Testimony of

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Chairman Smith, Ranking Member Johnson and Members of the Committee, I'm very pleased to be here today to talk about SLAC National Accelerator Laboratory's unique role in leading basic scientific research and innovation.

I am the director of SLAC, as well as an X-ray scientist with an extensive background in development of X-ray tools for advanced materials research.

SLAC is one of 17 national laboratories operated by the Department of Energy (DOE). As an Office of Science lab, SLAC's focus is on the delivery of scientific discoveries – enabling research leading to four Nobel Prizes – and major scientific user facilities to transform our understanding of nature and to advance the energy, economic, and national security of the United States. Our scientific user facilities are among the most important resources that SLAC and other national labs have to offer because they support the entire U.S. R&D enterprise. These are large, complex facilities with world-class research tools on a scale that no single company or university could afford to build and operate.

SLAC is operated by Stanford University for the DOE Office of Science. Our strong relationship with Stanford provides tremendous advantages in both research and operations. One aspect of this relationship is unique in the DOE national lab complex: DOE and Stanford worked together over the course of a year to develop a new management contract that streamlines many of our standard management processes, eliminates duplication and gives the lab more autonomy and local control, which makes us more efficient and effective. The new contract makes line managers responsible for meeting performance goals and incorporates many Stanford business practices, taking advantage of the university's long experience in operating large research institutions. For example, we have adopted the Stanford cyber security system after demonstrating that it exceeds DOE requirements; this allowed us to improve our cyber security at minimal cost. We are now piloting the new management agreement, and several national labs across the complex have expressed interest in understanding and applying this model.

SLAC was founded in 1962 as a laboratory dedicated to particle physics, using a two-mile-long electron accelerator to probe the smallest building blocks of matter. Today it is a vibrant multi-program lab with 1,500 employees and a research budget of approximately $300 million annually, with another $288 million in FY 2017 funding for major new scientific user facilities and tools. The bulk of our funding comes from the Basic Energy Sciences and High Energy Physics offices within the Office of Science.

With funding from Basic Energy Sciences, SLAC operates two premier X-ray user facilities, the Stanford Synchrotron Radiation Lightsource (SSRL) and the Linac Coherent Light Source (LCLS). These facilities are used by about 2,700 visiting scientists from universities, government labs and industry each year for experiments across a wide range of scientific fields.

SSRL was the first synchrotron X-ray facility in the world to make itself available on a competitive basis to visiting researchers. It's known for the elegant instrumentation it develops to tackle difficult scientific problems, and for its long tradition of giving visiting scientists the expert help they need to make their experiments successful. Work at SSRL was the basis for Roger Kornberg's 2006 Nobel Prize in chemistry for creating the first detailed picture of how instructions in DNA are copied onto messenger RNA, which ferries them to the cellular factories where proteins are made.

LCLS opened in 2009 as the world's first X-ray free-electron laser (XFEL), delivering the brightest and shortest X-ray pulses ever made. Like a camera with an incredibly brilliant flash and ultrafast shutter speed, LCLS allows scientists to make snapshots of chemical reactions and other important processes up to 120 times per second and then string these frames together into "molecular movies," revealing rapid-fire, molecular-scale changes in much finer detail than could ever be seen before. This is important in fields as diverse as the development of catalysts for industry; next-generation energy and computer storage technologies; pharmaceutical drug discovery; and understanding how to harness the properties of quantum materials.

In addition to operating these two X-ray facilities, SLAC researchers carry out world-leading research programs in materials, chemical, biological, plasma, and fusion energy sciences. These research programs operate with funding from the offices of Basic Energy Sciences, Fusion Energy Sciences and Biological and Environmental Research. They aim to answer the most challenging scientific problems within their fields and drive the development of new tools at our scientific user facilities. Optimizing the synergy between the lab's scientific user facilities and research programs enables SLAC to effectively carry out the mission of the Office of Science.

Increasingly, our scientists are also using their expertise and our facilities to work on applied energy science, including batteries, solar energy, and other technology developments aimed at enhancing U.S. competitiveness. They also assist companies with using our facilities to perform research that would be impossible for them to conduct on their own.

For instance, Applied Materials, the world's leading manufacturer of equipment for making semiconductor chips and displays, has been coming to SLAC for more than a decade for help to improve its manufacturing processes; at the other end of the spectrum, startups have used our facilities to analyze and improve materials for solar rechargeable batteries, smart windows and coatings that prevent dirt buildup on solar cells.

With funding from the office of High Energy Physics, SLAC continues to be a major contributor to exploring the frontiers of high-energy physics and cosmology from locations underground, on the Earth's surface, and in space. SLAC is leading an international collaboration that will carry out one of the most sensitive searches ever undertaken for particles of dark matter, which just received construction approval. We are also currently building the world's biggest digital camera for ground-based astronomy for the Large Synoptic Survey Telescope (LSST), which will conduct the widest, fastest and deepest sky survey ever undertaken from the top of a mountain in Chile. The survey, a collaboration between DOE and the National Science Foundation, will dramatically advance our knowledge of the dark energy and dark matter that make up 95 percent of the universe, as well as of galaxy formation and potentially hazardous asteroids. SLAC also makes significant contributions to the ATLAS experiment at Europe's Large Hadron Collider, where scientists continue to explore the properties of the Higgs boson and look for signs of new physics that will enhance our limited understanding of the physical world around us.

In the following, I would like to give you just a few examples that highlight the impact of SLAC research.

- New materials are critical for advances in many areas, from batteries and electronics to lighter, stronger structural components for cars, planes and other uses. Studies of materials at SLAC range from addressing here-and-now problems – for instance, working with industry to prevent flaws in metal parts made with 3-D printing – to fundamental studies of "quantum materials" and electron behavior that could lead to the creation of denser, faster circuits and entirely new methods for storing and processing information.

  To try to understand how electrons behave when confined in an extremely limited space, SLAC researchers have studied the thinnest possible layers – sheets of matter from just one to a few atoms thick. Using SLAC's unique suite of X-ray tools and related capabilities, researchers have been able to determine how electrons in these sheets respond on ultrafast time scales, in the range of millionths of a billionth of a second. Understanding this extremely rapid response is crucial for achieving the highest possible rates of information processing and is key for the advancement of information technology.

- Catalysts are specially designed materials that promote chemical reactions without themselves being consumed in the process. They're a vital part of industrial processes that underpin about a third of the nation's GDP, from cracking crude oil to make gasoline to producing the fertilizer needed to feed a rapidly increasing global population.

At SLAC, scientists lead the world in using theory and advanced computation to predict the best catalysts for targeted chemical reactions, and use X-ray beams and other experimental tools to watch catalytic reactions unfold at an atomic level under realistic industrial conditions. By combining theory and experiment, they are able to find new catalysts and make the ones we have today more efficient.

An important problem being investigated at SLAC is the identification of catalysts for the efficient transformation of natural gas, or methane, into easily transported liquid fuels like ethanol. SLAC scientists are also collaborating with researchers from Chevron and other oil companies to use SSRL X-rays to improve the performance of their industrial catalysts.

- In biology, X-rays reveal how proteins – workhorse molecules in all living things – function in our bodies and in nature. This gives scientists a better understanding of how disease develops so they can design tailor-made vaccines and medications. Pharmaceutical companies have come to SSRL for decades to investigate basic biological processes and test potential drug candidates; this work has contributed to the development of Tamiflu and treatments for melanoma, HIV and other diseases.

  The National Institutes of Health have been an important partner in this research for decades, supporting the development of X-ray equipment and other instruments at SSRL and more recently at LCLS, where about one-third of experimental time is now devoted to bioscience.

  In one LCLS study, experimenters recently discovered that a hormone receptor on the surface of human cells may be a good target for new medications related to cardiovascular conditions, neuropathic pain, inflammation, and tissue growth. This receptor receives signals from a hormone that helps regulate blood pressure, but its exact structure and function have been a mystery for decades. More than half of all the medications on the market today are aimed at blocking or activating receptors like this one that sit in the cell’s outer membrane, but in the past it’s been difficult to form them into large enough crystals for synchrotron X-ray studies to determine their structure. With LCLS X-ray pulses, the scientists were able to get the structure of the receptor from much smaller nanocrystals that are significantly easier to prepare. This capability opens up many new possibilities for developing medications to target a large number of membrane-embedded receptors that were previously out of reach.

The success of LCLS inspired countries around the world to plan or build their own X-ray free-electron lasers. XFELs have opened for experiments in Japan, Europe, South Korea and Switzerland. China is close behind, with plans to build an XFEL in Shanghai.

With this in mind, SLAC is constructing a major upgrade to LCLS in partnership with four other national labs and a university. This project, called LCLS-II, is scheduled to open in the early 2020s. It will significantly boost the power and capacity of the X-ray laser, adding a second X-ray laser beam that fires up to a million pulses per second and shines 10,000 times brighter, on average, than the one we have now.

This extraordinary pulse rate is by far the highest in the world, and it opens up entirely new possibilities for measuring systems as they are in nature, where things often fluctuate and vary from place to place. It will also provide the very high brightness needed to analyze materials and track chemical changes with exquisite resolution.

To make sure that America stays at the forefront of this vital technology, the Office of Basic Energy Sciences is also planning for the construction of a natural extension to LCLS-II known as LCLS-II-HE (for “high energy”). It would take advantage of the extensive infrastructure that is now in place for building LCLS-II to deliver a major leap in performance to the broadest possible cross-section of scientific users for the least possible additional investment. For instance, it will provide more power in the form of high-energy X-rays, addressing the needs of the 75 percent of our current user community who use this part of the X-ray spectrum in their experiments.

We are grateful for the work of this Committee, which advanced the recently passed HR 4376, the Department of Energy Research Infrastructure Act of 2018, authorizing funding for the LCLS-II-HE project. We are also pleased that the President’s FY 2019 Budget Request includes initial funding for this vital project.

With LCLS, we demonstrated that we can observe fundamental processes at atomic resolution and watch them evolve at a rate of 120 frames per second. LCLS-II will allow us to increase this rate to 1 million frames per second, so we can see how electrons move from one place to another during chemical reactions. LCLS-II-HE will extend that high pulse rate to the realm of individual atoms, so for the first time we’ll have all three of the capabilities we’re looking for: the ability to take snapshots with atomic resolution up to a million times per second while watching individual electrons go about their work.

These advances will be truly revolutionary, allowing us to watch chemistry and biology in action, fine-tune catalysts for industry, understand how materials function at a much deeper level and exploit quantum phenomena for future generations of devices in ways that cannot be done today.

In closing, I would like to thank the Committee for inviting me here today, and I look forward to your questions.