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Chairman Smith and Ranking Member Johnson, and members of the committee, thank you for the opportunity to appear before you. It is my honor to speak about the national laboratories and our world leading innovation in science.

I am Paul Kearns, director of Argonne National Laboratory, one of America's first and largest multipurpose science and engineering laboratories, located in Lemont, Illinois, near Chicago. Before becoming Argonne's interim director in January 2017 and director last November, I served for seven years as Argonne's Chief Operations Officer. Prior to Argonne, I held leadership positions at Battelle Global Laboratory Operations, Idaho National Engineering and Environmental Laboratory, and Pacific Northwest National Laboratory. I also served as a visiting professor in engineering and physical sciences at the University of Manchester in the United Kingdom.

I have dedicated my career to expanding the impact the national laboratories deliver through their unique mission of securing our nation and encouraging break-through discoveries in science and technology. It was the special mission of the laboratories that attracted me to the national laboratory system and it is the opportunity to work with such dedicated and talented people, on matters of immense global scale and impact that has kept me involved with the national laboratories.

Argonne is managed by UChicago Argonne, LLC for the U.S. Department of Energy (DOE) Office of Science. We are one of the 17 DOE national laboratories that together form a productive, world-leading research system. At Argonne, we pursue big, ambitious ideas that redefine what is possible. Our research pushes the boundaries of fundamental science, applied science, and engineering to solve complex challenges and develop useful technologies that can transform the marketplace and change the world.

Argonne traces its beginnings to experiments by the renowned physicist Enrico Fermi, who led researchers in creating the world's first self-sustaining nuclear reaction. From its initial mission to fulfill the promise of the atom as a new energy source, Argonne has continuously built upon and expanded its capabilities. We have grown into a multi-program laboratory addressing a range of major scientific and societal needs. In fiscal year 2017, we employed 3,200 people in the Chicago area, drawn from scores of scientific, technical, administrative, and operations fields, provided national scientific user facilities that supported 8,300 researchers, and hosted another 1,100 visiting research collaborators. Our fiscal year 2017 budget was $751 million, with approximately 80% of funds from DOE and the balance from the Department of Homeland Security, other government agencies, and the private sector.

At Argonne, our primary mission to deliver lasting impact to society. We believe in the vision that our science changes the world. Over the last seven decades, Argonne researchers have built the nation's first high-energy physics user facility, helped found quantum computing, led high-temperature superconductor research, developed an artificial leaf, invented molecular modeling, and much more. Argonne was home to three winners of Nobel Prize for Physics: Alexei Abrikosov (2003), for theories on superconductivity and superfluidity; Maria Goeppert-Mayer (1963) for explaining the shell structure of the atomic nucleus; and Fermi, who received the prize in 1938 for work on induced radioactivity by neutron bombardment and the discovery of transuranic elements, prior to his breakthrough that would mark Argonne's beginning. Building on that proud history of discovery and innovation, we will be known for our ideas and for safely delivering lasting impact on society through our exemplary research and operations.

Argonne's work now spans the spectrum from basic research to applied science in areas including discovery in materials, chemistry, physics, and biology, engineering of advanced energy systems, and computation and analysis. Argonne remains on the cutting edge as it extends its expertise into new scientific frontiers including synthesis science, quantum information science, neuromorphic computing, and catalysis.

In addition to our capabilities, Argonne is committed to delivering high impact science and building foundations for technologies that will shape our nation's future. Our major strategic initiatives are interdisciplinary, highly synergistic with one another and leverage the strengths of our broader research and development (R&D) enterprise. The laboratory's major initiatives build on our distinguishing capabilities in science, unique user facilities, and external collaboration networks and are targeted to deliver breakthroughs in science and technology in five areas that support DOE's missions and reflect our vision for the future. They include:

- Hard X-ray sciences
- Advanced computing
- Materials and chemistry
- Manufacturing science
- Fundamental study of the universe

Propelling Research through Our Scientific User Facilities

Our unique suite of scientific facilities includes a world-leading X-ray source, particle accelerator, supercomputers, a nanoscale science center, and the world's largest atmospheric research field site. These facilities expand our fundamental understanding of matter, materials, and their properties. As a nexus for 8,300 researchers, and 1,100 visiting research collaborators, in addition to our own 1,600 scientists and engineers, these facilities extend Argonne's impact well beyond our own laboratory.

- At the Advanced Photon Source (APS), we use hard X-rays to characterize materials at the atomic and molecular level so that we may understand, predict, and ultimately control the materials' properties. The intense X-rays of the APS helped Argonne design a leading battery cell technology and is helping us make additive manufacturing more reliable, internal combustion engines more efficient, and hypersonic flight more possible. The APS, funded by the Office of Science Basic Energy Sciences program, continues to have high impact in biosciences and drug discovery. As an example, Kaletra®, one of the most successful drugs used to stop the progression of the HIV virus into AIDS, got its start at the Advanced Photon Source; visiting scientists from Abbott Laboratories used x-ray crystallography techniques to pinpoint how the atoms of the drug interact with the viral protein. Recipients of the 2009 and 2012 Nobel Prizes in Chemistry conducted portions of their prize winning work at the APS.

- At the Argonne Leadership Computing Facility (ALCF), we run two supercomputers that are among the 20 fastest in the world. More than 30 of the 500 fastest supercomputers in the world can be found at DOE laboratories, funded by the Advanced Scientific Computing Research program of the Office of Science. At Argonne, we have applied our high-performance computing to challenges in energy, materials, extreme weather, medicine and more, with techniques such as simulations of more efficient jet engines and wind turbines. The Argonne Leadership Computing Facility leads a multi-laboratory team as part of the federal Precision Medicine Initiative with the National Cancer Institute (NCI) and plays a role in the MVP-CHAMPION initiative of the Department of Veterans Affairs (VA) and DOE. These collaborations are applying the labs' big data, artificial intelligence, and high performance computing capabilities to healthcare and genomic data to determine optimal treatment strategies, improve healthcare outcomes, and reduce costs.

- At our Center for Nanoscale Materials (CNM), we apply world-class capabilities in large scale synthesis, nanofabrication, massive parallel characterization, and computational materials discovery under one roof. Funding by the Office of Science Basic Energy Sciences program, CNM is one of five Nanoscience Research Centers (NSRCs) across the nation, first authorized by Congress a decade ago as part of the National Nanotechnology Initiative. As my colleague Supratik Guha, Director of CNM, testified before you last year, these NSRCs are a force in the quantum materials revolution that will enable technologies to transform everything from national security to drug design to data analytics.

- Argonne's Tandem Linac Accelerator System (ATLAS), funded by the Office of Science Nuclear Physics Program, is a leading facility for nuclear structure research in the United States. It provides a large community of users with a wide range of beams for nuclear reaction and structure research, as they probe astrophysical processes generating the chemical elements and test nature's fundamental symmetries and interactions.

- The Atmospheric Radiation Measurement Climate Research Facility – Southern Great Plains (ARM-SGP) is the world's largest and most extensive atmospheric research field site, located in Oklahoma. Funded by the Office of Science Biological and Environmental Research program, ARM-SGP instruments are arrayed across 9,000 square miles, with a heavily instrumented central facility on 160 acres near Lamont, Oklahoma. Scientists from Argonne and other institutions use data from ARM-SGP to advance scientific understanding of cloud, aerosol, and atmospheric processes, which supports improvements in models of the earth's climate.

Staking a Unique Approach to Science

Argonne's broad and deep domain knowledge and scientific facilities, coupled with our approach to deploying these assets for maximum benefit, distinguishes us as an institution. Argonne works across the continuum of science from basic, curiosity-driven efforts, to use-inspired science solving problems of global significance, to translation science in order to deliver meaningful societal impact consistent with our mission. This approach enables us to accelerate progress in science from discovery to impact. We are looking at ways to multiply the beneficiaries of the laboratory's knowledge across the many domains in which we work.

Science, simply put, is the pursuit of knowledge through systematic study executed via observation and experiment. It encompasses pursuits driven by curiosity: What happened immediately after the Big Bang leading to the creation of the known universe? Science also includes pursuits to solve problems: How can we make the U.S. power grid more resilient? At Argonne, we focus on asking the right questions that lead to developing knowledge that can result in positive change in the world.

The problems we work on are inherently multi-disciplinary, stemming from our roots in the Manhattan project, and bring together teams of talented scientists and engineers with relevant technical-domain expertise to work closely, leveraging our cutting-edge analytical capabilities, such as the APS and ALCF. Science is also an inherently collaborative activity. The laboratory works closely with other national labs, universities and with industry in the pursuit and application of new knowledge. Working with industry makes us smarter about practical solutions and enables our scientists and engineers to work with more relevance in the lab's core mission. This also provides the laboratory with more avenues for creating impact from the translation of our science to societal benefits.

Conventional wisdom states that the translational of advances in science to impact is a decades-long process. At the national laboratories, we have worked hard on accelerating this process from scientific discovery to impact by accelerating the speed with which researchers can execute experiments and simulations—for example, high throughput methods for analytical characterization and faster computers. Most recently, however, the laboratory's focus has shifted to the emerging paradigm in computing related to deep learning, machine learning and artificial intelligence. Through the use of these methods, scientists are now accelerating our learning process by using computers to enhance human insights. These advances have the potential to change a process that previously took decades to one that may take only a fraction of that time in the future.

Leveraging Our Discoveries for Transformational Impact

Our world-renowned work in energy storage serves as an excellent example of turning discovery into impact, and an achievement on which we hope to build as we endeavor to accelerate that discovery-to-impact process. Argonne's legacy of energy storage research dates to the 1960s. In the mid-1990s, the DOE provided sustained support for investigations aimed at a more stable and greater capacity electric vehicle battery. In 2000, the original lithium-rich Nickel-Manganese-Cobalt (NMC) blended cathode structure for which we are now known was patented; 2007 saw the beginning of worldwide licensing agreements with Argonne by companies including BASF, Toda America, and LG Chem, who now mass produce and market Argonne's patented materials for advanced batteries. In 2011, Argonne's technology made its market debut in the Chevy Volt.

Argonne also is utilizing basic science approaches as part of the Joint Center for Energy Storage Research (JCESR), DOE's battery and energy storage hub, to understand mechanisms and discover new paradigms for storing energy. JCESR has literally and figuratively changed the formula for developing next-generation batteries. Experiments with new battery materials at the bench have resulted in the discovery of revolutionary new materials for development of beyond-lithium-ion technologies.

The JCESR Operations Model, meanwhile, has integrated and amplified the effectiveness of 20 otherwise independent interdisciplinary scientific organizations – universities, industry, and national laboratories – as a single coordinated unit. This new paradigm for public-private partnership has enabled more than 200 researchers to magnify their efforts and achievements in discovery science, materials design, battery design, research prototyping, and manufacturing collaboration.

Our experience with JCESR has cultivated a new archetype of basic science leading ultimately to proof of concept, a model we are applying to various aspects of our Materials and Chemistry Strategic Initiative, including quantum information, catalysis, and new materials to address energy-water interdependence. In quantum information science, recent developments raise the prospects of a new, rapidly emerging computing architecture. Quantum offers unprecedented speed and efficiency advantages over conventional computing that can be applied to big challenges like exactly solving the electronic structure of large molecules. By enabling us to predict and invent new materials much quicker and more cheaply instead of relying upon trial and error experimentation, as we do today, our potential for progress in areas such as drug discovery are enormous.

Quantum computing also has big implications for cryptography—a quantum computer with its orders of magnitude advantage in speed would easily decrypt today's security codes—and in complex data analytics, where problems like large-scale traffic congestion routing problems can be resolved with unprecedented efficiency. Unique equipment developed at Argonne for research in nanomaterials, such as synchrotron based x-ray microscopy, is being used to "see" exquisitely small distortions in crystals used for building quantum bits.

Partnerships with the University of Chicago aim to fuel progress in quantum information. We have worked together to set up at the laboratory the "Quantum Factory," a comprehensive experimental facility for the synthesis of quantum materials with atomic layer precision. The University and Argonne also have collaborated with the Fermi National Accelerator Laboratory on the Chicago Quantum Exchange, which will develop a new generation of graduate students who will learn their skills in close collaboration with national laboratory scientists and academics.

With regard to catalysis—that is, the acceleration of a chemical reaction by a catalyst—Argonne aims to improve basic understanding of catalytic chemistry in the atomic to nanoscale level. Our research is ultimately focused on developing new catalysts for energy applications. The optimally efficient way to store energy is in chemical bonds, and our future research will be targeted to understand and develop new concepts for making and breaking those bonds when splitting water, reducing carbon dioxide, and adding new functions and capabilities to the carbon-hydrogen bonds found in natural gas.

The looming societal water crisis, together with the techno-economic implications of energy-water interdependence, has highlighted a need for new materials to improve the safety and efficient use of water. Argonne is working to devise effective new membranes, sorbents, sensors, catalysts, surface treatments, and coatings tailored for specific functions such as resisting the fouling of pipes and underwater surfaces by organisms like barnacles and algae.

Like the new directions we are pursuing in quantum information science, Argonne's new goals in catalysis and energy-water interdependence are grounded in collaboration among Argonne's own scientists specializing in nanoscience and technology, biology, chemical sciences and engineering, materials science, and molecular engineering. They are also supported by new external partnerships including the Institute for Molecular Engineering (IME) with the University of Chicago and the Northwestern (University)-Argonne Institute for Science and Engineering (NAISE).

Thriving on Partnership

The national labs are indeed at their best when they are working as part of an innovation ecosystem with academic, industrial, and entrepreneurial partners. In the realm of industry, laboratories have relevant capability, expertise, and nascent technology to "de-risk" innovations and accelerate commercialization. Through our Cooperative Research and Development Agreements and Strategic Partnership Projects, we provide mechanisms for companies to collaborate with national laboratories, and enable them to directly sponsor research and development at the labs.

Argonne is home to other unique programs that continue to expand our industrial relationships and efforts to help commercialize promising technology. Chain Reaction Innovations provides energy entrepreneurs with the laboratory tools, seed capital, and collaborators needed to grow and attract the long-term capital and commercial partners needed to scale and launch into the marketplace. The first cohort teams have raised $400,000 in external funding, including grants, prize money, and investments, and have also partnered with industry and developed prototypes; soon we will name the second cohort of entrepreneurs to the program. Argonne also participates in DOE's Executive in Residence Program, which allows company-employed scientists to work with laboratory senior technical staff during the later stages of technical development.

The Argonne Collaborative Center for Energy Storage Science, or ACCESS, and Argonne Design Works are other methods for extending our domain knowledge to industry, offering a concierge approach to pulling together exactly the expertise needed for a particular innovation. In addition, Argonne works with various federal agencies in a wide range of areas, including transportation, security, grid innovation, and the physical sciences, and is collaborating with municipalities including Chicago and Detroit on complex systems modeling and data-driven decision-making tools to improve efficiency, resiliency, sustainability and foster economic growth.

Forging New Directions

At Argonne, we are charting a course for the next horizon in U.S. scientific leadership through our major initiatives, drawing on our foundational strengths and leveraging our ever-expanding expertise to transform Argonne's contributions to discovery and innovation and produce breakthroughs that will change our nation and our world for the better.

Our Hard X-ray Sciences Initiative include a highly cost-effective revitalization of the facility, improving capabilities by orders of magnitude, maintaining our competitive advantage over other nations, and keeping the U.S. at the forefront of hard x-ray science for decades to come. The APS Upgrade will create the ultimate 3-D microscope, produce the world's brightest hard x-rays and transform our ability to understand and manipulate matter at the nanoscale. With this powerful, versatile tool, researchers will be able to observe individual atoms moving and interacting – in real time – deep inside real samples, biological organisms and complex engineered systems. This new microscope will make it possible to see changes at the molecular level that occur before a steel girder starts to crack, before a healthy brain succumbs to Alzheimer's, and before an electric car's battery begins to fail. We very much appreciate this Committee's strong support for the APS and its leadership in passing H.R. 4377, The Accelerating American Leadership in Science Act, out of the House of Representatives, authorizing funding to upgrade the facility. Additionally, we are very pleased the fiscal year (FY) 2019 President's Budget Request includes funding for the APS Upgrade and transitions the project to a separate line item construction project.

In our Advanced Computing Initiative, we look forward to the Argonne Leadership Computing Facility being the future home of Aurora, an exascale system will be at least 50 times faster than the nation's most powerful supercomputers in use today. Scheduled for deployment in 2021, the Aurora system is being developed by Intel in partnership with Cray and will be the first generation of a new architectural direction targeted at broad application performance with exceptional performance and energy efficiency. At the same time, Argonne researchers are developing new capabilities in machine learning and artificial intelligence—and looking beyond conventional computing technology to develop systems, algorithms, and applications based on new quantum and neuromorphic technologies—all as means to helping overcome the nation's biggest challenges in energy, materials, cancer and more.

Argonne's efforts in exascale are part of the larger push of the Exascale Computing Initiative (ECI), a collaboration of the DOE Office of Science, the National Nuclear Security Administration and six national laboratories. This collaboration aims to develop and deploy capable exascale systems with rich software environments and mission-critical application code, advance the integration of simulation, deep learning, and data capabilities into exascale platforms. Thank you to this Committee for your strong support of exascale and next generation computing. We are pleased that the FY2019 President's Budget Request also includes funding for ECI and advancing one of the nation's first exascale machines at Argonne.

Our Materials and Chemistry Initiative and its concentrations on energy storage, catalysis, quantum information, and energy-water interdependence will be elevated by our Materials Design Laboratory. In this state-of-the-art facility, researchers investigate structures at scales all the way from a single electron on up, study the interfaces where molecules come together in new materials, and test the properties of these materials under extreme conditions. The Materials Design Laboratory will be the final building to complete Argonne's Energy Quad—four adjoining buildings where energy and materials scientists can maximize their collaboration with one another and with partners from outside the lab.

In our initiative for fundamental study of the universe, known as Universe as Our Lab, we will be pioneering techniques to simulate the universe and detect elementary particles. We will drive advances in the measurement of cosmic microwave background radiation and develop forefront superconducting transition-edge sensor technology for particle and nuclear physics experiments.

Our Manufacturing Science and Engineering Initiative aims to boost industrial success in producing innovative materials for future energy technologies. Revolutionary energy technologies, which are essential to future American prosperity, will require efficient and scalable manufacturing of innovative devices based on new materials and chemistries. Our goal is to accelerate the progression from discovery to manufacturing demonstration by defining the scientific and engineering basis for scalable manufacturing of energy storage and transfer devices and exploring new manufacturing methods.

Continuing Support for U.S. Leadership in Science

America's national laboratories and their facilities are powerhouses of science, technology, and engineering. They are principal agents of execution on missions of national importance. Critical to the DOE mission of solving big problems in energy and national security, the labs attract some 30,000 users a year from government, industry and academia from all 50 states. Labs provide value at all points of a science and technology development cycle—not only seeding the gradual growth of new ideas but also reverse engineering to stabilize and improve ideas as they emerge in the market.

My fellow laboratory directors and I greatly appreciate this Committee's continued support for the national laboratory system and commitment to U.S. leadership in science and technology that is critical for our future. International competition remains as fierce as ever; our science infrastructure across the nation is the envy of the world, with many countries trying to replicate it. The DOE and its laboratories are advancing projects that will keep the U.S. at the forefront of science and innovation, with an aim to cement U.S. leadership for decades to come.

From longer lasting, faster charging vehicle batteries to personalized medical treatment, DOE labs and their one-of-a-kind facilities offer unparalleled scientific capabilities that have real societal impact. At Argonne, we are privileged to bring to bear decades of expertise in physics, materials and chemistry, math and computer science, life sciences, nuclear energy and more to help provide greater security and prosperity to Americans.

Thank you for your time. I welcome any questions you may have.