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Introduction

Chairman Smith, Ranking Member Johnson, and distinguished members of the Committee on Science, Space, and Technology, I thank you for the opportunity to testify today on the role of science, engineering, and research at Sandia National Laboratories, one of the nation's premiere national labs and the nation's largest Federally Funded Research and Development Center (FFRDC) laboratory. I am Dr. Susan Seestrom, Sandia's Associate Laboratories Director for Advanced Science & Technology (AST) and Chief Research Officer (CRO). As CRO I am responsible for research strategy, Laboratory Directed Research & Development (LDRD), partnerships strategy, and technology transfer. As director and line manager for AST I manage capabilities and mission delivery across a variety of the physical and mathematical sciences and engineering disciplines, such as pulsed power, radiation effects, major environmental testing, high performance computing, and modeling and simulation.

Prior to joining Sandia, I spent 30 years at Los Alamos National Laboratory, first as a scientist performing basic and applied research in nuclear physics and later in a variety of leadership positions, including Associate Laboratory Director for Experimental Physical Sciences and previously Associate Laboratory Director for Weapons Physics.

Sandia is a multimission laboratory owned by the U.S. Government and operated and managed by National Technology and Engineering Solutions of Sandia (NTESS), LLC[1] for the National Nuclear Security Administration (NNSA), part of the U.S. Department of Energy (DOE). Sandia currently operates with an annual budget of just over $3 billion and has grown to more than 12,200 workforce members plus contractors to meet all mission commitments. NNSA owns all Sandia facilities and is the sponsor of Sandia's FFRDC status. Industrial, academic, and nonprofit organizations have historically managed the DOE national laboratories and other major government-owned contractor-operated facilities.

As an FFRDC, Sandia meets special long-term research and development needs for the country. FFRDC status also means that Sandia operates in the public interest with objectivity and independence, is free from organizational conflicts of interest, and fully discloses its affairs

[1] National Technology and Engineering Solutions of Sandia, LLC. is a wholly owned subsidiary of Honeywell International Inc. under Department of Energy prime contract no. DE-NA0003525

to the sponsoring agency. Sandia operates as an autonomous organization or as an identifiable separate operating unit of a parent organization. Sandia does not use privileged information to compete with the private sector but may perform work for agencies other than its parent agency when the private sector is not able to perform specific work those agencies require.

Major Points of this Testimony

1) Sandia National Laboratories' core mission is to ensure the safety, security, and effectiveness of the nuclear deterrent.
2) Sandia's role in the nuclear deterrent mission rests on our strengths as a science-based engineering lab with capabilities that enable us to contribute world-class science to the nation. Our science and engineering capabilities are essential to solving current problems and anticipating and developing solutions to future national security challenges.
   a) Sandia does not stand alone—we build on and support the work of other DOE labs, industry, and academia to create a deep nationwide pool of expertise and capabilities.
3) Because of our deep scientific capabilities from our role in the NNSA nuclear deterrent mission, Sandia has expertise that we can extend to other DOE missions, including those advanced by DOE's Office of Science and Office of Energy Efficiency and Renewable Energy.
4) Sandia also needs to independently pursue research and development it has identified as critical to its many missions. Our Laboratory Directed Research & Development Program gives us the agility to pursue ideas that have the potential to broadly impact national security challenges today and in the future.

History of Sandia National Laboratories

Sandia's roots can be traced to the Manhattan Project and Los Alamos. In July 1945, J. Robert Oppenheimer established Z Division at Sandia Base in Albuquerque to perform stockpile development and non-nuclear component engineering. In 1949, at the urging of the Atomic Energy Commission, President Truman encouraged American Telephone and Telegraph Company (AT&T) to manage and operate Sandia as it separated from Los Alamos. In his letter to AT&T President Leroy Wilson, Truman captured what has become the spirit of Sandia: "In my opinion, you have here an opportunity to render an *exceptional service in the national interest.*" AT&T Bell Laboratories operated Sandia from November 1949 through 1992. In 1993, Martin Marietta Corp. became the management and operating contractor for Sandia National Laboratories, later merging with Lockheed to form Lockheed Martin Corp. Lockheed Martin operated Sandia Labs and managed Sandia Corporation until April 30, 2017.

On May 20, 2015, DOE announced its intention to compete the contract for Management and Operation (M&O) of Sandia. Following a full and open competition that generated unprecedented interest from across industry[2], on Dec. 16, 2016, NNSA announced it had awarded the M&O contract for Sandia to NTESS. A four-month transition period began in January 2017 and NTESS officially transitioned to the M&O contractor for Sandia on May 1, 2017.

[2] https://nnsa.energy.gov/mediaroom/pressreleases/nnsa-awards-sandia-national-laboratories-management-operating-contract

Given the rarity of such changes, DOE/NNSA, Sandia Corporation leadership, and incoming NTESS leadership were committed to minimizing the impacts of the contract competition on Sandia and helping employees focus on safely, securely, and efficiently delivering on Sandia's national security missions. The transition did result in turnover and reorganization of the executive leadership ranks. However, there were no reductions in workforce, and Sandia is expected to grow by a few hundred employees in fiscal year 2018. For the period from Oct. 1, 2016, to April 30, 2017, NNSA assessed Sandia had earned an overall "Excellent" rating by exceeding expectations in its leadership and critical mission areas.[3]

In the months following May 2017, Sandia has had several notable accomplishments. Sandia delivered the Annual Stockpile Assessment letter on schedule, continued execution of stockpile life extensions programs (LEPs) and alterations (ALTs) on schedule and on budget, had major successes with a hypersonic test flight and on Z experiments, and earned five R&D 100 awards. Informal assessments of employee morale after the transition appear positive; an all-employee survey was conducted in December 2017 and the results of that survey are expected in the coming weeks.

Nuclear Deterrence: Our Core Mission

Sandia's purpose is to develop advanced technologies to ensure global peace, primarily manifested through our core mission in nuclear deterrence. As one of three NNSA laboratories, Sandia has a critical role helping NNSA sustain and modernize the stockpile, providing foundational science and engineering capabilities to advance and sustain an effective nuclear deterrent in an evolving landscape. Sandia has responsibility for the weaponization of nuclear explosives through warhead system engineering and integration of non-nuclear components with the nuclear explosive packages designed by our two sister NNSA laboratories, as well as integration of the warhead with the delivery system, design of non-nuclear components including arming, fuzing, and firing systems, neutron generators to initiate nuclear yield, gas transfer systems, and critical nuclear safety and security systems. In addition, Sandia produces neutron generators and trusted specialty components. Within the U.S. nuclear weapons enterprise, Sandia is uniquely responsible for the systems engineering and integration of the nuclear weapons in the stockpile and for the design, development, qualification, sustainment, and retirement of nonnuclear components of nuclear weapons.

Sandia accomplishes these tasks using our capabilities in numerical simulation, physical sciences, and large-scale systems testing. Together, these capabilities give us an exquisite ability to predict the performance of nuclear weapons systems and components without underground weapons testing. Our resources in modeling and simulation combine to produce intellectual leadership in our workforce; a suite of tools for ensuring that weapon systems will survive current and anticipated conditions throughout their lifetimes; and the ability to sustain, modernize, design, produce, secure, and employ a portfolio of weapon systems that are flexible and responsive to changing requirements and threat conditions. Our modeling and simulation

[3] https://nnsa.energy.gov/sites/default/files/nnsa/multiplefiles/fy2017_sandia_per_-_6-2-2017_-_final_-publicly_releasable_version.pdf

work is conducted on behalf of NNSA's Research, Development, Test, and Experimentation (RDT&E) program.

An example of this work is Sandia's operation of large-scale test facilities for ensuring the safety and reliability of nuclear weapons systems by simulating natural and induced environments to evaluate performance during transportation, launch, re-entry, and impact. Data from these tests validate computer models used to more fully understand and predict system performance. Sandia test facilities include lighting simulation; a rocket sled track to study impacts and aerodynamics; equipment to test acceleration, deceleration, and vibration; and unique facilities for testing the effects of extreme heat, radiation, and pressure.

While Nuclear deterrence has been Sandia's core mission for nearly 70 years, the complex and multidisciplinary nature of this mission means Sandia is and always has been a source of essential science, technology, and engineering to resolve the nation's most challenging security issues. We leverage the skills, knowledge, and facilities required to design, deploy, and maintain the nation's nuclear deterrent to support other aspects of national security, including nonproliferation, energy security, and cybersecurity. We conduct that work for a host of stakeholders in addition to NNSA, including DOE, the Department of Homeland Security, the Department of Defense, and others. Examples of areas where Sandia has applied the synergy between our core nuclear weapons mission and our broader national security work include high-resolution radars that see through clouds and darkness; an adaptive, lightweight, and extremely accurate zoom riflescope prototype to aid our warfighters; satellite sensors that help the nation monitor worldwide nuclear activity from space; and technology that dramatically improves the endurance of legged robots to aid in disaster response. Technologies Sandia has developed and successfully transferred to industry include cleanrooms for microelectronics manufacturing, triggers for automobile airbags, and a device known as the Air Bearing Heat Exchanger, or "Sandia Cooler," with the potential to dramatically alter the electronics chip-cooling landscape in computing.

Sandia: A Multi-Program, Science-Driven Engineering Lab

The examples I have discussed of the synergy between our nuclear deterrent mission and our broader missions are made possible by the relationship between science and engineering at Sandia. Science asks why; engineering asks how. Science enables new tools and technology, and the engineering behind these tools and technology likewise enable new science in a "virtuous cycle" or positive feedback loop. In other words, science enables engineering advances that in turn allow scientists to ask new questions and find groundbreaking results. Researchers can think beyond the confines of a specific challenge to ask how Sandia and the United States can prepare for constantly changing threats to national security and the constantly evolving technology that contributes to those threats. When scientific research begins to conceptualize and understand those threats in theoretical space, engineers can begin the hard task of building solutions that address threats in the real world. The engineering advances intended for specific challenges can also contribute to unexpected scientific breakthroughs and a research and development environment characterized by creativity, innovation, and engaged staff.

For example, beginning in the 1960s as part of Sandia's mission to test weapon components in hostile radiation environments, Sandia has become the world leader in trillion-watt pulsed power science and technology, with the expertise needed to safely and efficiently operate pulsed power facilities. The 80-trillion-watt Z machine, the present world-leading pulsed power facility, efficiently creates extreme states of matter to address a broad range of nuclear weapon science issues. Beyond that mission, pulsed power offers the promise of a path to high-yield fusion for future weapons science studies and even fusion ignition. The high pressures and temperatures attained are also relevant to fundamental science such as astrophysics and planetary science.

At Sandia, the fundamental scientific research that underlies our nuclear deterrent mission also underpins our ability to work for stakeholders beyond NNSA, especially DOE Office of Science and other DOE programs. These sustained programs help us to pursue foundational research and build essential skills, expertise, and capabilities. In particular, our Office of Science programs serve a crucial role in allowing us to bring unique value to the DOE Office of Science, executing long-term scientific research on complex challenges beyond the capabilities of academia and industry. These efforts also enable us to deepen our strength in key areas by allowing us to develop and maintain unique scientific capabilities and nurture R&D staff.

For example, Sandia's research and development on hydrogen isotope gas transfer systems, first undertaken in the nuclear weapons programs, enabled our deep understanding of hydrogen effects on solid materials and broader contributions to the DOE Fusion Energy Science and Fuel Cell Technologies for Transportation missions. Our research on the fundamental materials science of hydrogen was made possible largely by Office of Science funds, and that work furthered our capabilities for safe and reliable design of hydrogen systems. That understanding in turn informed our research on hydrogen embrittlement in aging weapons systems.

Similarly, investment at Sandia in compound semiconductor materials research, heavily funded by the Office of Science Basic Energy Science/Materials Science & Engineering program yielded not only key contributions to the solid-state lighting revolution but to rad-hard heterojunction bipolar transistors critical to the life-extension programs for strategic re-entry systems.

Another prime example of our Office of Science efforts is the Center for Integrated Nanotechnologies (CINT) managed by Sandia in partnership with Los Alamos National Laboratory. CINT, one of five DOE Basic Energy Sciences-funded NanoScale Research Centers, makes use of a wide range of specialized facilities including the Microsystems Engineering, Science, and Applications (MESA) and the Ion Beam Facility (IBL) at Sandia and the National High Magnetic Field Laboratory at Los Alamos. CINT's vision is to become a world-leading resource for developing the scientific principles that govern the design, performance, and integration of nanostructured materials into the micro and macroscale worlds. This differentiating focus on nanomaterials integration involves the experimental and theoretical exploration of behavior over multiple spatial and temporal length scales, the development of novel synthesis and processing approaches, and an understanding of emergent behavior and new performance regimes.

CINT focus areas are quantum materials; in-situ characterization and nanomechanics; soft, biological, and composite nanosystems; and nanophotonics and optics. CINT has been especially successful in creating a growing number of Discovery Platforms that provide windows into the nanoscale dynamic properties of materials, a more meaningful measure of how nanosystems act in the real world. CINT has an impact far beyond Sandia and our missions: As a user facility, it provides researchers from universities, other national laboratories, and industry open access to our specialized instrumentation and expertise for experiments not possible at their home institutions.

Sandia is also a key participant in DOE's Exascale Computing Project (ECP), helping to advance application development and software technology for computing systems that are 50 to 100 times faster than the most powerful supercomputer in use today. The Exascale Computing Project is funded by both the DOE Office of Science and NNSA, consistent with the DOE mission to harness exascale computing power to improve U.S. economic competitiveness, national security, and scientific discovery. The ECP is therefore like many Sandia research efforts in that it brings together fundamental and applied science that spans nuclear weapons and many other national security missions.

Sandia's specific role in exascale computing is to provide leadership on software technology and advanced architectures to contribute to development of a software stack for exascale applications and architectures. Sandia also supports the development of operating systems, scalable solvers, performance portability, visualization software, and other key technologies. In addition to high-performance computing research for our nuclear deterrence mission, Sandia is involved with five Office of Science exascale application projects: We are leading work on applications simulating combustion engines and on clouds in the Earth's climate, and contributing to projects on wind energy plants, molecular dynamics, and quantum mechanics-based materials simulations.

Energy: An Important Sandia Research Focus

It is significant that much of our work on exascale computing and other Office of Science-related activity involves energy. Our defense preparedness and economic competitiveness are driven by the reliability and resilience, cost effectiveness, and technology advancement for our nation's energy systems—energy security and national security are closely intertwined. Sandia builds on the foundation created by its national security R&D to help create a secure energy future for the United States. Our technologies help plan for an uninterrupted and enduring supply of energy from domestic sources and assure the reliability and resiliency of the energy infrastructure. We seek a sustainable energy future by developing energy sources that are safer, cleaner, more economical and efficient, and less dependent on scarce natural resources.

For example, the CINT Office of Science program at Sandia has conducted fundamental scientific research that could be used for improvements in hydraulic fracking technology, aiding U.S. energy independence and our nation's economy. The R&D staff, skills, and capabilities behind that research are available at Sandia to pursue similar work in the future.

We conduct critical research and development on transportation energy security at the Combustion Research Facility (CRF), an internationally recognized DOE Office of Sciencesponsored collaborative effort. CRF scientists, engineers, and technologists conduct basic and applied research aimed at improving our nation's ability to use and control combustion processes. Knowledge gained from this research is transferred to industry to improve fuel efficiency and reduce emissions in light-duty and heavy-duty engines while enabling the diversification of fossil and bio-derived fuel sources. Research ranges from studying chemical reactions in a flame to developing laser diagnostics to observe mixing and combustion inside engines. We leverage our expertise in modeling and high-performance computing to develop predictive engineering models based on our physical observations and measurements. Work at the CRF therefore gives Sandia staff experience that extends to our core ND mission and other research. For example, Sandia researcher Jacqueline Chen was recently elected to the National Academy of Engineering for her contributions to the computational simulation of turbulent reacting flows with complex chemistry, which has ramifications far beyond the CRF.

Sandia R&D Builds and Depends on Partnerships

The CRF is a powerful example of the importance of partnerships to Sandia and our research. Much of the work at the CRF is done in collaboration with scientists and engineers from industry and universities. Every year, more than 100 visiting researchers collaborate side by side with CRF staff to develop new research methods and approaches, conduct experiments exploiting new facilities and techniques, and solve high-priority combustion problems. Our ability to attract the best researchers from around the world amplifies the DOE investment.

Overall, Sandia's industrial partners are numerous; CRF partners alone include every U.S. automaker, General Electric, John Deere, and Cummins, as well as ExxonMobil, Chevron, and Shell. In the past five years, Sandia has signed almost 4,000 partnership agreements (primarily including no fee agreements, cooperative research and development agreements, and license/government use notices) with more than 2,000 business partners, including small and startup businesses. Sandia's extensive partnering relationships with industry, academia, and other labs on complex research problems extend our foundational research understanding and contribute results that are applicable for both our partners and national security. Partnerships also create a community of U.S. scientists and engineers ready to promote innovation in many fields. Partnerships also benefit American consumers: Products that have become a part of peoples' daily lives and support the nation, such as solid-state lighting and high efficiency engines, came from Sandia R&D that was commercialized. Finally, partnerships feed back to our core mission: Sandia recently marked 25 years of working with The Goodyear Tire and Rubber Company through a CRADA to create better tires. In the process, Sandia has gained additional capabilities and expertise in computational mechanics that can be applied to other missions.

LDRD: Advancing our Research Capabilities

The LDRD program is an essential component in Sandia's research and development effort. LDRD is our primary source of discretionary funds, resources we can allocate to strategic research and development that is flexible and agile enough to anticipate and prepare for challenges beyond the horizon of present programs to a future of rapidly evolving threats. The LDRD program allows Sandia to invest in long-term, high-risk, and potentially high-payoff

R&D that builds, maintains, and stretches the Labs' science and engineering capabilities, including our R&D staff. These capabilities form the bedrock of our Nuclear deterrence mission. LDRD funds are also essential to Sandia's ability to anticipate and respond to evolving threats, one of our roles as an FFRDC.

The importance of LDRD funding to Sandia's core nuclear weapons mission is demonstrated by our series of projects from 1996 to 2007 that developed radiation-hardened trusted application-specific integrated circuits (ASICs). Standard semiconductors are vulnerable to radiation from natural sources and hostile environments, but these integrated circuits are critical to nuclear weapons, as well as nonproliferation and other national security applications. Using LDRD funds, Sandia developed a scientific understanding of the rich materials science and special processing techniques that allow us to design radiation-protection directly into chips. Sandia's radiation-hardened ASICs were an element of reducing the development costs of the W76-1 life extension program by more than 25 percent, and Sandia is now scheduled to provide more than 40,000 radiation-hardened ASICs to the nation's B61-12, W88 ALT 370, and Mk21/W87 stockpile modernization over the next 10 years.

In another example, in 2011 Sandia researchers initiated a microsystems-enabled photovoltaics (MEPV) LDRD project with the goal of developing a next-generation photovoltaic system with 40 percent conversion efficiency and the ability to provide power cost-competitive with the grid. The project resulted in tiny glitter-sized photovoltaic cells fabricated of crystalline silicon using microelectronic and microelectromechanical systems techniques common to today's electronic foundries. Sandia's MEPV technology led to 49 patent filings, seven issued patents so far, and a 2012 R&D100 award.

MEPV technology has since taken a significant step toward commercialization. In 2017, the Albuquerque startup mPower Technology Inc. licensed the technology for its Dragon SCALEs, small, lightweight, reliable, efficient, and flexible solar cells that fit into and power devices or sensors of any shape or size. The high-efficiency cells can be integrated into drones, biomedical and consumer electronics, and even wearable formats, and can be folded like paper for easy transport. Beyond the technology's obvious benefits in providing off-the-grid power for a host of applications and in reducing U.S. dependence non-renewable imported power, Dragon SCALEs will bring much-needed high-tech jobs to New Mexico. Like many civilian technologies developed with LDRD funds, MEPV also has potential for national security applications in satellites or in powering gear used by forward-deployed ground forces.

Projects funded through Sandia's LDRD program have impacts far beyond their original intent. The Ultra-Wide-Bandgap LDRD project developed the next generation of semiconductors that will enable ultra-compact and robust power converters for nuclear weapons systems, an important contribution to ensuring a safe, secure, and effective stockpile. In addition, the technology will also lead to ultra-efficient power converters for a more resilient electric power grid, winning Sandia a 2017 R&D 100 award.

The common threads linking these LDRD projects are Sandia's facilities for, experience with, and deep staff understanding of microsystems research, development, and prototyping. Sandia's work on semiconductors began in the late 1950s, when the shift from vacuum tubes to semiconductor electronics in weapons systems raised concerns about those electronics' vulnerability to radiation. Separately, in the late 1970s DOE Office of Science funding allowed Sandia to expand its research on compound semiconductors, which offered advantages such as greater radiation and temperature resistance than silicon semiconductors. Compound semiconductors, including heterojunction bipolar transistors, have since become essential to nuclear weapons and other national security applications. Today, Sandia's capabilities in this field are centered at the MESA complex, which integrates the scientific disciplines and fabrication facilities needed to research, design, and produce functional, robust, and integrated microsystems for national security and other applications. MESA is the only facility able to produce strategically radiation-hardened microelectronics for nuclear weapons and other national security applications.

Our history in semiconductors demonstrates how Sandia research that began from two independent starting points —nuclear weapons survivability and fundamental scientific research on semiconductors — has come together to further Sandia's many missions. That virtuous cycle continues today. The recently launched Strategic Inertial Guidance with MAtterwaves (SIGMA) LDRD project seeks to dramatically reduce the size, weight, and power requirements for an inertial sensor based on atom-interferometer (AI) technology, an effort made possible by Sandia's microelectronics R&D facilities and expertise. SIGMA is focused on improving the navigational capabilities of weapons systems, but the project could also lead to quantum sensors, a technology with potential in medicine, telecommunications, and other applications. Finally, the SIGMA project shows the importance of a research and development community that extends far beyond Sandia and the national labs. The atom-interferometer technology and other advances that make the project possible have their origins in academic and commercial research, and Sandia's ability to solve future security challenges cannot succeed without these partners.

In addition to funding specific projects, the LDRD program at Sandia helps us build science and engineering capabilities by attracting and retaining a world-class research community. LDRD allows Sandia to fund innovative research by early-career R&D staff, and relatively new employees perform a large percentage of LDRD research at the labs. For FY2014-2016, about 35 percent of LDRD labor charges were made by Sandia R&D technical staff with less than five years of service, including postdoctoral research staff. Among the full-time regular R&D staff with graduate degrees who power Sandia research, those funded by LDRD are more likely to stay at Sandia: For every three R&D graduate-degree staff who leave Sandia each year, only two LDRD-funded staff leave. Today's early career staff will in the future be leaders at Sandia, continuing our tradition of delivering exceptional service in the national interest to solve the unprecedented and unknown challenges to come.