. A perimeter defense is like a castle and moat defense; one builds a moat and wall around the protected center to keep the threat outside the castle and moat. In dynamic 5G environments, there is no castle. Instead, we need to think in terms of an in-depth defense strategy that assumes an adversary may be anywhere in the 5G environment. Continuous monitoring and rapid detection of unintentional faults and malicious attacks allow us to adapt in real time.

The 5G Initiative is developing multiple 5G testbeds across the country to demonstrate the efficiency and capability that 5G will enable for the Department of Defense. The testbeds provide the Services the ability to develop and test novel capabilities in at-scale environments

that would otherwise not exist. The testbeds represent 10 different projects spanning 14 military locations and representing over seven tactical and operational mission areas/use cases. At Hill AFB, the 5G Initiative develops technology to enable 5G networks to share spectrum with airborne radars dynamically. At Naval Base Coronado and Marine Corps Logistics Base Albany, the 5G Initiative is developing smart warehouse technology enabled by 5G. The technology will enable more efficient, accurate, and timely delivery of warfighting material. At Joint Base Lewis-McChord, the 5G Initiative develops Augmented Reality / Virtual Reality for the training environment.

Finally, ongoing dialogues with Service Programs of Record (PORs) ensure that the research projects address service requirements and that PORs are making plans to transition and incorporate successful 5G developments.

Autonomous Systems

DARPA's "Grand Challenges" on autonomous vehicles served as the primary catalyst for significant interest-and investment-by academia, industry, and government in autonomous systems. Building on this legacy, DoD application of intelligent, autonomous behaviors to robotic and unmanned systems (across all warfighting domains) is poised to allow humans and machines to team and achieve an overwhelming warfighting advantage not possible by humans or machines acting alone.

These behaviors increase efficiency by reducing the physical and/or cognitive loads on the warfighter; reduce risk to warfighters by reducing manned operation in harsh and unpredictable environments; and provide the potential to generate cost-effective combat mass. Moving beyond today's current limited fielding of intelligent autonomous systems that primarily support intelligence, surveillance, and reconnaissance activities with platform-level autonomous navigation, future capabilities will be applied across the spectrum of warfighting functions.

In the near-to-mid-term, autonomy efforts within research and engineering will result in advances in a number of areas, including; responsive fires support based for both manned and unmanned sensor and weapon systems; effective, resilient resupply using autonomous systems from point of manufacture to delivery; and joint all-domain and control enabled by autonomous systems increasing reconnaissance and surveillance ability.

To speed the development of these effective, appropriate, and safe intelligent autonomous systems, the DoD will continue to develop the digital engineering infrastructure necessary to design, fabricate, and test these systems throughout the entire Robotics and Autonomous System lifecycle. Successful fielding of these systems will leverage ongoing efforts to develop and implement a comprehensive Joint all domain command and control system as well as efforts to develop a secure cloud environment including a cloud-to-edge strategy suitable for contested environments. In concert, we must conduct virtual and live experimentation to fully explore future operational concepts as well as continue to develop sound, thoughtful, and ethical principles for the employment of Robotics and Autonomous Systems.

Biotechnology

Biotechnology will fundamentally change the future battlefield, and US adversaries (most notably China) are aggressively pursuing related capabilities. Furthermore, China has signaled

willingness to use this and other emerging technologies against their opposition without respect for protocols, conventions, or human rights. Biotechnologies hold potential to broadly impact defense capabilities; however, until recently, DoD investments have almost exclusively focused on medicine and chem-bio defense missions.

A key application of biotechnology to national security is the ability of bioindustrial manufacturing to generate novel, domestic, safe, and sustainable sources of critical supply chain components. For example, a project executed by ONR and NAVAIR China Lake demonstrated the use of engineered bacteria to produce linalool, which can be efficiently converted to jet fuel, diesel, gasoline, and high density missile fuels. Other DoD efforts, such as DARPA's Living Foundries program, have illuminated the potential for more than 1,000 DoD-relevant molecules to be produced using biology.

The Department is prioritizing partnerships with Industry, to include BIOMADE – the newly awarded Bioindustrial Manufacturing Innovation Institute (MII) – and in collaboration with the Services, is focusing biotechnology modernization on: (1) building a common foundation of physical and digital infrastructure to create a rapid prototyping pipeline, (2) identifying and prioritizing use cases for prototyping and demonstration, and (3) enhancing workforce development opportunities. Investing in a pipeline for advanced development of bioindustrially-sourced products will not only provide critical materials and capabilities for our warfighters and maintain our competitive advantage in the field, a robust industrial base will also ensure that the future global bioeconomy is made in America.

Directed Energy

Directed Energy Weapons can provide US forces with a high rate of fire weapon with a reduced logistical burden. This capability will be especially important as potential adversaries continue to develop advanced missile capabilities. We are working with the Services to accelerate operational weapon system development and operational experimentation, to build the industrial base, to develop the needed science and technology, and to carry out the capability development and demonstrations leading into programs of record.

Through our Laser Scaling Program, we are using industry to build 300 kW high-energy lasers by the end of 2022, and then we are increasing power to 500 kW by the end of 2025, and to 1000 kW by the end of 2028, all while reducing the size, weight, power, and thermal needs of these systems. Through our Rapid Prototyping Fund, the Navy will operationally test new laser and high-power microwave weapon prototypes at sea in 2020 and beyond. Further, we have partnered with the Special Operations Command to accelerate programs for airborne and land-based laser strike weapons. We have partnered with the Army Futures Command and the Navy to accelerate land- and sea-based laser and high-power microwave weapons for integrated air-and-missile defense, with initial demonstrations in 2022, key decisions in 2023, and initial capability in 2025.

In anticipation of new and more lethal directed energy weapons transitioning to programs of record, we are upgrading our test and evaluation capabilities with new infrastructure at the test ranges. Along with all this effort there is a tightly coupled science and technology effort aimed at lethality, beam control, propagation, power, and thermal management. Multi-domain mission analysis is being carried out to expand the range of missions and to enable directed energy weapons integration into the Joint Force.

Fully Networked Command, Control & Communications (FNC3)

To improve command, control and communications (C3) the department is focused on providing the capability to evolve rapidly and independently between systems, equipment and users. This effort involves integrating stove-piped C3 systems into a layered architecture. The FNC3 effort is closely tied to Joint All Domain Command and Control (JADC2) and together these efforts are synchronizing investments across the DoD to ensure that the Joint Force's C3 are interoperable, resilient and capable.

By breaking-up the current stovepipes, we can increase resilience and improve Quality of Service (QoS - data rate and latency).

We are also making rapid developments in software defined radios and investing digital active electronically scanned antennas and optical communications systems. This will strengthen the resilience of individual links, grow capacity, improve interoperability and enable rapid fielding of better waveforms and algorithms. DoD is already transitioning and taking advantage of these new capabilities, such as the upgrades to the Multifunctional Information Distribution System (MIDS), which includes Link-16, and the Warrior Robust Enhanced Network (WREN).

We are leveraging recent concepts in Software Defined Networking (SDN) such as network slicing, to manage all the available diversity and deliver the much needed resilience with the necessary Quality of Service. Our investments are targeted at optimizing SDN concepts to our DoD tactical and strategic networks, as they are different from the commercial networks where SDN has been implemented to date. The US Navy's Tactical Data Dissemination Initiative (TDDi) is an early transition of these SDN technologies. To improve interoperability between applications in the short term, machine-to-machine interoperability technologies (e.g. efficient translators) such as DARPA's STITCHES program are ready for transition.

In the medium and long-term the Department (led by the DoD CIO's Office) is moving towards a federated data-centric architecture to reduce the overhead associated with current approaches to interoperability. In support, we are investing in a data-centric approach to C2 messaging (known as Universal Command and Control – UC2) that takes advantage of a recent encoding innovation, variable format binary (e.g. ProtoBuf and EXI), to produce a C2 messaging standard that is simultaneously efficient, evolvable and broadly applicable. An initial demonstration of the data-centric C2 techniques applied to the Counter Unmanned Ariel Systems mission is planned for the end of this year. Improving our C2 applications ability to better infer relevant information from the available data and provide decision support is also key to better C2 with investments coordinated across multiple modernization portfolios including AI, Autonomy and FNC3.

Hypersonics

Hypersonic systems take advantage of speed, maneuverability and sustained flight in the altitude gap between air defenses and ballistic missile defenses to provide transformational capability for survivable, long-range, lethal, time-critical strike of heavily defended and high value targets. Hypersonic systems are enabled by innovations in highly integrated aerodynamic configurations, high temperature materials and structures, high speed propulsion, and advanced guidance, navigation and control. Over the past decade, focused research, development, test and evaluation has created the opportunity to rapidly transition developmental system concepts to weapon

system prototypes and to operational weapon systems. We are working in close coordination with the Services to accelerate development and fielding of multiple air, land and sea launched conventional hypersonic strike weapons to defeat targets of critical importance.

Our potential adversaries are rapidly evolving high-end offensive and defensive systems creating highly contested anti-access/area denial (A2/AD) environments that challenge our tactical battlefield dominance and necessitate the development of hypersonic strike capabilities. Additionally, our potential adversaries are aggressively pursuing, and now fielding a variety of hypersonic systems. This compresses the timescale on the tactical battlefield, creating asymmetry, which we are working to address. We will continue to implement our integrated strategy to enable fielding of operational prototypes in quantity from land, sea and air by the mid-2020s.

We are also working with the Missile Defense Agency to accelerate a comprehensive layered defeat capability against adversary tactical hypersonic weapons including kinetic defense in the terminal and glide phases of flight, as well as left-of-launch strike of missile launch complexes. The DoD hypersonics capability fielding strategy is being implemented through a highly coordinated set of programs across the services and agencies, to include a joint service memorandum of agreement and middle tier acquisition programs to effectively accelerate capability to the warfighter. Critical investments in our industrial base, our workforce, applied technology, and test infrastructure are being made to enable this acceleration and to pave the way for technical superiority for decades to come.

The Joint Hypersonics Transition Office (JHTO), which resides in our Advanced Capabilities directorate, works in close coordination with our Principal Director for Hypersonics to accelerate the development and transition of hypersonic technology to the warfighter. As the engineering and execution arm for hypersonics in the Office of the Secretary of Defense, the JHTO works closely with the Principal Director for Hypersonics to identify and address critical science and technology and workforce gaps and opportunities to ensure the success of the Hypersonics Strategy. In a resource-constrained environment with an adversary operating with more resources and faster development timelines, the JHTO addresses the need to accelerate and more efficiently develop hypersonic technologies by tying S&T investments directly to identified military needs, providing mechanisms for closer collaboration and coordination across the government, and identifying opportunities to tap into non-traditional performers such as universities and foreign allies.

The JHTO has five lines of effort aimed at increasing the speed of innovation in the U.S. and allied hypersonics enterprise:

1. the JHTO develops capability-based S&T roadmaps covering basic and applied research to guide the hypersonics S&T enterprise and funded $48M in FY2020 in 28 projects to accelerate technologies that address the most critical S&T gaps.

2. the JHTO is sponsoring an effort with Boeing and Aerojet and the AFRL to mature a propulsion design to enable a hypersonic cruise missile option for aircraft carrier-based F/A-18s and a joint USAF/USN missile.

3. the JHTO in November 2020 stood up a university consortium of applied hypersonics at the Texas A&M Engineering Experiment Station (TEES) that enables nearly 100 universities to work on applied hypersonics research, provide expertise to the government, and to address workforce gaps. The JHTO is funding $20 million a year in university research through the consortium and has made this research ecosystem available to the rest of the government to access applied hypersonics research.

4. As the lead for allied engagements in hypersonics, the JHTO is the co-chair of the Australia-US Hypersonics Working Group (HWG) formed in August 2020 to develop a bi-lateral strategy and coordinate S&T and activities in hypersonics.

5. the JHTO in October 2020 stood up the JHTO Systems Engineering Field Activity at NSWC Crane in Indiana to provide the systems engineering rigor to JHTO-funded S&T efforts to ensure that they can transition into our programs.

Quantum Science

Successes in the area of quantum science research at DoD demonstrates how early-stage research can have a multiplier effect in other areas important to national security. A clear line can be drawn to the 20+ years of basic research funding within the DoD, and the major successes we are now seeing in U.S. commercial industry related to atomic clocks, quantum computing, the growing importance of quantum sensors, and quantum networks. These quantum technologies have significant economic and national security impact, made possible as a result of long-term, dedicated basic research funding.

Recent increases in federal funding through the National Quantum Initiative Act have led to increased levels of coordination with government partners. Increased commercial investments in quantum computing and quantum sensors are leading to new opportunities for DoD to engage and look towards transitioning this technology for military advantage. DoD is focused on the long-term opportunities of this technology for both military and civil applications.

Advances in quantum science are only beginning, and there is much more potential to discover through research. As quantum technologies develop, their importance to our economy and to national defense are likely to increase.

Space

The US cannot cede its dominance in space. Space related work will enable the US economy, diplomacy, and the military.

The dominance of the US in space is being challenged. Potential adversaries are showing their ability to rapidly deploy space capabilities, they are extending their reach to the Moon, the area between the Moon and the Earth, and they are innovating with technologies that challenge norms of behavior and provide asymmetric advantages threatening both terrestrial and space capabilities.

We are exploring numerous game-changing technologies with the labs and international partners such as advanced quantum encryption, artificial intelligence and smaller satellites that provide more capabilities, and austere on-demand responsive launch systems. Most notably, we have

just initiated a new space research consortium program to mine the best and brightest researchers from universities and the tech base to focus on the hardest of space challenges identified collaboratively through a Board of Directors consisting of R&E, US Space Force, DARPA, DIU, Department of Energy, NASA and others. In addition to speeding the deployment of new space technologies through efforts like SpaceWerx and the space software factories, we are exploring cis lunar architectures and technologies such as space domain awareness, rapid maneuver and long-duration station keeping, through collaborative efforts in nuclear power and propulsion with the Department of Energy.

MISSILE DEFENSE AND SPACE DEVELOPMENT AGENCIES

The Missile Defense Agency (MDA), the Defense Innovation Unit (DIU), and the Space Development Agency (SDA) fall under the R&E umbrella. MDA and SDA are working on programs providing our nation with defense against some of the most advanced threats in the world. DIU plays an essential role in providing an entry point for innovators in the private sector to engage with needs of the DoD.

Missile Defense Agency

The Missile Defense Agency (MDA) is developing capability and technologies that address the evolving missile threat. MDA will develop a Next Generation Interceptor (NGI), which improves homeland missile-defense performance and survivability against the assessed rogue nation threats as part of the Missile Defense System (MDS). In FY 2021, MDA will award the design and development activities for two competitive NGI development contracts. The initiation of the NGI program and the continued Ground-based Midcourse Defense Service Life Extension Program will extend the existing Fort Greely, Alaska, and Vandenberg Air Force Base, California, capability to defend the homeland from ballistic missiles beyond 2030.

The Department is investing in technologies and studying capabilities to defeat regional offensive hypersonic weapons, the first element of which is to detect and track incoming missile threats. MDA delivered a capability for USINDOPACOM for real-time sensing and display of hypersonic and maneuvering vehicle tracks. This capability is operational now in support of the Missile Warning and Missile Defense missions. In collaboration with industry partners, US Space Force, USNORTHCOM, USSTRATCOM, USSPACECOM, and the Space Development Agency, MDA is pursuing a Hypersonic and Ballistic Tracking Space Sensor (HBTSS). Once deployed, HBTSS will become a key element of the MDS in hypersonic defense by providing a persistent, layered capability to detect and track dim boosting ballistic missiles, hypersonic glide vehicles, and raids in all phases of flight. MDA awarded two agreements earlier this year to industry to build an on-orbit prototype-demonstration space vehicle for a planned launch in 2023.

With the achievement of Initial Fielding in fourth quarter FY 2021 and operational acceptance in first quarter FY 2023, MDA will add the Long Range Discrimination Radar in Alaska into the MDS architecture to provide a persistent capability to defend the United States homeland against IRBMs and ICBMs. This past year the Department demonstrated the ability of the Patriot missile defense system to intercept a short-range ballistic missile target using THAAD/AN/TPY-2 track and discrimination data. MDA also is continuing to mature an integrated air and missile defense capability for regional defense.

MDA, in cooperation with the U.S. Navy, demonstrated early capability against maneuvering threats during flight-testing of the Standard Missile (SM)-6 Sea-Based Terminal (SBT) defense, and it will further demonstrate this capability against an advanced maneuvering threat-representative target later this year. We will continue to advance our SBT capability to address the regional hypersonic threat and will test that capability in the FY 2024 timeframe. MDA plans to accelerate the hypersonic missile defense program under a newly designated Glide Phase Intercept initiative to develop a capability to defeat a regional hypersonic threat. The eventual goal is providing greater depth of fire in a regional layered defense architecture. MDA is also pursuing advances in joint all-domain and global command and control to support USNORTHCOM in countering very long-range cruise missiles.

The Department's previous missile defense technology innovations have transitioned into weapon systems and vastly improved interceptor seeker capability, increased the speed and range of intercept with advances in propulsion, and increased the probability of single-shot kill using multifaceted tracking and discrimination algorithms. As an example, the technologies developed as part of the Multiple Object Kill Vehicle effort were presented to NGI bidders, and may be included in the proposals. Additionally, MDA invested in directed energy kill mechanisms, including multiple laser types, high-powered microwave, and component technologies to support development of sensors and interceptors, such as beam control and lethality. These investments allow the country to outpace the missile threat. We must continue to sustain, modernize, and expand the MDS by pursuing rapid, yet measured, development of advanced missile defense concepts and technologies for homeland and regional defense.

MDA is continually assessing emerging and disruptive technology for potential applications to missile defense utilization. Investments are being made in Artificial Intelligence, Machine Learning, Nanosat technology, Left-through-Right integration, Cybersecurity, and Quantum Science. Key to understanding the potential of technology has been the development of testbeds that allow MDA to exercise and demonstrate capabilities and test new concepts, algorithms, simulations, and software. MDA works extensively with partners, leveraging and expanding technology opportunities through cooperative, collaborative engagements with DoD partners, DoE labs, academia and U.S. allies and international partners.

MDA continues to drive for the inclusion of small businesses and universities through outreach, such as their Industry Innovation Summit and University Innovation Summit. These events present MDA's greatest technology challenges and offer one-on-one sessions for the Nation's most innovative minds to present their capabilities and solutions. MDA is committed to ensuring the use of small business to the maximum extent practicable, monitoring prime contractor performance to ensure contractors are achieving their proposed small business goals and objectives and have a mitigation plan in place to do so. MDA actively supports the DoD Mentor Protégé Program (MPP), currently overseeing five active DoD MPP agreements.

The MDA Small Business Advocacy Council (MDASBAC) consists of MDA large prime contractors dedicated to fostering and showcasing a superior collaborative environment to develop and promote successful small business relationships to achieve common goals. MDA has a robust outreach program and takes full advantage of the outreach resources administered by Procurement Technical Resource Centers / Small Business Development Centers to connect large defense contractors with viable small businesses to support the agency's mission.

Space Development Agency

The Space Development Agency (SDA) was established in March 2019 to develop and field an alternative National Defense Space Architecture and accelerate the deployment of next-generation space capabilities to the warfighter. SDA is developing capabilities to address a wide range of national security space needs identified in the DoD Space Enterprise Vision of August 2018. To address current near-peer threats, SDA is focused on the most urgent of these needs by delivering a mesh network that will provide low-latency data transport in space to enable advanced missile tracking and beyond-line-of-sight targeting of land and maritime targets.

At its second anniversary in the Department, SDA has shown itself to be a "constructive disruptor" in national security space. Its model is tied to two main pillars: ***proliferation*** of satellites in Low-Earth Orbit (LEO) and ***spiral development***, delivering new capabilities on-orbit every two years, starting in FY22. SDA's mission begins and ends with the warfighter, guiding SDA to stick to schedule so that needed capabilities are available for end users to address the threat at or ahead of need. The Agency has established a Warfighter Council to ensure the needs of the Combatant Commands, Services, Joint Staff, and Intelligence Community determine the minimum viable product for each tranche, or generation of satellites.

SDA is hitting its milestones and forming partnerships with the Services, Combatant Commands, and other DoD agencies to reduce risks and gain user insight. The agency delivered two satellites for launch nine months after receiving funding, was designated by the Department of Defense as the lead for the proliferated LEO Joint All-Domain Command and Control (JADC2) backbone, and awarded contracts for all four segments of its initial tranche. SDA is preparing to launch several capability demonstrations and risk-reduction experiments this year, in partnership with others from across the space enterprise, including DARPA, the Air Force Research Lab, Missile Defense Agency, and several small businesses developing state-of-the-art space technologies.

SDA actively seeks ways to leverage commercial advances in technology to enable its space architecture. New space companies are supplying satellites for the first generation of the architecture as well as the launch vehicle for that tranche. To kick off 2021, SDA published an update to the National Defense Space Architecture (NDSA) Systems, Technologies, and Emerging Capabilities (STEC) Broad Agency Announcement (BAA) seeking studies, technologies, and prototypes that enable Real-Time Global Awareness and Connectivity; Comprehensive Space-Based Sensing; and Omniscient Command, Control, and Execution. This BAA is in place to establish an "intellectual pipeline" to access ideas from across the community to inform the future architecture, enable leap-ahead improvements for future tranches, and enable new capability layers that address emerging warfighter needs. SDA is also focusing on maturing and transitioning technologies from America's small businesses, start-ups, and research institutions through a series of SBIR/STTR opportunities this spring.

In FY22, SDA will launch and operate the first tranche of satellites to demonstrate the Transport layer, the mesh network of communications satellites, and the Tracking layer, Overhead Persistent Infrared (OPIR) sensing satellites that provide missile warning, detection, and tracking capabilities. Tranche 1, the next generation of these capabilities, is slated for delivery in

FY 2024, followed by future generations every two years that will incorporate battle management command and control and other layers of capability needed to provide persistent global access to protect national security. In FY23, the SDA will transition to the Space Force in accordance with the direction of the National Defense Authorization Act for FY 2020.

CONCLUSION

Our mission is to foster technological dominance across the Department of Defense, ensuring the unquestioned superiority of the American joint force. We are dedicated to ensuring that the technological edge remains in our favor. This statement while comprehensive, is not exhaustive in capturing all the activities being undertaken to maintain technological dominance in the present and future. The projects and programs contained in this statement do provide important examples of how crucial innovation is to the national security of the United States. I thank you for your time and I look forward to your questions.