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

Submitted to the
House Armed Services Committee
Subcommittee on Cyber, Innovative Technologies, and Information Systems

Reviewing Department of Defense Science and Technology Strategy, Policy, and Programs for
Fiscal Year 2022: Fostering a Robust Ecosystem for Our Technological Edge

May 20, 2021

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Introduction

Thank you for the opportunity to address you as the PTDO USDR&E. R&E serves as the chief technology officer for the Department of Defense (DoD) and is responsible for ensuring the technological dominance of the American joint force. R&E is also committed to the priorities of Secretary of Defense Austin in defending the nation, taking care of people, and succeeding through teamwork. We are focused on innovation throughout the DoD and on accelerating modernization across the services.

As both Secretary Austin and Deputy Secretary Hicks have stated, the People's Republic of China is the pacing challenge for the United States military. New technology and innovation will be central to meeting that challenge. Presenting a credible deterrent to potential adversaries requires us to develop and field emerging technologies at speed and scale.

Investments in science, technology, and innovation today can pay dividends tomorrow. One such example of how science can pay off is early DARPA research into mRNA that recently enabled COVID-19 vaccines. This is just one example of the tremendous impact DoD investments can make: not just for our military, but for our nation as a whole. To continue this track record of success and guarantee a strong tomorrow, DoD must reaffirm its commitment to science, technology, and innovation today.

The United States is leading the world in innovation, but other nations, including potential adversaries, are moving quickly to close that gap. Innovation has always been an asymmetric advantage to the United States, but to maintain that advantage, DoD must identify technologies that will impact the battlefield of tomorrow and be prepared to develop those technologies into usable capabilities.

DoD's Modernization Priorities

By developing and transitioning emerging technologies, USD(R&E) plays an essential role in outfitting DoD's warfighter with cutting edge technology. In addition to providing the warfighter with the best technology and tools, USD(R&E) is committed to leveraging commercial technologies, supporting innovative manufacturing capabilities, and improving the return on DoD's investments.

By investing in basic science and technology (S&T), DoD pushes the scientific frontier forward and de-risks investment for private industry. By taking a leadership role in S&T, DoD invests in breakthrough technologies, sends clear demand signals to innovative private companies, and creates opportunities to transition cutting edge capabilities to the warfighter. Developments in micro grid directed energy, autonomy and AI are examples where DoD led research has resulted in commercialization and economic gain outside of the defense space.

Today, USD(R&E) is leading modernization initiatives across 11 critical technical areas, including microelectronics, cyber, autonomy, artificial intelligence, hypersonics, space, biotechnology, directed energy, quantum science, FNC3 and 5G. For these 11 technologies, R&E is responsible for developing roadmaps that will guide these technologies from basic research all the way to fielding.

In the future, USD(R&E) looks forward to assessing its modernization priorities in the context of the forthcoming National Defense Strategy. To set these priorities smartly, USD(R&E) will constantly assess progress, technological maturity, and unique DoD use cases. USD(R&E) will also ensure that it develops

and fields priority technologies in a smart and efficient manner. Transitioning technology from the laboratory to the warfighter requires clear management, investment and focus. To improve technology transition, USD(R&E) is:

- Investing in basic research and developing tomorrow's workforce;
- Cultivating diversity;
- Fostering an innovative culture;
- Partnering with the private sector; and
- Leveraging the innovation inherent in small businesses; and
- Pushing the boundaries of technology to open new commercial markets.

I look forward to discussing DoD's technology priorities, as well as our efforts to improve technology transition, with sub-Committee today.

Prioritizing Technology Transition

By investing in early stage technology, DoD can act as an incubator for the private sector and can pioneer entire new markets. Today, USD(R&E) is pushing forward on a number of emerging technology areas that may have enormous benefits to the warfighter and are already offering secondary benefit to the nation. Emerging technologies in the areas of hypersonics, autonomy, and directed energy are examples of promising transition.

Hypersonics: The common hypersonic glide body (C-HGB) is currently transitioning to the services and now forms the basis of the Army Long Range Hypersonic Weapon and Navy Conventional Prompt Strike programs. C-HGB is a proven hypersonic glide body developed by Sandia national labs. The effort demonstrated the ability to deliver conventional effects thousands of miles away in 20 minutes or less with a high degree of accuracy and survivability. In addition to the potential capability to the warfighter, the development team transitioning expertise to industry for future development and production of capability.

Autonomy: Schools, offices, military bases, and manufacturing floors may require disinfection between shifts to minimize the spread of infection or contamination. The Decon-X (DX1) disinfecting system has proven its effectiveness in Europe, but currently lacks the mobility and autonomy to disinfect spaces without an operator. This Advanced Robotics for Manufacturing (ARM) project is aimed at adding mobile autonomous capabilities to the DX1 room disinfection system to automate the consecutive treatment of multiple rooms and spaces within workplaces. The addition of mobility and autonomous navigation to the DX1 will enable the robot to move from room to room and perform a series of treatments with little to no human intervention. A demonstration of the robotic system will be available in Fall 2021.

Autonomy: The Low Cost Attritable Strike Demonstration (LCASD) program was developed by the Director of Defense Research and Engineering, Advanced Capabilities (DDR&E(AC)) in collaboration with the United States Air Force with the goal of providing a developmental prototype and low-cost manufacturing techniques for a Program of Record. LCASD and the associated XQ-58A Valkyrie platform will increase Joint Force lethality per the National Defense Strategy by proving a long range, high performance attritable unmanned aerial system that can be used for both strike and intelligence, surveillance, and reconnaissance gathering missions. In addition, the data and software suites from this

project will be used within other unmanned systems. Best practices and lessons learned will inform the nation's defense industrial base on new, low-cost manufacturing methods.

Microgrid: R&E prototype investments have addressed critical needs in the mission areas of contested logistics and directed energy while having impact on our climate and energy footprint. We developed a prototype for a vehicle centric, mobile, fast forming, secure, intelligent microgrid that provides ad hoc, resilient power for next generation directed energy and missile defense technologies. The prototype vehicle microgrid enables on-the-move power generation to enable advanced capabilities for maneuver forces; improved logistics through reduced fuel consumption; and, faster setup, transport, and redeployment of power generation systems. In FY 2020, the prototype transitioned to the Army for use with THAAD and other systems. The potential also exists to employ this technology for civil disaster relief in cases such as in the aftermath of a hurricane or wildfire.

Investing in Basic Research to Develop Tomorrow's Workforce

DoD's commitment to basic research today is foundational to its ability to field cutting edge capabilities and to develop its future S&T workforce. For example, USD(R&E)'s Multidisciplinary University Research Initiatives Program (MURI) funds basic research using three to five-year university grants aimed at addressing DoD's hard problems and training its next generation of researchers. Programs similar to MURI, including Advanced Robotics for Manufacturing (ARM), American Institute for Manufacturing Integrated Photonics (AIM photonics) and the Advanced Regenerative Manufacturing Institute called BioFabUSA, use investments in basic research as a vehicle to develop breakthrough technology, train tomorrow's technology leaders. These programs help DoD modernize its future workforce in critical technology areas, including autonomy, microelectronics, and biotechnology.

Microelectronics: AIM Photonics offered a "Fabless Design of Photonic Integrated Circuits within the AIM Foundry Ecosystem" course for a second time this summer. Over 2,000 students enrolled in the six-week summer edX course in integrated photonic circuit design, with 159 students enrolling in the course and having access to the software tools, using over 14,716 hours of computational time. 95 students submitted photonic integrated circuit designs as part of the course.

Biotechnology: BioFabUSA developed the "TEMPtation" game to introduce students in grades 7-12 to the world of Tissue Engineered Medical Products (TEMPs) and biomanufacturing. This online game ran for several weeks, challenging students to learn about the TEMP industry while winning prizes. The goal was to expose students to careers in this industry while they are still choosing high school and college course work. Forty BioFabUSA members were featured. This activity helps BioFabUSA meet their goal of closing the skills gap in tissue and organ manufacturing by providing training opportunities to non-college bound youth and help prepare for future STEM workforce.

Autonomy: AIM is working to launch the first national resource that will connect workers with vetted training opportunities in robotics for manufacturing: roboticscareer.org. The resource will be structured as a public website and is set to launch in 2021. Over 10,000 robotics education programs across the United States will be identified on the website, with some programs endorsed as meeting the highest standards in the robotics industry in the categories of Relevance to the Industry, Effective Curriculum, and Efficiency of the Training, Impact of the Program, Program Sustainability and Transportability. These standards were developed in partnership with experts in the ARM ecosystem and government.

Cultivating a Diverse Workforce

To maintain its innovation edge, the United States must continue to lead the world in creativity, science, and academics. At DoD, this means looking for the best and brightest from all fields, from the social scientists to mechanical engineers. Beyond subject matter diversity, DoD is also committed to expanding its engagement with small businesses, start-ups and disruptive forces in the business and technology space. And when it comes to people, USD(R&E) prioritizes diversity in its workforce and promotes diversity in the scientific and academic community.

For example, the USD(R&E) Lightweight Innovations for Tomorrow (LIFT) program supports Heroes' Alliance, a Detroit nonprofit focused on empowering youth in urban communities through education and workforce development. LIFT has partnered with Heroes' Alliance to house their Cooperative Learning Center - an after-school science, technology, engineering, and math (STEM) program focused on vehicle technology where students from six Wayne and Oakland County high schools design, build, test and race electric and solar vehicles.

USD(R&E) also recently launched the Center of Excellence in Networked Configurable Command, Control and Communications for Rapid Situational Awareness (COE-NC4) at the University of California, Riverside. COE-NC4 is a \$7.5 million program administered by the Army Research laboratory and part of USD(R&E) historically black colleges and universities and Minority-Service Institutions. The COE-NC4 supports the Department's commitment to building a diverse pipeline of science, technology, engineering, and mathematics talent. This center will integrate underrepresented students into essential research efforts by way of design projects, colloquia, and internships at defense laboratories and provides participants with a pathway to graduate studies while fostering awareness of critical research that impacts our national security.

Another way DoD is fostering a more diverse workforce comprised of highly skilled and dedicated individuals is through our SMART Scholarship program outreach at Historically Black Colleges and Universities and Minority-Serving Institutions (HBCU/MI). Since 2018, 57 DoD STEM scholars who took part in the DoD HBCU/MI Program and Service component initiatives have accepted jobs with defense laboratories. DoD's partnerships with HBCUs/MIs not only strengthens the nation by building a workforce more reflective of the nation, but helps build a stronger national defense.

Additionally, USD(R&E)'s MxD was selected to join a national project led by The Century Foundation and the Urban Manufacturing Alliance to advance racial equity in manufacturing. The groups, selected through a competitive process and funded by Lumina Foundation, strategize solutions to the U.S. manufacturing sector's national recruitment challenges, deepen relationships between employers and communities, and develop credential-based training programs. MxD's selection and participation in this project are possible through the positive reputation and track record of MxD Learn's workforce development portfolio.

Fostering an Innovative Culture

Culture is a critical component not only of DoD's workforce, but also of innovation as well. There are many parts of DoD where innovation is a strong part of the established organizational culture. However, DoD must continually expand and strengthen a culture of innovation throughout the Department. To do

this, USD(R&E) will seek to replicate recent successes, including space, cyber, and social science programs—Hack-A-Sat, VICEROY, and Minerva—and drive change across the military Services.

Space: The Hack-A-Sat program was developed by the Director of Defense Research and Engineering, Advanced Capabilities (DDR&E(AC)) in collaboration with the United States Air Force with the goal of determining vulnerabilities in DoD satellites. Hack-a-Sat energized hackers from around the world by offering the public the opportunity to legally hack into actual DoD satellites, a unique crowd-source approach to learning of emerging infrastructure threats. By watching the world’s best hackers at work, DoD identifies cutting-edge hacking strategies and developing new offensive and defensive approaches to space and cyber protection. Later this fiscal year, DoD space and cyber experts will use their observations of the hackers to develop a set of new CONOPS for space and cyber operations.

Cyber: The “Virtual Institutes for Cyber and Electromagnetic Spectrum Operations Research and Employ” (VICEROY) Program objective is to accelerate and focus the development of foundational expertise in critical cyber operational skills for future military and civilian leaders. The program augments traditional college curricula with high-impact, experiential learning opportunities that are specifically tailored to meet current and future cyber workforce demands. The goal is to create more ROTC and civilian graduates who are workforce ready for the Cyber Mission Forces, DoD Information Network Operations, and the Research and Engineering Science and Technology Enterprise. This effort is managed by OUSD(R&E) and executed in partnership with the Air Force Research Lab’s Information Directorate and their Partnership Intermediary, the Griffiss Institute. VICEROY follows a consortia model where regional “virtual institutes” are formed through strategic partnerships between institutions of higher learning, local industry, and local and federal government.

Social Science: The Minerva Research Initiative (MRI) is a social science basic research grants program that aims to improve DoD understanding of the social, cultural, behavioral, and political forces that shape regions of the world of strategic importance to the U.S. MRI is innovative and unique in DoD as it spans both the R&D and Policy sides of the Department. Leadership across the Department collaborates to identify and support basic social science research issues in need of attention and to integrate those research insights into the policy-making environment. MRI is actively seeking out research topics that are clearly aligned with national defense priorities. Through this program, the DoD complements other R&E programs by maintaining a strong interest in research proposals generated from our HBCU/MI partner institutions, and from other appropriately diverse teams, such as Professional Military Education Institutions, especially as they contribute their valuable perspectives on the social dynamics of the policy and technology challenges facing the nation.

Partnering with the Private Sector

Strengthening public/private partnerships is a priority for USD(R&E). The department has a number of programs to expand public/private partnerships and will be looking to expand these opportunities in the future. DoD is currently pursuing public/private partnerships to develop a number of programs in priority emerging technology areas such as directed energy, cyber, microelectronics, biotechnology and space.

Directed Energy: High Energy Laser weapons (HEL) are an example of how DoD is able to de-risk technology. Multiple entities across the DoD have developed common goals for HEL weapons resulting in a High Energy Laser Scaling Initiative. This initiative is funding four companies to develop four different 300 kW class HELs to be used by the Services for demonstrations and testing. In addition, this program is a good example of DoD joint experimentation as the program is managed by OUSD (R&E) with substantial involvement from the Services and MDA. This avoids three separate and potentially competing Service Programs. Through these investments, DoD is able to demonstrate to industry what is possible and what is needed to provide DoD with military class lasers. The goal of HELSI is to provide the Services with the confidence they need to begin ordering HELs from an industry with proven capability.

Cyber: IQM Research Institute, an independent, Michigan-based 501c(3) non-profit organization has been instrumental in connecting DoD technology with cybersecurity Vice Presidents at major automobile companies and associations. The results include the identification cybersecurity concerns and the development of future standards to help close security gaps.

This OUSD(R&E)-funded activity identifies collaborative cybersecurity research and development opportunities within the commercial and DoD vehicle cybersecurity ecosystems. It recommends DoD-developed technological solutions for potential transition or transfer into future commercial platforms, as a means of promoting long-term enhancement and sustainment of vehicle cyber resiliency.

An additional benefit of these engagements has been an impact on R&E strategy for vehicle cybersecurity investment under the “Robust Low-level Cyber Attack-resilience for Warfighting Vehicles” project. This project ensures that technologies being developed are high-impact, high probability of transition success, and insert technology into early stages of the supply chain, in order to promote a higher return on investment.

Microelectronics: Our national defense relies on domestic manufacturing of microelectronics. The department is working closely with commercial partners to enhance and advance domestic production. The Department has two programs aimed at increasing domestic productive of microelectronics. The Rapid and Assured Microelectronics Prototyping (RAMP) program, is aimed at advancing leading-edge microelectronics design methods and incentivizing fabless companies to onshore production. The State-of-the-art (SOTA) Heterogeneous Integrated Packaging (SHIP) effort is leveraging Intel’s state of the art commercial packaging design and manufacturing capabilities for developing defense specific heterogeneous multi-chip packages. These support DoD specific requirements including extremely high processing in restricted size, weight & power (SWaP) environments, the need to move terabytes of data in real-time, and customization and optimization for DoD specific applications. Multi-chip package prototype demonstrators have been selected in partnership with the defense industrial base to customize commercial flows and establish an environment that supports design and production for DoD programs. Design concepts from over 20 programs were represented including Navy shipboard radar, electronic warfare/software-defined-radio, Army air to ground radar, advanced sensor applications, AI hardware acceleration and hardware security/cyber resilience.

Biotechnology: The DoD Manufacturing Technology Office, along with the Principal Director for Biotechnology within OUSD (R&E), awarded a 7-year Cooperative Agreement to BioMADE to develop a Manufacturing Innovation Institute (MII) dedicated to biomanufacturing for non-biomedical applications. BioMADE joins a network of eight other DoD MIIs. MIIs are public private partnerships that bring together industry, non-profits, and academia with federal and state agencies to accelerate

innovation by investing in industrially relevant manufacturing technologies with broad applications. Each MII provides support to propel research and development products to commercialization and economic viability. In partnership with government, industry, and academia, BioMADE will ultimately build a sustainable, domestic, end-to-end bioindustrial manufacturing ecosystem that will enable domestic bioindustrial manufacturing at all scales, develop technologies to enhance U.S. bioindustrial competitiveness, de-risk investment in relevant infrastructure, and expand the biomanufacturing workforce to realize the economic promise of industrial biotechnology. Not only will this bioindustrial manufacturing ecosystem support a more resilient domestic supply chain and ecosystem, this same ecosystem will accelerate technology development for essential DoD needs.

Biotechnology: A collaboration between DoD ONR Global and UK's DSTL is focused on developing novel battery technology that leverages synthetic biology to improve battery performance. This work, performed by Naval Research Laboratory, University of Utah, and the commercial company Touchlight, has the potential to revolutionize portable battery technology by avoiding safety risks of current technologies, reducing weight to improve transport, and providing renewable energy capabilities, all while producing a power output capacity that outcompetes lithium ion batteries. By partnering with a US Ally and supporting leading researchers and innovators, we can de-risk technology for the DoD that also has strong commercial and economic importance to the US.

Space: The Defense Innovation Unit (DIU) strengthens national security by accelerating the adoption of leading commercial technology throughout the military and by growing the national security innovation base. The Peacetime Indications & Warning project, within DIU's space portfolio, recently awarded contracts to two first-time DoD vendors to provide low-cost, commercially available radar and small-satellite imagery with advanced computer vision algorithms. In the same vein, the Missile Defense Agency (MDA), followed a commercial hosting model for the rapid development and fielding of small sensors which process intercept data and deliver near-real-time assessments to the Ballistic Missile Defense System. This capability yielded payloads in orbit in half the time of traditional space programs with an estimated \$700M cost savings to the Government. Both capabilities enhance the Department's situational awareness around the world, facilitate timely analysis of emerging threats, and allow for data and information-sharing with allies and partners.

Leveraging the Innovation Inherent in Small Businesses

DoD strives to capture innovation from all sectors of the economy. Small businesses, startups, and other disruptive entities offer significant contributions to future technology development and the rate of return is quite high. For small business there has been see a 22:1 rate of return for the investment. To leverage this innovation, DoD Small Business and Technology Partnerships (SBTP) recently announced a list of 137 critical research topics to the small business community in order to solicit bids to solve DoD issues. Small businesses will present proposals for funding and development with the goal of transitioning technology to the field.

In order to unlock and reveal emerging novel capabilities across industry, academia, small businesses, and non-traditional offerers, USD(R&E) issues a Global Needs Statement (GNS). The Global Needs Statement focuses on Secretary of Defense priorities, addressing near-peer competition, and delivering operational prototypes. USD(R&E) created an agile special notice process that lowers barriers to entry

and encourages direct industry-government exchanges to enhance participation from small business and non-traditional contractors.

In 2020, over 1300 partners submitted proposals to address DoD modernization and joint interest areas, many of these submissions from non-traditional contractors. Through industry engagement such as this, as well as through dedicated prototyping efforts, the Advanced Capabilities Directorate has delivered 36 new capabilities, enabled 19 new capabilities, and transitioned an additional 40 highly-innovative prototypes to users from across the innovation space, including small businesses, non-traditional performers, academia, and UARCs.

Investment in small business R&D is not only paying dividends to the warfighter, but it's also making a real and significant impact to many Americans each and every day. DoD small business R&D investments has fostered new and innovative products for the civilian market, allowed our nations scientists and engineers to take risks that they might not have taken on cutting edge projects, and made real and lasting impacts that have contributed to national prosperity. Over the last 23 years, DoD's \$14.4 Billion investment in small business R&D has directly resulted in \$347 Billion in nationwide economic output and created over 1.5 million jobs.

Pushing the boundaries of technology to open new commercial markets

In addition to partnering with the private sector and leveraging small business innovation, DoD plays an important role de-risking early stage technology. By de-risking immature technology, DoD's investments have a multiplier effect later as new commercial markets open. Today, USD(R&E) is pushing the market forward in a number of emerging technology areas, including AI, biotechnology, and autonomy. Areas such as these offer enormous benefits to the warfighter, and can to offer significant secondary economic benefits to the nation.

AI: The Department of Defense's Defense Innovation Unit (DIU) is seeing good results on a program that uses AI combined with commercial off-the-shelf wearable-devices to identify if the wearer has contracted COVID-19 up to two days before symptoms show. Early testing is promising and shows that COVID detection is possible up to 48 hours before the first symptoms appear. This capability is not only useful to the military as it plans to deploy and manage the health of service members, but also can benefit the larger health care system.

Biotechnology: The America Makes Manufacturing Innovation Institute connected the additive manufacturing industry to the medical care provider community to accelerate design and clinical review of 3D-printed PPE medical devices in short supply. The project used a centralized process developed at America Makes, and in partnership with the Food and Drug Administration, National Institute of Health (NIH), and Veterans Affairs to match capabilities with health care needs in the NIH 3D Print Exchange for open-sourced designs to be fast-track reviewed.

NextFlex, in partnership with Aionx, utilized novel RNA sequencing technology from CSI to prove the environmental contamination existence and transmission pathway; and refined and expanded production capacity of antimicrobial mats called cleanSURFACES. Any time microbes contact a mat's 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.

Manufacturing times Digital (MxD) is working with BioFabUSA in collaboration with the FDA and two pilot manufacturers to develop and validate digital twins of their production, which allows emergency scenario exploration without operational impact. This multi-institute project will optimize supply chain and production pharmaceutical life sciences manufacturing gaps and promote advanced digital design capabilities to expand U.S. pharmaceutical manufacturing capacity.

Autonomy: The department is also developing promising results with unmanned air vehicles (UAVs). These offer valuable overhead imaging both in commercial applications and on the battlefield. The Air Force's Agility Prime program will further extend those applications to personnel mobility where over 200 companies are leveraging advances from hybrid and electric cars to create electric vertical takeoff and landing aircraft. This military research is a promising technology for transition into the consumer market.

New traffic rules are needed to fully realize the commercial potential of UAVs. The nearly complete Resilient Autonomy Joint Capability Technology Demonstration (JCTD), a collaboration between the Office of the Undersecretary of Defense for Research and Engineering, NASA, and the FAA seeks to solve future air traffic challenges. This NASA led collaboration extends an autonomy architecture initially developed to avoid air-to-ground collisions, which has saved the lives of at least ten F-16 pilots.

The JCTD seeks to develop a robust architecture and methodology for certifying fully autonomous systems, testing the maturity of the technology and informing airworthiness requirements to enable future autonomy in unpiloted aircraft. Under the Resilient Autonomy approach, the system prioritizes human safety over preventing damage to property while damage prevention is prioritized over the completion of the mission by following a set of programmed rules of behavior. These rules of behavior allow better mission management while always maneuvering within the acceptable performance limits of the aircraft.

Thus far, the software has been provided to several DoD users including the Special Operations Command (MQ-1C Gray Eagle), the Air Force Research Laboratory (Skyborg), and the Army's Unmanned Aircraft Systems Project Management Office (for potential application Future Vertical Lift). Additionally, the software has also been provided to the FAA who are looking at application to a general aviation aircraft integrated with a commercial autopilot.

Conclusion

To guarantee the unquestioned superiority of the United States' armed forces, USD(R&E) is committed to building a strong foundation of science and technology today to produce cutting edge technology of tomorrow. While the United States continues to lead the world in science, technology and innovation, it is no secret that potential adversaries are attempted to catch up and surpass the United States. To maintain a technological edge on the battlefield of tomorrow USD(R&E) is focusing on priority emerging technology, building a strong foundation to enable the transition of technology from the laboratory to the warfighter and strengthening our national economy.