Testimony of

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Committee on Science, Space, and Technology
Subcommittee on Energy and Environment

Department of Energy User Facilities: Utilizing the Tools of Science to Drive Innovation Through Fundamental Research

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Chairman Harris, Ranking Member Miller and Members of the Subcommittee, I am pleased to be here today to provide my perspective on the role of SLAC National Accelerator Laboratory (SLAC) in the U.S. scientific enterprise, with a particular emphasis on how the Linac Coherent Light Source is transforming key research disciplines and has the potential to drive new industrial applications.

Let me begin with a few words on national laboratories in general and the role they play in advancing scientific innovation in the United States. The Office of Science in the Department of Energy (DOE) operates 10 national laboratories that focus on fundamental research. Over the last 50 years, this research has contributed to making the U.S. a global leader in scientific research, and has yielded discoveries that have greatly benefited society and the human condition, from better sources of energy to new drugs and therapies for diseases such as cancer.

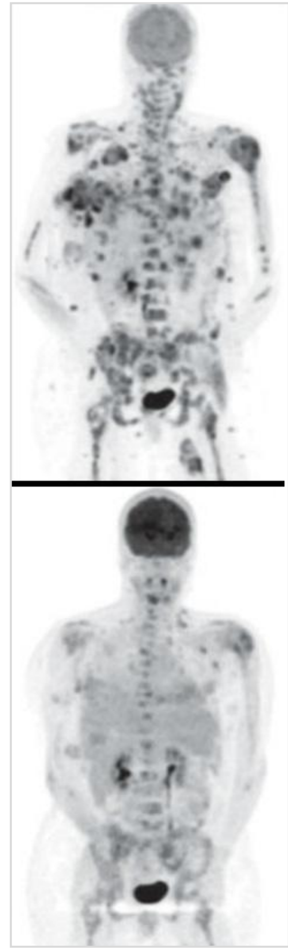
I am the Director of SLAC, a multi-program national laboratory managed and operated by Stanford University for the DOE. SLAC has an annual operating budget of about $300M/year, most of which comes from the Basic Energy Sciences (BES) budget of the DOE. That budget supports 1,700 scientists, engineers and staff. SLAC was established in 1962 as a high energy physics center, and has evolved over the years into a multi-program laboratory. As part of our mission, we operate two major facilities used by thousands of scientific researchers each year from around the world. We, and other national laboratories, refer to these as “user facilities.”

SLAC’s two major facilities are the Stanford Synchrotron Radiation Lightsource (SSRL), which has been in operation for many years and serves approximately 1,500 users annually, and the Linac Coherent Light Source (LCLS), which was completed in 2010 and currently serves about 500 users annually. An expansion of LCLS, which I will discuss shortly, is currently underway, in part to accommodate the high demand from scientists for access to this unique facility. Like other large-scale DOE user facilities, the LCLS and SSRL are open on a competitive basis to scientists from industry, academia, private foundations and government laboratories. They provide world-class research tools on a scale that no single company or university could hope to afford. They represent a prime example of public-private partnership, where government invests in infrastructure that allows for basic research, which is then translated into applicable technologies by the private sector. Access to these tools is especially critical for start-up companies because it allows them to advance the development of their products at a reasonable cost.

Light source user facilities at SLAC, Argonne, Brookhaven and Lawrence Berkeley National Labs that produce intense X-rays have been doing scientific research with tremendous societal impact for several decades. These facilities serve a broad suite of scientific disciplines and provide tools that industry can use for drug discovery and other applications.

X-rays are powerful tools because they penetrate through objects (a property familiar to anyone who has been in a doctor’s office). X-rays also let us see where atoms are in materials. I would like to share with you just one example of the difference these facilities have made using these X-ray tools.

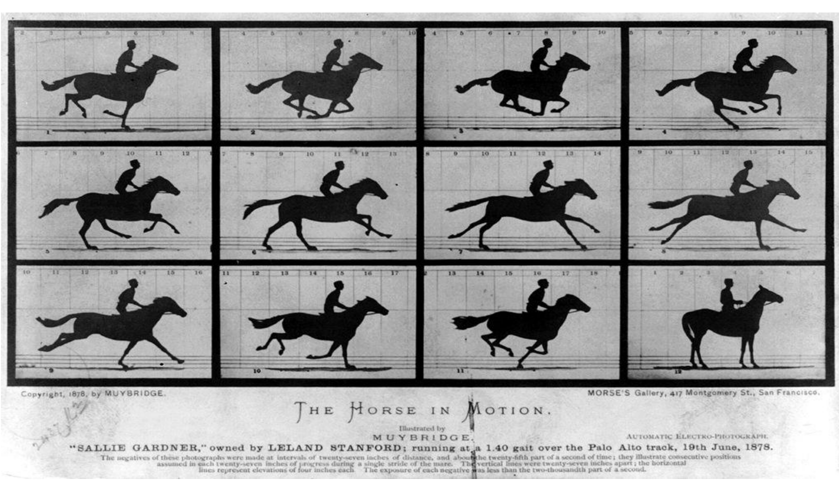
X-ray data derived using light source capabilities at SLAC, Argonne and Berkeley Labs has been used to determine the molecular structure of a mutated protein involved in stage-four malignant melanoma. With this structure, a Berkeley-based drug discovery company, Plexxikon, was able to develop a drug, vemurafenib, that could stop the spread of this deadly disease. Clinical trials of vemurafenib showed remarkable results for patients with advanced melanoma who had the mutation and for whom conventional treatments had been ineffective. Many were seriously ill or near death. But when they started taking vemurafenib, most patients suddenly experienced complete or partial regression of their tumors. Despite the dramatic clinical trial results — patients receiving the drug lived six months longer than those in the study who did not — vemurafenib is not yet a cure for melanoma, as the tumors returned after six months. However, the X-ray technique used in the drug's discovery is one that enables pharmaceutical companies to generate new drug candidates quickly, demonstrating how valuable these facilities can be for the private sector as well as for applications that advance human health.



After taking Plexxikon's vemurafenib for just two weeks, nearly all of the advanced malignant melanoma patients in a clinical trial showed dramatic improvement. Before (top) and after (below) PET scans showed a significant drop in metabolic activity associated with tumors in this patient, for example. Image courtesy of Plexxikon, Inc.

At SLAC, exploiting our decades of experience in building forefront accelerators, we have just turned on the newest X-ray user facility among national laboratories and are using it to open a completely new frontier. The Linac Coherent Light Source, or LCLS, is an X-ray laser whose pulses are brighter (with 1,000 times more X-rays per pulse) and faster (10,000 times shorter in time) than any achieved before. Those ultra-bright, ultra-short pulses are revolutionizing our ability to look at matter on the atomic scale.

Let me illustrate the power of the LCLS with an analogy. In the 1800s there was a lot of interest in the mechanics of how a horse galloped. (If you go to the National Gallery and look at pictures painted before the late 1870s, you will see many imaginative renderings of galloping horses.) There was a famous bet involving Senator Leland Stanford, the founder of Stanford University, on how a horse galloped, and whether all four hooves left the ground. Eadweard Muybridge, a well-known British photographer, devised a camera with a very fast shutter speed to resolve the bet by taking a series of stop-action pictures of a galloping horse. With this series of pictures, the question was finally resolved, and we know as a result that a galloping horse does, in fact, take all four hooves off the ground at once.

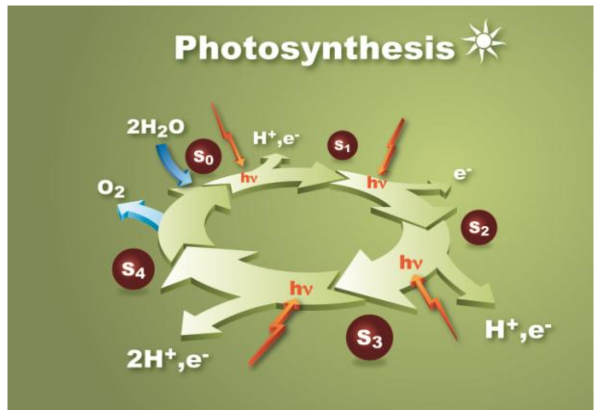


Now imagine if we could take X-ray pictures with the equivalent of a fast shutter speed and string them together to make stop-action movies of atomic processes. These movies would show atoms and electrons moving on their natural timescale and allow us to watch a chemical reaction atom by atom and step by step. This is the new scientific frontier opened by the LCLS.

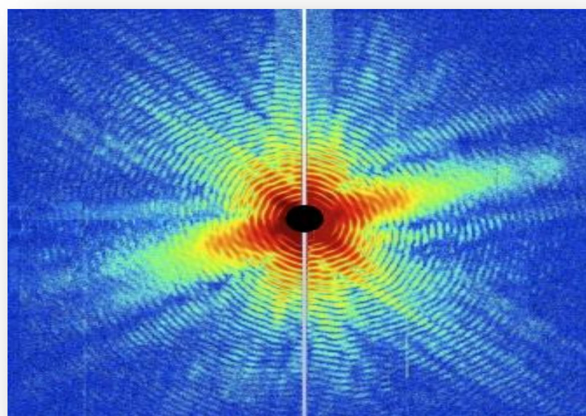
The LCLS was only completed in 2010, so we are in the early stages of exploiting this revolutionary new tool. But let me give you a few examples to illustrate the science we are achieving today and the promise for the future in terms of industrial involvement and benefits to society:

1. LCLS will allow us to better examine high-resolution structures of membrane proteins that are drug targets already, but cannot be extensively studied today due to technical limitations with existing X-ray facilities. Membrane proteins control traffic in and out of the cell and serve as docking points for infectious agents and disease-fighting drugs; in fact, they are the targets of more than 60 percent of the drugs on the market. Yet scientists know the structures of only a handful of the estimated 30,000 membrane proteins in the human body. There is considerable hope that LCLS will allow us to better "see" membrane proteins and extend our ability to do structure-based drug development in areas much like the melanoma drug we discussed earlier, leading to commercial applicability and near-term societal benefits.

2. We hope to use LCLS to understand photosynthesis in much the same way that Muybridge understood the galloping horse. Experimenters are attempting to take a series of stop-action pictures to make the equivalent of a movie of this most basic of life processes, focusing on the critical step of splitting water to make oxygen. We have long known the basics: photosynthesis takes CO_2 and water in and we get sugars and O_2 out. It is a multi-step process and we know some but not all of how it works. With an understanding of how this engine works, we can start to reengineer it and exploit it in new ways to develop better, more efficient sources of energy. I believe it will be a decade or more before society directly benefits or an industrial application emerges, but I am also confident that with time this will be game-changing on a global scale.



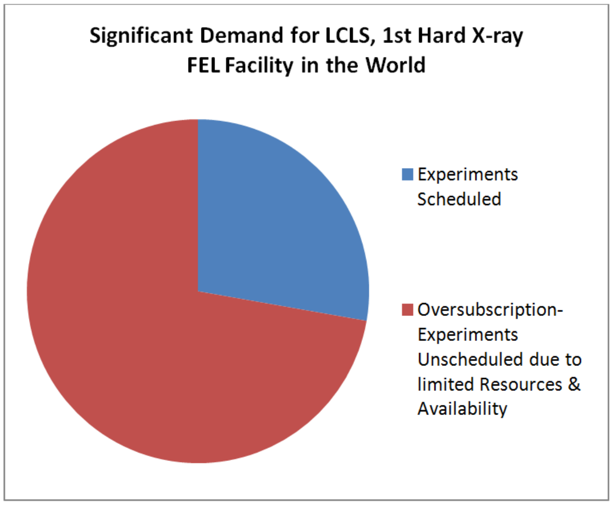
3. More speculative, but even more revolutionary, is the LCLS's ability to image viruses and possibly some day, selected cells. This is definitely in early technology development but the potential is enormous, as it might offer revolutionary new insights into the workings of the living cell.



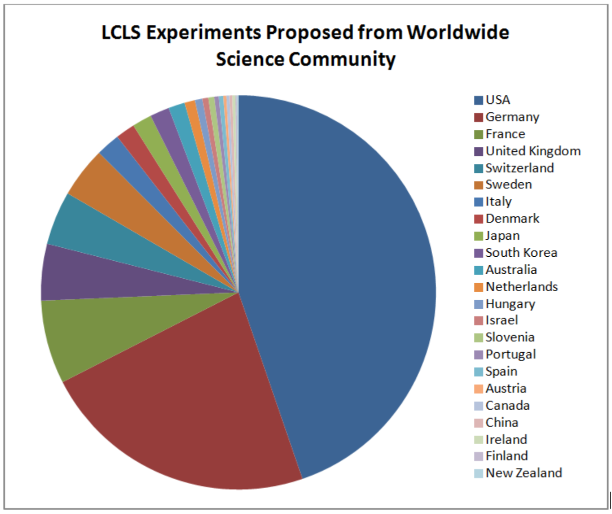
Mimivirus particle imaged by LCLS
Courtesy of Tomas Ekeberg

4. Virtually everything in our daily life involves catalysts, from turning crude oil into the gas in our cars, to processing cotton to make our clothes, to the hydrogenation of fats to make margarine. Often catalysts have been discovered by trial and error and we don't understand in detail how or why they work. The LCLS is starting to develop the technology to make stop-action movies of catalysts in action. When this works we will have the ability to design catalysts in a much more controlled fashion, allowing chemists to gain an in-depth understanding of the catalytic cycles on molecular levels while guiding new catalyst design. Because 90 percent of all commercially

produced chemical products involve catalysts at some stage in the process of their manufacture, and catalytic processes generated approximately $900 billion in products worldwide in 2005, the potential for economic impact is enormous. (Reference: Wikipedia)



The LCLS is unique in the world in its ability to deliver ultrafast, ultra-bright X-rays with the promise of revolutionizing our understanding in areas of biology, materials and chemistry. It is a facility that is expensive to build and to operate, and no one industry or research enterprise can afford to build an LCLS for itself. The federal government, through the Office of Science in the DOE, funds the building and operations of the facilities, and scientists from around the world compete for beam time with peer-reviewed proposals. In a case like LCLS, where we have to reject three proposals for every one that we accept, we must ensure that the best science gets the beam time.



The idea of an X-ray free electron laser started in the U.S., and the LCLS is the first one in the world to be built and operating. However, soon there will be significant worldwide competition as other countries are working hard to catch up, particularly now that they see how well the LCLS is performing. Japan has recently turned on a smaller version of the LCLS. A large X-ray free electron laser will turn on in Germany in the second half of this decade, and China and Switzerland are committed to building machines, as well.

The LCLS is at an early stage of development, but we are already working to expand the capability and capacity of this discovery-class machine with LCLS-II. LCLS-II is supported in the President's Budget Request and is included in the House Energy and Water bill as part of the BES budget. LCLS-II is a critical step to keep us competitive in this important area of research well into the next decade. As I hope I have made the case, these facilities have the potential to do breakthrough science that with time will lead to industrial applications and benefits to society. We currently are world leaders in many areas of science with our user facilities. We will need continued stable funding for the DOE Office of Science and a commitment to stay at the leading edge by ensuring strategic exploitation of existing facilities along with plans for future facilities in order to keep our world-leading position. I believe this is essential to ensure continued benefits to society and enhanced industrial competitiveness that comes from the science done at these user facilities in the decades to come.

Mr. Chairman and Members of the Subcommittee: let me end with a somewhat philosophical statement. More than 400 years ago, Flemish spectacle makers invented a spyglass to be able to see and identify ships when they were still far from harbor to see if they were friend or foe. Galileo made the spyglass 10 times more powerful and turned it on the planets, seeing them with a detail never before possible, and he revolutionized our understanding of the cosmos and our place within it.

LCLS was built because we knew that studying materials on the atomic time and distance scales would open new horizons, as we are already seeing in drug discovery and materials research. But we all believe that with this new X-ray source, a billion times brighter than anyone has ever had before, the biggest surprises are yet to come.

Thank you for the opportunity to provide my perspective as SLAC's Director. I will be happy to answer any questions you may have.