# DEPARTMENT OF ENERGY USER FACILITIES: UTILIZING THE TOOLS OF SCIENCE TO DRIVE INNOVATION THROUGH FUNDAMENTAL RESEARCH

## HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TWELFTH CONGRESS

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THURSDAY, JUNE 21, 2012

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# DEPARTMENT OF ENERGY USER FACILITIES: UTILIZING THE TOOLS OF SCIENCE TO DRIVE INNOVATION THROUGH FUNDAMENTAL RESEARCH

**THURSDAY, JUNE 21, 2012**

House of Representatives,
Subcommittee on Energy and Environment,
Committee on Science, Space, and Technology,
*Washington, DC.*

The Subcommittee met, pursuant to call, at 9:31 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Andy Harris [Chairman of the Subcommittee] presiding.

RALPH M. HALL, TEXAS
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EDDIE BERNICE JOHNSON, TEXAS
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U.S. HOUSE OF REPRESENTATIVES

# COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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## Subcommittee on Energy & Environment

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

Thursday, June 21, 2012
9:30 a.m. - 11:30 a.m.
2318 Rayburn House Office Building

Witnesses

**Dr. Antonio Lanzirotti,** Chairman, National User Facility Organization

**Dr. Persis Drell**, Director, SLAC National Accelerator Laboratory

**Dr. Stephen Wasserman**, Senior Research Fellow, Translational Science & Technologies, Ely Lilly and Company

**Ms. Suzy Tichenor**, Director, Industrial Partnerships Program, Computing and Computational Sciences, Oak Ridge National Laboratory

**Dr. Ernest Hall,** Chief Scientist, Chemistry and Chemical Engineering/Materials Characterization, GE Global Research

**U.S. HOUSE OF REPRESENTATIVES**
**COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY**
**SUBCOMMITTEE ON ENERGY & ENVIRONMENT**

# HEARING CHARTER

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

Thursday, June 21, 2012
9:30 a.m. - 11:30 a.m.
2318 Rayburn House Office Building

## PURPOSE

On Thursday, June 21, 2012, at 9:30 a.m. in Room 2318 of the Rayburn House Office Building, the Subcommittee on Energy and the Environment of the Committee on Science, Space, and Technology will hold a hearing entitled *"Department of Energy User Facilities: Utilizing the Tools of Science to Drive Innovation through Fundamental Research."* The purpose of this hearing is to examine the role the Department of Energy's (DOE) national scientific user facilities play in enabling basic research that drives innovation and economic growth. Additionally, the hearing will examine challenges and opportunities associated with user facility planning and management.

## WITNESS LIST

- **Dr. Antonio Lanzirotti,** Chairman, National User Facility Organization
- **Dr. Persis Drell**, Director, SLAC National Accelerator Laboratory
- **Dr. Stephen Wasserman**, Senior Research Fellow, Translational Science & Technologies, Ely Lilly and Company
- **Ms. Suzy Tichenor**, Director, Industrial Partnerships Program, Computing and Computational Sciences, Oak Ridge National Laboratory
- **Dr. Ernest Hall,** Chief Scientist, Chemistry and Chemical Engineering/Materials Characterization, GE Global Research

## Office of Science Overview

The mission of the Department of Energy's Office of Science (SC) is the delivery of scientific discoveries, capabilities, and major scientific tools to transform the understanding of nature and to advance the energy, economic, and national security of the United States.[1] To achieve this mission, SC supports basic research activities in the following areas: advanced scientific computing, basic energy sciences, biological and environmental research, fusion energy sciences, high energy physics, and nuclear physics. SC's operations take place in three main areas: selection and management of research (47 percent of SC's $4.9 billion FY 2013 budget request); operation of world-class, state-of-the-art scientific facilities (38 percent); and design and construction of new facilities (14 percent) (Figure 1).[2]

Figure 1. Office of Science funding distribution.


SC aims to carry out its mission through support in the following three areas:[3]

- Energy and Environmental Science, focused on advancing a clean energy agenda through fundamental research on energy production, storage, transmission, and use, and on advancing our understanding of the earth's climate through basic research in atmospheric and environmental sciences and climate change;

[1] http://science.energy.gov/about/
[2] *Ibid.*
[3] *Ibid.*

- The Frontiers of Science, focused on unraveling nature's mysteries—from the study of subatomic particles, atoms, and molecules that make up the materials of our everyday world to DNA, proteins, cells, and entire biological systems; and

- The 21st Century Tools of Science, national scientific user facilities providing the Nation's researchers with the most advanced tools of modern science including accelerators, colliders, supercomputers, light sources, neutron sources, and facilities for studying the nanoworld.

**Office of Science User Facilities**

This third category—national scientific user facilities—is a unique and defining characteristic of SC. The origins of these facilities trace back to the Manhattan Project, where the challenges associated with building the first nuclear weapons demanded large, multi-purpose facilities that later became the focus of the country's first national laboratories. DOE states that these facilities—the large machines for modern science—"offer capabilities unmatched anywhere in the world and enable U.S. researchers and industries to remain at the forefront of science, technology, and innovation. Approximately 26,500 researchers from universities, national laboratories, industry, and international partners are expected to use the Office of Science scientific user facilities in FY 2013."[4] According to the National User Facility Organization (NUFO), scientific user facilities (most but not all of which are supported by SC) were home to experiments that have resulted in 23 Nobel Prizes from 1939 until today.[5]

A January 6, 2012 Office of Science memorandum provides the following definition of a user facility: [6]

> "A user facility is a federally sponsored research facility available for external use to advance scientific or technical knowledge under the following conditions:
>
> - The facility is open to all interested potential users without regard to nationality or institutional affiliation.
> - Allocation of facility resources is determined by merit review of the proposed work.
> - User fees are not charged for non-proprietary work if the user intends to publish the research results in the open literature. Full cost recovery is required for proprietary work.
> - The facility provides resources sufficient for users to conduct work safely and efficiently.
> - The facility supports a formal user organization to represent the users and facilitate sharing of information, forming collaborations, and organizing research efforts among users.
> - The facility capability does not compete with an available private sector capability."

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[4] http://science.energy.gov/about/
[5] http://www.nufo.org/files/NUFO_Brochure.pdf
[6] http://science.energy.gov/~/media/_/pdf/user-facilities/Office_of_Science_User_Facility_Definition_Memo.pdf

Currently, the Office of Science supports 31 user facilities (Appendices I and II) across its six program directorates. They include supercomputers, particle accelerators, x-ray light sources, neutron scattering sources, and other large scale facilities that enable researchers to pursue new scientific discoveries.

Over half of these are located in the Basic Energy Sciences (BES) directorate and are focused on enabling cutting-edge physical and life sciences research with a broad range of potential applications. For example, BES supports five x-ray light sources used to examine the atomic and electronic structure of a wide array of materials and chemicals.[7] The research undertaken at these light sources by academia, government, and industry has resulted in numerous breakthroughs and innovations ultimately applied to advances in industry sectors such as aerospace, medicine, semiconductors, chemicals, and energy.

*Budget, Planning, Management, and Operations*

Most SC user facilities are expensive to construct and operate, typically costing several hundred million dollars or more. For example, two of the most recently completed facilities—the Spallation Neutron Source at Oak Ridge National Laboratory and the Linac Coherent Light Source at SLAC National Accelerator Facility—cost $1.6 billion and approximately $415 million to construct, respectively.[8]

The Office of Science is generally well regarded for its effectiveness in planning, developing, and constructing user facilities on time and on budget. This record is considered successful in part due to a rigorous planning and budget control process known as the Critical Decision, or CD, process. The CD process, formalized in DOE Order 413.3A—Program and Project Management for the Acquisition of Capital Assets—requires a series of high level reviews and decision-making as a facility project advances.[9]

According to DOE, each of the five Critical Decisions mark "an increase in commitment of resources by the Department and requires successful completion of the preceding phase or Critical Decision."[10] Collectively, the Critical Decisions affirm the following:

CD 0: There is a need that cannot be met through other than material means;
CD 1: The selected alternative and approach is the optimum solution;
CD 2: Definitive scope, schedule and cost baselines have been developed;
CD 3: The project is ready for implementation; and
CD 4: The project is ready for turnover or transition to operations.

Once facility construction has completed and transitioned into operations and research, Office of Science programs typically provide significant ongoing support to manage and operate facilities (Table 1). Support for merit-reviewed research undertaken by both intramural and extramural scientists is also provided by SC, as well as by other Federal agencies.

[7] http://science.energy.gov/~/media/bes/suf/pdf/BES_Facilities.pdf
[8] http://energy.gov/sites/prod/files/maprod/documents/LCLS.pdf
[9] http://science.energy.gov/~/media/pdf/opa/pdf/o4133a.pdf
[10] *Ibid.*

Table 1. Office of Science Program and Facility Operations Budgets.[11]

| Program | FY12 Total Budget ($ millions) | FY12 User Facility Operations* ($ millions) |
|---|---|---|
| Advanced Scientific Computing Research (ASCR) | 440.9 | 248.3 |
| Basic Energy Sciences (BES) | 1,688.1 | 730.6 |
| Biological and Environmental Research (BER) * | 609.6 | 201.7 |
| High Energy Physics (HEP) | 790.8 | 221.6 |
| Nuclear Physics (HP) | 547.4 | 289.3 |
| Fusion Energy Sciences (FES)* | 401.0 | 129.7 |

* Table figures do not include facilities research support, with the exception of BER and FES directorates, which do.

*Innovation and Industrial Use*

A 2010 report by DOE's Basic Energy Sciences Advisory Committee (BESAC), *Science for Energy Technology: Strengthening the Link Between Basic Research and Industry*, examined challenges and opportunities associated with realizing the technological and economic potential of scientific user facilities.[12] The report noted that these user facilities allow researchers to "peer deep inside objects and probe surfaces in ever increasing detail, enabling an understanding of complex materials and chemistry with resolution and sensitivity that is not achievable by any other means. Facilities of this type are well beyond the resources of individual research institutions or companies."[13]

The report also concluded that opportunities exist for user facilities to better engage and improve industrial usage without deviating from their fundamental mission to broadly advance science. Specifically, the report made the following recommendations with respect to user facilities:

- The user facilities are ideally suited to addressing a wide range of science questions with significant technological impact. BES and the user facilities could consider a number of options that would allow the facilities to better serve the industrial user community without deviating from their mission to advance scientific understanding of materials and chemical processes.
- To the extent possible, it would be desirable to have more uniform procedures for access and use across the various user facilities to expedite coordinated use of multiple facilities by industry and other research organizations.
- Evaluation of proposals could take into consideration technological impact in addition to scientific merit.

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[11] Source Department of Energy Fiscal Year 2013 Budget Request.
[12] http://science.energy.gov/~/media/bes/pdf/reports/files/set_rpt.pdf
[13] *Ibid.*

- Peer review of proposals could include a greater number of industry reviewers.
- The facilities might consider setting aside a modest fraction of the facility time for "quick response" projects from industry and basic science users.
- User facility staff researchers could be incentivized and rewarded for assisting non-expert users from industry, and facilities could increase their outreach to industry by holding workshops to gain greater understanding of industrial needs and barriers to increased participation.
- These activities are within the technology transfer mission of the laboratories and could significantly enhance the development of clean energy technology.
- User facilities could be encouraged to develop and broaden industrial participation. Some possibilities include greater industrial participation on Scientific Advisory Committees, or possibly the development of a separate Industrial Advisory Board.
- These would help to develop better communications with the facility Director and staff regarding industrial needs for access, as well as new capabilities, instrumentation and beamlines.

## Appendix I[14]

**U.S. Department of Energy**
**Office of Science User Facilities, FY 2012**

| Facility | Host institution |
|---|---|
| **Advanced Scientific Research Computing (ASCR)** | |
| National Energy Research Scientific Computing Center (NERSC) | LBNL |
| Argonne Leadership Computing Facility (ALCF) | ANL |
| Oak Ridge Leadership Computing Facility (OLCF) | ORNL |
| Energy Sciences Network (ESnet) | LBNL |
| **Basic Energy Sciences (BES)** | |
| ***Light Sources*** | |
| Advanced Light Source (ALS) | LBNL |
| Advanced Photon Source (APS) | ANL |
| Linac Coherent Light Source (LCLS) | SLAC |
| National Synchrotron Light Source (NSLS) | BNL |
| Stanford Synchrotron Radiation Light Source (SSRL) | SLAC |
| ***Neutron Sources*** | |
| High Flux Isotope Reactor (HFIR) | ORNL |
| Spallation Neutron Source (SNS) | ORNL |
| Lujan at Los Alamos Neutron Science Center (LANSCE) | LANL |
| ***Nanoscale Science Research Centers*** | |
| Center for Functional Nanomaterials (CFN) | BNL |
| Center for Integrated Nanotechnologies (CINT) | Sandia/LANL |
| Center for Nanophase Materials Sciences (CNMS) | ORNL |
| Center for Nanoscale Materials (CNM) | ANL |
| The Molecular Foundry | LBNL |
| ***Electron Microscopy Centers*** | |
| National Center for Electron Microscopy (NCEM) | LBNL |
| Electron Microscopy Center for Materials Research | ANL |
| Shared Research Equipment Program (ShaRE) | ORNL |
| **Biological and Environmental Research (BER)** | |
| Environmental Molecular Sciences Laboratory (EMSL) | PNNL |
| Atmospheric Radiation Measurement Climate Research (ARM) | Global network |
| Joint Genome Institute (JGI) | LBNL |
| **Fusion Energy Sciences (FES)** | |
| DIII-D | General Atomics |
| National Spherical Torus Experiment (NSTX) | PPPL |
| Alcator C-Mod | MIT |
| **High Energy Physics (HEP)** | |
| Proton Accelerator Complex | FNAL |
| Facility for Advanced Accelerator Experimental Tests (FACET) | SLAC |
| **Nuclear Physics (NP)** | |
| Continuous Electron Beam Accelerator Facility (CEBAF) | TJNAF |
| Holifield Radioactive Ion Beam Facility (HRIBF) | ORNL |
| Relativistic Heavy Ion Collider (RHIC) | BNL |
| Argonne Tandem Linac Accelerator System (ATLAS) | ANL |

Note: This list reflects facility status as of the beginning of the fiscal year and does not reflect changes in facility status enacted in appropriations law for FY 2012.

[14] http://science.energy.gov/~/media/_/pdf/user-facilities/Office_of_Science_User_Facility_Definition_Memo.pdf

## Appendix II

**Office of Science User Facility Descriptions** (condensed from DOE materials)[15]

**ASCR User Facilities**

The Advanced Scientific Computing Research program supports the operation of the following national scientific user facilities:

- Energy Sciences Network (ESnet):
  The Energy Sciences Network, or ESnet, is a high-speed network serving thousands of Department of Energy researchers and collaborators worldwide. Managed and operated by the ESnet staff at Lawrence Berkeley National Laboratory, ESnet provides direct connections to more than 30 DOE sites at speeds up to 10 gigabits per second. Connectivity to the global Internet is maintained through "peering" arrangements with more than 100 other Internet service providers.
- Oak Ridge National Laboratory Leadership Computing Facility (OLCF):
  Home to Jaguar, a Cray XK6 capable of 3.3 thousand trillion calculations a second—or 3.3 petaflops—the OLCF combines world-class staff with cutting-edge facilities and support systems. The center serves elite scientists from all areas of the research community through programs such as the Department of Energy's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program, ensuring it will be a computing powerhouse for the foreseeable future. In 2012, nearly a billion processor hours on Jaguar were awarded to 35 INCITE projects from universities, private industry, and government research laboratories, representing a wide array of scientific inquiry, from combustion to climate to chemistry.
- Argonne Leadership Computing Facility (ALCF):
  The ALCF provides the computational science community with a world-class computing capability dedicated to breakthrough science and engineering. It began operation in 2006 to coincide with the award of the 2006 INCITE projects and the research being conducted at the ALCF spans a diverse range of scientific areas - from studying exploding stars to designing more efficient jet engines to exploring the molecular basis of Parkinson's disease. The resources at the ALCF include an IBM Blue Gene/P system nicknamed Intrepid, and a BG/P system named Surveyor. Intrepid possess a peak speed of 557 Teraflops and a Linpack speed of 450 Teraflops, making it one of the fastest supercomputers in the world.
- National Energy Research Scientific Computing (NERSC) Center:
  As a national resource to enable scientific advances to support the missions of the Department of Energy's Office of Science, the National Energy Research Scientific Computing Center (NERSC), operated by the Lawrence Berkeley National Laboratory, annually serves approximately 3,000 scientists throughout the United States. These researchers work at DOE laboratories, universities, industrial laboratories and other Federal agencies. Computational science conducted at NERSC covers the entire range of scientific disciplines, but is focused on research that supports DOE's missions and scientific goals.

[15] http://science.energy.gov/user-facilities

**BES User Facilities**

The Basic Energy Sciences program supports the operation of the following national scientific user facilities:

**Synchrotron Radiation Light Sources**

- National Synchrotron Light Source (NSLS):
The NSLS at Brookhaven National Laboratory, commissioned in 1982, consists of two distinct electron storage rings. The x-ray storage ring is 170 meters in circumference and can accommodate 60 beamlines or experimental stations, and the vacuum-ultraviolet (VUV) storage ring can provide 25 additional beamlines around its circumference of 51 meters. Synchrotron light from the x-ray ring is used to determine the atomic structure of materials using diffraction, absorption, and imaging techniques. Experiments at the VUV ring help solve the atomic and electronic structure as well as the magnetic properties of a wide array of materials. These data are fundamentally important to virtually all of the physical and life sciences as well as providing immensely useful information for practical applications. NSLS will be replaced by a new light source, NSLS-II, which is currently under construction.
- Stanford Synchrotron Radiation Lightsource (SSRL):
The SSRL at SLAC National Accelerator Laboratory was built in 1974 to take and use for synchrotron studies the intense x-ray beams from the SPEAR storage ring that was originally built for particle. The facility is used by researchers from industry, government laboratories, and universities. These include astronomers, biologists, chemical engineers, chemists, electrical engineers, environmental scientists, geologists, materials scientists, and physicists.
- Advanced Light Source (ALS):
The ALS at Lawrence Berkeley National Laboratory, began operations in October 1993 as one of the world's brightest sources of high-quality, reliable vacuum-ultraviolet (VUV) light and long-wavelength (soft) x-rays for probing the electronic and magnetic structure of atoms, molecules, and solids, such as those for high-temperature superconductors. The high brightness and coherence of the ALS light are particularly suited for soft x-ray imaging of biological structures, environmental samples, polymers, magnetic nanostructures, and other inhomogeneous materials. Other uses of the ALS include holography, interferometry, and the study of molecules adsorbed on solid surfaces. The pulsed nature of the ALS light offers special opportunities for time resolved research, such as the dynamics of chemical reactions. Shorter wavelength x-rays are also used at structural biology experimental stations for x-ray crystallography and x-ray spectroscopy of proteins and other important biological macromolecules.
- Advanced Photon Source (APS):
The APS at Argonne National Laboratory is one of only three third-generation, hard x-ray synchrotron radiation light sources in the world. The 1,104-meter circumference facility—large enough to house a baseball park in its center—includes 34 bending magnets and 34 insertion devices, which generate a capacity of 68 beamlines for experimental research. Instruments on these beamlines attract researchers to study the structure and properties of materials in a variety of disciplines, including condensed matter physics, materials sciences, chemistry, geosciences, structural biology, medical imaging, and environmental sciences. The high-quality, reliable x-ray beams at the APS have already brought about new discoveries in materials structure.
- Linac Coherent Light Source (LCLS):
The LCLS at the SLAC National Accelerator Laboratory (SLAC) is the world's first hard x-ray free electron laser facility and became operational in June 2010. This is a milestone for x-ray user facilities that advances the state-of-the-art from storage-ring-based third generation synchrotron light sources to a fourth generation Linac-based light source. The LCLS provides laser-like

radiation in the x-ray region of the spectrum that is 10 billion times greater in peak power and peak brightness than any existing coherent x-ray light source.

**High-Flux Neutron Sources**

- Spallation Neutron Source (SNS):
  The SNS at Oak Ridge National Laboratory is a next-generation short-pulse spallation neutron source for neutron scattering that is significantly more powerful (by about a factor of 10) than the best spallation neutron source now in existence. The SNS consists of a linac-ring accelerator system that delivers short (microsecond) proton pulses to a target/moderator system where neutrons are produced by a process called spallation. The neutrons so produced are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations.
- High Flux Isotope Reactor (HFIR):
  The HFIR at Oak Ridge National Laboratory is a light-water cooled and moderated reactor that began full-power operations in 1966 at the design power level of 100 megawatts. Currently, HFIR operates at 85 megawatts to provide state-of-the-art facilities for neutron scattering, materials irradiation, and neutron activation analysis and is the world's leading source of elements heavier than plutonium for research, medicine, and industrial applications. The neutron-scattering experiments at the reveal the structure and dynamics of a very wide range of materials. The neutron-scattering instruments installed on the four horizontal beam tubes are used in fundamental studies of materials of interest to solid-state physicists, chemists, biologists, polymer scientists, metallurgists, and colloid scientists.
- Los Alamos Neutron Science Center (LANSCE):
  The Lujan Neutron Scattering Center (Lujan Center) at Los Alamos National Laboratory provides an intense pulsed source of neutrons to a variety of spectrometers for neutron scattering studies. The Lujan Center features instruments for measurement of high-pressure and high-temperature samples, strain measurement, liquid studies, and texture measurement. The facility has a long history and extensive experience in handling actinide samples. The Lujan Center is part of LANSCE, which is comprised of a high-power 800-MeV proton linear accelerator, a proton storage ring, production targets to the Lujan Center, the Weapons Neutron Research facility, Proton Radiography, and Ultra-Cold Neutron beam lines, in addition to an Isotope Production Facility, along with a variety of associated experiment areas and spectrometers for national security research and civilian research.

**Electron Beam Microcharacterization Centers**

- The Electron Microscopy Center (EMC) for Materials Research:
  The EMCMR at Argonne National Laboratory provides in-situ, high-voltage and intermediate voltage, high-spatial resolution electron microscope capabilities for direct observation of ion-solid interactions during irradiation of samples with high-energy ion beams. The EMC employs both a tandem accelerator and an ion implanter in conjunction with a transmission electron microscope for simultaneous ion irradiation and electron beam microcharacterization. It is the only instrumentation of its type in the western hemisphere. Research at EMC includes microscopy based studies on high-temperature superconducting materials, irradiation effects in metals and semiconductors, phase transformations, and processing related structure and chemistry of interfaces in thin films.
- National Center for Electron Microscopy (NCEM):
  The NCEM at Lawrence Berkeley National Laboratory provides instrumentation for high-resolution, electron-optical microcharacterization of atomic structure and composition of metals,

ceramics, semiconductors, superconductors, and magnetic materials. This facility contains one of the highest resolution electron microscopes in the U.S.

- Shared Research Equipment (SHaRE):
  The SHaRE User Facility at Oak Ridge National Laboratory makes available state-of-the-art electron beam microcharacterization facilities for collaboration with researchers from universities, industry and other government laboratories. Most SHaRE projects seek correlations at the microscopic or atomic scale between structure and properties in a wide range of metallic, ceramic, and other structural materials. A diversity of research projects has been conducted, such as the characterization of magnetic materials, catalysts, semiconductor device materials, high Tc superconductors, and surface-modified polymers. Analytical services (service microscopy) which can be purchased from commercial laboratories are not possible through SHaRE.

**Nanoscale Science Research Centers**

- Center for Nanophase Materials Sciences (CNMS):
  The CNMS at Oak Ridge National Laboratory is a research center and user facility that integrates nanoscale science research with neutron science, synthesis science, and theory/modeling/simulation. The building provides state-of-the-art clean rooms, general laboratories, wet and dry laboratories for sample preparation, fabrication and analysis. Equipment to synthesize, manipulate, and characterize nanoscale materials and structures is included. The CNMS's major scientific thrusts are in nano-dimensioned soft materials, complex nanophase materials systems, and the crosscutting areas of interfaces and reduced dimensionality that become scientifically critical on the nanoscale. A major focus of the CNMS is to exploit ORNL's unique capabilities in neutron scattering.
- Molecular Foundry:
  The Molecular Foundry at Lawrence Berkeley National Laboratory (LBNL) makes use of existing LBNL facilities such as the Advanced Light Source, the National Center for Electron Microscopy, and the National Energy Research Scientific Computing Center. The facility provides laboratories for materials science, physics, chemistry, biology, and molecular biology. State-of-the-art equipment includes clean rooms, controlled environmental rooms, scanning tunneling microscopes, atomic force microscopes, transmission electron microscope, fluorescence microscopes, mass spectrometers, DNA synthesizer and sequencer, nuclear magnetic resonance spectrometer, ultrahigh vacuum scanning-probe microscopes, photo, uv, and e-beam lithography equipment, peptide synthesizer, advanced preparative and analytical chromatographic equipment, and cell culture facilities.
- Center for Integrated Nanotechnologies (CINT):
  The CINT focuses on exploring the path from scientific discovery to the integration of nanostructures into the micro- and macro-worlds. This path involves experimental and theoretical exploration of behavior, understanding new performance regimes and concepts, testing designs, and integrating nanoscale materials and structures. CINT focus areas are nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and the nanoscale/bio/microscale interfaces.
- Center for Functional Nanomaterials (CFN):
  The CFN at Brookhaven National Laboratory focuses on understanding the chemical and physical response of nanomaterials to make functional materials such as sensors, activators, and energy-conversion devices. The facility uses existing facilities such as the National Synchrotron Light Source and the Laser Electron Accelerator facility. It also provides clean rooms, general laboratories, and wet and dry laboratories for sample preparation, fabrication, and analysis.
- Center for Nanoscale Materials (CNM):
  The CNM at Argonne National Laboratory focuses on research in advanced magnetic materials, complex oxides, nanophotonics, and bio-inorganic hybrids. The facility uses existing facilities

such as the Advanced Photon Source, the Intense Pulsed Neutron Source, and the Electron Microscopy Center. An x-ray nanoprobe beam line at the Advanced Photon Source is run by the Center for its users.

**BER User Facilities**

The Biological & Environmental Research program supports the operation of the following national scientific user facilities:

- William R. Wiley Environmental Molecular Sciences Laboratory (EMSL):
  The mission of the EMSL at the Pacific Northwest National Laboratory (PNNL) in Richland, Washington, is to provide integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation. The facilities and capabilities of the EMSL are available to the general scientific and engineering communities to conduct research in the environmental molecular sciences and related areas.
- Joint Genome Institute (JGI):
  The Office of Science / U.S. Department of Energy Joint Genome Institute in Walnut Creek, California, unites the expertise of five national laboratories—Lawrence Berkeley, Lawrence Livermore, Los Alamos, Oak Ridge, and Pacific Northwest—along with the HudsonAlpha Institute for Biotechnology to advance genomics in support of the DOE missions related to clean energy generation and environmental characterization and cleanup. The vast majority of JGI sequencing is conducted under the auspices of the Community Sequencing Program (CSP), surveying the biosphere to characterize organisms relevant to the DOE science mission areas of bioenergy, global carbon cycling, and biogeochemistry.
- Atmospheric Radiation Measurement Climate Research Facility:
  The Atmospheric Radiation Measurement (ARM) Climate Research Facility is a multi-platform national scientific user facility, with instruments at fixed and varying locations around the globe for obtaining continuous field measurements of climate data. The ACRF promotes the advancement of atmospheric process understanding and climate models through precise observations of atmospheric phenomena.

**FES User Facilities**

The Fusion Energy Sciences program supports the operation of the following national scientific user facilities:

- DIII-D Tokamak Facility:
  DIII-D, located at General Atomics in San Diego, California, is the largest magnetic fusion facility in the U.S. and is operated as a DOE national user facility. DIII-D has been a major contributor to the world fusion program over the past decade in areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layers physics using a "magnetic divertor" to control the magnetic field configuration at the edge of the plasma.
- Alcator C-Mod:
  Alcator C-Mod at the Massachusetts Institute of Technology is operated as a DOE national user facility. Alcator C-Mod is a unique, compact tokamak facility that uses intense magnetic fields to confine high-temperature, high-density plasmas in a small volume. One of its unique features are

the metal (molybdenum) walls to accommodate high power densities. Alcator C-Mod has made significant contributions to the world fusion program in the areas of plasma heating, stability, and confinement of high field tokamaks, which are important integrating issues related to ignition of burning of fusion plasma.

- National Spherical Torus Experiment (NSTX):
  NSTX is an innovative magnetic fusion device that was constructed by the Princeton Plasma Physics Laboratory in collaboration with the Oak Ridge National Laboratory, Columbia University, and the University of Washington at Seattle. It is one of the world's two largest embodiments of the spherical torus confinement concept. NSTX has a unique, nearly spherical plasma shape that provides a test of the theory of toroidal magnetic confinement as the spherical limit is approached. Plasmas in spherical torii have been predicted to be stable even when high ratios of plasma-to-magnetic pressure and self-driven current fraction exist simultaneously in the presence of a nearby conducting wall bounding the plasma. If these predictions are verified, it would indicate that spherical torii use applied magnetic fields more efficiently than most other magnetic confinement systems and could, therefore, be expected to lead to more cost-effective fusion power systems in the long term.

**HEP User Facilities**

The High Energy Physics program supports the operation of the following national scientific user facilities:

**Proton Accelerator Complex**

The Proton Accelerator Complex at Fermi National Accelerator Laboratory is composed of the accelerator complex and several experiments—both actual and proposed--that utilize its protons. The complex currently operates two proton beams that are used to generate neutrinos for short and long baseline neutrino experiments.

Booster Neutrino Beam: The Booster accelerator is a ring 1500 feet in circumference that receives 400 MeV protons from the linac and accelerates them to 8 GeV. These protons then strike a 71-cm long beryllium target used to generate an intense muon neutrino beam used for two short baseline neutrino oscillation experiments, one currently operating, the other planned.

Neutrinos at the Main Injector (NuMI): The Main Injector takes the 8 GeV protons from the Booster and accelerates them to approximately 150 GeV. As in the Booster, these highly energetic protons strike a target—in this case a carbon target—to generate muons that subsequently decay to muon neutrinos. The result is the most intense neutrino beam in the world. The muon neutrino beam is used for studies of both the disappearance of muon neutrinos and the appearance of non-muon neutrinos such as electron and tau neutrinos.

**Facility for Advanced Accelerator Experimental Tests (FACET)**

FACET is a 23 GeV electron-beam driven plasma wakefield accelerator test facility located at SLAC National Accelerator Laboratory. It has been optimized for tests of plasma wakefield acceleration with high energy beams of electrons or positrons with short duration pulses. It is open to all users that need such beams with access based on peer review of annually solicited proposals.

**NP User Facilities**

The Nuclear Physics program supports the operation of the following national scientific user facilities:

- Relativistic Heavy Ion Collider (RHIC):
  RHIC at Brookhaven National Laboratory is a world-class scientific research facility that began operation in 2000, following 10 years of development and construction. Hundreds of physicists from around the world use RHIC to study what the universe may have looked like in the first few moments after its creation. RHIC drives two intersecting beams of gold ions head-on, in a subatomic collision. What physicists learn from these collisions may help us understand more about why the physical world works the way it does, from the smallest subatomic particles, to the largest stars.
- Continuous Electron Beam Accelerator Facility (CEBAF):
  The CEBAF at the Thomas Jefferson National Accelerator Facility, is a world-leading facility in the experimental study of hadronic matter. Based on superconducting radio-frequency (SRF) accelerating technology, CEBAF is the world's most advanced particle accelerator for investigating the quark structure of the atom's nucleus. To probe nuclei, scientists use continuous beams of high-energy electrons from CEBAF.
- Argonne Tandem Linear Accelerator System (ATLAS):
  ATLAS is a national user facility at Argonne National Laboratory in Argonne, Illinois. The ATLAS facility is a leading facility for nuclear structure research in the United States. It provides a wide range of beams for nuclear reaction and structure research to a large community of users from the US and abroad. About 20% of the beam-time is used to generate secondary radioactive beams. These beams are used mostly to study nuclear reactions of astrophysical interest and for nuclear structure investigations. Beam lines are also available for experiments where Users bring their own equipment.

Chairman HARRIS. The Subcommittee on Energy and Environment will come to order.

Good morning. Welcome to today's hearing entitled "Department of Energy User Facilities: Utilizing the Tools of Science to Drive Innovation through Fundamental Research." In front of you are packets containing the written testimony, biographies and Truth in Testimony disclosures for today's witness panel. I now recognize myself for five minutes for an opening statement.

Good morning, and welcome to today's hearing. The purpose of the hearing is to examine the role DOE scientific user facilities play in enabling the fundamental research that advances basic understanding of the physical world while also driving innovation and economic growth.

Approximately half of the Office of Science's $5 billion budget is dedicated to the design, construction and operation of these major scientific user facilities. They can perhaps best be described as the most powerful machines of modern science: X-ray light sources, supercomputers, neutron sources, particle accelerators and similar tools that allow study of the most complex properties of matter and energy. For example, the Linac Coherent Light Source, LCLS, which we will hear about today, can capture images of atoms and molecules in motion with an incredible shutter speed of less than 100 femtoseconds, approximately the time it takes for light to travel the width of a human hair.

The science undertaken at LCLS and similar facilities has a direct and significant impact on innovation, driving discoveries with potential to advance and transform applications from medicine to materials to computing and semiconductors. Today's hearing will focus particularly on these innovation-enabling facilities and their relevance and importance to U.S. industry and the economy.

As with nearly every energy R&D issue this Subcommittee oversees, budget prioritization is key and only of growing importance as we continue to confront record debts and deficits.

The President has been clear that his priority within the DOE is development and commercialization of green energy technologies. For example, his budget calls for over $1.5 billion in new spending by the Office of Energy Efficiency and Renewable Energy, an 84 percent year-over-year increase. By comparison, the Administration is only requesting a 2.4 percent, or $118 million, increase for the Office of Science. I believe the President's priorities are misplaced.

His record of massive spending increases on green energy programs has come under widespread criticism, with government intervention in the clean energy marketplace tending to pick winners and losers while distorting the allocation of capital and resulting in numerous examples of troubling political cronyism.

By contrast, DOE construction and operation of major scientific user facilities is generally well regarded and represents a key component of the scientific enterprise that is central to American innovation and economic competitiveness. It cannot be met by individual companies or entities.

While funding increases for any program will be hard to come by as we work to address the fiscal crisis facing the country, the basic research supported by the Office of Science and DOE user facilities should remain a high priority.

I thank the witnesses for being here and look forward to a productive discussion regarding potential opportunities to improve planning, management and operation of DOE user facilities to better leverage these important scientific resources.

[The prepared statement of Mr. Harris follows:]

PREPARED STATEMENT OF SUBCOMMITTEE CHAIRMAN ANDY HARRIS

Good morning and welcome to today's hearing on "Department of Energy User Facilities: Utilizing the Tools of Science to Drive Innovation Through Fundamental Research."

The purpose of this hearing is to examine the role DOE scientific user facilities plays in enabling the fundamental research that advances basic understanding of the physical world while also driving innovation and economic growth.

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I thank the witnesses for being here and look forward to a productive discussion regarding potential opportunities to improve planning, management, and operations of DOE user facilities to better leverage these important scientific resources.

I now recognize Ranking Member Miller for his opening statement.

Chairman HARRIS. I now recognize Ranking Member Miller for his opening statement.

Mr. MILLER. Thank you, Mr. Chairman.

The Department of Energy user facilities are and should be a core focus of this Committee's jurisdiction. This hearing gives Committee members and the public an opportunity to better understand the indispensable role that the Department of Energy user facilities plays in our Nation's innovation enterprise. The taxpayer has billions of dollars invested in these facilities, and we should examine just what we get for that investment.

In short, we get scientific capabilities that do not exist elsewhere either in the private sector or in academia. Academic and industry researchers are able to break new scientific ground, as well as accelerate the process for translating scientific discovery into marketable products. At user facilities, federal funds support more efficient cars and trucks; more effective drugs; lighter and stronger materials; cheaper and more durable batteries; cleaner power plants; reduced reliance on foreign energy; a clearer picture of our changing climate; and even a better understanding of the origins of the universe and the nature of space and time.

Perhaps most important, we get the talent and technologies that provide for stronger and more competitive high-tech and manufacturing sectors in the United States. We get jobs.

I don't see much distance between Republicans and Democrats in terms of supporting the Office of Science and sustaining these facilities at a level where they can truly contribute to our Nation's competitiveness. I hope my Republican colleagues do not use this hearing to justify an arbitrary and unrealistic line around the appropriate role of government in the energy technology space. We have seen a dangerous and misguided effort to label DOE activities beyond basic research, as if that is clearly defined concept, as picking winners and losers and crowding out private investment for the purpose of cutting research in clean energy technologies and slashing budgets of EERE and ARPA–E, in other words, picking losers.

This perspective assumes that technology always develops in a linear way, that there are no market failures or valleys of death, and that the private sector and the market have the capacity and incentive to support real innovation fully on its own—on their own.

On the contrary, the testimony from this panel of experts shows the complexity and difficulty that technology developers face in moving from idea to marketable product. It is dogma, and not market reality, that dictates that we draw a line around what resources we provide to our Nation's innovators to be competitive.

The Office of Science user facilities are an essential tool for helping many academics and industry researchers get beyond otherwise daunting scientific or technological problems, and I expect that they will always be a shared priority of both Democrats and Republicans.

But we would be well served to remember that these user facilities are by no means the only tools that we have at our disposal. What we have come to regard as the applied programs at DOE, such as EERE and ARPA–E, can play an equally important role in moving concepts and technologies through research barriers that a light source or a computer alone couldn't solve. Far from picking winners, these programs identify the other gaps, the white spaces, where some extra resources and guidance might help the developer get beyond some technological risk and accelerate the development. If you want to see what picking a winner looks like, check out what our competitors in Europe and Asia are doing to support innovation and domestic companies there.

And if you truly want to make government work for people, facilitate our domestic industrial sector's race for global technological leadership, and bring real jobs to the United States, we will drop the stale, dogmatic and often illogical constraints that keep us from taking advantage of our government resources. Our economy was built on science, much of it government-supported science. From achievements in the human genome to sending a man to the Moon, the Federal Government has effectively supported a strong innovation backbone for a century of economic success. Why stop now? Why limit ourselves when the stakes are so high?

Mr. Chairman, I yield back.

[The prepared statement of Mr. Miller follows:]

PREPARED STATEMENT OF SUBCOMMITTEE RANKING MEMBER BRAD MILLER

Thank you, Mr. Chairman. The Department of Energy user facilities are a core focus of this Committee's jurisdiction. This hearing gives Committee Members and the public an opportunity to better understand the indispensible role that the Department of Energy user facilities plays in our Nation's innovation enterprise. The taxpayer has billions of dollars invested in these facilities, and we should examine just what we get for that investment.

In short, we get scientific capabilities that do not exist anywhere else in the private sector or academia. Academic and industry researchers are able to break new scientific ground, as well as accelerate the process for translating scientific discovery into marketable products. At user facilities, federal funds support more efficient cars and trucks; more effective drugs; lighter and stronger metals; cheaper and more durable batteries; cleaner power plants; reduced reliance on foreign energy; a clearer picture of our changing climate; and even a better understanding of the origins of the universe and the nature of space and time.

Perhaps most important, we get the talent and technologies that provide for stronger and more competittive high-tech and manufacturing sectors in the U.S. We get jobs.

I don't see much distance between Republicans and Democrats in terms of supporting the Office of Science and sustaining these facilities at a level where they can truly contribute to our Nation's competitiveness.

I hope my Republican colleagues will not use this hearing to justify drawing an arbitrary and unrealistic line around the appropriate role of government in the energy technology space. We have seen a dangerous and misguided effort to label DOE activities beyond basic research as "picking winners and losers" and "crowding out private investment" for the purpose of cutting research in clean energy technologies and slashing budgets of EERE and ARPA–E.

This perspective assumes that technology always develops in a linear fashion, that there are no market failures or "valleys of death," and that the private sector and the market have the capcity and incentive to support real innovation fully on their own.

On the contrary, the testimony from this panel of experts shows the complexity and difficulty that technology developers face in moving from idea to marketable products. It is dogma, and not market reality, that dictates where we draw a line in providing government resources to help our Nation's innovators to be competitive.

The Office of Science user facilities is an essential tool for helping many academics and industry researchers get beyond otherwise daunting scientific or technological problems, and I expect that they will always be a shared priority of both Democrats and Republicans.

But we would be well served to remember that these user facilities are by no means the only tools we have at our disposal. What have come to be regarded as the "applied" programs at DOE, such as EERE and ARPA–E, can play an equally important role in moving concepts and technologies through research barriers that a light source or supercomputer can't solve.

Far from picking winners, these programs identify the other gaps, or "white spaces," where some extra resources and guidance might help the developer get beyond some technological risk and accelerate the development process. If you want to see what picking a winner looks like, just check out what our counterparts in Europe and Asia are willing to do to support innovation and domestic companies.

If we truly want to make government work for the people, facilitate our domestic industrial sector's race for global technological leadership, and bring real jobs back to the U.S., then we will drop the stale, dogmatic, and often illogical constraints that keep us from fully taking advantage of our government's resources. Our economy was built on science. From achievements in the human genome to sending a man to the Moon, the Federal Government has effectively supported a strong innovation backbone for a century of economic success. Why stop now when the stakes are so high? Why limit ourselves?

Chairman HARRIS. Thank you very much, Mr. Miller.

If there are Members who wish to submit additional opening statements, your statements will be added to the record at this point.

At this time, I would like to introduce our witnesses. The first witness is Dr. Tony Lanzirotti, Chairman of the National User Facility Organization. He is a Senior Research Associate at the University of Chicago's Center for Advanced Radiation Sources. He has been a research scientist with the University of Chicago since 1999 and helped develop and operate X-ray beam lines for the user community at multiple DOE facilities.

Our next witness is Dr. Persis Drell, the Director of the SLAC National Accelerator Laboratory. Dr. Drell is an expert in particle astrophysics research. Prior to being named the director, Dr. Drell served as a Professor and Director of Research at the laboratory. Previously, Dr. Drell held positions at Cornell University's Laboratory of Nuclear Studies and Physics Department.

I now yield to Mrs. Biggert to introduce our third witness, Dr. Wasserman.

Mrs. BIGGERT. Thank you, Mr. Chairman.

Our third witness today is Dr. Stephen Wasserman, Senior Research Fellow in the Translational Science and Technologies Department at Eli Whitney—I mean Ely Lilly and Company. He is the Director of the Lilly Research Laboratory's Collaborative Access Team at the Advanced Photon Source located at Argonne National Laboratory in my district. Prior to joining Ely Lilly, Dr. Wasserman was a Senior Director of SGX Pharmaceuticals and he has also served as a Senior Director for DC. Genetics. Thank you, and welcome, Dr. Wasserman.

Chairman HARRIS. Thank you, Mrs. Biggert.

Our fourth witness today will be Ms. Suzy Tichenor, Director of Industrial Partnerships Program for Computing and Computational Sciences at Oak Ridge National Laboratory. Ms. Tichenor has more than 20 years of experience in creating partnerships and programs at all levels of the government, private sector and not-for-profit organizations. Prior to joining Oak Ridge, she was Vice President of the Council on Competitiveness and directed the council's High-Performance Computing Initiative where she served as the Principal Investigator for high-performance computing-related grants.

I now yield to the gentleman from New York, Mr. Tonko, to introduce our fifth witness.

Mr. TONKO. Thank you, Mr. Chair.

I am very pleased to introduce Dr. Ernest Hall, the Chief Scientist for Materials Characterization in the chemicals and chemical engineering domain at General Electric's Global Research Center in Niskayuna, New York. Dr. Hall, for whom I have great respect, has been with GE since 1979 and was promoted to Chief Scientist in 2008. He serves on a number of scientific advisory boards to the Department of Energy and is an author of over 175 technical papers. He recently was elected President of the Microscopy Society of America. Dr. Hall has a great deal of experience working at our

DOE facilities. We are very fortunate to have him with us to testify this morning. Welcome and thank you for being here and to offer us your expert testimony on the importance of these DOE user facilities. So welcome, Dr. Hall.

Chairman HARRIS. Thank you very much, Mr. Tonko.

As our witnesses should know, spoken testimony is limited to five minutes each, after which the Members of the Committee will have five minutes each to ask questions.

I now recognize our first witness, Dr. Lanzirotti, to present his testimony.

**STATEMENT OF DR. ANTONIO LANZIROTTI, CHAIRMAN, NATIONAL USER FACILITY ORGANIZATION**

Mr. LANZIROTTI. Chairman Harris, Ranking Member Miller and distinguished Members of the Committee, I thank you for this opportunity to testify. My name is Antonio Lanzirotti. I am a Senior Research Associate with the University of Chicago's Center for Advanced Radiation Sources, and it has also been an honor for me to serve this past year as the elected Chair of the National User Facility Organization. It is in that capacity that I am here testifying before you today.

Our organization was established to facilitate communication among researchers that utilize our Nation's scientific user facilities and facility administrators and stakeholders. We are a volunteer, nonprofit group, and it is our hope that through these efforts we can educate our scientific peers and the American public of the availability, benefits and significance of research conducted at these facilities and provide a conduit for the user community to disseminate recommendations of what we perceive are their operational needs.

Today, our organization represents the almost 45,000 scientists who conduct research at the 46 largest federally funded facilities in the United States. Of these, 36 facilities are managed by DOE, representing almost 37,000 scientists each year. These users reside in all 50 states, in the District of Columbia, in our U.S. territories, and many are international scientists that travel here to conduct their research using these tools. These scientists come from close to 600 universities in the United States. Roughly 7,000 of them are students and postdoctoral researchers who depend on access to facilities to complete their education and train to be future scientists and engineers.

Our community includes scientists from 400 unique companies, including 45 Fortune 500 companies, who often use multiple facilities in their research. These facilities allow us to study our world and our universe with efficiencies orders of magnitude higher than what is possible with smaller-scale instruments at our home institutions. It would simply be too costly and complex today for facilities such as these to be constructed and operated by universities or industry on their own.

These thousands of researchers also leverage their access to DOE user facilities to maximize their productivity, research funded not only by DOE but NSF, NIH, NASA, DOD and private industry, to name only a few.

The tremendously broad scope of science these facilities have allowed us to address is often underappreciated, impacting virtually every scientific field of study both in fundamental and applied sciences. For example, synchrotron X-ray facilities have revolutionized the way that diffraction data is being collected. Macromolecular protein crystallography using these sources has allowed researchers to study biological molecules such as proteins, viruses and nucleic acids to a resolution higher than five angstroms. This high resolution has allowed life scientists to elucidate the detailed mechanisms by which these molecules carry out their functions in living cells, and the societal benefits of this research are tangible. As an example, scientists from Plexxikon, a Berkeley-based drug discovery company, used this technique to cocrystallize a mutated protein involved in the development of malignant melanoma along with molecular lead compounds for candidate drugs. Identifying the most promising lead allowed them to identify potential drug candidates that could stop the disease's spread. This led to the development of a new drug that has been demonstrated to successfully treat patients with late-stage or inoperable forms of the disease, receiving FDA approval in August of 2011.

Material scientists are using these facilities to improve integrated circuit designs for chip verification. Engine designers are using facilities to design catalysts for improving engine efficiency and reducing emissions. Companies such as GE are using DOE computing facilities to model complex flow in developing quieter, more fuel-efficient wind turbines and jet engines, and scientists have used these facilities for fundamental research, for example, investigating the sources of dark matter and dark energy in our universe.

In the last 10 years, we have entirely new classes of facilities that are transforming our research such as the Nano Science Centers and the LCLS. New facilities under construction, such as NSLS–II at Brookhaven and vital upgrades such as the planned LCLS–II upgrade in SLAC and the APS upgrade at Argonne, are necessary for improving efficiency and capacity and for delivering new capabilities to keep U.S. facilities world leading.

Yet in building capacity and improving efficiency, facilities have experienced funding shortfalls that often prevent them from operating at optimum levels, keeping instruments upgraded and providing adequate number of staff to support user research to maintain our Nation's leadership position. Providing operating budgets that allow these facilities to achieve their designed-for capacity and to hire and retain top scientific and technical talent should be a high priority.

National user facilities provide a broad research infrastructure that enables researchers to access specialized instrumentation and capabilities as well as technical expertise from experienced scientists and engineers. Access to these facilities enables scientists to pursue frontier research leads to fundamental scientific discoveries and enables downstream technological developments for real-world industrial applications. The United States is unique in having such a large array of user facilities. Many countries have some subset, but no other country provides access to such a diverse group of facilities covering so many areas, giving the United States academic and industrial researchers unequaled opportunities.

Thank you.

[The prepared statement of Mr. Lanzirotti follows:]

The **FUTURE** of America is the
**RESEARCH** of **TODAY**

NATIONAL
USER
FACILITY
ORGANIZATION

**U.S. House of Representatives Committee on Science, Space, and Technology**

**Subcommittee on Energy and Environment**

**Hearing on Department of Energy User Facilities: Utilizing the Tools of Science to Drive Innovation through Fundamental Research**

**June 21, 2012**

**Written Testimony Regarding the National User Facility Organization and the role of DOE's user facilities in the U.S. scientific enterprise.**

**Dr. Antonio Lanzirotti**
**Chairman, National User Facility Organization**
**Senior Research Associate, The University of Chicago**

**Written Testimony**

## Introduction

Chairman Harris, Ranking Member Miller and distinguished members of the Committee, I thank you for this opportunity to testify. My name is Antonio Lanzirotti, I am a Senior Research Associate at the University of Chicago's Center for Advanced Radiation Sources. It has also been an honor for me to serve this past year as the elected Chair of the National User Facility Organization and it is in that capacity that I am here today.

Founded in 1990, our organization was established in the hopes of facilitating communication among researchers that utilize our nation's scientific user facilities and facility administrators and stakeholders. We are a volunteer, non-profit entity and it is our hope that through these efforts we can educate our scientific peers and the American public of the availability, benefits and significance of research conducted at these facilities and provide a conduit for the scientific user community to disseminate recommendations of what we perceive are their operational needs.

## Diverse Scientific User Community

Today the National User Facility Organization (NUFO) represents the almost 45,000 scientists who conduct research at the 46 largest federally funded user facilities in the United States. Of these, 36 facilities are managed by the Department of Energy, hosting almost 37,000 scientists each year.[1] These users reside in all 50 States, the District of Columbia, in our U.S. territories, and many are international scientists that travel here specifically to conduct their research using these tools.[2] They come from close to 600 universities in the U.S. and from more than 400 universities abroad. Roughly 7,000 of these users are students and postdoctoral researchers who depend on access to facilities to complete their education and train to be future scientists and engineers.[3]

Our community includes scientists from 400 unique companies including 45 Fortune 500 companies and 22 Fortune 100 companies. Companies such as General Electric, General Motors, Eli Lilly, IBM, Procter & Gamble, Boeing, Pfizer, Intel, Honeywell

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[1] Complete listing of facilities at which users are NUFO members is available at http://www.nufo.org/facilities.aspx. We have also assembled posters highlighting each facility which is available at http://www.nufo.org/posters.aspx .

[2] Please see appended "Institutions that Conduct Research at U.S. National User Facilities". List was compiled by the National User Facility Organization (NUFO) through queries of Facility Administrators.

[3] These metrics have been compiled by NUFO through queries of Facility Administrators. There are certainly differences in how each individual facility gathers these types of metrics and what and how often they require users to provide them. Additionally many scientists may utilize multiple facilities, so these values reported to us represent individual researchers at each individual facility.

International, DuPont, Abbott Laboratories, Northrop Grumman, and Hewlett-Packard have used multiple facilities in their industrial research.[4]

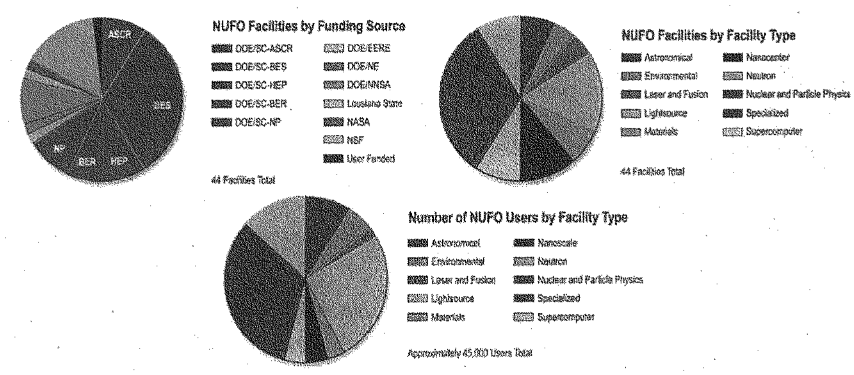


Figure 1: Demographics of the National User Facility Organization (NUFO) user community as of February 2012. Upper left denotes the primary funding agency for facility operations. Upper right denotes the type of facility and Bottom shows what fraction of our membership utilizes each facility type.

These facilities allow us to study our world and our universe in unprecedented detail with efficiencies orders of magnitude higher than what could be accomplished with smaller-scale instruments at our home institutions. It would simply be too costly and complex today for facilities such as these to be constructed and operated by universities or industry on their own.

These thousands of researchers also leverage their access to Office of Science User Facilities to maximize their productivity, research funded not only by the Office of Science but also NSF, NIH, NASA, DOD, DARPA, NNSA, EPA, NIST, DOA and private industry to name only a few.

**Broad Scientific and Industrial Impact**

The tremendously broad scope of science these facilities have allowed us to address is often underappreciated, impacting virtually every scientific field of study both in fundamental and applied sciences.

In the life sciences, for example, the high-brightness synchrotron X-ray facilities operated by the Office of Science have revolutionized the way that diffraction data from macromolecular crystals are being collected, as I am sure my colleague Dr. Wasserman will attest to. Macromolecular or Protein Crystallography using synchrotron X-ray

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[4] Data was compiled by NUFO again querying Facility Administrators. Compiled list is attached at end of this testimony and also available online at http://www.nufo.org/files/Fortune_500.pdf .

sources have allowed researchers to study biological molecules such as proteins, viruses and nucleic acids (RNA and DNA) to a resolution higher than ~5 Å. This high resolution has allowed life scientists to elucidate the detailed mechanism by which these macromolecules carry out their functions in living cells and organisms and the benefit of this research to the American people is tangible. As an example, scientists from Plexxikon, a Berkeley-based drug-discovery company[5], used this technique to co-crystallize a BRAF mutated protein involved in the development of malignant melanoma along with small molecule lead candidates. Identifying the most promising lead then allowed them to identify potential drug candidates that could stop the disease's spread. This led to the development of a new drug, Zelboraf (Vemurafenib), that has been demonstrated to successfully treat patients with late-stage or inoperable forms of the disease, receiving FDA approval in August, 2011.[6]

Our material science community in particular is actively utilizing these tools to help develop methods that can ultimately be ported from one-of-a-kind technologies at a national user facility to broader adoption in private industry. For example, current lithography technology in production by semiconductor manufacturers can allow them to print circuits as small as 32 nanometers in width. Industry researchers today are using DOE scientific user facilities to develop new Extreme ultraviolet (EUV) lithography technologies[7] that, when commercialized, will allow manufacturers to print circuit patterns onto computer chips with feature sizes smaller than 12 nanometers, providing factors of 10 improvements in speed and memory capacity compared to today's most powerful chips.[8]

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[5] **A. Pollack**, Studies Find Two New Drugs Effective Against Advanced Melanoma, The New York Times. (2011).; **Tsai J**, Lee JT, Wang W, Zhang J, Cho H, Mamo S, Bremer R, Gillette S, Kong J, Haass NK, Sproesser K, Li L, Smalley KS, Fong D, Zhu YL, Marimuthu A, Nguyen H, Lam B, Liu J, Cheung I, Rice J, Suzuki Y, Luu C, Settachatgul C, Shellooe R, Cantwell J, Kim SH, Schlessinger J, Zhang KY, West BL, Powell B, Habets G, Zhang C, Ibrahim PN, Hirth P, Artis DR, Herlyn M, Bollag G (2008) Discovery of a selective inhibitor of oncogenic B-Raf kinase with potent antimelanoma activity. Proc Natl Acad Sci USA 105:3041–3046

[6].FDA approval August 17, 2011. Work conducted at the Advanced Photon Source at Argonne National Laboratory, the Stanford Synchrotron Radiation Lightsource at SLAC National Accelerator Laboratory and the Advanced Light Source at Lawrence Berkeley National Laboratory.

[7] **P. Naulleau**, C. Anderson, L.-M. Baclea-an, D. Chan, P. Denham, S. George, K. Goldberg, B. Hoef, G. Jones, C. Koh, B. La Fontaine, B. McClinton, R. Miyakawa, W. Montgomery, S. Rekawa, and T. Wallow, "The SEMATECH Berkeley MET pushing EUV development beyond 22-nm half pitch," Proc. SPIE 7636, 76361J (2010); **P. Naulleau**, C. Anderson, L. Baclea-an, P. Denham, S. George, K. Goldberg, G. Jones, B. McClinton, R. Miyakawa, I. Mochi, W. Montgomery, S. Rekawa, and T. Wallow, "Using synchrotron light to accelerate EUV resist and mask materials learning," Proc. SPIE 7985, 798509 (2011).

[8] Work conducted at the Advanced Light Source at Lawrence Berkeley National Laboratory.

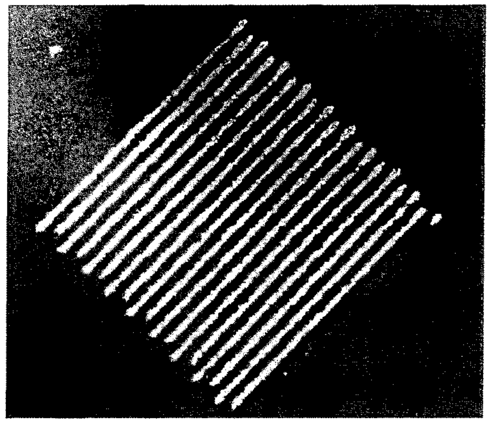

Figure 2: Using an experimental photosensitive spin-on inorganic ultrathin imaging film (photoresist) provided by Inpria Corporation, 16-nm lines and spaces were printed on the SEMATECH Berkeley Microfield Exposure Tool (MET) at the Advanced Light Source using a pseudo phase shift mask mode.

These smaller feature sizes also raise interesting issues with respect to technologies that can be used in chip verification, again an area where DOE scientific user facilities are playing an important and unique role. Consider that the vast majority of integrated circuits (ICs) are manufactured in commercial foreign foundries. Critical infrastructure and defense systems cannot afford the risk of untrusted electronic components embedded in them. For the U.S. DoD and Intelligence Communities to continue to have access to the highest performance possible in ICs, it is essential to continue use of overseas ICs, and not just those manufactured in U.S. trusted foundries[9]. DARPA's Integrated Circuits Integrity and Reliability of Integrated Circuits (IRIS) program and its recently concluded Trusted Integrated Circuits (TRUST) program are examples of government efforts to develop technology to determine unambiguously if an IC is free of malicious circuits inserted during the design or manufacturing process. A key approach for circuit evaluation is non-destructive imaging of its physical structure. However, as integrated-circuit process technologies become more complex (e.g., finer pitch dimensions, many layers of metallization, flip-chip packaging, multi-die stacks, etc.), nondestructive analysis becomes corresponding more challenging. Metallic interconnect and via structures range from micron to sub-micron dimensions and the technology node of critical dimensions for transistor components is projected to be 22 nanometers by 2015. The four DOE synchrotron facilities support modalities such as X-ray absorption and fluorescence Computed Micro- and Nano-Tomography that are proving critical for the development of new imaging methods for non-destructive chip estimation.

[9] Defense Science Board Task Force on High Performance Microchip Supply, February, 2005.Available at http://www.acq.osd.mil/dsb/reports/ADA435563.pdf .

Such techniques are being developed today at these facilities (funded through DARPA) by companies such Xradia Inc. in collaboration with Southern California Information Sciences Institute[10]. These techniques may someday provide a component of a new reliability paradigm to protect U.S. systems against malware attacks.

Unique instruments available for catalysis research have also helped companies such as Cummins Inc., which designs, manufactures, distributes and services engines and related technologies, develop catalyst solutions for removing $NO_x$ emissions from lean-burn engines. The emissions after-treatment system the company and user facilities helped develop based on this research increased the 2007 Heavy-Duty Dodge Ram's fuel efficiency by 25%.[11]

Companies such as General Electric, represented by Dr. Ernie Hall here today, are utilizing Office of Science advanced supercomputing facilities to study the complex flow of air in wind turbine airfoils and jet exhaust nozzles and using simulations to understand and predict flow. Such information is critical in developing quieter, more fuel-efficient wind turbines and jet engines and improving engine life cycles in an extremely competitive global market.[12] For our U.S. industrial user community access to and partnerships with such user facilities are vital in helping U.S. industries maintain manufacturing excellence and technological leadership in a globally competitive environment. [13]

For many of these industrial researchers, prompt access to such facilities is critical in addressing problems of National importance. As an example, Intevac Photonics is a leading developer of night vision sensors and was contracted by the Army Night Vision Laboratory to develop a next-generation device called the Short Wavelength Infrared imager, or SWIR, for long-range identification of targets. It would use less energetic wavelengths of infrared light for illumination, which is safer for human eyes and provides greater sensitivity in unfavorable conditions. Such imagers are also quite small, so they can be used, for example, in unmanned aerial vehicles; and they work at distances of

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[10] Work conducted at Stanford Synchrotron Radiation Lightsource at SLAC National Accelerator Laboratory; **M. Bajura**, G. Boverman, J. Tan, G. Wagenbreth, C. M. Rogers, M. Feser, J. Rudati, A. Tkachuk, S. Aylward, P. Reynolds "Imaging Integrated Circuits with X-ray Microscopy" Proceedings of the 36th GOMACTech Conference, March 2011, Orlando, FL.

[11] http://science.energy.gov/stories-of-discovery-and-innovation/127001/ ; Work conducted at the Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory.

[12] http://www.genewscenter.com/Press-Releases/GE-Global-Research-To-Partner-With-Livermore-National-Lab-and-Universities-On-Supercomputing-Project-3788.aspx ; http://www.alcf.anl.gov/articles/argonne-leadership-computing-facility-inspiring-innovation-industry-through-science ; Testimony of Raymond L. Orbach, Director, Office of Science, U.S. Department of Energy, before the U.S. House of Representatives Committee on Science, July 16, 2003.; Work done at the Argonne Leadership Computing Facility, Argonne National Laboratory and the Oak Ridge Leadership Computing facility, Oak Ridge National Laboratory.

[13] As an example, please see attached letter to Dr. Chu from Cosma International. Work done at the High Temperature Materials Laboratory, Oak Ridge National Laboratory

up to 20 kilometers. Based on a different semiconductor than previous devices – indium phosphide (InP), rather than gallium arsenide (GaAs) – when the completed device went through performance testing and a serious problem emerged. It quickly lost efficiency when kept at high temperatures for an extended period, as if sitting on a shelf during a desert deployment. With prompt access to photoemission spectroscopy instruments at one of our DOE user facilities, they discovered that the standard cleaning process used to prepare the surfaces of GaAs semiconductors was inadequate for the InP material. The researchers developed new surface cleaning procedures, and when Intevac incorporated them into the manufacturing process, the shelf-life problem went away. What's more, the sensor's sensitivity increased significantly.[14]

Our scientists have also used these facilities to make fundamental discoveries of the nature of our universe, discovering all elements of the sub-structure of visible matter in the universe from anti-protons to heavy quarks, from heavy leptons to neutrinos. Today these instruments are on the verge of helping us discover the sources of dark matter, dark energy and the generators of mass in the universe. For example, heavy ion collision experiments at these facilities have recently produced a liquid of strongly interacting quarks and gluons with a temperature 250,000 times hotter than the center of the Sun. Such discoveries have given us a surprising idea of what the universe was like just after the Big Bang some 14 billion years ago – a nearly perfect liquid with practically no viscosity, or resistance to flow.[15]

**Community and Facility Needs**

Whether we wish to study the history of our universe, isolate the subatomic building blocks of matter, visualize and manipulate matter at the atomic scale for industrial applications, develop new technologies to support U.S. security or understand the causes of disease and develop next generation drugs to combat them, there are DOE facilities that we increasingly rely on to help us conduct this research.

As users, we continuously ask for new state-of-the-art capabilities. New facilities invariably lead to higher efficiency in the long term, but they also lead us to tackle harder, more complex and time intensive research and development projects. In the last ten years we have entirely new classes of facilities available to us, such as the nanoscience centers and the Linac Coherent Light Source (LCLS), that are transforming our research. New facilities such as NSLS-II at Brookhaven, a synchrotron facility which will provide world leading X-ray brightness, and vital upgrades such as the planned LCLS-II upgrade at SLAC and the APS upgrade at Argonne are necessary steps in

[14] Research conducted at the Stanford Synchrotron Radiation Lightsource at SLAC National Accelerator Laboratory and the Advanced Light Source at Lawrence Berkeley National Laboratory.
[15] http://www.nytimes.com/2010/02/16/science/16quark.html?_r=1 , "In Brookhaven Collider, Scientists Briefly Break a Law of Nature", NY Times, February 15, 2010. Work conducted at Relativistic Heavy Ion Collider, Brookhaven National Laboratory.

ensuring we can improve efficiency and capacity and also deliver new capabilities to keep U.S. facilities world-leading. DOE's Office of Science in particular has become impressively adept at delivering new capabilities and facilities on time, on budget, and with performance that typically exceeds the original design specifications. Yet in building capacity and improving efficiency, historically it seems facilities have experienced funding shortfalls that often prevent them from operating at optimum levels, providing adequate number of staff to support user research and deploying upgrades as quickly as possible to maintain our Nation's leadership position. Providing operating budgets that allow these facilities to operate at their designed-for capacity and to hire and retain top scientific and technical talent should be a high priority.

Technological upgrades such as improved detectors, robotics, improved instrumentation, enabling remote computation and access to facilities all require sustained funding yet prove cost effective in the long term to improve efficiency and capacity. As new facilities come on-line and older facilities are retired, these types of efforts will be critical in meeting demand from the scientific community and keeping them competitive with the suite of new facilities being built abroad. Partnerships with academic institutions, industry and other federal research entities that enable new capabilities should be fostered. These types of partnership can provide tremendous leverage in funding that benefits all facility users, but aren't attractive for partner institutions if there is not a clear return on investment.

And as these facilities increasingly attract new user communities and reach out to industry to make them aware of how these facilities can be further utilized, more standardized requirements for access across the DOE complex are still needed that will make it easier for academia and industry to use these world-class research tools. However, it is important to recognize that a "one size fits all" approach to user access may not be optimal in some cases. For individual university PI's and smaller businesses in particular, which may not have large numbers of dedicated research staff, assistance and engagement from the facility can be a significant factor in ensuring their research experience is successful.[16]

**Conclusions**

In conclusion, national user facilities provide a broad research infrastructure that enables researchers to access specialized machines, instrumentation and capabilities as well as technical expertise from experienced facility scientists, engineers, and physicists that would otherwise be unavailable from their home institutions. Access to these facilities enables scientists to explore the frontier research questions of our time,

[16] "Science for Energy Technology: Strengthening the Link between Basic Research and Industry A Report from the Basic Energy Sciences Advisory Committee", John C. Hemminger (chair), August, 2010. http://science.energy.gov/~/media/bes/pdf/reports/files/setf_rpt.pdf .

leads to fundamental scientific discoveries and enables downstream technological developments for real-world industrial applications. The U.S. is unique in having such a large array of user facilities. Many countries have some subset, but no other country provides access to scientists to such a diverse group of facilities covering so many areas, giving U.S. academic and industrial scientists unequaled opportunities for research.

National User Facility Organization

# Institutions that Conduct Research at U.S. National User Facilities

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**MINNESOTA**

3M
aixACCT Systems, Inc.
Carleton College
Concordia College
Diagnostic Biosensors, LLC
Gustavus Adolphus College
Hysitron Inc.
IBM
Krell Institute
Mayo Clinic
Medtronic, Inc.
Orono High School
Saint Cloud State University
Seagate Technology
The Hormel Institute
University of Minnesota, Minneapolis
University of Minnesota, Twin Cities

**MISSISSIPPI**

Alcorn State University
Army Engineer Center
Engineering Research Development Center, Waterways Experiment Station
Jackson State University
Mississippi State University
Naval Research Laboratory
The University of Southern Mississippi
U.S. Army Corps of Engineers
U.S. Engineer Research and Development Center

**MISSOURI**

Brewer Science, Inc.
DOC/NOAA/NWS/NCEP Aviation Weather Center
Donald Danforth Plant Science Center
Honeywell Federal Manufacturing & Technologies, LLC
Incident Response Training Department
Kansas City Plant
Midwest Biomed Research Foundation
Missouri University of Science and Technology
Monsanto Company
Parkway South High School
Saint Louis University
Southwest Missouri State University
The Washington University
Truman High School
Truman State University
University of Missouri, Columbia
University of Missouri, Kansas City
University of Missouri, St. Louis
Veterans Administration Medical Center
Washington University

**MONTANA**

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Carroll College
Montana State University
The University of Montana

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Air Force Weather Agency
Creighton University
University of Nebraska, Omaha
University of Nebraska, Lincoln

**NEVADA**
Desert Research Institute
National Weather Service
Nevada Cancer Institute
Sable Systems International
The EXAFS Company
TUI
University of Nevada, Las Vegas
University of Nevada, Reno

**NEW HAMPSHIRE**
AmberWave Systems Corporation
Dartmouth College
Neslab Instruments, Inc.
Photonis
Plymouth State University
TotalView Technologies
University of New Hampshire
USACE - Cold Regions Research and Engineering Laboratory (CCREL)

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AZ Electronic Materials US Corp.
BASF Catalysts LLC
Bell Laboratories
BioDelivery Sciences International
Bristol-Myers Squibb
Continuum Dynamics Inc.
ExxonMobil
Geophysical Fluids Dynamics Lab
Hamamatsu Corporation USA
High Performance Technology Inc.
Hoffmann-LaRoche, Inc.
Institute for Advanced Study
Merck & Co., Inc.
Montclair State University
Nanonex Corporation
Nanopowder Enterprises, Inc.
National Oceanic and Atmospheric Administration (NOAA)
NEC Research Institute
New Jersey Institute of Technology
Princeton University
Rudolph Technologies, Inc. - Metrology Business Unit
Rutgers, the State University of New Jersey
Sanofi-Aventis
Schering-Plough Research Institute
Seton Hall University
Stevens Institute of Technology
U.S. Army
Unilever Research, U.S.
University of Medicine and Dentistry of New Jersey

X-Ray Instrumentation Associates

**NEW MEXICO**
Anemometry Specialists
Center for Orthopedic Sports
Eastern New Mexico University
JD Instruments LLC
Los Alamos National Laboratory
Motorola
NanoMR Inc.
National Security Technologies, LLC @ Los Alamos Operations (LAO)
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New Mexico State University
Sandia National Laboratories
Senior Scientific
Senspex Inc.
Star Cryoelectronics Inc.
Voss Scientific

**NEW YORK**
Adapco Group
Advanced Design Consulting, Inc.
Akzo Nobel Chemicals, Inc.
Alfred University
American Museum of Natural History
AWS Truewind, LLC
Bard College
Binghamton University
Brookhaven National Laboratory
Brooklyn College of The City University of New York
Cara Therapeutics, Inc.
CD-Adapco
Chromalloy
City College of New York
City University of New York (CUNY)
Clarkson University
Cold Spring Harbor Fish Hatchery
Cold Spring Harbor Laboratory
Columbia University
Cornell University
Corning, Inc.
Courant Inst
Delphi Automotive Systems
Dow Chemical Company
Eastman Kodak Company
Fordham University
GE Global Research Center
Gene Network Sciences
General Electric Company
Global Foundries
Hamilton College
Hauptman-Woodward Medical Research Institute
Hofstra University
Hunter College, CUNY
IBM
Iona College
John Jay College
Kitware, Inc.
Knolls Atomic Power Laboratory
Lucent Technologies

Marymount Manhattan College
Memorial Sloan-Kettering Cancer Center
MESO Inc.
MiTeGen
Moldflow Corporation
Mount Sinai School of Medicine
NASA Goddard Institute for Space Studies
Nassau Community College
New York Medical College
New York State College of Ceramics
New York State Department of Health
New York Structural Biology Center
New York University
NYC Dept. of Environmental Protection
Philips Research
Photonics Industries International, Inc.
Polytechnic Institute of New York University
Queens College of the The City University of New York
Queensborough Community College of CUNY
R. Browning Consultants
Rensselaer Polytechnic Institute
Research Foundation of SUNY
Reservoir Labs
Rochester Institute of Technology
Roswell Park Cancer Institute
Sarah Lawrence College
SGK Nanostructures, Inc.
Siemens Corp
St. John's University
St. Joseph's College
State University of New York, Albany
State University of New York, Binghamton
State University of New York, Buffalo
State University of New York, Farmingdale
State University of New York, Geneseo
State University of New York, Old Westbury
State University of New York, Onconta
State University of New York, Oswego
State University of New York, Plattsburgh
State University of New York, Stony Brook
State University of New York, Syracuse
Suffolk Community College
SUNY Upstate Medical University
SVC
Syracuse University
T&V Services, Inc.
Tech-X Corp Williamsville
The Graduate Center, CUNY
The River Project
University of Albany
University of Rochester
Vassar College
Wadsworth Center, New York State Department of Health
Weill Cornell Medical College
Yeshiva University

**NORTH CAROLINA**
American Barmag Corporation
Army Research Office
Atriax Components, Inc.
Duke University
International Technology Center

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Magnequench Technology Center
National Institute of Environmental Health Sciences (NIEHS)
NOAA, NESDIS, NCDC
North Carolina A&T State University
North Carolina State University
Renaissance Computing Institute
RTI International
Syngenta Biotechnology Inc.
University of North Carolina, Asheville
University of North Carolina, Chapel Hill
University of North Carolina, Charlotte
Wake Forest University

**NORTH DAKOTA**
North Dakota State University
University of North Dakota

**OHIO**
Air Force Research Laboratory
Applied Sciences, Inc.
Battelle Columbus
Berea City School District
Bowling Green State University
Byrd Polar Research Center
Case Western Reserve University
City of Cleveland
Cleveland Clinic Foundation
Cleveland State University
Cuyahoga Valley Space Society
Denison University
Diamond Innovations, Inc.
Edison Welding Institute, Inc.
Equistar Chemicals
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Innovative Scientific Solutions Inc.
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Lake Shore Cryotronics, Inc.
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Norcold Inc.
Oberlin College
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Ohio University
Ohio Wesleyan University
Pegasus Technical Services, Inc.
Procter & Gamble
Shepherd Chemical Company
Taitech, Inc.
The Timken Company
Third Millennium Metals, LLC
U.S. Air Force
UES, Inc.
Universal Technology Corporation
University of Akron
University of Cincinnati
University of Dayton Research Institute
University of Toledo
Wright State University
Youngstown State University

**OKLAHOMA**
3D Icon
Frontier Electronic Systems Corp.
Halliburton Energy Services
Johnson & Associates
National Severe Storms Laboratory
Northern Oklahoma College (NOC)
Oklahoma State University
Oklahoma Wind Power Initiative
Rogers State University
The Samuel Roberts Noble Foundation, Inc.
The University of Tulsa
U.S. Army Corps of Engineers - Tulsa District
University of Oklahoma
University of Oklahoma Health Sciences Center
University of Oklahoma, Cooperative Institute for Mesoscale Meteorological Studies (CIMMS)
U.S. Department of Agriculture, Agricultural Research Service
Warning Decision Training Branch

**OREGON**
Concordia University
FEI Company
Intel Corporation
Lane Community College
National Energy Technology Laboratory
Oregon Health Sciences University
Oregon State University
Portland State University
Reed College
SpectraWatt
TOK America
University of Oregon

**PENNSYLVANIA**
3-Dimensional Pharmaceuticals
Air Products and Chemicals, Inc.
Arcadis G&M, Inc.
Arkema, Inc.
Bechtel Marine Propulsion Corporation
Bettis Atomic Power Laboratory
Bloomsburg University
Bryn Mawr College
Bucknell University
Carnegie Mellon University
Children's Hospital of Philadelphia
Clarion University of Pennsylvania
Collegiate Academy
Dickinson College
Drexel University
Duquesne University
Eastern University
First Solar, Inc.
Fox Chase Cancer Center
Franklin & Marshall College
Gettysburg College
GlaxoSmithKline
Haverford College
II-VI Incorporated
Indiana University of Pennsylvania
Johnson & Johnson
Johnson Matthey, Inc.
Kutztown University of Pennsylvania
Lafayette College
Lehigh University
Lockheed Martin Space Systems
Merck Sharp & Dohme Corporation
Morphotek, Inc.
Muhlenberg College
National Energy Technology Laboratory
Naval Surface Warfare Center
Olympus America Inc.
Rhodia, Inc.
SCHOTT North America, Inc.
SmithKline Beecham Pharmaceuticals
Swarthmore College
Temple University
The Fox Chase Cancer Center
The Pennsylvania State University
The Wistar Institute
Thomas Jefferson University
University of Pennsylvania
University of Pittsburgh
University of Scranton
Ursinus College
Villanova University
Vitae Pharmaceuticals
Westinghouse
Wobblimind Media

**RHODE ISLAND**
Brown University
University of Rhode Island

**SOUTH CAROLINA**
Clemson University
College of Charleston
Francis Marion University
Furman University
Medical University of South Carolina
Savannah River National Laboratory
University of South Carolina
Westinghouse Electric Company LLC
Westinghouse Savannah River Company
Wofford College

**SOUTH DAKOTA**
Black Hills Institute
South Dakota School of Mines and Technology
South Dakota State University
University of South Dakota

**TENNESSEE**
Austin Peay State University
East Tennessee State University
Eastman Chemical Company
EDP Biotech Corporation
Fisk University
Information International Associates, Inc.
Middle Tennessee State University
Myricom, Inc.
National Institute for Computational Sciences
Oak Ridge Associated Universities

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Oak Ridge National Laboratory
Rhodes College
St. Jude Children's Research Hospital
Tennessee State University
Tennessee Technological University
The Orion Foundation
University of Memphis
University of Tennessee, Knoxville
Vanderbilt University
Y-12 National Security Complex

**TEXAS**
Abilene Christian University
Amarillo College
Austin College
Baker Hughes Incorporated
Baylor University
ChevronTexaco Inc.
El Paso Community College
ExxonMobil
Four State Research
Freescale Semiconductor, Inc.
Frito-Lay North America
GSI Environmental, Inc.
'nnovar Scientific, Inc.
INTECSEA
Lamar University, Beaumont
Marlow Industries, Inc.
MechanOptics Engineering
Molecular Structure Corp.
Nalco
NASA
National Space Biomedical Research Institute
Plano Senior High School
Prairie View A&M University
Raytheon IIS, Garland Division
Rice University
Rigaku Americas Corporation
SAIC - Houston
Sam Houston State University
SEMATECH
Southwest Foundation for Biomedical Research
Southwest Research Institute
Texas A&M University
Texas Christian University
Texas Instruments Inc.
Texas Southern University
Texas State University
The Dow Chemical Company
The Methodist Hospital Research Institute
Trinity University
Universities Space Research Association
University of Houston
University of North Texas
University of Texas M. D. Anderson Cancer Center
University of Texas, Arlington
'niversity of Texas, Austin
.Jniversity of Texas, Brownsville
University of Texas, Dallas
University of Texas, El Paso
University of Texas, Pan American
University of Texas, San Antonio
University of Texas, Houston
Wyle Laboratories, Inc.

**UTAH**
EDAX-TSL
ATK Launch Systems
Boeing Company
Brigham Young University
MOXTEK, Inc.
NOAA NWS CBRFC
University of Utah
US Synthethics Corporation
Utah State University
VIRGINIA
Analytical Services & Materials (AS&M), Inc.
BAE Systems
College of William and Mary
Defense Threat Reduction Agency
Eastern Virginia Medical School
Ecopulse, Inc.
Federal Highway Administration
George Mason University
Hampton University
Howard Hughes Medical Institute
ITT
James Madison University
Metalsa Roanoke Inc.
MITRE Corporation
NASA Langley Research Center
National Geospatial-intelligence Agency
National Institute of Aerospace
National Radio Astronomy Observatory (NRAO)
National Science Foundation
Naval Surface Warfare Center Dahlgren Division
Norfolk State University
Old Dominion University
SAI McLean
SAIC
Science Systems and Applications, Inc. (SSAI)
Synthonics, Inc.
Thomas Jefferson National Accelerator Facility
University of Virginia
Virginia Commonwealth University
Virginia Polytechnic Institute & State University
Virginia State University
Washington and Lee University
Washington University

**VERMONT**
Middlebury College
University of Vermont

**WASHINGTON**
Bernard Walter Consulting
Boeing Commercial Airplanes
Children's Hospital and Regional Medical Center
Cray, Inc.
DyNuSim
Emerald Biostructures, Inc.
Fred Hutchinson Cancer Research Center
Hummingbird Scientific
Infinia Corporation
MediChem Research, Inc./AXAS
Pacific Northwest National Laboratory
Seattle Biomedical Research Institute
Seattle Children's Research Institute
Seattle Pacific University
Sienna Technologies, Inc.
STI Optronics, Inc.
The Boeing Company
Thyen-med
U.S. Environmental Protection Agency
University of Washington, Seattle
Washington Closure Hanford
Washington State University
Washington State University, Tri-Cities
Western Washington University
Whitman College
Woodruff Scientific LLC

**WEST VIRGINIA**
Marshall University
Morgantown ETC
National Energy Technology Laboratory
ProLogic, Inc.
West Virginia University

**WISCONSIN**
ARL Inc
Bruker AXS, Inc.
General Electric Medical Systems
Marquette University
Medical College of Wisconsin
Promega Corporation
Union Semiconductor Technology Corporation
University of Wisconsin, La Crosse
University of Wisconsin, Madison
University of Wisconsin, Stout
University of Wisconsin, Whitewater
University of Wisconsin, Milwaukee
University of Wisconsin, Platteville
University of Wisconsin, Stevens Point

**WYOMING**
University of Wyoming

**DISTRICT OF COLUMBIA**
Embassy of Australia
Carnegie Institution of Washington
Catholic University of America
Children's National Medical Center
George Washington University
Georgetown University
Howard University
NASA - Headquarters
National Museum of Natural History
National Oceanic and Atmospheric Administration
Naval Research Laboratory
Office of Management and Budget

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Office of Science and Technology Policy (OSTP)
Smithsonian Institution
U.S. Department of Energy

**PUERTO RICO**
Arecibo Observatory
Infotech Aerospace Services
Interamerican University de Puerto Rico
National Astronomy and Ionosphere Center (NAIC)
University of Puerto Rico, Cayey
University of Puerto Rico, Humacao
University of Puerto Rico, Rio Piedras
University of Puerto Rico, San Juan

**VIRGIN ISLANDS**
University of the Virgin Islands

# The FUTURE of America is the RESEARCH of TODAY

NATIONAL USER FACILITY ORGANIZATION

**The Fortune 500 and National User Facilities**

47 of the Fortune 500 companies, with research and development facilities in 27 states, use 17 National User Facilities operated by the United States Department of Energy Office of Science and 1 by the National Science Foundation. The research undertaken by these corporations is wide-ranging, encompassing biology, chemistry, physics, material science and computing. The experiments performed at the facilities support the creation of diverse products, including new pharmaceuticals, advanced materials for semiconductors and vehicular batteries, telecommunications satellites, and consumer goods.

The User Facilities provide an effective way for industrial organizations to leverage the cutting-edge capabilities offered by modern science. The results enable advances in technological development and permit the United States to remain competitive in a global economy.

**Facilities Used**

ACRF – ARM Climate Research Facility

ALS - Advanced Light Source, Lawrence Berkeley National Laboratory

APS - Advanced Photon Source, Argonne National Laboratory

ALCF - Argonne Leadership Computing Facility, Argonne National Laboratory

CFN - Center for Functional Nanomaterials, Brookhaven National Laboratory

CNM - Center for Nanoscale Materials, Argonne National Laboratory

EMSL - Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory

HFIR - High Flux Isotope Reactor, Oak Ridge National Laboratory

HTML - High Temperature Materials Laboratory, Oak Ridge National Laboratory
LANSCE - Los Alamos Neutron Science Center, Los Alamos National Laboratory
Molecular Foundry, Lawrence Berkeley National Laboratory
NERSC - National Energy Research Scientific Computing Center, Lawrence Berkeley National Laboratory
NHMFL – National High Magnetic Field Laboratory, Florida State University
NSLS - National Synchrotron Light Source, Brookhaven National Laboratory
OLCF - Oak Ridge Leadership Computing Facility, Oak Ridge National Laboratory
SNS - Spallation Neutron Source, Oak Ridge National Laboratory
SSRL - Stanford Synchrotron Radiation Laboratory, SLAC National Accelerator Laboratory
TANDEM - Tandem Van de Graaff Accelerator Facility, Brookhaven National Laboratory

**Summary of Research**

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| Exxon Mobil | 2 | Baton Rouge, LA<br><br><br>Annandale, NJ<br>Baytown, TX | APS<br><br><br>NSLS | Characterization of feedstocks for the petroleum refining industry (NSLS)<br>Polymer composites (NSLS)<br>Microporous materials (NSLS)<br>Transformation of sulfur in fuel materials (APS, NSLS)<br>Operates four X-ray analysis beamlines (NSLS) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| Chevron | 3 | Mountain Pass, CA<br>Richmond, CA<br>Houston, TX | ALS<br>APS | Structural transformations of minerals (APS)<br>Proprietary research (ALS, APS) |
| General Electric | 4 | Niskayuna, NY<br>W. Milwaukee, WI | ALCF<br>ALS<br>APS<br>LANSCE<br>NERSC<br>NSLS<br>OLCF | Nanoscale gas sensors (ALS)<br>Computational modeling of engines (NERSC)<br>Computational modeling of wind turbines and jet engines (ALCF, OLCF)<br>Computational modeling of gasification (OLCF)<br>Catalyst characterization (APS)<br>Isotope production (LANSCE)<br>Characterization of advanced materials – transportation batteries, ceramic coatings in gas turbines, industrial gas sensors, solar panels (NSLS) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| Ford Motor | 8 | Dearborn, MI | ALS<br>APS<br>EMSL | Fuel combustion (ALS)<br>Characterization of fuel sprays in engines (APS)<br>Catalysts for control of automotive exhaust (EMSL) |
| Hewlett-Packard | 10 | Palo Alto, CA<br>Corvallis, OR | CNM<br>EMSL<br>LANSCE<br>SSRL | New materials for electronic paper (SSRL)<br>Properties of memory resistive devices (CNM)<br>Test of weather modeling software (EMSL)<br>Failure mechanisms of semiconductors (LANSCE) |
| General Motors | 15 | Flint, MI<br>Warren, MI | APS<br>EMSL<br>HFIR<br>HTML<br>NERSC<br>SNS | Analysis of fuel cells (APS)<br>Hydrogen storage for fuel cells (HFIR, SNS)<br>Conversion of heat to electricity in vehicles (HFIR, HTML)<br>Efficiency and emissions of gasoline engines (NERSC)<br>Mitigation of particulates from engine exhaust (EMSL) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| International Business Machines | 20 | San Jose, CA | ALCF | Strain in electronic materials (APS, CNM, SSRL) |
| | | Yorktown Heights, NY | ALS | Microelectronic connections and photovoltaics (SSRL) |
| | | Austin, TX | APS | Properties of nanoparticles and nanoparticle/polymer composites (Molecular Foundry) |
| | | | CFN | Lithographic materials for semiconductors (ALS) |
| | | | CNM | Semiconductors (APS) |
| | | | EMSL | Characterization of materials for the manufacture of computer chips (NSLS) |
| | | | LANSCE | Magnetic materials (EMSL) |
| | | | Molecular | Control of environmental contamination (EMSL) |
| | | | Foundry | Computer disk drives (LANSCE) |
| | | | NSLS | Supercomputer design (ALCF) |
| | | | SSRL | Operates X-ray analytical facility (NSLS) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| Procter & Gamble | 22 | Needham, MA | ALCF | Computation modeling for consumer goods, foods, fire control materials (ALCF) |
| | | Cincinnati, OH | APS | Fuel cell and battery materials (NSLS) |
| | | Fairfield, OH | EMSL | Pharmaceutical development (APS) |
| | | Mason, OH | HFIR | Biocompatible nanoparticles (EMSL) |
| | | | NSLS | Medical materials, including drug delivery and human tissue replacement (HFIR, SNS) |
| | | | SNS | |
| Boeing | 28 | Albuquerque, NM | ALCF | Computational modeling of turbulence in aircraft, wind turbines, heat exchangers, buildings (ALCF) |
| | | Kirkland, WA | APS | Aerodynamic modeling of airplanes (OLCF) |
| | | Renton, WA | EMSL | Analysis of semiconductor failures (LANSCE) |
| | | Seattle, WA | LANSCE | Evaluation of contaminant removal devices (EMSL) |
| | | | OLCF | Materials research (APS) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| Johnson & Johnson | 33 | Exton, PA<br>Spring House, PA | APS | Pharmaceutical development (APS) |
| United Technologies | 37 | East Hartford, CT<br>South Windsor, CT | NERSC<br>NSLS<br>OLCF | Design of new catalysts (OLCF)<br>Modeling of fire-fighting foams (OLCF)<br>Catalysts for fuel cells (NSLS)<br>Simulation of fuel flow in jet engines (NERSC) |
| Pfizer | 40 | Groton, CT<br>San Diego, CA<br>South San Francisco, CA | ALS<br>APS<br>NHMFL<br>NSLS<br>SSRL | Pharmaceutical development (ALS, APS, NSLS, SSRL)<br>Protein separation (NHMFL) |
| Lockheed Martin | 44 | Sunnyvale, CA<br>Newtown, PA | TANDEM | Effect of cosmic rays on spacecraft performance (TANDEM) |
| Dow Chemical | 46 | Albany, NY | ALS<br>APS<br>NSLS | Materials for semiconductor lithography (ALS)<br>Polymers for building materials (APS)<br>Characterization of polymers (NSLS) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| Northrup Grumman | 61 | Redondo Beach, CA<br>Rolling Meadows, IL<br>Chantilly, VA | APS<br>TANDEM<br>OLCF<br>SSRL | Efficiency of DNA delivery in cells (APS)<br>Climate models and projections (OLCF)<br>Characterization of nanoparticles (SSRL) |
| Intel | 62 | Chandler, AZ<br>Lacey, CA<br>Santa Clara, CA<br>Windsor, CO<br>Hudson, MA<br>Northborough, MA<br>Albuquerque, NM<br>Aloha, OR<br>Hillsboro, OR<br>Portland OR | APS<br>LANSCE<br>Molecular<br>Foundry<br>SSRL | Creation and characterization of new polymers (Molecular Foundry, SSRL)<br>Heat removal in integrated circuit packages (Molecular Foundry, SSRL)<br>Development of new semiconductor structures (APS)<br>Failure rates in semiconductors (LANSCE) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| Caterpillar | 66 | East Peoria, IL<br>Mossville, IL | APS<br>EMSL<br>HTML | Characterization of stress in materials (APS)<br>Mechanism of corrosion in bearings (HTML)<br>Catalysts for treatment of diesel exhausts (EMSL) |
| Honeywell International | 74 | Glendale, AZ<br>Peoria, AZ<br>Phoenix, AZ<br>Tucson, AZ<br>Sunnyvale, CA<br>Clearwater, FL<br>Des Plaines, IL<br>Coon Rapids, MN<br>Eden, MN<br>Fridley, MN<br>Minneapolis, MN<br>Kansas City, MO | APS<br>CFN<br>HTML<br>LANSCE<br>NSLS<br>SSRL<br>TANDEM | Materials for semiconductor manufacturing (APS)<br>Effect of cosmic rays on microelectronic components (TANDEM)<br>Failure rates in semiconductors and electronics (LANSCE)<br>Characterization of catalysts and adsorbents (APS, CFN, HTML, NSLS, SSRL)<br>Proprietary research (ALS) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| | | Hopewell Junction, NY<br>Pleasant Valley, NY<br>Essex Junction, VT<br>Redmond, WA<br>Sammamish, WA<br>Brampton, Ontario<br>Mississauga, Ontario | | |
| Abbott Laboratories | 75 | North Chicago, IL<br>Worcester, MA | ALS<br>APS<br>NHMFL<br>NSLS | Pharmaceutical development (ALS, APS, NSLS)<br>Antibody recognition in human immune system (NHMFL) |
| Merck | 85 | Rahway, NJ<br>West Point, PA | ALS<br>APS | Pharmaceutical development (ALS, APS) |
| DuPont | 86 | Wilmington, DE | APS<br>EMSL<br>HFIR<br>Molecular Foundry | Properties of polymer nanocomposites (APS, HFIR, SNS, Molecular Foundry)<br>Computational modeling of intermolecular forces (EMSL) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| | | | SNS | |
| Oracle | 105 | Santa Clara, CA<br>Redwood Shore, CA | LANSCE | Failure rates in semiconductors and electronics (LANSCE) |
| 3M | 106 | Minneapolis, MN | APS | Fuel Cells (APS) |
| Deere | 107 | Moline, IL | APS | Studies of strain in materials (APS) |
| Motorola | 110 | Tempe, AZ<br>Austin, TX<br>Tel-Aviv, Israel | EMSL<br>LANSCE | Failure testing of semiconductors (LANSCE)<br>Materials for improved semiconductors (EMSL) |
| Eli Lilly | 112 | Indianapolis, IN<br>San Diego, CA | ALS<br>APS<br>SSRL | Pharmaceutical development (ALS, APS, SSRL) |
| Bristol-Myers Squibb | 114 | Lawrenceville, NJ<br>Princeton, NJ | APS<br>EMSL<br>NSLS | Pharmaceutical development (APS, EMSL, NSLS) |
| Halliburton | 158 | Duncan, OK | APS | Properties of cement (APS) |
| Amgen | 159 | South San Francisco, CA<br>Thousand Oaks, CA | ALS<br>APS | Pharmaceutical development (ALS, APS) |
| Medtronic | 160 | Brooklyn Center, MN | APS | Batteries for medical applications (APS) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| Monsanto | 197 | Chesterfield, MO | APS | Proteins characterization for agricultural biotechnology (APS) |
| Sun Microsystems | 204 | Mountain View, CA<br>Redwood City, CA<br>San Jose, CA<br>Sunnyvale, CA | LANSCE | Failure rates in semiconductors and electronics (LANSCE) |
| ITT | 214 | Fort Wayne, IN<br>Herndon, VA | ACRF<br>APS<br>NERSC | Studies on anesthetics (APS)<br>Development of scientific visualization software (NERSC) |
| SAIC | 215 | Frederick, MD<br>Maclean, MD | APS<br>NERSC | Characterization of proteins from coral (APS)<br>Analysis of wind energy technology (NERSC) |
| Cummins | 218 | Columbus, IN | EMSL<br>HTML | Control of diesel exhaust (EMSL)<br>Composition and mechanical properties of steels and filters for engines (HTML) |
| Texas Instruments | 223 | Dallas, TX<br>Plano, TX | APS<br>EMSL | Films for microelectronic fabrication (EMSL)<br>New microstructures for transistors (APS) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| | | Sherman, TX<br>Stafford, TX | LANSCE | Failure rates of semiconductors (LANSCE) |
| Thermo Fisher Scientific | 234 | Bremen, Germany | EMSL | Technology for improved characterization of large molecules and mixtures (EMSL) |
| Boston Scientific | 279 | Natick, MA<br>St. Paul, MN | EMSL<br>LANSCE | Failure rates in semiconductors (LANSCE)<br>Computational modeling of human lungs (EMSL) |
| Eastman Kodak | 297 | Rochester, NY | EMSL<br>NSLS | Mechanism of image generation in medical radiography (NSLS)<br>Conducting polymers (EMSL) |
| Western Digital | 304 | San Jose, CA | SSRL | Thin films for computer disk drives (SSRL) |
| Ball | 307 | Boulder, CO | TANDEM | Resistance to radiation of semiconductors for spacecraft and military (TANDEM) |
| Advanced Micro Devices | 390 | Santa Clara, CA<br>Sunnyvale, CA<br>Fort Collins, CO<br>Boxborough, MA | LANSCE | Failure rates of semiconductors (LANSCE) |

| Company | Fortune 500 Rank | Locations | User Facilities | Research |
|---|---|---|---|---|
| | | Austin, TX | | |
| Corning | 391 | Corning, NY | EMSL<br>HTML | Ceramics of diesel exhaust filters (HTML)<br>Rheological dynamics of particle suspensions (EMSL) |
| Applied Materials | 421 | Boise, ID | EMSL | Magnetic devices for medical, military and data storage (EMSL) |
| Micron Technology | 432 | Boise, ID<br>Star, ID | LANSCE | Failure rates in semiconductors and electronics (LANSCE) |
| Agilent Technologies | 461 | Santa Clara, CA | NHMFL | Ultra-high resolution optical imaging (NHMFL) |
| Rockwell Collins | 462 | Tustin, CA<br>Melbourne, FL<br>Cedar Rapids, IA<br>Ely, IA | LANSCE | Failure rates in semiconductors and electronics (LANSCE) |

MAGNA
COSMA BODY SYSTEMS
EAGLE BEND MFG. INC.

Dr. Steven Chu
Secretary of Energy
S/Forrestal Building
1000 Independence Ave, SW
Washington DC 20585-0121

March 6th, 2012

RE: Oak Ridge National Laboratory's High Temperature Materials Laboratory User Program

Dear Mr. Secretary:

The Body & Chassis Systems Division of Cosma International, a subsidiary of Magna International (Magna), manufactures hot-stamped components for vehicular structures at its Eagle Bend facility in Clinton, Tennessee, which employs 750 people. These components are subsequently supplied to OEMs for incorporation into bodies in white. Some of these components are made with advanced high-strength steels, which enable the use of thinner components to achieve significant weight reductions and improved fuel efficiency without sacrificing safety.

We are writing to you today to express our deepest appreciation for the technical support provided to Cosma and Magna by Dr. Edgar Lara-Curzio and his research team at the High Temperature Materials Laboratory (HTML) at the Oak Ridge National Laboratory. We contacted Dr. Lara-Curzio in late November last year requesting urgent assistance to identify the mechanisms responsible for the failure of components manufactured at Eagle Bend during assembly of bodies in white at an OEM's plant. We turned to ORNL's High Temperature Materials Laboratory for:

- its wide array of powerful tools for materials characterization;
- the expertise of the staff in operating these instruments;
- most importantly the staff's understanding of the relationships between manufacturing processes and the microstructure and physical and mechanical properties of materials;
- the opportunity to work side-by-side with the HTML research team.

Even more significant were the virtually instantaneous HTML response to our call for help, and the staff's "can do" attitude in working late and during the Thanksgiving holidays. Such rapid turn-around is critical to solving industrial manufacturing problems and allowed both Eagle Bend and the OEM to determine a solution and continue production.

**MAGNA**
**COSMA BODY SYSTEMS**
**EAGLE BEND MFG, INC.**

Eagle Bend's experience working with ORNL's High Temperature Materials Laboratory demonstrates the wisdom and value of Federal investments in user facilities at the National Laboratories. These facilities make available capabilities and expertise that industry cannot afford to acquire and/or maintain, and their collaborative environment facilitates innovation and helps accelerate the commercialization of technologies. Furthermore, in situations like the one we just experienced, they have the expertise to assist industry in solving problems that affect productivity and competitiveness.

Magna International and its subsidiaries will continue to look to the High Temperature Materials Laboratory for our future characterization needs and recommend it as a partner to help U.S. industries maintain manufacturing excellence and technological leadership in a globally competitive environment.

Sincerely,

Steve Esman (General Manager) Allan Navarro (Quality Manager)

cc: Dr. Henry C. Kelly, Acting EERE Assistant Secretary
Patrick B. Davis, Vehicle Technologies Program Manager
Dr. Carol L. Schutte, Lead, Vehicle Technologies Program, Materials Technology Team Lead
Dr. Thom Mason, Director, Oak Ridge National Laboratory
Dr. Leo Christodoulou, Advanced Manufacturing Office, Manager

The **FUTURE** of America is the
**RESEARCH** of **TODAY**

NATIONAL
USER
FACILITY
ORGANIZATION

**Testimony Summary**

The National User Facility Organization (NUFO) represents the almost 45,000 scientists who conduct research at the 46 largest federally funded user facilities in the United States. Of these, 36 facilities are managed by the Department of Energy, hosting almost 37,000 scientists each year. They come from a variety of institutions and the research these scientists conduct at these facilities is extremely diverse. These scientists come from 53 US States & Territories and ~1,200 institutions, many are international scientists. Researchers from 400 unique companies including 45 Fortune 500 companies and 22 Fortune 100 companies use these facilities. Roughly 7,000 of these users are students and postdoctoral researchers. The research impacts virtually every scientific discipline, both in applied and fundamental sciences. Life scientists utilize these facilities to understand disease and develop new diagnostic technologies and drug treatments and materials scientists utilize these instruments to develop next generation technologies (semiconductors, catalysts, dynamic simulations for transportation technologies, new materials in supporting National security interests). New facilities coming on-line and state-of-the-art upgrades to existing facilities will play important roles in ensuring we remain competitive with research being conducted abroad and to meet rapidly increasing demand for research time. Operating funds to ensure that existing facilities operate at optimum levels is critical to ensure they help maintain our Nation's leadership position in scientific research.

The **FUTURE** of America is the
**RESEARCH** of **TODAY**

NATIONAL USER FACILITY ORGANIZATION

**Short Narrative Biography**

Antonio Lanzirotti is a Senior Research Associate at The University of Chicago's Center for Advanced Radiation Sources (see attached *curriculum vitae*). He has been a University of Chicago research scientist since 1999 and helped develop and operate X-ray beamlines for the user community at both the National Synchrotron Light Source at Brookhaven National Laboratory (Upton, New York) and the Advanced Photon Source at Argonne National Laboratory (Argonne, Illinois) where he is currently stationed. He received both his Bachelor of Science (1985) and Master of Science (1988) degrees from the New Mexico Institute of Mining and Technology (Socorro, New Mexico) in Geology. He received his Ph.D. degree in Earth Sciences from Stony Brook University (Stony Brook, New York) in 1995. Prior to joining the University of Chicago he was a National Science Foundation post-doctoral fellow (University of Massachusetts at Amherst) and worked for Professional Service Industries, Inc. (Oakbrook Terrace, Illinois). Lanzirotti is the 2011-2012 elected Chair for the National User facility Organization, which helps represent the interests of scientists who conduct research at U.S. national scientific user facilities.

Chairman HARRIS. Thank you very much.

I now recognize Dr. Drell for five minutes to present her testimony.

**STATEMENT OF DR. PERSIS DRELL, DIRECTOR, SLAC NATIONAL ACCELERATOR LABORATORY**

Ms. DRELL. Chairman Harris, Ranking Member Miller and Members of the Subcommittee, I am very pleased to be here today to talk about SLAC National Accelerator Lab and the Linac Coherent Light Source.

As you are going to be hearing from other witnesses, DOE user facilities producing intense beams of X-rays have been doing research with tremendous societal impact for several decades. X-rays are particularly sensitive scientific tools, powerful scientific tools because they see through matter and they tell us where atoms are. At SLAC, we have just turned on the newest X-ray facility, the Linac Coherent Light Source, or LCLS, whose ultra-bright, ultra-short pulses of X-rays are revolutionizing our ability to look at matter by letting us for the first time see motion on the atomic time scale.

So I want to illustrate the power of LCLS with an analogy. In the late 1800s, there was a lot of interest in the mechanics of how a horse galloped. There was a famous bet involving Senator Leland Stanford, and the bet was about whether all four hooves of the horse left the ground. Eadweard Muybridge devised a camera with a very fast shutter speed to resolve the bet by taking a series of crisp stop-action pictures, putting them together into a movie, which you see shown here. As you can see, this movie resolved the question, and we know as a result that a galloping horse does, in fact, take all of its four feet off the ground when it gallops.

Now, just imagine if we could do this at the atomic scale. Imagine if we could take a series of crisp stop-action pictures of chemistry in motion and watch a reaction atom by atom and step by step, and this is the new scientific frontier that has been opened by the Linac Coherent Light Source.

Right now, as I speak, experimenters at SLAC, users at our facility, are trying to understand photosynthesis, that very basic life process, by taking a series of stop-action pictures in much the way that Muybridge took a series of stop-action pictures of the galloping horse.

We have long known that in photosynthesis, we take $CO_2$ and water, put it together with sunlight and we make oxygen and sugars, but with a multi-step process we don't know the details. With an understanding of how it works, we can start to re-engineer it and exploit it in new ways. I think it will be a decade or more, just to manage expectation, before society directly benefits or an industrial application emerges, but I am also confident that with time, this will be game-changing.

More speculative applications of the LCLS but maybe even more revolutionary have to do with LCLS's ability to image viruses and perhaps some day even selected cells. This is in the early technology development stage but the potential is enormous as it might offer revolutionary new insights into the workings of the living cell.

So the LCLS is unique in the world in its ability to deliver these ultra-fast, ultra-bright X-rays, but there is significant worldwide competition coming as Japan, Germany, China and Switzerland are all moving to catch up, particularly now that we have demonstrated that this works.

To stay competitive, we are already working to expand the capability and capacity of this discovery-class machine with the LCLS–II. The 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, for which we are very appreciative.

User facilities like the LCLS are expensive to build and operate. No one industry or research enterprise can afford to build one for itself. The Federal Government through the Office of Science and DOE, funds the building and operations of the facilities at the national labs, and scientists from around the world compete for beam time with peer-review proposals. We are currently preeminent in many areas of science with our user facilities. We will need continued stable funding for the DOE Office of Science to keep our world-leading position.

Mr. Chairman, Members of the Subcommittee, let me end with a somewhat philosophical statement. Over 400 years ago, Flemish spectacle makers invented a spyglass, and the reason they invented the spyglass was to be able to see ships far from harbor to tell if they were friend or foe. Galileo took that spyglass, made it better by a factor of 10, turned it on the heavens, and revolutionized our view of the cosmos. The LCLS was built because we knew that tudying materials on the atomic time and distance scales would open new frontiers in drug discovery, materials and chemistry research. But all of us believe that with this new X-ray source, a billion times brighter than anyone has had before, the biggest scientific surprises are yet to come.

Thank you for the opportunity to provide my perspective as SLAC's Director, and I look forward to your questions.

[The prepared statement of Ms. Drell follows:]

Testimony of

Persis Drell, Ph.D.
Lab Director
SLAC National Accelerator Laboratory

Before the
United States House of Representatives
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

June 21, 2012

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.

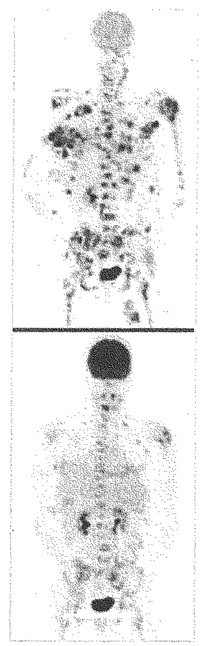
Light source user facilities at SLAC, Argonne, Brookhaven and Lawrence Berkeley National Labs that produce intense X-rays have been doing scientific research with tremendous societal impact for several decades. These facilities serve a broad suite of scientific disciplines and provide tools that industry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

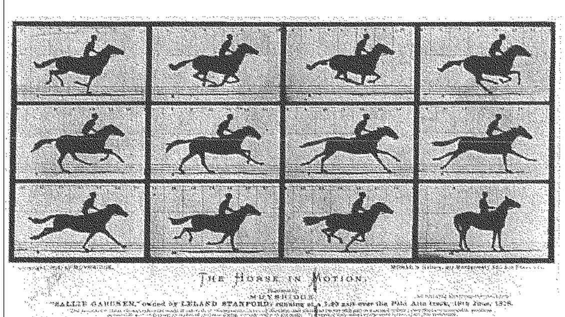
X-ray data derived using light source capabilities at SLAC, Argonne and Berkeley Labs has been used to determine the molecular structure of a mutated protein involved in stage-four malignant melanoma. With this structure, a Berkeley-based drug discovery company, Plexxikon, was able to develop a drug, 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.

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.



*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.*

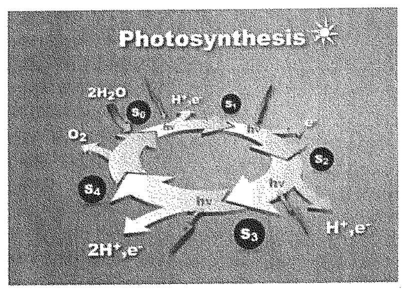



Now imagine if we could take X-ray pictures with the equivalent of a fast shutter speed and string them together to make stop-action movies of atomic processes. These movies would show atoms and electrons moving on their natural timescale and allow us to watch a chemical reaction atom by atom and step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

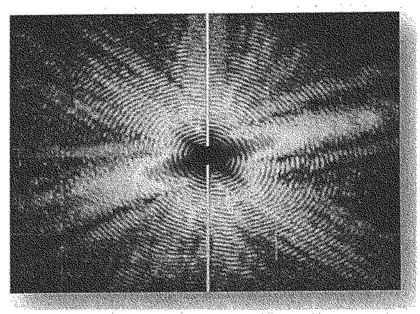
The LCLS was only completed in 2010, so we are in the early stages of exploiting this revolutionary new tool. But let me give you a few examples to illustrate the science we are achieving today and the promise for the future in terms of industrial involvement and benefits to society:

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.

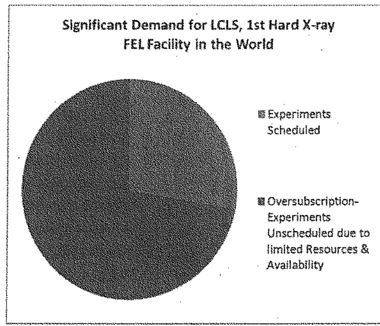


*Mimivirus particle imaged by LCLS*
*Courtesy of Tomas Ekeberg*

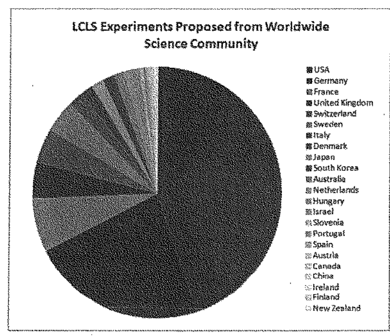
4. Virtually everything in our daily life involves catalysts, from turning crude oil into the gas in our cars, to processing cotton to make our clothes, to the hydrogenation of fats to make margarine. Often catalysts have been discovered by trial and error and we don't understand in detail how or why 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.

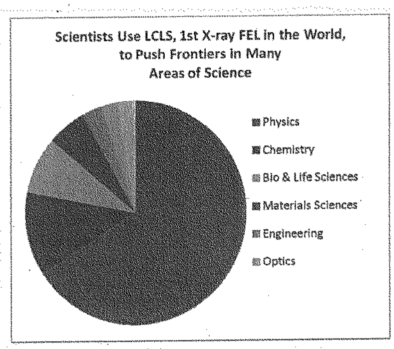


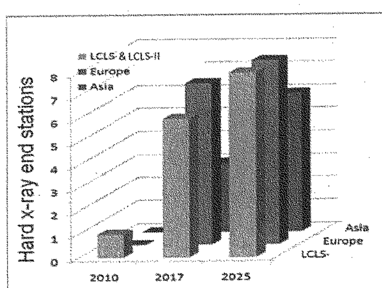

The LCLS is at an early stage of development, but we are already working to expand the capability and capacity of this discovery-class machine with LCLS-II. LCLS-II is supported in the President's Budget Request and is included in the House Energy and Water bill as part of the BES budget. LCLS-II is 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.



One-Page Summary Outline of Testimony of

Persis Drell, Ph.D.
Lab Director
SLAC National Accelerator Laboratory

Before the
United States House of Representatives
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

June 21, 2012

1. Introduction
2. X-ray user facilities have been doing basic research with societal impact for decades
    a. Examples: Melanoma; H1N1; Aids; Night vision goggles
3. New frontier x-ray user facility: LCLS ---ultra bright (x1000 more x-rays per pulse) ultra short (x10,000 shorter in time) x-ray pulses than ever before available
    a. Short pulses→allows stop action pictures of atomic processes. Example of galloping horse – movies of atomic processes
    b. Unlock secrets of photosynthesis and catalysis
    c. Structure and time-resolved function of single molecules
    d. 3D imaging and dynamical studies of bio-world
4. Unique, world leading facilities such as LCLS are national facilities too expensive for any one university or any one industry to afford
    a. Built by the government and every one competes for time on an equal footing
    b. Peer reviewed proposals, the best science gets beam time
    c. LCLS at early stage of development. We are already working to expand the capability and capacity of this discovery class machine with LCLS-II.
5. The biggest surprises are yet to come
    a. Galileo built his first telescope 10 times better than any other telescope to be able to see ships farther from harbor and tell if they were friend or foe. He then turned his telescope on the heavens and revolutionized our understanding of the cosmos
    b. 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 understanding. 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.

Chairman HARRIS. Thank you very much.
I now recognize Dr. Wasserman to present his testimony.

## STATEMENT OF DR. STEPHEN WASSERMAN, SENIOR RESEARCH FELLOW, TRANSLATIONAL SCIENTIST AND TECHNOLOGIES, ELY LILLY AND COMPANY

Mr. WASSERMAN. Chairman Harris, Ranking Member Miller, and Members of the Subcommittee, my name is Stephen Wasserman. I am a Senior Research Fellow in the Translational Science and Technologies Department of Lilly Research Laboratories, the research arm of Ely Lilly and Company. It is a pleasure to be here this morning to describe our company's work at the Advanced Photon Source of Argonne National Laboratory, one of the four X-ray synchrotron user facilities operated by the United States Department of Energy. The partnership between our company and the APS is an important part of our effort to deliver innovative new medicines to the patients who need them.

Lilly has been a continual user of the Advanced Photon Source since the first days of the facility. Today we operate our own X-ray beam line for protein crystallography, the Lilly Research Laboratory's Collaborative Access Team, LRLCAT, of which I am the Director. Each year, we analyze more than 10,000 crystalline samples. Most of these crystals contain both proteins that are targets for the treatment of disease and small chemical compounds of interest in the development of potential new medicines.

The experiments at the APS permit us to examine the interaction between the protein and small molecule atom by atom and to develop innovative new ways to optimize that interaction. Through this detailed microscopic view, we seek to maximize the efficacy of new pharmaceuticals and minimize side effects.

Today our company has more than 10 experimental compounds in phase I and phase II clinical trials that were developed with the aid of the Advanced Photon Source. In addition, experiments at the APS support research on more than one-third of the protein targets in Lilly's early-stage drug discovery portfolio. The therapeutic research areas that benefit from the APS are diverse including cancer, diabetes, autoimmune, psychiatric disorders and neurological conditions such as neurodegeneration and pain.

Our work on the protein known as beta secretase, a potential target for the treatment of Alzheimer's disease, is illustrative of the interface between experiments at the APS and Lilly's drug discovery research. The crystallographic effort that included the APS has to date resulted in the determination of the three-dimensional structures of more than 400 different compounds bound to the protein. The total effort in developing a molecule that can be tested in clinical trials extends far beyond our experiments in crystallography. Considerable work was required to design candidate molecules and evaluate their properties involving our colleagues in biology, chemistry, data analysis and medicine. This endeavor has resulted in an investigational new drug whose phase II clinical testing will soon commence.

We urge Congress to continue to support our country's national user facilities and the national laboratories in which many are located. The Advanced Photon Source and other U.S. synchrotron sources need a reliable funding stream. The quality of the data obtained at the APS cannot be duplicated elsewhere in the United States. If the light sources were not available or their operating schedule substantially reduced, we at Lilly would be forced to consider moving our experiments to other countries. We have performed recently, or are scheduled to perform in the near future, experiments in Canada, the United Kingdom, France and China. Reliance on facilities outside the United States, however, would slow the pace of our research and impact how soon new treatments become available to patients.

The relationship between the national user facilities and their users is strong. This relationship can be enhanced by further development of the technical and organizational environment the facilities provide. Potential enhancements include modifications to the agreements between user and facility, especially for industrial and proprietary users and operators of individual beam lines from outside the Department of Energy.

The addition of automation to speed the execution of experiments and reduce future costs would maximize scientific value for the facilities. Implementation of upgrades for the core machines and, where present, ancillary experimental stations is necessary. We at Lilly have seen how with time operations can be held hostage to deprecated and aging equipment. Indeed, that was one of the motivations for our own recent upgrade at LRLCAT. The APS and its sister facilities have similar issues though on a much larger scale.

As Drs. Drell and Lanzirotti have already noted, the national user facilities are too large for any one organization, corporate or academic, to consider building on its own. The United States Government had foresight to recognize that it alone could construct this scientific infrastructure. By creating and running such facilities, it provides an essential service for the country's technological development. The result is a collection of scientific resources of which the Nation should be justly proud.

In conclusion, I would like to return to a statement we made at the exhibitions on national user facilities that the NUFO organization presented for Congress at the end of March. Recently in meetings on Capitol Hill, a colleague echoing the opening of Charles Dickens' *A Tale of Two Cities* described the current environment for science as the best of times and the worst of times. Dickens' worst, best and worst, are, however, absolute; science is rarely so. It continually builds on what is already known. That is why science must always move forward rather than being executed intermittently. A better descriptor of the promise of national user facilities for our future can be found in a slight modification of the end of Dickens' novel. Provided the federal budget for national user facilities remains intact, the research and innovation at these facilities will be a far, far better thing that we do than we have ever done.

Thank you.

[The prepared statement of Mr. Wasserman follows:]

**Stephen R. Wasserman**
**Senior Research Fellow**
**Eli Lilly and Company**
**June 21, 2012**

**Summary**

Eli Lilly and Company is a long-standing user of the Advanced Photon Source, one of four X-ray synchrotron light sources operated by the US Department of Energy. We currently operate our own X-ray beamline for protein structure at the APS, the Lilly Research Laboratories Collaborative Access Team, LRL-CAT. The partnership between our company and the APS is an important part of our effort to deliver innovative, new medicines to the patients who need them.

Lilly has more than 10 experimental compounds in Phase I and Phase II clinical trials that were developed with the aid of the Advanced Photon Source. Experiments at the APS support research on one-third of the protein targets in Lilly's early stage drug discovery portfolio. The therapeutic research areas that utilize the APS include cancer (oncology), diabetes, autoimmune, psychiatric disorders, and neurological conditions such as neurodegeneration (Alzheimer's) and pain.

National User Facilities such as the Advanced Photon Source are essential for the nation's technological development. They are, however, too large for any one organization, corporate or academic, to consider building on its own. In creating the User Facilities the government has provided a great service to the nation. Continued high-level funding to keep them operating and at the state of the art is important for the economic and technological advancement of the United States.

The relationship between the National User Facilities and their users is strong. This relationship can be enhanced by further development of the technical and organizational environment the facilities provide. Potential enhancements include modifications to the agreements between user and facility, especially for proprietary users and operators of individual beamlines from outside the DOE. The addition of automation to speed the execution of experiments and reduce future costs would maximize scientific value from the facilities. Implementation of upgrades for the core machines and, where present, ancillary experimental stations will ensure that users continue to have the opportunity to employ the unique and powerful capabilities of the User Facilities in their scientific investigations.

**Statement of**
**Dr. Stephen R. Wasserman**
**Director, Lilly Research Laboratories Collaborative Access Team**
**Senior Research Fellow, Translational Science and Technologies**
**Eli Lilly and Company**

**Before**

**The United States House of Representatives**
**Committee on Science, Space, and Technology**
**Subcommittee on Energy and Environment**

**June 21, 2012**

Chairman Harris, Ranking Member Miller and Members of the Subcommittee,

It is a pleasure to be here this morning to describe Eli Lilly's work at the Advanced Photon Source (APS) of Argonne National Laboratory, one of the four X-ray synchrotron user facilities operated by the United States Department of Energy. The partnership between our company and the APS is an important part of our effort to deliver innovative, new medicines to the patients who need them.

We urge Congress to continue to support our country's National User Facilities and the National Laboratories in which many are located. We strongly agree with the sentiment recently expressed by the Director of Argonne National Laboratory, Eric Isaacs: "The work we do in the national laboratories promises to dramatically accelerate the discovery and development of new materials, technologies, and processes–and ultimately, those efforts will power the expansion of the American economy." As we will illustrate today, these new materials include pharmaceuticals.

National User Facilities such as the Advanced Photon Source are too large for any one organization, corporate or academic, to consider building on its own. The United States government had the foresight to recognize that it alone could construct this scientific infrastructure. By creating such facilities, it provides an essential service for the nation's technological development. Continued high-level funding to keep these facilities operating and at the state of the art is important for the economic and technological advancement of the United States.

**Lilly and the Advanced Photon Source**

Lilly has been a continual user of the Advanced Photon Source since the first days of the facility. Today, we operate our own x-ray beamline for protein crystallography, the Lilly Research Laboratories Collaborative Access Team (LRL-CAT). Each year we analyze more than 10,000 crystalline samples. Most of these crystals contain both proteins that are targets for the treatment of disease and small chemical compounds of interest in the development of potential new medicines. The experiments at the APS permit us to examine the interaction between the protein and small molecule atom-by-atom and to develop innovative new ways to optimize that interaction. Through this detailed, microscopic view, we seek to maximize the efficacy of new pharmaceuticals and minimize side effects.

Today our company has more than 10 experimental compounds in Phase I and Phase II clinical trials that were developed with the aid of the Advanced Photon Source. In addition, experiments at the APS support research on one-third of the protein targets in Lilly's early stage drug discovery portfolio. The therapeutic research areas that utilize structure-based drug design are diverse, including cancer (oncology), diabetes, autoimmune, psychiatric disorders, and neurological conditions such as neurodegeneration (Alzheimer's) and pain.

Our work on the protein known as β-secretase, a potential target for the treatment of Alzheimer's Disease, is illustrative of the interface between experiments at the APS and Lilly's drug discovery research. The crystallographic effort that included the APS has, to date, resulted in the determination of the three-dimensional structures of more than 400 different compounds bound to the protein. But the total effort in developing a molecule that can be tested in clinical trials extends far beyond our experiments in crystallography. Considerable effort was required to design the properties of the candidate molecules, in order that the final compound could be administered orally but still enter the brain. Our biological colleagues tested the compound and its precursors for efficacy, while computational chemists developed models for the physical properties of early stage molecules and their interactions with the protein. We also tested molecules against other proteins that are fairly similar to β-secretase, in order to predict and diminish side effects. Not surprisingly, this diverse research extended over many years. It has resulted in an investigational new drug, whose phase II clinical testing will soon commence (www.clinicaltrials.gov).

The number of scientists needed to execute these experiments and analyses across the entire Lilly portfolio is large. The subset that interacts with the APS and the data from the synchrotron is more than 150. These researchers are involved directly in preparing the samples that are sent to LRL-CAT, analyzing the data that we return to them, and using the conclusions from these experiments in their pursuit of innovative pharmaceuticals.

The experimental medicines undergoing clinical trials represent only the tip of the iceberg in the use of structural biology within Lilly's drug discovery efforts. Even negative results that do not detect an interaction between compound and protein often influence future scientific directions. In other cases, the association that is found is different from the hypothesis that directed the original experiment. In a recent example, such a result led to a reassessment of the approach to be pursued with a protein target.

We are able to rapidly disseminate the results of our work at the APS throughout the company. On average, evaluated experimental results are available to our Lilly colleagues in San Diego, Indianapolis, the United Kingdom, Spain and China within 14 minutes of completion of the analysis at the APS. During normal operations, the median time between when a sample is created and when the experiment at LRL-CAT is finished is less than 1.6 days, including the time required to ship the sample overnight to the synchrotron. This speed allows us to execute crystallographic analyses as quickly as other assays used in discovery pharmaceutical research. Virtually all of the data acquisition process is automated, permitting us to execute up to several hundred experiments each day, day in and day out. In 2011, using this system, Lilly solved more than 940 structures of proteins and protein-ligand complexes, including 29 novel discovery targets.

At the APS, we obtain data of a quality that cannot be duplicated elsewhere in the United States, including our own laboratories. We recognize the great value of this quality for the pharmaceutical discovery process. We are not alone in this recognition. Virtually every large pharmaceutical and biotechnology company operating in the United States uses the APS or one of the other DOE-funded synchrotrons. Indeed x-ray light sources are the *de facto* standard for protein crystallography. Of the approximately 8300 x-ray structures of biological macromolecules publicly disclosed worldwide in 2011, more than 85% utilized data acquired at synchrotron sources (source: http://biosync.sbkb.org). 35% of these structures came from the four DOE x-ray synchrotrons, making the United States the world-leader in this scientific area.

The power and capabilities offered by the Advanced Photon Source are even more critical for the class known as membrane proteins, which includes the G-protein coupled receptors that are the targets for a significant fraction of the pharmaceuticals available today. These proteins present significant difficulties in crystallization and the crystals obtained are extremely small. Because of their small dimensions, crystallographic analysis of these materials is only possible using high-intensity light sources such as the APS.

Lilly has committed its own resources for its research at the APS. SGX Pharmaceuticals, a company Lilly acquired in 2008, built the original beamline. We have a dedicated staff based at Argonne National Laboratory that maintain and operate LRL-CAT. In 2011, we completed an upgrade of the facility. This investment increased our sample capacity to 540 crystals at a time and doubled the speed at which we can execute X-ray measurements.

Lilly pays the DOE mandated fees for all its proprietary experiments at the Advanced Photon Source. These fees fully reimburse the Department of Energy for the cost of generating the X-rays we use. In addition, following DOE regulations, we provide, at no cost, up to 25% of the available time at the beamline to non-proprietary users from universities and other organizations. In this way, we effectively pay back the Department of Energy for its original investment in building the synchrotron.

**Challenges and Opportunities**

The most significant challenge we face in the use of the Advanced Photon Source is the uncertainty in federal funding for the APS. While this uncertainty is understandable given the current federal budgetary climate, the user facilities need a reliable funding stream so that they can continue to operate at the current level. If the APS and the other US synchrotron sources were not available or their operating schedules substantially reduced because of funding cuts, we would be forced to consider moving our X-ray measurements to light sources in other countries. We have performed recently, or are scheduled to perform in the near future, experiments in Canada, the United Kingdom, France and China. Reliance on facilities outside the United States, however, would slow the pace of our research and impact how soon new treatments become available to patients. It would also affect competitiveness and possibly employment here in the United States.

An opportunity for improvement can be found in the user agreements for the National User Facilities, particularly the intellectual property provisions contained therein. The DOE has recently modified these agreements. The current terms do offer some enhancement in interactions between facility staff and users. However, the new agreements are not appropriate for beamlines operated by organizations outside the DOE. We have been working with Argonne to rectify this inadvertent oversight. The provisions on intellectual property and ownership of inventions continue to have significant ambiguities for proprietary users, even though they have paid the proprietary fee. Our agreements with light sources in Canada, England, and France exhibit much greater clarity in this area: "if you pay, you own", even when facility staff directly participate in the experiment.

Another possibility for enhancement is in the efficiency of experimental execution. In developing LRL-CAT, we have emphasized automation and efficiency of beamline operations and data collection. As discussed above, this capability permits us to rapidly return data to our scientific colleagues. We recognize that facilities such as the Advanced Photon Source require significant fiscal resources for each hour of operation. By minimizing the time for each experiment, however, we can reduce the cost for the measurement, even within a fixed hourly cost. A benefit of such an approach is that the scientists' can focus their efforts on the most value-added activities.

Finally, the APS is currently engaged in the early stages of an upgrade to the facility. We ourselves have seen how, with time, operations can be held hostage to deprecated and aging equipment. Components purchased more than 10 years ago for LRL-CAT are no longer manufactured or are approaching their end of life. Indeed, that was one of the motivations for our recent upgrade at the beamline. The APS and other user facilities have similar issues, though on a much larger scale. Investments in upgrades, and ongoing continuous improvement afterward, will ensure the operations of the National User Facilities into the future.

**Conclusion**

The National User Facilities, including the Advanced Photon Source, are a scientific resource of which the nation should be justly proud. No other country has an equivalent variety of capabilities for investigation and analysis.

Science usually has long time horizons. 10 to 15 years can pass before an initial result yields a useful application. It can be difficult to discern the effectiveness of an investment made today. For this reason, scientific research undertaken now may not appear important. It is, something we at Lilly know well as we pursue new pharmaceuticals.

When we ask the government to provide capabilities that facilitate innovation, we in turn take on a responsibility to use these capabilities prudently, both scientifically and fiscally. In this way we can continue an environment of public trust that will guarantee our future technological health.

June 21, 2012

Argonne, IL

**Appendix to the**
Statement of
Dr. Stephen R. Wasserman
Director, Lilly Research Laboratories Collaborative Access Team
Senior Research Fellow, Translational Science and Technologies
Eli Lilly and Company

Before

The United States House of Representatives
Committee on Science, Space, and Technology
Subcommittee on Energy and Environment

June 21, 2012

"Rapid-access, high-throughput synchrotron crystallography for drug discovery", *Trends in Pharmacological Sciences*, May, 2012, Vol. 33, No. 5, pp. 261-267.

Review

Cell PRESS

# Rapid-access, high-throughput synchrotron crystallography for drug discovery

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**Synchrotron X-ray sources provide the highest quality crystallographic data for structure-guided drug design. In general, industrial utilization of such sources has been intermittent and occasionally limited. The Lilly Research Laboratories Collaborative Access Team (LRL-CAT) beamline provides a unique alternative to traditional synchrotron use by pharmaceutical and biotechnology companies. Crystallographic experiments at LRL-CAT and the results therefrom are integrated directly into the drug discovery process, permitting structural data, including screening of fragment libraries, to be routinely and rapidly used on a daily basis as part of pharmaceutical lead discovery and optimization. Here we describe how LRL-CAT acquires and disseminates the results from protein crystallography to maximize their impact on the development of new potential medicines.**

## The challenge

Pharmaceutical and biotechnology companies are currently facing enormous pressure to improve research and development productivity. This pressure reflects rapidly declining revenues due to loss of patent exclusivity and other pricing constraints, and historic lows in the number of annual approvals of new chemical and biological entities [1]. Recent estimates suggest that ~30% of the attrition in drug discovery and development can be attributed to toxicity detected during preclinical animal testing or safety concerns that arise in subsequent human trials [2]. Most failures are thought to result from binding of drug candidates to one or more undesirable off-targets. A further ~30% of the attrition of new clinical candidates results from efficacy failures, when engagement of the target protein is inadequate or fails to produce the desired clinical outcome [2].

Efforts have been under way for more than a decade to make structural biology central to the drug discovery process [3–6]. The goal has been to use structures of proteins (drug targets and off-targets) and protein–ligand complexes to directly and rapidly influence the discovery and optimization of lead compounds and the selection of drug candidates. As the premier method for visualizing the interaction between compound and protein, crystallography can help to minimize off-target effects by guiding medicinal chemistry efforts towards specific and selective interaction with the target. Such an approach to innovation seeks to combine what is now technically feasible in structural biology with what we must accomplish if the industry is to continue to prosper. The challenge, however, is twofold. Traditional crystallography pipelines in pharmaceutical and large biotechnology companies rarely do justice to the speed at which structures of protein–ligand complexes can now be determined. Because of current economic realities within the industry, this situation is unlikely to change. In addition, routine daily access to synchrotron X-ray sources, the most efficient route to high quality data, is uncommon.

## The infrastructure

The past decade has seen dramatic advances in the infrastructure available for structural guidance of drug discovery. Rapid crystallographic data collection from small samples (~10–100 μm for the longest dimension) is now routinely available at an ever-growing number of third-generation synchrotron sources (BioSync: A structural biologist's guide to high energy data collection facilities; http://biosync.sbkb.org/). These sources exploit insertion devices to provide very small, intense and highly directional X-ray beams [7,8]. Unlike in-house laboratory sources, which are limited to X-ray wavelengths corresponding to the $K_\alpha$ emission lines of various metals, synchrotron facilities offer access to a continuous range of X-ray energies. With this flexibility and the relative ease with which we can now prepare samples that substitute Se-methionine for methionine, determination of a new protein structure via measurement of X-ray phases can often be accomplished with just one crystal [9,10]. In 2011, publicly disclosed experimental structures of biological macromolecules exceeded 9200 worldwide (Protein Data Bank, http://www.pdb.org). Approximately 93% of the structures came from X-ray experiments, the overwhelming majority of which (~90%) were performed at synchrotron sources (http://biosync.sbkb.org/). Although deposition of structures to the PDB by industry represents a small fraction of all public disclosures (<10%), most industrial structures are not published. Extrapolating

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from internal efforts, we estimate that industry determines in excess of 10 000 macromolecular structures annually.

X-ray data collection for co-crystal structure determination of protein–ligand complexes has become incredibly efficient. For most complexes, minimal upstream sample preparation time is required to produce modest-sized crystals (~50 μm for the longest dimension). At third-generation synchrotron sources, the time for acquisition of diffraction data is typically no more than 15 min from start to finish. With state-of-the-art detectors, the process is complete within 5 min. The quality and speed advantages of synchrotron sources for this mainstay experiment have long been recognized [11].

## Towards fully-integrated structure-guided drug discovery

At Lilly Research Laboratories (LRL), we are focused on using structure to improve the prospects of discovering molecules that engage the target with minimal binding to other, off-target proteins. Making this happen has entailed improving the odds of success for challenging *de novo* structure determinations and increasing the speed with which we can characterize target–ligand interactions in three dimensions. Using our proprietary LRL-Collaborative Access Team X-ray beamline (LRL-CAT), located at the Advanced Photon Source of Argonne National Laboratory, we have integrated structure determination into the Lilly lead discovery and optimization pipeline by providing co-crystal structure data on the same time scale as routine biochemical assays or biophysical measurements (such as surface plasmon resonance [12]) of compound binding. Our approach seeks to maximize the impact of structural information on the discovery of new drug candidates. Following this model, LRL determined more than 900 structures of proteins and protein–ligand complexes during 2011, including 29 novel discovery targets, two of which were integral membrane proteins.

## The what

Accomplishing this end involved:

1. Minimizing upstream efforts in sample preparation by enabling data collection from the smallest possible crystals that exhibit acceptable diffracting power;
2. Providing near-immediate access to the synchrotron;
3. Sharing information regarding sample provenance between the laboratory creating the sample and the beamline;
4. Streamlining crystal handling and mounting at the beamline;
5. Minimizing the need for redundant data collection from replicate samples;
6. Maximizing the accuracy and diffraction resolution limits of data collected from a given sample; and
7. Automating data reduction and interpretation to deliver protein–ligand co-crystal structure information with minimal, if any, human intervention immediately following data collection.

## The how

Traditional modes of synchrotron utilization are not compatible with a requirement that structural data be available within days of compound synthesis or biochemical assay. Even so-called rapid access mechanisms at synchrotron sources take far too long for the lead discovery and optimization process, which ideally has a cycle time (compound design, chemical synthesis, characterization and molecular redesign) of no more than a few weeks. Figure 1 shows the structural biology process for drug discovery and the location of the compound design cycle within the overall paradigm.

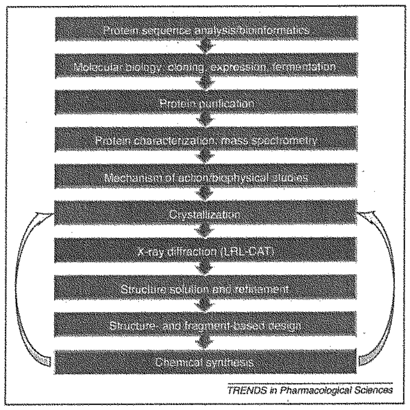
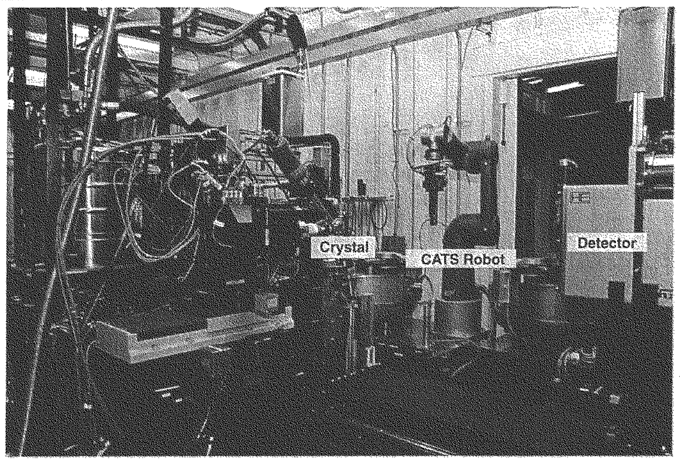



**Figure 1.** The structural biology process within drug discovery. The compound design cycle is applied iteratively to optimize the interaction between ligand and target.

Lilly has addressed this medicinal chemistry imperative by creating a just-in-time system for synchrotron protein crystallography. The LRL-CAT beamline operates without a pre-determined user schedule. Crystals are examined as they come through the door by an experienced full-time staff who operate and maintain the beamline and perform all crystallographic experiments.

In 2011, LRL-CAT evaluated 12 270 crystalline samples for diffraction quality and collected 4282 X-ray datasets. On average, a crystal completes its beamline odyssey in less than 2 days following its creation at a Lilly research site in San Diego or Indianapolis. With the aid of robust information and crystal tracking systems, LRL-CAT routinely manages several hundred samples at any given time. The Lilly Structural Biology Laboratory Information Management System (LIMS) stores all information pertaining to each protein crystal, from the original DNA construct design through protein expression, purification and crystallization to the completed structure. The LIMS system uses Oracle® for the database component, ensuring scalability to meet future needs. Each sample sent to the beamline is identified through a barcode system that includes failsafe redundancy. The barcode provides the link between the physical sample and the LIMS database information.

In addition to the LIMS data management system, the design of the hardware for the facility minimizes the need for




TRENDS in Pharmacological Sciences

**Figure 2.** The crystallography end station at LRL-CAT, showing the crystal position, CATS robot for crystal mounting and CCD detector.

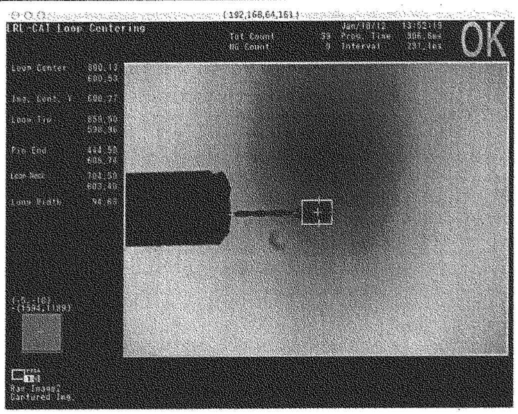
human intervention. LRL-CAT was constructed with commercial and custom robotic hardware and software optimized to fully automate X-ray crystallography (Figure 2). Sample queuing, mounting, centering, crystal quality evaluation, data collection, data reduction and transmission to remote Lilly research facilities are all managed by a single control system. With a high-capacity crystal-handling robot, the system can operate unattended for days at a time.

Sample queuing utilizes LIMS data to prioritize samples for evaluation of crystal quality and data collection. Lilly structural biologists assign a priority to each crystal based on the current status of the drug discovery portfolio and whether the sample is a co-crystal or an attempt at a new protein structure. This priority and the age of the sample are combined with a requirement to minimize the time expended on robotic manipulations to create the experimental queue for crystallographic analysis. The latter requirement recognizes that sequential analysis of crystals that are located near each other in the robot is more efficient. Manual overrides are available for handling special cases when necessary.

Sample mounting is performed by the Cryogenic Automated Transfer System (CATS) robot [13], a commercial system with a customized capacity of 540 crystal samples. The robot contains two storage dewars, each of which can store 27 EMBL/ESRF-type baskets [14]. Unlike the original CATS robot, which used a static configuration, the plate holding the baskets rotates into position for access by the multi-axis robot that transfers the sample onto the goniostat. The robot has a very low failure rate (<0.1%). Most failures are due not to the robot, but to defects in the materials used to mount the crystals, particularly the base on which the crystal is mounted and the plastic cryovial in which it is stored. In virtually all cases, problematic samples can be rescued through operator intervention. Operational errors with the robot are minimized by requiring the use of just one type of base and cryovial, both from a single manufacturer. The robot includes an autofill system for liquid nitrogen. Software prevents the robot from running in the event of a failure of the liquid nitrogen supply. The storage dewars maintain the samples at cryogenic temperatures for more than 12 h after loss of liquid nitrogen. Automatic text messages to the staff ensure that the cryogenics will be restored before loss of samples can occur.

Once a crystal has been placed on the sample stage, a vision recognition system identifies the center of the nylon loop containing the crystal (Figure 3) and places the center of this minute sample stage within the incident X-ray beam. In its current incarnation, the centering process requires 24 s using a single camera. Despite variations in loop size and orientation, the system is highly robust. It correctly places more than 97% of the samples in the X-ray beam without manual intervention. The success of the vision system software relies in part on a strong commitment from the upstream crystallization laboratories to use loops of a size commensurate with that of the crystal.

For each diffraction experiment, whether for crystal quality evaluation or data collection, 14 parameters are needed. These parameters include a crystal identification number, location of the sample within the CATS robot (four parameters), X-ray energy, setting of the undulator insertion device for beam attenuation, specimen-to-detector distance, initial phi angle for the crystal goniostat, number of oscillation images, oscillation range for each frame,




TRENDS in Pharmacological Sciences

**Figure 3.** Automated sample alignment in the X-ray beam. The vision software system identifies several reference points for the sample mount (red and green crosses). The centroid of the sample mount (orange cross) is brought to the position of the X-ray beam.

spacing in phi for successive images (45 minus the oscillation range for screens, 0 for data sets), next frame to be collected and exposure time. The total number of parameters required to control automatic collection throughout the course of a typical day at LRL-CAT is in the thousands. Manual entry of such a volume of data by beamline operators is simply not feasible. Within the LRL-CAT paradigm, the required information is either stored in the LIMS database or can be calculated from entries resident therein. Thus, the mechanics of data collection for several hundred samples at a time can be defined in a matter of seconds by the LRL-CAT staff.

The imperative of rapid delivery of protein–ligand structures to our chemistry design teams (consisting of crystallographers, medicinal and synthetic organic chemists and computational experts) dictates that diffraction experiments focus only on samples likely to yield useful information. After an initial series of diffraction images has been acquired from a crystal, another software system, based on interpretation of output from standard software (d*trek [15] and mosflm [16]), provides a quality score and estimated diffraction resolution limit for each crystalline sample. From October 2005, when the scoring system was first deployed, to the end of 2011, more than 65 000 crystals have been evaluated at LRL-CAT. Scoring results from each of these crystals are permanently resident in the beamline database.

Within the LIMS database, replicate samples are linked as a group. Such linkage permits selection of the crystal within the group that has the highest quality score for subsequent data collection. Only crystals that meet the required minimum quality, reach the requested diffraction resolution and represent the best crystals within a group of duplicate samples, progress to data collection. During measurements, care is taken to optimize data quality through consideration of a crystal's diffraction limit when selecting the specimen-to-detector distance. The X-ray dose is matched to the diffracting power of the crystal to control the number of overloaded reflections. In addition, previous experience on susceptibility to radiation damage is used to adjust the incoming X-ray beam, particularly for anomalous experiments. Empirical data, derived from examination of thousands of crystals, have been used to create algorithms that automatically calculate the exposure time used for each image and the intensity of the X-ray beam. This approach, which contrasts with *ab initio* calculations on acceptable X-ray doses [17], has proven effective.

Once a diffraction measurement is complete, an automatic data reduction system transforms the recorded oscillation images into experimental structure factor amplitudes. Experience has demonstrated that none of the four commonly used programs (xds [18], mosflm [16], d*trek [15] and HKL2000 [19]) successfully indexes and integrates every dataset. LRL-CAT uses the first three of these programs in combination. Following integration, the data reduction pipeline sorts, scales and truncates the data. For well-defined discovery projects, known crystal symmetry and unit cell dimensions are furnished automatically from LIMS to the data reduction system. The scaling results are evaluated by internally developed quality control software, which examines R factors, data multiplicity, completeness and intensity. The resolution of the scaled data is compared to that possible given the X-ray wavelength and sample-to-detector distance to ensure that all relevant data have been collected. Overall, more than 80% of the data sets collected at LRL-CAT reach the desired resolution limit and meet other standards of quality. Samples that do not pass quality control after automatic processing are flagged for individual evaluation by LRL-CAT staff.

The final phase of the crystallographic process at the beamline involves transmission of the experimental structure factors to Lilly scientists in Indianapolis and San Diego. The median time for transmission is <14 min following completion of data collection. For most samples, further automatic processing at these remote locations is then used to convert the structure factors into an experimental electron density map, followed by a refined three-dimensional structure. In the case of protein–ligand co-crystals, the database stores the location of the appropriate model for molecular replacement to be used for each protein target during solution of the structure. For most LRL-CAT co-crystal structures, human intervention first occurs on visual inspection of how the ligand engages the target.

The Lilly system for synchrotron-based crystallography requires the ability to routinely and rapidly execute diffraction experiments, combined with robust information management. Tracking of the pipeline at LRL-CAT involves sifting through large amounts of data, including 55 individual pieces of information per sample. For a full complement of 540 samples in the CATS robot, the total number of database cells queried is ~30 000. Despite the volume of data, LRL-CAT personnel are able to determine the current status of experiments using a single web page. Furthermore, LRL-CAT is able to rapidly disseminate results to scientists at the originating laboratories. The Lilly structural biologists in San Diego and Indianapolis are able to see the images from the initial crystal evaluation within 1 min of completion of the experiment at the Advanced Photon Source.

LRL-CAT supports prodigious throughput. In comparison, Astex determined 54 structures in 80 h using in-house laboratory X-ray sources, robotic hardware and an automatic data reduction system [20].The same set of experiments can currently be done in 9 h at LRL-CAT and on a similar time scale at other synchrotron facilities. The synchrotron offers the added advantage of superior data quality, particularly for small crystals whose diffraction may not even be observed with a home source. Astex also examined approximately 160 crystals and acquired 50 datasets in 20 h at the European Synchrotron Radiation Facility [21]. The advantage at LRL-CAT is access to equivalent productivity throughout the year rather than on an occasional basis (Box 1).

On average, one-third of the crystals examined at LRL-CAT proceed to full data collection. The diffraction data for automatic quality evaluation are acquired in <2.2 min, including sample placement. Full datasets require ~10 min. For both types of experiment, data reduction is performed in the background while the next sample is being analyzed. Today, given the 3:1 ratio between total crystals and datasets collected, LRL-CAT can process (evaluate and, when appropriate, collect) more than 200 crystals in 24 h. Such bandwidth allows Lilly to use crystallography to screen small chemical fragments for binding to target proteins [22]. The core Lilly fragment library, consisting of ~2000 compounds, can be crystallographically screened against a target protein in a matter of days.

The functionality of LRL-CAT has been made available to scientists external to Lilly (http://lrlcat.lilly.com) [23–26]. Samples from academic general users of the Advanced Photon Source and industrial partners are tracked and analyzed using the same systems employed for internal crystals. Data reduction to experimental structure factors is performed after collection for both acceleration of subsequent structure determination and quality control. Direct delivery of the data, including diffraction images, to the external laboratory is accomplished through secure file transfer (sftp). The traditional requirement that samples be available for a prescheduled run at the synchrotron facility is eliminated, thereby providing our external users with data on a just-in-time basis.

**Box 1. BACE**

The automated sample handling, collection and data reduction process at LRL-CAT is optimized for protein–ligand co-crystals. The following example is drawn from our experience with the human β-secretase enzyme (BACE), a potential target for treatment of Alzheimer's disease [40]. In total, we have determined more than 400 co-crystal structures of Lilly compounds bound to BACE. Thus far, two drug candidates have been advanced to clinical trials (www.clinicaltrials.gov). The speed with which we can determine co-crystal structures using LRL-CAT is exemplified by the following typical timeline.

8:03 a.m.: Crystal placement on goniostat begins (LRL-CAT).
8:05 a.m.: Data set collection begins.
8:14 a.m.: Data reduction begins.
8:39 a.m.: Transmission of reduced data to Lilly San Diego.
8:47 a.m.: Molecular replacement begins (San Diego).
9:03 a.m.: Initial molecular replacement complete.
After the initial structure solution has been found, a preliminary electron density map of the active site of the protein is generated (Figure 4a).
9:50 a.m.: Automatic ligand refinement complete.

Further work may be required for structure deposition to the Protein Data Bank (Figure 4b).

## What's next?

### *Minibeams for integral membrane proteins*

Structure-based drug discovery for integral membrane proteins, including G protein-coupled receptors, is fast becoming a reality [27]. Crystals of these challenging targets tend to be quite small (<10 μm for the longest dimension), generally smaller than those produced with soluble proteins. Data quality for these systems can be improved by matching the size of the incident X-ray beam to that of the sample. Decreased beam sizes reduce the background coming from X-rays scattered by parts of the sample mount that do not contain the crystal, thereby improving the signal-to-noise ratio. Smaller beams may also reduce the effect of radiation damage on the data acquired [28]. Several X-ray beamlines have pioneered use of minibeams defined by pinhole collimators (diameter ~1–20 μm) [29,30]. The state of the art is being further refined with the advent of true microfocused beams [31]. These next-generation microbeams concentrate all the available X-rays coming from the synchrotron into a ~1-μm beam, providing advantages similar to mini-beams for even smaller crystals [32].

Integral membrane proteins are often prepared in lipidic cubic phase (LCP) [33], which is optically opaque. Because the crystals cannot be visualized directly, alignment

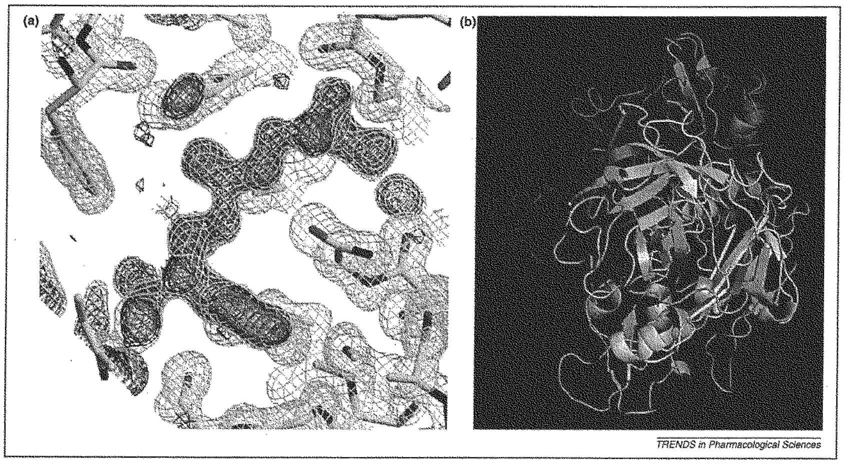



**Figure 4.** **(a)** Automatically generated electron density map of a ligand (blue contour) in the active site of human β-secretase. The atomic stick figure shows the enzyme structure (red, oxygen; blue, nitrogen; yellow, carbon). **(b)** Ribbon drawing of the β-secretase protein–ligand complex. The color in the protein chain follows the standard spectrum (red, N terminus; blue, C terminus).

of the crystals with small X-ray beams (≤10 μm) currently involves rastering across the sample mount to identify the precise location of the crystal [34]. Alternative detection methods such as second-harmonic generation from optically active crystals have been tested at synchrotron facilities, but are not yet routinely available [35]. LRL-CAT recently added a minibeam collimation system to its experimental arsenal. We are currently modifying the vision recognition software to provide guidance for the rastering system. The goal is fully automated positioning of crystals and mounts of all shapes and sizes.

### *Pixel array detectors (PADs)*

PADs have recently been developed for protein crystallography [36,37]. These instruments offer two distinct advantages over the previous generation of detectors based on charge-coupled devices (CCD). First, the time required for detector readout is less than 5 msec compared with ~1 s readout and a total dead time of ~1.8 s for CCDs. Because typical X-ray exposures are of the order of 1 s, PADs can support continuous data collection without the need to open and close the X-ray beam shutter as the crystal begins and completes its rotation on the sample stage [38]. Data collection with a PAD can therefore be completed within 1–3 min instead of the 6–9 min required for CCDs. Second, PADs directly detect incident X-rays as opposed to measuring visible light generated from the X-rays by a phosphorescent film on the face of the CCD. PADs are more sensitive and when the rapid readout is used to fine-slice the measured diffraction, provide data with a superior signal-to-noise ratio. At LRL-CAT, installation of a PAD system would permit complete analysis of more than 345 crystals in 24 h.

PADs and other high-speed detectors will change how crystallography beamlines operate. Instead of initial evaluation of sample quality followed by prioritized data collection, PADs will be used to 'shoot first and ask questions later' (Oral history: Michael Rossman; http://virologyhistory.wustl.edu/rossmann.htm) [39]. Evaluation of crystal quality increasingly will be performed after data collection. The information management burden will increase commensurately, furthering reliance on sophisticated LIMS systems.

## Future X-ray beamline access limitations

During the early to mid 1990s, synchrotron access for protein crystallography was the exception, not the rule as it is today. Worldwide, there are currently more than 130 synchrotron endstations for macromolecular crystallography (http://biosync.sbkb.org). These facilities offer more than sufficient capacity to meet the needs of both academia and industry. However, most such beamlines are funded and often owned and operated by governmental agencies that are now facing or soon will face significant financial pressures. Within the next 5 years, there is a very real possibility that time for macromolecular crystallography at synchrotron beamlines will again become a limited resource. How should our community respond? We can and should become better advocates for our science to governments and taxpayers, emphasizing the potential impact on human health and disease. We should also strive to improve the efficiency with which we use synchrotron X-rays. In principle, worldwide coordination among synchrotron facilities could result in on-demand access to beamlines. This goal remains elusive, even within a single country or geographical area. In the meantime, the LRL-CAT operational model represents the most efficient way to access the advantages offered by synchrotron crystallography.

## Concluding remarks

The benefits that accrue from intensive use of high-resolution structures of protein–ligand complexes in the drug discovery process are clear. At Lilly, structural biology is now used for approximately half of the discovery portfolio. We expect that the impact of synchrotron crystallography will become even more significant as discovery targets become more challenging and the innovation imperative becomes more pressing.

## Acknowledgement

We thank the members of the Lilly structural biology and chemistry design teams for their constructive feedback on LRL-CAT operations. Use of the Advanced Photon Source is supported by the US Department of Energy, Office of Science, Office of Basic Energy Sciences under Contract No. DE-AC02-06CH11357.

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Chairman HARRIS. Thank you very much.

I now recognize Ms. Tichenor for five minutes to present her testimony.

## STATEMENT OF MS. SUZY TICHENOR, DIRECTOR, INDUSTRIAL PARTNERSHIPS PROGRAM, COMPUTING AND COMPUTATIONAL SCIENCES, OAK RIDGE NATIONAL LABORATORY

Ms. TICHENOR. Mr. Chairman, Ranking Member Miller and Members of the Subcommittee, thank you for the opportunity to appear before you today. My name is Suzy Tichenor and I am Director of the High-Performance Computing Partnership Program at Oak Ridge National Laboratory in Oak Ridge, Tennessee. It is an honor to provide this testimony on the role of the Oak Ridge leadership computing user facility and our HPC partnership program in strengthening the U.S. scientific enterprise.

As a DOE lab, Oak Ridge actually manages nine national scientific user facilities including the Oak Ridge Leadership Computing Facility, which I will refer to as OLCF from here on. These distinctive experimental and computational facilities enable research essential to accomplishing DOE missions. In addition, the DOE user facilities are open to all interested and potential users and are allocated on the basis of rigorous merit review of the proposed work. The OLCF is home to one of DOE's most powerful supercomputers for open science research, a Cray XK6 called Jaguar. It is also home to a rare team of some of the most experienced computational scientists in the world. As we like to say, it is the people, and we are very blessed to have some of the very best. This combination of leadership computing systems and world-class expertise gives researchers and opportunity to tackle challenges that are well beyond the capabilities of their internal resources.

In 2009, we established an industrial HPC partnership program to make the OLCF more accessible to industry, and we consider the program to be a triple win. Oak Ridge and DOE benefit from the opportunity to engage with some of the best thinking in corporate America as companies pursue scientific challenges in their quest to develop innovative products and services, and often these science challenges are very complementary to research that is underway at the lab. U.S. industry benefits through the reduction in time to insight and time to solution that it gains from access to the OLCF resources, and as industry, Oak Ridge and DOE advance in their science understanding, they are strengthening the Nation's innovation infrastructure and creating competitive advantage for the country through new discoveries enabled by these partnerships. After only three years, we are seeing very encouraging evidence that our industry program is helping to expand and accelerate U.S. industrial use of large-scale modeling and simulation for competitive gain with real results.

GE Global Research and United Technologies Research are each using Jaguar to tackle different problems relating to more energy-efficient jet engines. A one percent reduction in the specific fuel consumption can save billions of dollars over the life of a fleet of airplanes, so UTRC, for example, is using Jaguar to better understand the air-fuel interaction in combustors, a critical component of aircraft engines, and access to Jaguar enabled UTRC to run simulations that were 64 times larger than what they could do in-house. GE used Jaguar to study for the very first time the unsteady air flows in the blade rows of turbo machines such as the very large-diameter fans that are used in modern jet engines. Unsteady simulations are orders of magnitude more complex than simulations of steady flows, and GE simply was not able to do these on their in-house systems.

But GE realized another benefit from access to our user facility. The insights that they gained from their project at OLCF provided the substantial return on investment justification they needed for significant upgrade to their own HPC capabilities in-house, and they made those upgrades after the project was completed.

Small companies, the backbone of the economy, also benefit from the user facility. Ramgen Power Systems, a small, Seattle-based energy R&D firm, is using our HPC tools and expertise to accelerate the development of a novel compression system for carbon sequestration, and in the process, they have really become the poster child for dramatic advances that a company can make in its own modeling and simulation abilities. When they began their project, they were only able to really use successfully several hundred processors and now they are successfully running ensembles of simulations using over 120,000 processors. This has reduced what used to be months of work and research to a mere eight hours. These are the game-changing advances that companies can achieve and the return on investment that the country receives from this particular user facility.

The industrial HPC partnership program is also providing a gateway for companies to tap into other resources and facilities at the lab that they may not have been aware of if they had not been working with us. For example, one firm that used Jaguar is now expanding its work to include more detailed modeling and simulation of materials with researchers at our center for Nanophase Materials Science user facility and are coupling that with experimental analysis that tapes into the neutron-scattering research capabilities at our Spallation Neutron Source user facility. So this is really very exciting to see a firm integrate the capabilities of multiple user facilities at the lab to tackle much more complex scientific problems.

In summary, by enabling companies to realize the benefits of high-performance computing through access to the OLCF, Oak Ridge is helping companies make progress on important scientific challenges with strategic business implications and, in so doing, is strengthening the Nation's innovation infrastructure for national security and economic strength.

Thank you, and I would be happy to answer any questions.

[The prepared statement of Ms. Tichenor follows:]

# Statement of Suzy Tichenor
## Director, Industrial HPC Partnerships Program
## Computing and Computational Sciences Directorate
## Oak Ridge National Laboratory

**Before the**
**Subcommittee on Energy and Environment**
**Committee on Science, Space, and Technology**
**U.S. House of Representatives**
**June 21, 2012**

## Hearing on Department of Energy User Facilities: Utilizing the Tools of Science to Drive Innovation through Fundamental Research

Mr. Chairman, Ranking Member Miller, and members of the Committee: Thank you for the opportunity to appear before you today. My name is Suzy Tichenor, and I am Director of the Industrial Partnerships Program in the Computing and Computational Sciences Directorate of Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tennessee. It is an honor to provide this testimony on the role of the Industrial Partnerships Program in the U.S. scientific enterprise.

### Introduction

As a U.S. Department of Energy (DOE) laboratory, ORNL manages nine national scientific user facilities, including the world's most powerful accelerator-based source of neutrons for research, the Spallation Neutron Source; one of the world's most powerful research reactors, the High Flux Isotope Reactor; one of five DOE nanoscale science research facilities, the Center for Nanophase Materials Sciences; and one of DOE's two leadership supercomputing centers, the Oak Ridge Leadership Computing Facility (OLCF). These distinctive experimental and computational facilities enable research essential to accomplishing DOE missions. In addition, as DOE user facilities, they are made available for external use to advance scientific and technical knowledge under certain conditions. Specifically, these federally sponsored facilities are open to all interested potential users, but facility resources are allocated on the basis of rigorous merit review of the proposed work. There is no fee for nonproprietary work, but if the results are strictly proprietary, full cost recovery is required. Finally, the facility capability does not compete with an available private sector capability.

By making its facilities available to external users, including U. S. industry, DOE increases the return on the nation's investment in these unique and expensive scientific tools and the experts who know how to apply them to address cutting-edge scientific problems. Because few companies or universities have the resources needed to develop and manage facilities on this scale or to maintain the large, scientifically diverse research staff needed to support them, the design, construction, and operation of user facilities has become a signature of ORNL and other DOE national laboratories.

In fiscal year (FY) 2011 alone, the national user facilities of DOE's Office of Science served more than 26,500 users from government, academia, and industry, representing all 50 states and the District of Columbia. A benchmarking study conducted by the National User Facility Organization found that 47 Fortune 500 companies took advantage of DOE user facilities in 2011 to conduct research supporting the creation of new products including pharmaceuticals, advanced materials for semiconductors and vehicular batteries, telecommunications satellites, and consumer goods.

**Role of the Industrial Partnerships Program in the U.S. Scientific Enterprise**

The OLCF is home to one of the Department of Energy's most powerful supercomputers for open scientific research, a Cray XK6 called Jaguar that can deliver 3.3 petaflops. That's 3.3 thousand trillion calculations per second. Work is now in progress to upgrade this system to 20 petaflops, and by the end of the year we hope to be the world's most powerful supercomputer.

This upgrade has been carefully planned to allow the OLCF to continue meeting the needs of users for leadership science. Jaguar is currently supporting dozens of projects in astrophysics, biology, chemistry, engineering, geosciences, materials science, and nuclear fusion.

The OLCF delivers high-end science not only by fielding HPC systems tailored to provide the best possible performance on scientific applications, but also by building and maintaining teams of applied mathematicians, computer scientists, and experts in the underlying physics to produce the codes that run effectively on these new machines and also drive development of future architectures and algorithms. The combination of leadership systems, forefront computational tools, and world-class expertise available through the OLCF gives researchers an opportunity to tackle challenges that are beyond the capabilities of their in-house systems or other systems elsewhere in the world.

In 2009, ORNL established the Industrial HPC Partnerships Program to enable industry to access the high-performance computing (HPC) tools and expertise at the OLCF. The goal of the program is to enable innovation by helping companies of all sizes, from startups to members of the Fortune 500, to solve strategic, competitively important computational problems that cannot be addressed on their internal HPC systems. After only three years, we see encouraging evidence that the program is helping to expand and accelerate U.S. industrial use of HPC for national competitive gain, with tangible benefits to ORNL and DOE, U.S. industry, and the nation.

ORNL and DOE benefit from the opportunity to engage with some of the best thinking in corporate America as companies pursue complex scientific challenges in their quest to develop innovative products and services. Working directly with these companies also provides ORNL and DOE with valuable insights into industry needs, not only for specific innovations but also for HPC resources. U.S. industry benefits through the reduction in time-to-insight and time-to-solution that it gains through access to the leadership-class HPC systems, open software, and computational and scientific expertise available only through OLCF. And as industry, ORNL, and DOE advance in their scientific understanding, they are strengthening the nation's innovation infrastructure and creating competitive advantage for the country through new discoveries enabled by these partnerships.

**Driving New and Improved, Energy-Efficient Industrial Applications**

The cost and availability of energy, coupled with heightened environmental concerns, are causing companies to reexamine the design of products from large jet engines and industrial turbines to automotive engines to everyday household products like shampoos and detergents that rely on petroleum-based ingredients and require large quantities of water to manufacture. Their customers and the country are demanding products that have lower energy requirements and reduced environmental impact. Many of the scientific challenges that companies must address to meet these demands complement and intersect important research that Oak Ridge is pursuing to meet DOE mission requirements.

The aerospace industry is striving to develop quieter, more energy efficient jet engines. The automotive industry is working to deliver vehicles with improved fuel economy and lower emissions by developing new engine designs, new catalysts, and lower-cost batteries for hybrid and all-electric vehicles. The nuclear power industry is facing demands to operate today's nuclear power plants beyond their original design lifetimes while developing and deploying new advanced nuclear energy systems, driving demand for computational tools to enhance safety and reduce the need for experimental testing of new materials and fuels. The complexity of these design and analysis problems, coupled with the need for nearer term results, often requires access to computing capabilities that are far more advanced than those available in corporate computing centers. The OLCF is helping to address this gap by providing access to leadership systems and experts not available within the private sector.

For example:

GE Global Research and United Technologies Research Center (UTRC) are each using Jaguar to tackle different problems related to jet engine efficiency. The impact of even a small change is enormous. A 1% reduction in specific fuel consumption can save $20B over the life of a fleet of airplanes (20,000 engines × 20-year life).

UTRC is using Jaguar to better understand the air-fuel interaction in combustors, a critical component of aircraft engines. Spray formation and evaporation of liquid fuel play a key role in the performance, stability, and emissions of aeroengine combustors. Experimental limitations in characterizing this process make simulation an important analysis alternative. Access to Jaguar enabled UTRC researchers to run simulations that were 64 times larger than those they could run on their in-house systems. Accurate computational prediction of spray distribution is critical for the design of next-generation fuel injectors and more efficient combustors to reduce the emissions, lower the noise, and enhance the fuel efficiency of aircraft engines.

Access to OLCF and the Jaguar supercomputer allowed GE to study, for the first time, unsteady flows in the blade rows of turbomachines, such as the large-diameter fans used in modern jet engines. Unsteady simulations are orders of magnitude more complex than simulations of steady flows, and GE was not able to attempt this on its in-house systems. GE engineers also ran their largest-ever computational fluid dynamics simulation on Jaguar.

In addition to making progress on an important scientific challenge with strategic business implications, GE also realized two other very important benefits from access to the OLCF.

- First, the insights that GE gained from its project at OLCF provided substantial return-on-investment justification for a significant upgrade in GE's in-house HPC capabilities.
- Second, access to Jaguar enabled GE to dramatically increase the scalability of important in-house software, something it could not do without access to a much larger HPC system than it had in house. That software now runs on GE's new, larger high-performance computer, enabling the company to tackle more difficult problems than it could previously.

But large companies are not the only ones that benefit from access to large-scale computers, Small companies, the backbone of the economy, also have complex and competitively important problems that they can't resolve on their in-house systems.

Ramgen Power Systems, a small, Seattle-based energy R&D firm, is using the HPC tools and expertise at OLCF to accelerate the development of a novel compression system for carbon sequestration. Ramgen has modified the conventional "build and test" development process by using large-scale modeling and simulation with Jaguar to optimize the technology performance. Anticipated testing of prototypes this summer is being guided by simulations at the OLCF.

Ramgen is a "poster child" for the dramatic advances a company can achieve in its modeling and simulation abilities when it has access to OLCF. When Ramgen began their project 2 years ago, they were only able to use several hundred compute processors. With the expertise and computing power of the OLCF, they now are successfully running ensembles of simulations using over 120,000 processors. This reduced what used to be months of work to a mere 8 hours. These are the game-changing advances that companies can achieve and the return on investment that the country receives through this user facility.

These are just a few examples of the cutting-edge scientific work that companies are pursuing at OLCF. Other firms that have used this user facility include Boeing, Ford, General Motors, semiconductor manufacturer Global Foundries, Procter & Gamble, and Smart Truck Systems, a small South Carolina firm that developed award-winning add-on parts for long-haul 18 wheeler trucks to greatly improve their fuel efficiency

The participation of Westinghouse, the Electric Power Research Institute (EPRI), and the Tennessee Valley Authority in DOE's first Energy Innovation Hub, the Consortium for Advanced Simulation of Light Water Reactors (CASL), also offers an interesting example of industry engagement in HPC. CASL is using HPC, including the resources of the OLCF, to address key nuclear industry goals, spanning the gamut from basic research through engineering development to commercialization. For example, Jaguar is enabling high-fidelity calculations of radiation transport in next-generation reactors. The embedding of industry partners assures relevance and focus for CASL's development of advanced modeling and simulation methods and investigation of new fuel designs.

**Prioritization of ORNL's Computing and Computational Sciences Activities**

The models developed for management of DOE's scientific user facilities have worked well in making these facilities available for external use to advance scientific and technical knowledge. These facilities typically receive far more proposals for access than can be accommodated, testifying to their broad utility for addressing scientific challenges. The peer-review processes used to select the proposals ensure that these unique tools are applied to the most compelling research problems.

For the OLCF, peer-review processes focus not only on the potential scientific and technical impact of the proposed work, but also on the need for leadership-class computing resources. In addition, the multiple allocation models established for the OLCF are making it possible for companies to engage at different levels depending on their needs.

ORNL's activities in computing and computational sciences will continue to be closely aligned with DOE priorities for sustaining a vibrant science and engineering enterprise, transforming the nation's energy systems, and enhancing national security. In addressing these priorities, ORNL will continue to work closely with industry to achieve its missions and to deliver practical solutions to problems of national importance.

**Strategic Direction of the Industrial Partnerships Program**

The Industrial HPC Partnerships Program is also providing a gateway for companies to tap into other resources at ORNL that they may not have been aware of had they not been working with OLCF. This offers unique opportunities to integrate computational modeling and experimental validation in much larger scale problems for much greater accuracy and insight, and to do so in an integrated environment. For example, one firm that has made important progress using Jaguar at OLCF is expanding its work to include more detailed modeling and simulation analyses with researchers at the Center for Nanophase Materials Sciences, coupled with experimental analyses that tap into the neutron scattering research capabilities at the Spallation Neutron Source.

By enabling companies to realize the benefits of HPC, the Industrial HPC Partnerships Program at ORNL is helping to strengthen the nation's capacity to address "grand challenges" in clean energy and national, homeland, and global security. And as DOE develops new mechanisms to make it easier for industry to collaborate with the national laboratories, the program will take advantage of these mechanisms to sustain and scale its partnerships with industry.

## Suzy Tichenor

**Director, Industrial Partnerships Program**
**Computing and Computational Sciences Directorate**
**Oak Ridge National Laboratory**

Suzy Tichenor is Director of the Industrial Partnerships Program of the Computing and Computational Sciences Directorate at Oak Ridge National Laboratory, the largest science and energy laboratory of the U.S. Department of Energy (DOE). This program provides companies with access to the Laboratory's two leadership-class high-performance computing (HPC) user facilities—DOE's Oak Ridge Leadership Computing Facility and the National Science Foundation's National Institute for Computational Sciences—and to the resources and expertise of the Directorate.

Ms. Tichenor has more than 20 years of experience in creating partnerships and programs at all levels of the government, private sector, and not-for-profit organizations. Prior to joining ORNL, she was Vice President of the Council on Competitiveness and directed the Council's High Performance Computing Initiative. There she served as the Principal Investigator for HPC-related grants from DOE's Office of Science, the National Nuclear Security Administration, NSF, and the Defense Advanced Research Projects Agency (DARPA). Previously she held senior positions at Cray Research, a start-up health care firm, and a national non-profit organization.

Chairman HARRIS. Thank you.

I now recognize our final witness, Dr. Hall, for five minutes to present his testimony.

**STATEMENT OF DR. ERNEST HALL, CHIEF SCIENTIST, CHEMISTRY AND CHEMICAL ENGINEERING/MATERIALS CHARACTERIZATION, GE GLOBAL RESEARCH**

Mr. HALL. Chairman Harris, Ranking Member Miller, Congressman Tonko and Members of the Committee, I am pleased to share with you General Electric's perspective on how the Department of Energy programs and processes can be strengthened to better serve the needs of industrial partners and the demands of the energy marketplace. I commend the Committee for focusing on a topic that has far-reaching implications for ensuring the future competitiveness and growth of our Nation's economy.

As you have heard, I represent GE Global Research in upstate New York, where we have 2,000 research employees working every day to develop and deliver critical technologies to our businesses. We support a global company with interests that span several industries from energy, aviation and transportation to water, health care and finance.

Today, America's companies are facing increasing global competition and environments that require us to innovate differently. With materials in shorter supply, manufacturing becoming more complex, and pressure rising to get new products to market faster, it is clear that a strong commitment to innovation and the ability to rapidly commercialize new technology will be a key factor in who succeeds.

Fortunately for the United States, our innovation remains the world's best. We have a wealth of world-class universities, federally funded research and development centers, and industrial research labs producing great technology. To fulfill the promise of these investments in these institutions, we must update our innovation model by increasing collaborations across this network, working more in parallel between the domains of design innovation, manufacturing innovation and materials innovation, and making sure science and technology objectives are in concert with industrial needs.

Our work with various DOE scientific user facilities serves as a good example of these collaborative models. The Basic Energy Sciences facility for synchrotron, neutron and electron studies of the structure and chemistry of materials provides a compelling illustration.

Later this summer, GE will open its new $100 million high-tech battery business in Schenectady, New York, creating 350 manufacturing jobs at full capacity.

One of the key technical challenges in developing our battery was improved fundamental understanding of the battery chemistry. At the National Synchrotron Light Source at Brookhaven National Lab, GE scientists were able to work with scientists from Rutgers and Brookhaven to measure the chemical processes on full operating commercial battery cells. This synchrotron provided access to the most advanced characterization capabilities that no one institution, university or industry could afford to construct or fully utilize. It allowed us to gain a greater understanding of our battery's materials and systems than we could using our own instrumentation inhouse and shows what can result when you match the world-class research capabilities of these facilities and our universities with an industry need.

In my written testimony, I cite other examples including work at Argonne National Lab and other BES facilities where we are working on 3D microscopy techniques to improve the materials of aircraft engines and gas turbines and conducting fundamental studies on photovoltaic devices.

As you have heard, another truly great asset America has is our network of high-performance computing resources at the national labs. As in many other industries, computational modeling and simulation plays a critical role in addressing many of the research problems we face at GE. The ability to carry out experiments in a faster, more robust way, high-performance computing provides an invaluable tool in accelerating innovation, leading to new product development, particularly in the energy sector.

You have heard about the work that we have been doing with GE's newest cutting-edge aircraft engine, the GEnx, powering Boeing's new 787 Dreamliner and incorporating capabilities that were enabled through high-performance computing. We believe, as Ms. Tichenor said, that another one to two percent in fuel reduction in fuel consumption can be achieved, which would translate into hundreds of millions of dollars in annual fuel savings to the aviation industry, increasing the competitive posture of U.S. manufactured aircraft engines and retaining more jobs in our U.S.-based aircraft engine factories, achieving those reductions through high-performance computing.

We have also recently been selected by Lawrence Livermore National Lab to participate in an incubator program, hpc4energy, which will focus on next-generation fuel injectors, and we also have ongoing programs with Argonne and Oak Ridge national labs in advanced turbo machinery design.

I hope these brief examples illustrate the great value of DOE's scientific user facilities.

I would like to conclude, very briefly, with a few recommendations on how DOE programs and facilities could be strengthened and made more effective. We encourage continued investment in major scientific user facilities and in particular funding to staff and optimally operate and utilize these very complex facilities. U.S. industry and scientists would be at a clear disadvantage with respect to their global counterparts without access to these cutting-edge capabilities. Most important, policies need to be enacted that expand industrial access to these facilities.

Second, DOE lab and user facility investment need to be prioritized to focus on the key challenges associated with energy technologies from basic science through applied research leading to scale and commercialization.

Finally, we need new collaborative models that allow different stakeholders—government, university and large and small companies—to come together and advance science and technology programs in new ways. In our written testimony, we point to the SEMATECH model, which brought together many parties within the semiconductor industry to help reestablish American leadership in this area of technology.

Chairman Harris, I want to thank you again for the opportunity for GE to testify. It is an important and timely conversation as we look to ways to enhance America's future economic competitiveness and capacity for new growth and jobs.

[The prepared statement of Mr. Hall follows:]

Statement of:

Ernest L. Hall
Chief Scientist
GE Global Research

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

**Introduction**

Chairman Harris, Ranking Member Miller and members of the Committee, I am pleased to share with you General Electric's perspective on how Department of Energy's (DOE) programs and processes can be strengthened to better serve the needs of industrial partners and demands of the energy marketplace. Further, I will address the effect that partnerships with DOE and the use of DOE user facilities drive innovation all the way through to the marketplace. I want to commend the Committee for focusing on a topic that has far reaching implications for ensuring the future competitiveness and growth of our nation's economy.

I am Ernie Hall, a Chief Scientist in the Chemistry, Chemical Engineering and Materials Characterization Domain at GE Global Research, GE's centralized research and development organization. We have the proud distinction of being America's first industrial research lab, with a legacy of innovation dating back to our founder, Thomas Edison, in the late 1800s. Since that time, GE scientists and engineers have been at the center of major innovations that have transformed the way people live: lights and appliances in every home; the dawn of radio and TV broadcasting; jet engines that enabled modern commercial and military aircraft; medical imaging systems that transformed health care; and power generators, transformers and transmission lines that built the modern electrical grid to power it all.

Today, GE is a global company with business operations in more than 100 countries around the world. Our interests span several industries, ranging from energy, aviation and transportation to water, healthcare and finance, and we have more than 300,000 employees working every day to develop and commercialize breakthrough products and technologies that are helping to promote a cleaner, more sustainable future.

At our Research headquarters in Upstate New York, GE has 2,000 of the best and brightest technologists representing every scientific and engineering discipline. Our mission today is the same as it was when our Lab was founded – to drive innovations that create new or better GE products that meet the needs of our customers and society.

**Increasing global competition by updating innovation approach – Improving programs and processes**

Today, American companies face an increasingly competitive global environment that requires us to innovate differently. With materials in shorter supply, manufacturing becoming more complex and pressure rising to get new products to market faster, it's clear that a strong commitment to innovation and the ability to rapidly commercialize new technology will be a key factor in who succeeds.

Fortunately for the U.S., our innovation network is strong and remains the world's best. We have a wealth of world-class universities, Federally Funded Research & Development Centers, and industrial research labs producing great technology. To fulfill the promise of our investments in these institutions, we must update our innovation model by increasing the collaboration across this network and by working more in parallel between the domains of design innovation, manufacturing innovation, and materials innovation. Adopting these changes in the context of industrial needs and a concerted effort to increase the breadth and depth of our technical talent pipeline will create tangible commercial opportunities that create jobs and grow America's manufacturing base.

**DOE partnerships and user facilities - making a difference**

To a great extent, GE's experience in partnering with DOE and leveraging their user facilities has provided a good roadmap for how federal agencies can help companies drive technological innovation and gain a competitive advantage in the global marketplace. I would like to discuss a few specific examples where collaborations with DOE have supported GE's manufacturing and job growth right here in America. First, DOE Basic Energy Sciences (BES) Scientific User Facilities (SUF) for synchrotron (x-ray), neutron, and electron studies of the structure and chemistry of materials.

Later this summer, GE will open its new $100 million high-tech Battery business in Schenectady, NY. With more than 250 hires already on board, the new plant will create 350 manufacturing jobs at full capacity. The new sodium battery (NaMx) being produced was developed at GE's Global Research Center in Niskayuna, just miles from where the new plant is located.

One of the key technical challenges in developing the battery was improved fundamental understanding of the battery chemistry. Sodium technology has been around for several decades. But to make the product GE envisioned, we recognized that improvements in the chemistry would be essential. This is where the DOE's BES Scientific User Facilities played an important role.

At the National Synchrotron Light Source at Brookhaven National Lab, GE scientists were able to work with scientists from Rutgers and Brookhaven to allow for observation of the chemical processes that occurred during the charge/discharge process of full-size commercial cells of GE's new NaMx batteries. These experiments provided unprecedented insight into the basic battery chemistry, which supported further developments that helped us ready this technology for the marketplace.

In this example, the use of BES Scientific User Facilities provided access to the most advanced capabilities that no one institution (university or industry) could afford to construct or utilize fully. They provided us with much greater capabilities – for example, higher energy, higher resolution, and higher throughput – for understanding materials and systems than instrumentation in our own research laboratories. More importantly, it shows what can result when you pair the world-class research capabilities of these facilities and our universities with an industry need. It not only has resulted in new manufacturing growth and hundreds of new jobs, GE's new sodium battery represents a new energy storage solution that will help address some of our most pressing energy challenges.

The battery example also shows how university, DOE staff and industrial scientists can combine their research strengths achieving non-linear results that steer new technological innovations to market. In this case, university and DOE staff scientists developed the unique tools and techniques for advanced materials characterization that industrial scientists were able to use to support their product development efforts.

In addition to GE's work with National Synchrotron Light Source at Brookhaven National Lab, I can cite other examples as well. We are currently working with scientists from Carnegie-Mellon University and Argonne National Lab to develop 3-D x-ray microscopy techniques that will allow us to more completely understand how engineering materials behave and will have impact on increasing the efficiency and reliability of GE's aircraft engines and turbines. Also, we have started to work with the Bay Area Photovoltaic Consortium (BAPVC), funded within the DOE SunShot Initiative, to get access to tools for fundamental studies on CdTe photovoltaic devices, aimed at improving efficiency and performance of our PV product. The Solar industry right now is extremely competitive, and it is clear that the development of new technologies will be essential for any company looking to succeed in this space.

Additionally, we are making strain distribution measurements on Ni-base superalloys and coating systems for engine and turbine components to better understand crack initiation and failure mechanisms, using the Advanced Photon Source and algorithms and software developed at universities and DOE labs.

**DOE High Performance Computing (HPC) resources key to driving Innovation**

Another truly great asset America has is our network of HPC resources at the National Labs. They provide an invaluable tool in accelerating new technology and product developments, particularly in the energy sector. I would like to discuss a few examples where the use of high performance computing has enabled GE to accelerate important product developments in the energy and aviation sectors.

As in many other industries, computational modeling and simulation plays a critical role in addressing many of the research problems we face at GE. This is especially true when you are developing complex machinery such as a 300+ megawatt gas turbine at the core of an industrial power plant or aircraft engines with enough thrust to power the latest commercial and military aircraft.

Historically, GE has used commercial off-the-shelf computing clusters to perform modeling and simulation for these types of applications. Typically, the codes we use run on tens or hundreds of processors, which can take from a few hours to as long as a few weeks to run. With this type of capability we are able to optimize the design of individual components, but do not have enough computational horsepower to optimize even subsystem designs of our products.

Access to high-performance computing provides a virtual infrastructure to carry out these experiments in a faster, more robust way, moving from optimizing single components to optimizing whole systems. This, in turn, can help to greatly accelerate our introduction of new, cleaner energy products.

Recently we have been collaborating with the U.S. Department of Energy's National Labs, leveraging their knowledge and resources to tackle some very important problems in the energy field. We have ongoing programs with Argonne and Oak Ridge National Labs related to advanced turbomachinery design.

GE's newest, cutting-edge, aircraft engine, the GEnx, which is one of the engines powering Boeing's new 787 Dreamliner, incorporates advanced capabilities that were enabled through high-performance computing modeling and simulation. With continued access to these resources we are confident we can do even more to improve its performance.

The GEnx has a six-stage low-pressure turbine, the design of which demanded modeling and simulation exercises of extreme complexity. We believe that we can achieve another 1%-2% reduction in fuel consumption by doing an even more detailed analysis of all six stages of the turbine simultaneously. This level of analysis hasn't been possible until the advent of the today's latest generation of super computers. A 1%-2% improvement in engine fuel efficiency translates to hundreds of millions of dollars in annual fuel savings to the aviation industry, increases the competitive posture of US manufactured aircraft engines, and importantly, retains more jobs in our US-based aircraft engine factories.

To support this advanced research on the GEnx, we are utilizing Oak Ridge National Labs Jaguar supercomputer to help us better understand airflow dynamic that can in turn, improve the fuel efficiency of the design.

More recently, we have been selected by Lawrence Livermore National Laboratory (LLNL) to participate in an incubator program, "hpc4energy," which will use high-performance computing (HPC) in an effort to accelerate development of next-generation fuel injectors for GE's engine fleet. Global Research will collaborate with Arizona State University (ASU) and Cornell University on this project.

As part of the project, GE will have six months of dedicated access to a portion of the Sierra supercomputer - one of the most powerful in the world – to study the physics behind the working of the fuel injector to optimize its design. This could yield new insights that only the power of supercomputing can help capture and ultimately, accelerate our research timeline for delivering this new technology to the marketplace. Aircraft fuel injectors are being studied in this trial, but successful testing of this computer simulation methodology could yield new insights that benefit other GE products, including the fuel injectors used in locomotives and land-based gas turbines. The methodology could even potentially be applied to study nebulizers for aerosol delivery.

**Recommendations**

Earlier in my testimony, I discussed the need for a new innovation approach that will strengthen America's ability to compete in a global economic landscape. I would like to discuss in more detail of what we mean and in the process, provide some recommendations for the Committee to consider. Essentially, we believe the US innovation model has to evolve in three significant ways.

1. **Innovation needs to be prioritized to meet industry's needs** – The example of GE's new high-tech Battery plant is a great example of how an industry need shaped the program focus around technology developments that supported product development. More importantly, it highlighted a successful way that university, DOE staff and industrial scientists can work effectively together to direct innovation into the marketplace.

   With respect to the DOE BES SUFs specifically, we should encourage continued growth in programs that allow for more university/ government lab/ industry partnerships structured in this way. And with regard to US competitiveness, it is certainly clear that we would be at a significant disadvantage with respect to material research if we did not have access to these "big science" facilities. Other parts of the developed world (Europe, Asia) have made major investments in similar scientific user facilities, and many have policies that make them more accessible to industry. I have seen great improvement in the attitude of DOE BES toward industry over the past 5 years, but we need to continue to push for a more use-base science focus.

   DOE BES has facilitated a number of effective workshops over the past few years to explore how the basic research of BES can best help the development of US technology in energy. One specific example was the "Science for Energy Technology" workshop in 2010 that I attended along with several other GE researchers. The workshop developed a series of Priority Research Directions (PRD) for a number of renewable technologies which reflected the key scientific challenges that BES could help address. This was a great start, but there needs to be more mechanisms for continuing industrial engagement and communication of technical progress on the PRDs.

2. **Commit and focus resources -** More resources need to be directed to use-based research to ensure that innovation is more directly tied to a business outcome. As mentioned, this worked well when GE partnered with National Synchrotron Light Source at Brookhaven National Lab because the research activities were tied to an industry effort to develop and commercialize new technology. This also has worked well when the National Labs provide industry access to their supercomputing resources to conduct important research that can accelerate their ability to develop and deploy new technology. The current program GE Global Research has with the Livermore National Lab is a great example. The time we have been allotted on their supercomputer through the "hpc4energy" program could greatly accelerate our efforts to develop and commercialize new fuel injector technology for jet engines.

   Going forward, we would like to see more programs like the "hpc4 energy" program that encourage industry engagement with the National Labs and American universities. For example, promoting industry participation in DOE's INCITE and ALCC programs are two areas this could be achieved.

   A final observation on this recommendation relates again on the DOE BES SUFs, which I can make based on my role on the various DOE BES advisory committees. First, it is clear that the US needs to invest in the construction and upgrade of the Scientific User Facilities, and DOE has a good record here. The most recent example is the $1 billion construction of the new National Synchrotron Light Source II at Brookhaven. However, it is also important that DOE receives sufficient funding for the maintenance, operation, and optimum use of these facilities. In my experience, this is the area of greatest need at the present time.

3. **Create structured partnerships –** To allow small and medium- sized businesses to rise and to accelerate new innovations that directly support economic growth and new jobs; we need to

encourage more structured partnerships that allow different stakeholders to come together and collaborate in a way where everyone can benefit. The establishment of SEMATECH by the U.S. semiconductor industry in response to increasing competition from Japan is a great model to pattern these ecosystems after.

In the late 1980s, the U.S. semiconductor industry responded to industry's rise in Japan's by forming a government and industry consortia for basic and applied research. This association, SEMATECH, is an ecosystem of private and public players in the broader semiconductor community (device makers, universities, governments, national laboratories, and the entire industry supply chain).

Together, they worked to successfully to re-establish U.S. leadership in the semiconductor industry space. It was a model that initially was government enabled through both funding and policy changes. But in less than a decade, it became a self-sustaining system driven principally by private resources. The SEMATECH Board of Directors voted to seek an end to matching federal funding after 1996, reasoning that the industry had returned to health and should no longer receive government support.

As they mark their 25th anniversary this year, the semiconductor industry is growing and thriving in the US today. We believe that much like the semiconductor brought together big and small players together to re-establish their leadership, American companies can benefit from this type of research model that encourages more industry-focused innovation.

**Conclusion**

Chairman Harris, I want to thank you again for the opportunity for GE to comment on how DOE programs and processes can be strengthened to better serve the needs of private industry in the energy sector. Facing an increasing competitive global environment, this is an important conversation to have as we look to for ways to enhance America's future economic competitiveness and capacity for new growth and jobs.

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Chairman HARRIS. Thank you very much. I want to thank the witnesses for being available for questioning today, reminding Members the Committee rules limit questioning to five minutes. I will open the round of questions, and I am first going to recognize the gentleman from California, Mr. Rohrabacher, for five minutes.

Mr. ROHRABACHER. Thank you very much, Mr. Chairman, and let me compliment the panel. You crammed so much information into so little time. You must have had some computers helping you out to develop that strategy because it was just amazing.

Let me just touch on some points here. We are going through this period of time in Washington, D.C., where we have got this budget deficit hanging over our head. All right. It is hanging there, and there was a quote from some New York politician who said the sword of Damocles is hanging right over Pandora's Box or something like that. We have got a major challenge before us. How can we actually—and you very well explained the value of what your facilities provide this country and provide the world in terms of scientific exploration and development of new ideas, making them real. What percentage of that work that is done is done on scientific research specifically for the DOE and how much is done with private-sector groups and is there a way—and who then owns the actual intellectual property that is being developed by this great investment? Is there a way that we can in some way tap into that as a means to help finance your operations? All the way down, whoever is the most expert on that.

Dr. LANZIROTTI. One of the things that is often underappreciated for many of the Office of Science facilities is that access to the facilities is done through a peer-review process. In fact, it is varied by the different facilities but, you know, from what we have done in terms of looking at metrics for the industrial community utilization is seven percent, 10 percent. The vast majority is actually from the research university community done through peer review, you know, from different organizations. So the benefit is really in terms of the research that they do, the fundamental research. You know, the industry users take that information and make it more into an applied research component, and it is that access to the facilities that we can't get in terms of what we do at our home institutions that lets us produce, you know, the fundamental science for the country.

Mr. ROHRABACHER. Well, take the engines, the jet engines we were talking about. It was a good point. If we can make these jet engines with the equipment that we have one percent more efficient, we have saved hundreds of millions of dollars for somebody. Is that possible? Number one, do Boeing and these companies, how much do they pay, and should they then if they achieve something, should you—how much of that is owned by your research facilities and by your institutions, by the government?

Dr. HALL. So I would just make the point that our use of the scientific user facilities is part of a very large technology development program that is taking place in-house in which, for example, GE is investing millions, in some cases billions, of dollars to bring a technology to marketplace, particularly a technology as complicated as a new aircraft engine platform, a new engine. And so that is our investment, our stake in this. As part of that development, we will use the national user facilities in a non-proprietary way doing research that is open to the world to see and to benefit from, and we will use those results as part of our technology development.

Mr. ROHRABACHER. Is that paid for? Is there a fee involved to this facility to the Federal Government?

Dr. HALL. The vast amount of what we do is actually done open through the proposal process and so it is non-proprietary, publishable research. There is a fee structure for any proprietary research, for any research we want to do where we do not want to reveal the results of those.

Mr. ROHRABACHER. So you only pay for that you are going to fence off, but there is no fee just to go in and utilize the facility?

Dr. HALL. With the caveat that we need to pass the usual scientific quality screens. This is done——

Mr. ROHRABACHER. Oh, yeah, sure. I understand that.

Well, thank you very much, Mr. Chairman.

Chairman HARRIS. Thank you very much.

I now recognize the Ranking Member, Mr. Miller, for five minutes.

Mr. MILLER. Thank you, Mr. Chairman.

Dr. Hall, we do hear a lot about government picking winners and losers in this Committee, crowding out private investment, particularly in energy, by sponsoring applied research and later stage, any kind of later stage activity. But is there really that little space to invest that what the government does is going to crowd out private investment? And what does it really take to pick a winner? Could you give us an example showing the steps that have to go, that really go into moving an idea from research to the marketplace and how much investment is involved?

Dr. HALL. Well, I can speak to my experience, and that is that today's technologies are incredibly complex and very difficult to move from the area of idea through discovery, feasibility, pre-product, product and finally into the marketplace. In my testimony, I talked a lot about the need for collaboration across university and government lab and industry in order to accelerate those innovations and enhance America's competitiveness. The investments that the Department of Energy make in technologies are at the—in the area of discovery and initial feasibility, and these are extremely useful to explore very high risk but potentially very high reward concepts.

Further, there is, as you know, great difficulty in that area of funding that moves beyond feasibility into, you know, building a plant, perhaps a many-hundred-dollar plant in order to produce a technology. And so broad partnerships such as the SEMATECH model, I think, are very important in order to accelerate this technology development and make America most competitive in this rapidly changing world.

Mr. MILLER. And how do our efforts compare with what our competitors in Europe and Asia are doing to accelerate technologies? Dr. Hall again, yes.

Dr. HALL. Well, if we look specifically at the scientific user facilities, we know that for other parts of the world such as the E.U. and Asia and even Canada, their scientific user facilities are much more aggressive in seeking industrial users with the encouragement of their governments. We see that in many cases targets such as 20 percent of the utilization of the scientific user facilities by industry are set where in the United States—and perhaps other members of the panel have more information on that. My understanding is the numbers are around five to seven percent.

But it is important to understand that in addition to simply setting targets, one needs to put in the structures and policies that make the use of the scientific user facilities and the government labs more inviting to industry. One needs to have these facilities fully staffed. One needs to have the policies to provide particular help for small businesses, for example. One needs to continue to do the outreach and education about what our government labs can bring to private industry in order to enhance their technology development. It is our observation, I think, that other parts of the world, the governments realize clearly that they need to assist their industry in order to be globally competitive and we see this in many cases.

Mr. MILLER. We do—there is a debate within this Committee and within Congress on the distinction between applied versus basic research, and curiously, it seems to justify lavish funding for nuclear and fossil fuel research, which appear to be mature industries that are already well funded, and to justify cutting research for vulnerable new technologies, emerging technologies. How would you define applied versus—Dr. Hall again—applied versus basic research and how useful is that distinction?

Dr. HALL. In my world, that is not a distinction that we use very much. We think about, you know, going from idea to feasibility to sort of pre-product demonstration to product development to commercialization, and where you make that distinction between basic and applied is difficult to see. At my lab at Global Research, we are primarily working in the discovery part, which you might call basic research, but what we always have is an eye on how do we commercialize this, how do we pull in the ideas of manufacturing and design and materials availability into the process even at the discovery phase. So technology development these days is, I think, much more complicated than just a simple description of basic and applied.

Mr. MILLER. My time has expired.

Chairman HARRIS. Thank you very much.

I would like to remind the Members, we would like to limit it to five minutes. We have a very long series of votes coming up on the Floor, and I would like to complete the hearing and adjourn before we leave for the votes. So again, just reminding the Members, try to keep the questions to five minutes.

I recognize the gentleman from Texas, Mr. Neugebauer, for five minutes.

Mr. NEUGEBAUER. Thank you, Chairman, and thank you for calling this hearing.

I want to kind of go back with the line of questioning that Mr. Rohrabacher was talking about, and I think all of us are trying to figure out with the limited resources that we are going to have if we are going to leave any kind of future for our children and grandchildren, we are going to have to look at prioritizing the way we spend the American taxpayers' hard-earned money, and I think, Dr. Lanzirotti, you said that only 12 percent of the research going on at the laboratories is really applied research, and I guess that would mean that 88 percent of it is then fundamental research. Is that correct?

Dr. LANZIROTTI. More specifically, I think when we look across the user facilities that at least we represent that those would be classified as industrial researchers, people that come from industry tends to average around seven percent, 10 percent. It really depends on the type of facility. Computing facilities, for example, may attract more industrial users than light sources, for example. But it does mean that the vast majority of the researchers in many of the facilities that we see are from research universities, from other laboratories, but much of the research they do may be fundamental or what you call basic research but they are also doing applied research at the university level as well.

At the Advanced Photon Source, for example, we talked a little bit today about some of the work that we are doing in drug discovery through macromolecular crystallography. Many of the consortia that we see at the Advanced Photon Source are university laboratories that are doing, you know, drug discovery and looking at macromolecular crystals for next-generation drugs. So you can classify that as applied science but it comes from the university environment.

Mr. NEUGEBAUER. So here is a follow-up question then. If GE, for example, Dr. Hall said, you know, when they go in and they are going to do non-proprietary research, they don't pay any user fee because they are going to share whatever findings that they have. When they are doing proprietary, then they are paying for that. I think the question is, are the universities like when they are using the labs, are they paying—because they are getting grants to do certain research but then they come over to a national lab, do they bring that research money? Are they paying fees to the laboratory to support the overhead there?

Dr. LANZIROTTI. No.

Mr. NEUGEBAUER. They are not?

Dr. LANZIROTTI. No.

Mr. NEUGEBAUER. So I guess the question, it is kind of twofold, is, if there is great value to these national laboratories, and I think the panel has expressed that, do we really kind of need to look at then the possibility of changing that funding model some where, you know, GE and other companies say, you know, there is value here even when we are doing proprietary or non-proprietary research there, we are going to make sure, we want to contribute to that? Because I was at a fairly major electronic company not too long ago, and we were talking about, you know, this very issue, and we were talking about, you know, one, of lowering the corporate tax rates and leaving more investable money in the economy to create jobs, and one of the questions I asked is, you know, would you then be willing and open then to, for example, in the funding of laboratories and some of the research, since we are going to let the corporation keep more of that money, would you be willing to contribute to that, and I think the answer was yes.

What I like about that is that it is another part of the review process. I know you said you do peer review when you are looking at who gets to use the laboratory. I mean, I just can't walk in there and say I would like to work on an experiment. You probably wouldn't let me, and when you look at my science grades, you for sure probably wouldn't let me. But the other token of that is, I think that the private sector also, you know, is another review of that where they are willing to invest their dollars. Dr. Hall, what would be your response to something like that?

Dr. HALL. So as I understand the question, you were talking about the tradeoff between, say, lowering corporate tax rates and then increasing costs for using government facilities. Is that correct?

Mr. NEUGEBAUER. Yes.

Dr. HALL. One aspect of that that one has to realize is again for a global company like GE, we will look globally at where we can do research at the lowest possible cost because we have to worry about our competitiveness as well. You know, we have facilities near our research facilities in Europe and in Asia and we would need to look at that overall cost. But, you know, I don't think I can speak to the tradeoff between tax rates and cost of facilities at this time.

Chairman HARRIS. Thank you very much.

I recognize the gentlelady from California, Ms. Lofgren, for five minutes.

Ms. LOFGREN. Thank you, Mr. Chairman. I will be quick because I know that we are going to have votes called.

This has been wonderful to hear you, and Dr. Drell, it is great to see you. I see you all the time at home.

You know, one of the things I didn't hear today was any concern or objection to the Department of Energy management of the use of these facilities. That is being done really through the peer-review process, and it is such a contrast to what I am hearing for those national labs that are being managed by NNSA. I am wondering, Dr. Lanzirotti, as the chief of the users group, have you had an opportunity to take a look at the National Academy report on the NNSA management of the national security labs?

Dr. LANZIROTTI. I actually haven't had an opportunity.

Ms. LOFGREN. Well, I am going to do this. I am going to give you a copy of this, and I am going to ask a favor of you to take a look at it and whatever insights you have, I would very much appreciate receiving and I am sure other Members of the Committee would as well.

Dr. LANZIROTTI. I would be very pleased to discuss that with the community and——

Ms. LOFGREN. The other thing I would like to mention, I just received a copy of a letter from April from Oxford University from the head of the user group for the national ignition facility talking about the micromanagement of the science from the user groups trying to use that facility. It is a two-page letter. It asks that we make it available to other Members of the Committee, but I would like you, if you wouldn't mind, to take a look at this letter as well and to give whatever insights you might have on how to correct this concern.

[The information may be found in Appendix 2.]

Ms. LOFGREN. The other question I have, and maybe I will ask Dr. Drell because I visit her lab all the time; you know, when I go to the lab, I see scientists from all over the world, really smart people who are coming here, inventing things, and it makes me remember that those postdocs, if they are from Britain, we make them go home and start their companies there. Do you think our immigration policies of forcing the smartest people in the world who want to become Americans with us is a positive thing for the advance of science here in the United States?

Dr. DRELL. Let me say I am not an expert on immigration policy, but I will say that the healthy flow of international scientists to our facility, because our beam time is allocated on a peer-review basis and the best science gets the beam time, that is the lifeblood of the institution and so being able to have outstanding scientists from around the world, many of whom eventually do either stay or find a reason to come back, is essential for science in this country.

Ms. LOFGREN. Thank you.

I am going to yield back so that other Members can have a chance to ask. Thank you very much.

Chairman HARRIS. Thank you very much.

I recognize the gentlelady from Illinois, Mrs. Biggert.

Mrs. BIGGERT. Thank you, Mr. Chairman.

Maybe, Dr. Wasserman, you can talk a little bit about the user agreements that you have with Argonne National Lab and how Ely Lilly is working with the lab to update agreements but how, you know, what you do with the proprietary.

Dr. WASSERMAN. So, for background, all the experiments that we do at Ely Lilly at the Advanced Photon Source come under proprietary user agreements so the DOE calculates what full cost recovery for providing the X-rays at the facilities takes and we reimburse at that rate to the government for every experiment that we do. So all of our work is done in a proprietary mode.

That said, much of the intellectual property provisions within the user agreements under proprietary mode give much of the rights to the user to develop as we do with pharmaceuticals. There are a few ambiguities that are not—that remain, particularly in what rights does the government to inventions that may come from the facility, etc. This contrasts with other facilities that we use outside the United States where they basically have if you pay, you own. And so it is a little bit more complicated in the United States in order to maintain a proprietary footprint.

Mrs. BIGGERT. And you say in your testimony that you pay the fees for all the proprietary but that sometimes you provide available time on that to non-proprietary users from the universities so that they have the ability to do that without fees?

Dr. WASSERMAN. Right. So the Department of Energy, at least for the facilities at the synchrotrons, requires that 25 percent of each beam line—some give more—provide time for academic users on each facility. So even if you built it yourself, you are providing time for outside users. We actually do those experiments for people. They send us the samples and we do the experiments for them with our own staff, finding that is a particularly efficient way to operate.

Mrs. BIGGERT. Then obviously everybody has been talking about the upgrade that is needed at the Advanced Photon Source. How would that help you to accelerate the drug characterization?

Dr. WASSERMAN. There are two aspects to that. One is the basic age of the machine. The APS will be 20 years old in three years, and anything of this complexity needs a checkup once in awhile, probably more often than 20 years, and that is one of the things that is planned within the Department of Energy Office of Science. The other is what the enhanced capabilities of the upgrade will give. For example, a class of targets known as membrane proteins gives very small crystals. They are very hard to grow larger and the enhanced capabilities that would come from the upgrade of the APS would allow us to get much better quality information that we are able to do even today with a state-of-the-art facility.

Mrs. BIGGERT. There is a question that NIH has a budget of over $30 billion to work on health and enhance life. Because of the great contributions of the light sources to advancing NIH's mission, do you think that some of their budget might go to the Department of Energy to work on this?

Dr. WASSERMAN. Well, in the sense, it already has. NIH contributed to the upgrade of the Stanford Synchrotron Radiation Laboratory when that was done a number of years ago. They fund the majority of the beam lines for protein crystallography that are currently at the APS. So the DOE facilities do have input, both scientific and financial, from the National Institutes of Health even today.

Mrs. BIGGERT. Thank you. And I will yield back.

Chairman HARRIS. Thank you very much, and if we keep going at about four minutes a question, we will do just fine.

I am going to recognize the gentleman from New York, Mr. Tonko.

Mr. TONKO. Thank you, Mr. Chair, and let me thank our panelists. I think you have underscored the value added of our user facilities and should motivate and inspire us.

You have all discussed how these user facilities have been invoked by industry and academia to advance an array of clean-energy technologies, but listening to the talk around Washington, one might conclude that such things are a pipe dream and destined to fail unless propped up by government programs. If run time at the user facilities is awarded based on competitive solicitations, how is it that there are so many clean-energy projects and why would you suggest are there so many industrial partners focused on clean-energy technologies if there isn't real potential for profit? Any of you want to address that?

Ms. TICHENOR. I am not from the business side, obviously, but the companies that make applications for time at our user facility are doing it because there is a business driver. They are pursuing this research because they believe that ultimately it makes good business sense. It is going to somehow drive new products, new services and drive their profitability in the end. It could be—maybe it is a regulatory demand, maybe it is a customer demand. Most of the time it is customer demands that are driving this,, and so I would say that is why they are coming in and pursuing those kinds of projects and that kind of research. But I am going to defer to the private-sector people on the panel here.

Dr. HALL. So I just wanted to stress that at General Electric, we are investing huge sums of money in renewable-energy areas. You heard me speak of a few examples. I did not speak about wind, but that has been a tremendous success story for our company and I hope for the world. You heard the story about battery. We are creating jobs. We are creating large factories. We are investing a large amount of money. We are also looking at solar technologies and trying to solve the critical technical problems associated with increasing the efficiency and making those products commercially viable, and when we use the user facilities, the reason we get time at those facilities is we are looking at the key science questions around these technologies, and it is critical that we solve, American industry and America solves these key questions, both for the future of renewable energy in the United States and also for the global competitiveness of our companies, and to solve these problems, as I have stressed before, we need to continue to have a collaborative model. We work with universities. We work with these government labs. We invest a huge amount of our own resources, and that is really what has pushed these technologies forward and enabled us to do things such as build a new high-tech battery plant in Schenectady, New York.

Mr. TONKO. Thank you.

Dr. Wasserman, were you going to add to that or——

Dr. WASSERMAN. Since most of our work is not in the energy area, I think I will defer to Dr. Hall.

Dr. LANZIROTTI. I would make one point. From our perspective in the user community, the American public and you as their representatives are going to dictate through the funding that you make available, you know, what the national needs are. Those of us in the scientific community, based on what funding is available, you know, where industry sees that there are economic initiatives, we will take those and we will use the national laboratories and the tools that we have to address them, and that's one of the things that is really unique about these instruments is that regardless of what you task us to do in science, we are going to use these facilities to try to address them.

Mr. TONKO. That is wonderful.

With a minute remaining then, Mr. Chair, I will yield back.

Chairman HARRIS. Thank you very much.

I am going to reserve my time and I will yield to the gentleman from California, Mr. McNerney.

Mr. MCNERNEY. Thank you, Mr. Chairman.

I certainly enjoyed listening to your testimonies so far, but you are putting your best foot forward. I understand that.

Dr. Drell, I have a little technical question here concerning the LCLS. Now, you said it called the Linac Coherent Light Source. Is it also monochromatic? So in other words, is it a laser?

Dr. DRELL. Yes, it is an X-ray laser.

Mr. MCNERNEY. Wow.

Dr. DRELL. It is a free-electron laser so it is not like your normal laser. I don't know how technical you would like me to get here. I would be happy to get as technical as you would like. But we take a beam out of our electron Linac, very small emittance beam, a billion electrons and a 30-micron sphere, put it in 100 meters of undulator magnets that have been aligned to better than a tenth of the width of a human hair and we get lasing radiation out. We have actually just recently been able to make that nearly transform limited pulses.

Mr. MCNERNEY. Very good.

Dr. DRELL. It is a spectacular instrument.

Mr. MCNERNEY. It is. Wow. I didn't know that was going to happen in my lifetime.

Dr. DRELL. Please come visit us and let me show you for yourself.

Mr. MCNERNEY. I will do that.

Dr. Lanzirotti, about the Joint Genome Institute, how has that JGI contributed to bringing genomic-based solutions and products to the marketplace?

Dr. LANZIROTTI. Well, we don't have anyone here from Lawrence Berkeley today, who would probably be better able to speak to that directly, but let me speak a little bit for the user community of JGI, and again, it is an opportunity to make available to the broader user community advanced sequencing tools. That is something that at the level that JGI provides it to the scientific community, it is something we don't have available, and it is a very vibrant community. JGI today hosts about 1,800 users a year. Last year, they published 188 publications. They looked at sequencing the genome of microbes that were found at the bottom of the Deepwater Horizon well to understand, you know, how we can use what microbes are doing to actually clean up hydrocarbons in the future. They published the first publicly available sequence for soybean, which gives us insight, for example, into how nitrogen is fixed in organisms so, you know, for crop rotation, and if you look at it in terms of what they can accomplish, JGI produced 40 trillion bases of sequence data last year using their advanced sequencing tools. That is amazing, and it takes us as users from not just collecting genome data but actually to understand what the function of individual genes is.

Mr. MCNERNEY. It sure would be interesting to see a sort of return on investment in terms of federal money invested and commercial value generated, but I think that is a pretty complicated question.

Dr. Wasserman, I heard some proposals to cut funding for user facilities that are not energy related. Would that affect your work?

Dr. WASSERMAN. It depends on whether one considers the Advanced Photon Source an energy-related facility or not. At the moment, half of its work is the traditional realm of the Office of Science of the DOE, chemistry, physics and materials. The other half is the biological side. So we clearly benefit from the investment the DOE has done and that is why we have built our own beam line, our own research facility at the place. But if the emphasis on energy work continues, we presume that the APS will continue to function and therefore we will benefit as well.

Mr. MCNERNEY. Thank you.

I think I will yield back.

Chairman HARRIS. If the gentleman would like another minute, if you have questions. We were just notified that the votes will be at 11:00, so if you want to—do you have another question?

Mr. MCNERNEY. I do. Thank you, Mr. Chairman.

Ms. Tichenor, you mentioned that the industrial benefits from partnering with the national user facilities. Can you elaborate a little bit on how the partnerships help advance and develop our national interests?

Ms. TICHENOR. Well, I think they help from multiple perspectives. First, I think it is in the national interest to have companies that are strong and the companies that are coming and doing research are doing that research there to strengthen their own firms, to make them competitive, and competitive companies here are going to contribute to the economy, and I am not the economist here at the table—I don't know if we have one—but I think that is a good thing.

But, you know, there is a lot of intellectual sharing that goes on with the users that come to the user facilities and the lab researchers that are there. We learn a tremendous amount. The labs don't have a lock on all the intellectual capital in the country. There is a tremendous amount of very, very good science that goes on in the companies, and when you provide these user facilities, and I can only speak, of course, about our own leadership computing facility, it is like a brain magnet. I mean, it attracts really, really smart people, and we want to be surrounded by smart people. We learn. And a lot of the work that is being done in industry, the scientific work, is very complementary often to work that is underway at the labs and so it becomes a meeting place where the ideas can be shared.

Mr. MCNERNEY. Thank you.

This is an excellent example of how very well-targeted money from the government can benefit the society at large, so thank you for your testimony this morning.

Chairman HARRIS. Thank you very much. I am going to continue to reserve my time.

The gentlelady from California is recognized for five minutes.

Ms. LOFGREN. Thank you, Mr. Chairman, and I am going to just follow my colleague, Mr. McNerney, in the benefits to everybody of the federal investment in science, technology.

Where in the process when it is federally funded is this research made available to whoever would be interested? Example: I have heard that in medicine, it isn't until the final paper comes out that then it becomes public but the studies and the results of those studies step by step by step are not published, and the medical scientists have said to me, we start over and over many times in our research because those basic research finds that might not even have anything to do with that original research was going to be about is not made available. So am I talking about something that works that you can help me with?

Dr. WASSERMAN. In the biological field, there are two types of publication. There is the standard paper, which to our academic colleagues is their product of their scientific work, and we do that as well when we have reached a completion stage of the science that we do on a proprietary basis out of the APS. There is a second level of publication, which is supported through the National Institutes of Health known as the Protein Data Bank, which is a collaboration within the United States and with other protein data banks operated in Asia and Europe, and together these data banks allow you to deposit structures of proteins that other people can use, possibly ourselves in development of medicines, other university researchers who may be working in a related area, and so that can be made quite quickly. It is a requirement of publication to put your data into the Protein Data Bank, but there are many other structures that are available there for the general researcher that are put there well before publication occurs.

Ms. LOFGREN. Dr. Hall.

Dr. HALL. And I think one way of thinking about these user facilities is that they are tools. They are tools that we use to build amazing technology products and tools that we use to build American competitiveness. And those tools, as Ms. Tichenor indicated, are constantly being developed, and if I can again use the battery technology development as an example, we saw that Rutgers and Brookhaven had developed a tool to do a certain thing. We saw how it could be adapted to help us understand the chemistry that was happening in batteries and improve our product. We did that. The world saw what we were doing with batteries. Other people working on batteries came from other companies and universities and used the tools that we had developed and the methods that we had developed. So everyone benefits. Other researchers will use that tool in a slightly different way. So the key is that we all work together to continue to improve these tools. That will accelerate the technology development in the country, and that just happens all the time.

Ms. LOFGREN. But it is preventable that we don't hold back in our government facilities in sharing——

Dr. HALL. All the work that we did was done in a completely non-proprietary, open way, and Brookhaven has publicized that, trying to build a very large consortium around being a center for battery research.

Ms. LOFGREN. I will yield back, Mr. Chairman. Thank you very much.

Chairman HARRIS. Well, thank you very much, and I will recognize myself, I guess, to close the round of questioning.

And I am going to just follow up a little bit, I think, some of the things that the gentleman from Texas had asked. You know, since they are government facilities, obviously political issues arise, and I frequently get asked in town hall meetings and by constituents, look, why don't we keep, you know, American investments in America, you know, why do have what amounts to foreign aid, and so I am going to delve a little bit into the idea that we are letting foreign entities use these facilities, which are in the end funded by American tax dollars.

So first of all, and I guess, Dr. Drell, listen, thanks for coming and not talking about more fascinating technology which I will never understand, but is it true that foreign applicants have access on an equal basis with American applicants to your facility, for instance?

Dr. DRELL. That is true. The peer-review process does not look at where a proposal comes from. It looks at the quality of the science, and that is reciprocated at facilities around the world.

Chairman HARRIS. Okay. And that was my other question, is it in fact reciprocated because it is a different model. For instance, the NIH, which I am much more familiar with, you know, as far I know, I think you have to be an American, you know, the principal investigators, that they have to be American or American entities.

Dr. DRELL. To get a grant——

Chairman HARRIS. Yes.

Dr. DRELL [continuing]. A specific grant, you would need to be—to fund your research group, to fund your postdocs, to fund your graduate students.

Chairman HARRIS. Sure, but my——

Dr. DRELL. But beam time——

Chairman HARRIS. Right, but those are—both flow from American taxpayer dollars. You know what I mean?

Dr. DRELL. Yes.

Chairman HARRIS. So the average American looking at it is going wait a minute, you know, we are kind of subsidizing this foreign entity, but it is, as far as what you are saying, we have access, our scientists have access to their instruments. We probably just have better and wider variety of instruments, we would like to think.

Dr. DRELL. At the moment, certainly, in that realm. I would also like to emphasize that most—many of the teams, let me say, that have international participation also have U.S. participation. It is rare to have a team that is exclusively——

Chairman HARRIS. Sure. It is part of a collaborative effort.

Ms. Tichenor, is that true at your facility also?

Ms. TICHENOR. Basically, it is. I mean, DOE does not distinguish in their peer-review proposal process between different countries. They are looking for the most cutting-edge science, and in fact, that is what the facility was funded to do, right, is to support the most cutting-edge science and so the peer-review process winnows through all of those applicants to do that. Another way to think about it is, when you have foreign researchers there, we are not paying for those researchers. We don't fund them, right. Their own countries are. So their own countries are making an enormous investment in that research, and we get the benefit of it. We provide the tool but we get the benefit of all that investment that they have made and those people and that time and then we get access to all the results.

Chairman HARRIS. Again, believe me, I get it. I mean, I get that science shouldn't have boundaries but again, once you ask the government to participate, politics, which is——

Ms. TICHENOR. Understood.

Chairman HARRIS. Are there equivalent facilities overseas, facilities, supercomputing facilities, for instance, that our—or do we really have the best in the world so really it is kind of a one-way street?

Ms. TICHENOR. Well, we are pretty fortunate right now that we have got some of the top systems. Now, this fluctuates, you know, because systems constantly are being upgraded. But there are certainly very similar, maybe not at any point in time one country has the most powerful system than another but they do leapfrog each other, and many of those are in university and national laboratory environments where, again, those countries have made a similar determination. We want to attract the best brains and so they make them available.

Chairman HARRIS. At your two facilities, what is the estimate of the percent of foreign use, Dr. Drell?

Dr. DRELL. At the LCLS, it is 50 percent right now.

Chairman HARRIS. Fifty percent?

Dr. DRELL. Right.

Chairman HARRIS. Ms. Tichenor?

Ms. TICHENOR. You know, I would have to get back to you and get——

Chairman HARRIS. Ballpark?

Ms. TICHENOR. I don't know. I wouldn't even want to—it is highly collaborative. It is highly collaborative.

Chairman HARRIS. No, I understand that.

And I am just going to close with just a kind of rhetorical question, I guess, for Dr. Wasserman and Dr. Hall, because you are the two private entities. You know, what is floated around here on Capitol Hill is that for some reason if a company is successful and profitable, they should pay a little bit more, and, you know, that is floated around now for small businesses. Should we go to a sliding scale for fees for user facilities? You know, if you are a profitable company, you pay more? What do you think? Do you think that is a good idea, you are more profitable, you pay a higher fee to the government? You can call it a tax to use the facility if you want.

Dr. HALL. Well——

Chairman HARRIS. It is a rhetorical question. You don't have to answer.

Listen, I want to thank all the witnesses for their valuable testimony and the Members for their questions. The Members of the Committee may have additional questions for you, and we will ask you to respond to those in writing. The record will remain open for two weeks for additional comments from the Members.

The witnesses are excused. Thank you all for coming. The hearing is now adjourned.

[Whereupon, at 10:57 a.m., the Subcommittee was adjourned.]

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

The **FUTURE** of America is the
**RESEARCH** of **TODAY**

NATIONAL USER FACILITY ORGANIZATION

**U.S. House of Representatives Committee on Science, Space, and Technology**

**Subcommittee on Energy & Environment**

**Hearing on Department of Energy User Facilities: Utilizing the Tools of Science to Drive Innovation through Fundamental Research held June 21, 2012**

**Response to Subcommittee "Questions for the Record"**

**Dr. Antonio Lanzirotti, Ph.D.**
**Chairman, National User Facility Organization**
**Senior Research Associate, The University of Chicago**

**Response to Ms. Lofgren's Questions**

During the hearing on June 21st Ms. Lofgren's asked me to address the questions (summarized below). I welcome the opportunity to provide what assistance I can and thank the Congresswoman for her interest and engagement on this matter.

Q1: "Have you had an opportunity to take a look at the National Academy report on the NNSA management of the national security labs? Take a look at it and whatever insights you have I would very much appreciate receiving. And I'm sure other members of the committee would as well."

Q2: "I just received a copy of a letter from April from Oxford University from the head of the user group for the National Ignition Facility talking about the micromanagement of the science from the user groups trying to use that facility. It's a two-page letter. I'd ask that we make it available to other members of the committee. But I'd like you, if you wouldn't mind, to take a look at this letter as well and to give whatever insights you might have on how to correct this concern."

**Response:**

Representative Lofgren raised two questions that relate to management of laboratories overseen by the National Nuclear Safety Administration (NNSA). Specifically we were asked to (1) examine a letter the Ms. Lofgren received dated April of this year from Dr. Justin Wark (Oxford University), who currently serves as Chair of the National Ignition Facility's User Group. Dr. Wark's letter describes recent difficulties in scheduling time for user experiments at the NIF facility. I have been asked to comment to what degree these issues may reflect micromanagement of the science program by NNSA. Ms Lofgren asked me to give whatever insights I may have on how to correct this concern. I was also asked to (2) examine the recent National Academy report on the NNSA management of the national security labs and provide any relevant comments from the perspective of scientific User communities. Given that NUFO represents Users of scientific facilities, we feel it is only appropriate for us to comment on both these issues with regard to how they impact access by the scientific community as well as facility efficiency and productivity in meeting User needs.

The National User Facility Organization (NUFO) membership currently includes users from six scientific user facilities that receive NNSA funding to support operations. These include the National Ignition Facility (NIF), the Jupiter Laser Facility (JLF) and the Center for Accelerator Mass Spectrometry (CAMS), all at Lawrence Livermore National Laboratory; facilities at Los Alamos National Laboratory that are part of the Los Alamos Neutron Science Center (LANSCE) including the Proton Radiography (pRad) facility and the Weapons Neutron Research (WNR) facility; and the Laboratory for Laser Energetics (OMEGA) at the University of Rochester. All these NNSA-supported facilities provide unique capabilities that simply cannot be produced at other laboratories. They all have a core mission in national security science in understanding and maintaining the nation's nuclear deterrent without testing. However, their uniqueness provides one-of-a-kind opportunities in fundamental and applied research that directly translates in to high user demand for access. For example, research proposed by the burgeoning user community at NIF will allow scientists to explore the physics of the newly discovered exoplanets, explore studies in experimental astrophysics, and utilize the collisionless shock waves that can be launched and provide insight into the formation of the intergalactic magnetic field. The willingness for DOE to make these unique tools available to the broader scientific community for research should be commended and fostered.

To help address Representative Lofren's question, we solicited input from the User Organizations of these facilities that are NUFO members and solicited additional information from Dr. Wark to better understand the situation at NIF that led their User Organization to express concerns.

Additional information regarding User concerns at NIF

Let me first provide some additional information regarding the situation at NIF that generated concern on the part of their scientific User community. To better understand the concerns, we feel it is appropriate to give some historical perspective as we understand it. An active and viable user program at NIF was encompassed within the scope outlined in the 1997 NIF Facility Use Plan for NIF-oriented fundamental science. It was formally announced to the wider international community in September of 2009, with a call for proposals in 2010. The community was informed that it was envisaged that 15% of the time on the NIF would be available for its use as an open user NNSA facility. A peer-review proposal call came in July 2010 and eight programs (out of 40 submitted to the call) were recommended for allocation. With active encouragement from DOE, the initially approved group self-organized to form the "NIF User Group", which now numbers in excess of 250 scientists. The user community, upon being informed that they were successful in the peer reviewed process, has garnered further financial support and employed postdocs and graduate students to undertake the work. Their expectation of obtaining time on the NIF at the 15% level was endorsed by Dr. Donald Cook in his memo of 20 August, 2010 to Dr. Bill Brinkman, and is consistent with what has been promised to the fundamental science community for at least five years.

To date, however, none of these eight experiments have received dedicated NIF shots (although one group has executed shots in a "ride-along" mode to programmatic work). It is in this context that the NIF community expressed its concerns about the original draft guidance from NNSA. Since that time, it is our understanding that the actual guidance given to the NIF director allows up to 40% of NIF time for non-SSP shots, but given the pressure to achieve ignition, that may still leave the science users with little dedicated time to start their programs. Discussions are still ongoing with the Director of the NIF and with NNSA, but there is still extreme concern in the User community about the present situation.

User Community perspectives in the context of the National Academies of Science report

A number of factors obviously contribute to providing users of DOE scientific facilities the most advanced instruments for research and the highest quality of support. I believe that, for the Users of these facilities, the most pressing concerns generally are issues that result in barriers to access and impacts to experimental efficiency. The issues highlighted above reflect how barriers to access are hindering the nascent NIF user community, a community pressing to use a new (for the academic community) facility. For the more established User communities at Los

Alamos (WNR and pRad) and the University of Rochester's Laboratory for Laser Energetics (OMEGA) I have received no indication that major issues exist in the ability of these facilities to support User programs. For those users that are allocated time, the data they collect appears to be of high quality and of high scientific impact and the facility scientists that support the user program appear to be dedicated, knowledgeable, and committed to providing users the highest quality of support. We are confident that Users of the NIF facility would similarly receive the highest quality support and use their access for great scientific achievements if the barriers to access can be resolved.

From what we have learned from our User communities, we do not know if these access issues reflect micromanagement of the science program at NIF by NNSA or if this problem is related to the management issues highlighted in The National Academies report. Similarly, as noted, we do not know of particular issues at other NNSA-supported user facilities that are potentially impacted by findings identified in this report. However, as Users of these facilities, whether they are supported by NNSA or BES or other entities, we recognize that unforeseen events arise that can impact the amount of time that is expected to be available for external science programs. At NNSA-supported facilities unexpected needs may arise to support a lab's core mission in national security science. At all DOE User facilities, unexpected budgetary constraints do occur that can force facility directors to cut operating schedules below previously stated levels. While this is understandable, it must be understood that scientists make tangible investments in time and research funding and engage students in projects based on assumptions of how much time will be available for User science. I would argue that for these facilities to foster cutting-edge research and productive user communities, a good-faith effort must be made to provide access at levels consistent with stated intentions.

Our sense is that there is now a tangible effort underway between NNSA and the Office of Science to share lessons-learned and best practices for user facilities across the Department, with an important goal of evaluating access models and how facilities balance mission needs with needs of the Users. An important example of this effort is a User Facility Forum scheduled for July 19, 2012 in Washington D.C.(Forrestal building) coordinated jointly by NNSA and the Office of Science. The User community (represented by NUFO) was asked to participate in this program and we are eager to see what recommendations are put forward. As always, the scientific user community of these facilities is happy and eager to provide our advice and perspective if it is useful.

**Response to Written "Questions for the Record"**

Below I provide responses to the Subcommittee's "Questions for the Record". I thank the entire Committee for the opportunity to clarify my comments and the interest and engagement of Members on these matters.

**Question #1**: In general, how do other countries manage intellectual property associated with user facility research conducted using government resources?

a. Please provide any recommendations regarding potential opportunities to improve DOE's current user facility IP structure.

**Response:**

We thank the Committee for this follow-up question; issues regarding intellectual property (IP) associated with work conducted at federally funded research facilities are of significant interest to the scientific user community and there is currently a very vigorous discussion underway among federal agencies, scientists, and publishers on this topic.

How do other countries manage intellectual property associated with user facility research conducted using government resources?

As you may imagine, there is significant diversity in international approaches to IP generated from experiments at "public" scientific user facilities. As an organization, NUFO is probably not best suited to characterize other countries' IP policies; we would presume that DOE itself has looked at these issues in developing its facility policies. Obviously Agreements between Users and Facilities that specify IP rights can be very complex. However, in a hope of providing a useful framework for discussion and highlighting some of the differences, we have solicited some information from our counterparts at a suite of international user facilities that provide similar capabilities to user facilities in the DOE complex with roughly similar-sized user communities. Admittedly, this is not a complete sampling of international approaches and doesn't express the details of what may be included in their respective User Agreements. We are providing only what has been expressed to us in a condensed manner. However, this does demonstrate that although there are general similarities in approach there are also some notable differences that also exist.

At most of these facilities, there is recognition of the differences between IP generated from proprietary versus non-proprietary work. Obviously we would recommend DOE be solicited directly for details and accuracy on their User Agreements since we are only summarizing our understanding of the language included in Agreements we have examined. Our understanding is that in the U.S., User Agreements between DOE facilities supported by BES and user institutions for non-proprietary work generally specify that the Government shall have Unlimited Rights in Technical Data first produced or specifically used in the performance of the work at the facility. The User retains the right to use this data for its private purposes subject to patent, security or other provisions that may be specified in the Agreement. For proprietary work, the User retains "Unlimited Rights" to use, duplicate or disclose technical data, in whole or in part, in any manner and for any purpose whatsoever, and to permit others to do so. DOE (and/or the facility Contractor) retains unlimited rights to any technical data furnished to it by the User that is not marked as "Proprietary Data". The agreements define what is considered "Proprietary Data".

We have solicited input from four foreign synchrotron light source facilities: the European Synchrotron Radiation Facility (ESRF) in Grenoble, France; the Canadian Light Source (CLS) in Saskatoon, Canada; the Diamond Light Source (DLS) in Oxfordshire, United Kingdom; and the SPring-8 synchrotron radiation facility in Hyogo Prefecture, Japan. These four facilities share similar community IP requirements and concerns to the four synchrotron light sources managed by BES.

The ESRF tells us that all IP generated from experiments that use their public (peer review or non-proprietary) program belongs to the User groups concerned, unless there is a clear collaborative aspect with ESRF scientists in which case it would be shared. However, as in the U.S., the public peer review experiments must publish their results - although patent protection may be applied beforehand to be funded, of course, by the IP owners. All IP generated by their commercial (i.e., paying for access or proprietary) industrial users belongs to those users unless there are specific contractual conditions otherwise. The commercial clients do not need to publish and all results remain confidential.

SPring-8 informs us that any intellectual property rights resulting from the use of SPring-8 belong to those who conducted the research. In the event that users have applied for a patent or other form of intellectual property protection for the results obtained through the use of SPring-8, they are required to promptly notify the facility when the application is published. SPring-8 makes no distinction between proprietary and non-proprietary as to who owns the IP.

The Canadian Light Source informs us that they have standard arrangements in place for the bulk of situations they encounter with Academic and Industrial users (which they classify as their two primary user steams); however a few Agreements are negotiated for unique situations. Academic users are required to publish analytical results, including data, analysis of data, patents or patentable subject matter relating to the use of the facility. The CLS retains rights to any methodology, analytical techniques, process, etc. that relate to the conduct of work or operation of the CLS facility, including software, equipment, information, or other technology developed by CLS. The Academic User also grants license for use at CLS for any facility-related IP it may develop through its use of their facility. For Industrial, paid projects that are performed by CLS staff, the facility assigns experiment-related IP rights to the client but retains rights to any methodology, analytical techniques, process, etc. that relate to the conduct of work or operation of the CLS facility. As with U.S. facilities, the goal of the industrial paid projects is to recover actual costs (including staff time). The CLS also tells us that they occasionally have Industrial clients who come in to perform experiments onsite themselves. These Industrial clients are offered a reduced rate reflective of the actual costs. The IP arrangements are the same. Anything facility-related is retained by CLS; anything research-project related belongs to the Industrial User.

The Diamond Light Source in the U.K. specifies that intellectual property for non-proprietary work (including copyrights, design rights, patents and trademarks, and all other similar or other monopoly or property rights whether registrable or not) originating with either party prior to the commencement of use of DLS Facilities ("Background IP") shall remain the property of the party introducing such Background IP. The parties shall not have any rights to the Background IP of the other party. The User will own the IP in any results generated solely using their materials and solely based on Background IP owned or licensed to them. IP arising from research carried out by the User using DLS' Background IP or incorporating significant contributions of DLS employees ("Joint IP") shall be jointly owned by the User and DLS as tenants in common in equal shares unless otherwise agreed by both parties in writing. The use of the Joint IP is decided on a case-by-case basis at a later date. For proprietary Users, unless expressly stated to the contrary in their Contract, nothing in the Contract assigns or transfers any Intellectual Property Rights or grants either party any license to use any Intellectual Property Rights originating with the other party prior to the commencement of the Contract, except that DLS (and any sub-contractor of DLS) may use, for the purpose of performing its obligations under the Contract, all information, software and materials (including the Samples) supplied to it by or on behalf of the Customer. DLS then agrees to assign to the Customer the Intellectual Property Rights in the Results.

Recommendations regarding potential opportunities to improve DOE's current user facility IP structure

For the very small subset of international facilities we have highlighted here, it seems to me that IP rights for proprietary work are generally comparable to those specified within DOE (and specifically BES) User Agreements. These policies seem appropriate for IP protection and in keeping with international practice. The differences primarily seem to be with respect to IP rights for data collected as part of non-proprietary work. At least for these facilities, the more general practice is that IP generated from experiments that access facilities for non-proprietary research unambiguously belongs to the User groups concerned, unless there is a clear collaborative aspect with facility scientists, in which case it would be shared. This seems to differ from the policy in place at the DOE BES facilities (or at the very least is not as clear with respect to non-proprietary IP rights).

Neither I nor NUFO have a particular recommendation as to which approach for non-proprietary work is most appropriate for IP protection at DOE facilities. It seems fair to conclude that at some facilities abroad ownership of intellectual property clearly rests with the User. The current policy for access to DOE facilities for non-proprietary research specifies in practicality that the IP output from basic research is publication in open literature and this is in keeping with international practice.

However, I think it should be noted that, for Universities and Companies, the IP specifications set forth within the master user agreements used at DOE facilities often seem to generate confusion, take a very long time to implement and can be a disincentive and a stumbling block for smaller institutions or businesses in accessing facilities. Better clarity in language to make clear what the intent of the agreement is (particularly with respect to IP rights and User liability) would be tremendously helpful. This is often exacerbated by the fact that organizations that wish to access user facilities at different Laboratories must sign a standard agreement for each

Laboratory because each is operated by a different contractor. Provisions in these standard agreements may even vary from laboratory to laboratory and negotiations over these provisions start afresh with each discussion. It would be helpful if a single, master, DOE-wide agreement on intellectual property and liability issues, applicable to all contractor operated facilities, could be executed to provide access to any and all of (at least) the BES user facilities. This would avoid laboratory contractors' individually negotiating user agreements. We believe that DOE recognizes this issue and has been working to effect changes. We also recognize how difficult a task this is to address given that, within DOE, some policies and regulations incorporated in user agreements are mandated by law while others are imposed by the facility contractor. We as an organization are always more than happy to help in that discussion if it's useful.

We also recognize that there is an ongoing broader discussion at the Federal level, in consultation with the U.S. scientific community, as to whether data collected by recipients of federal research funding or by scientists using federally funded facilities for non-proprietary research should be made publically available. I personally believe that the approach taken by the Office of Science and Technology Policy is the correct one. More specifically, input is gathered by OSTP from all interested parties via Requests for Information on the subject of Public Access to Digital Data Resulting from Federally Funded Scientific Research. I believe this open approach fosters vigorous discussion not only with Federal agencies but also among the scientific community and is more likely to generate recommendations that have broader acceptance.

**Question #2**: Please provide any further detail regarding your recommendation for additional partnerships between new user communities and DOE facilities.

a. Specifically, you note "more standardized requirements for access across the DOE complex are still needed that will make it easier for academia and industry to use these world-class research tools." What sort of requirements are you referring to?

**Response:**

Recommendations for additional partnerships

I thank the Committee for the opportunity to expand on my statements regarding partnerships between user communities and DOE user facilities. As I'm sure the Committee is aware, such partnerships with universities, industries or government agencies other than DOE have had various different incarnations over the years. Such partnerships obviously allow facilities to leverage material capital from dedicated users to the lasting benefit of the facility. In tight budgetary times, these investments provide significant leverage for facilities. However, from the user community perspective there is even a larger benefit in that such partnerships provide intellectual capital that the facility itself may lack.

As an example, at synchrotron facilities today life scientists constitute the largest single user group, pursuing research interests that are outside the traditional mission of BES. Partnerships between facility stewards with NIH, BER, universities and pharmaceutical industries both in the past and today have been invaluable in providing resources and scientific staff for beamlines that specifically address the needs of life science users. It is my belief that the ability of facilities to successfully tackle many of the most important scientific problems increasingly depends on facility stewards working with industry and university partners in a comprehensive collaboration.

I also believe there are opportunities to foster new partnerships designed to tackle specific scientific goals or attract new user communities. As stated by Dr. Ernest Hall in his testimony, industrial users in particular can significantly benefit from more structured partnerships that allow different stakeholders to come together and collaborate to ultimately benefit the broader scientific community. I also very much agree with Dr. Hall that SEMATECH is an excellent example of the types of partnerships that can bring broad collaborative involvement. The SEMATECH (SEmiconductor MAnufacturing TECHnology) consortium formed as an industrial partnership among leading chipmakers and the federal government to address a specific industrial and scientific problem: improvement in chip manufacturing capabilities. That partnership included investments on the part of the consortium in equipment and scientific staff at DOE scientific user facilities to tackle the problem. As a result of SEMATECH's work, within 10 years of their formation, the domestic semiconductor industry had grown by 16%. The benefit to U.S. industries (broadly and not for the benefit of one specific company or university) was very clear. I believe we should foster similar partnerships to tackle overarching problems–be they in energy technologies, environmental sciences, materials and manufacturing, life sciences or in supporting the missions of other agencies such as NIH, DARPA, NASA, etc.

Fostering such new partnerships first and foremost requires an educational initiative on the part of DOE in collaboration with experienced users who know the scientific questions. Supporting such educational initiatives does require a small amount of initial funding but should be viewed as an investment towards future achievement and efficiency. I would also point out that within the Office of Science there has been a move away from the stewardship models (so-called "steward-partner models") of the past for its new facilities. I believe that this change has unintentionally generated some ambiguity for potential partners that should be carefully evaluated. For these new facilities, it is not clear how partnerships between a facility and another institution are formed; the benefit of such a partnership for the outside institution may also be ambiguous; and potential partners do not always understand how (or if) their investment gives them a voice in the scientific direction of the facility. Clarifying these requirements for new facilities in open discussion with potential partners will help ensure that we encourage industrial use and provide incentive for both industry and universities to develop mutually engaging relationships, rather than discouraging investment.

The need for more standardized requirements for access across the DOE complex

My statement regarding more standardized access refers primarily to the User Agreements each institution must establish with the laboratory. To access user facilities at different laboratories, each university and industrial company must sign a standard agreement for each laboratory because each laboratory is operated by a different contractor. Provisions in these standard agreements sometimes vary from laboratory to laboratory, which means that negotiations over these provisions start afresh with each discussion. These user agreements invariably are a source of concern to the users' institutions. It would be helpful if a single master DOE-wide agreement applicable to all contractor operated facilities could be executed to provide access to any and all of the BES user facilities. This would avoid laboratory contractors' individually negotiating user agreements. For users, this would decrease the legal costs of conducting research at more than one facility. Such flexibility would also allow for the relocation of research programs from oversubscribed facilities to ones that are underutilized, something that is very difficult given current requirements. From the users' perspective, there is benefit in having facilities across the DOE complex working together for scientific benefit rather than separately. Simplifying a user's ability to more seamlessly tackle scientific problems by using multiple facilities and giving facilities the ability to efficiently guide users to other, more suitable, resources within the DOE complex should be encouraged. Again, I believe DOE is trying to move in this direction but to be fair, since each laboratory is operated by a different contractor, implementing such a recommendation could necessitate a re-evaluation of agreements between National Labs and contractors.

Another area for improvement is for reciprocity in training among differing facilities. While we understand that facilities have unique safety requirements, there are also areas of significant commonality. Yet, users who access multiple facilities are required to essentially be trained repeatedly on the same material, which for them is frustrating and inefficient. Areas where reciprocity is sensible without compromising safety should be identified. I would also like to point out with regards to the User Agreements that for many industrial partners the aspects of the agreements that deal with issues of liability can be the most difficult to resolve. While IP rights can be protected through declaring proprietary access, the dark cloud of unlimited liability in either money or time hanging over their heads whenever they run experiments or operate equipment can be very hard to accept.

**Question #3**: Your testimony says, "It is important to recognize that a 'one size fits all' approach to user access may not be optimal in some cases." Can you describe how various users differ in practice and research?

**Response:**

I thank the Committee for the opportunity to discuss this issue further. As I stated in my testimony, I believe that it is in the best interest DOE, the scientific user community and the Nation to attract new scientific communities and industrial users to our facilities and make them aware of how they can be utilized in their research. Educational offerings for new user communities are important in this respect.

For those of us that have worked closely with User Facilities for a long time and have seen the rapid growth of inexperienced user communities, it is very apparent how certain user groups require different levels of support or different modes and levels of access dictated by the technical requirements of their studies.

For example, while most users come to DOE facilities for individual experiments, others need recurring and/or rapid access to address their scientific requirements. Facilities currently have some flexibility to meet these needs, and this flexibility should be retained and expanded where appropriate. For example, those users studying biological and soft matter systems may require extensive support in preparing their samples for neutron or X-ray beam time on-site. Access to protein expression and crystallization facilities and polymer and ligand synthesis facilities at synchrotron and neutron facilities are invaluable to these user communities and require investments to implement. Increasingly, DOE facility managers are recognizing this need and are planning to build support facilities to accommodate them, for example the planned biology village for NSLS-II, the automated crystallization facility planned for APS, and the deuteration and crystallization facilities at LANSCE and SNS and HFIR.

Users with time-sensitive biological samples may also require rapid access to beam lines, often within a short 24-hour window of having prepared their sample for analysis. Industrial users similarly may require characterization of new materials with rapid throughput methods to accelerate discovery. This requires not only access policies that can accommodate these needs, but often technological investments to enable them such as robotics for sample manipulation and remote access computing so that Users can mail in samples and collect data from their home institutions. For these efforts, the facility needs to make dedicated and concerted efforts in developing and executing required technologies.

As pointed out by the Basic Energy Sciences Advisory Committee in their report on "Strengthening the Link between Basic Research and Industry," industrial users also often require slightly modified review criteria when they submit proposals for non-proprietary research. While these proposals should still be reviewed on the basis of scientific merit, modifying review criteria to also weigh technological impact will allow them to compete more fairly.

Another point I would make is that having respected scientific staff on hand at the facility that are knowledgeable of the science the user community is hoping to address is invaluable. This can be difficult since the natural tendency of a Facility is to hire scientists that address, first and foremost, the technical requirements of the facility in operating their instruments efficiently. But the interaction between facility scientists that understand the scientific questions the visiting users are hoping to address can make all the difference in ensuring a successful experiment. Partnerships between facilities and external institutions such as universities and industry where the Partner contribution includes providing knowledgeable staff to support facility instruments has historically been an extremely valuable method of providing expertise the facility itself may lack. These partnerships have historically been highly successful and should continue.

**Question #4**: It is longstanding policy for most research conducted at scientific user facilities to be transparent and published in the open literature. However, it seems concerning that the United States' top international competitors not only get access to and benefit from the research conducted at U.S. user facilities, they can even compete to use these machines themselves. Is there any way we can change policies to better benefit U.S. companies and citizens without disrupting longstanding practice of open scientific inquiry?

**Response:**

The Committee is quite right that it is longstanding international policy that most research conducted at scientific user facilities is intended to be transparent. Both U.S. and international policy (generally) is for access to foreign facilities to be effectively reciprocal, an approach that benefits the entire scientific community. The requirement for publication in peer-reviewed literature as a condition for non-proprietary facility access reflects the reality that open-science is conducted as if there were no national borders. As a result, not only do U.S. and international scientists benefit from the research conducted at U.S. user facilities, U.S. researchers benefit from studies conducted by scientists at facilities abroad, regardless of their nationality.

I do believe it is very reasonable (and healthy for science) to periodically ask if existing policies need adjustment to ensure that U.S. companies and citizens are not encountering barriers to access of U.S. facilities as a result of this competitive environment. Each facility type tends to have unique user community dynamics in this respect. What I mean is that some facility types tend to have larger international participation from visiting scientists, typically because they have unique instruments or specialty programs that are not available elsewhere. However, we can look at metrics for the Advanced Photon Source (APS) at Argonne National Laboratory as a reasonable indicator of the level of foreign usage. Of the DOE user facilities, the APS hosts the largest number of Users (as defined by BES) annually, roughly 4000 per year, and the scientific usage cuts across many disciplines. If we examine Foreign Visits and Assignments (FVA) for the APS we see that approximately 46% of the users annually are foreign nationals. However, if we look at how many of these users are from foreign institutions, we see that this category only accounts for 6% of almost 4000 users that come to the APS each year. In other words, although we host a large number of foreign nationals, these scientists are generally students and faculty at U.S. universities and scientists at U.S. companies that simply are not U.S. citizens.

For industrial access it is again reasonable to ask if this competitive policy impedes access by U.S. companies relative to foreign ones. Again taking the APS as an example, only about 2% of the experiments conducted at the facility annually are proprietary in nature and only 0.2% of work done at APS is proprietary work conducted by foreign industries. Clearly, foreign proprietary research is only a tiny fraction of the total work conducted. Additionally, for proprietary or IP-protected research, the current system offers opportunities for laboratory and DOE management to determine whether the proposed research is in the national interest. I would argue that based on these levels of usage by U.S. users, particularly for proprietary access, further regulations or restrictions seem unwarranted.

I would also, respectfully, like to make some personal observations on this topic. I believe that competition is healthy for the scientific endeavor. U.S. scientists are better having to engage in collegial competition with our international counterparts. In science, communication implies cross-fertilization. The communities surrounding U.S. science facilities become richer for seeing firsthand what our colleagues from abroad are working on. While it is certainly true that they may take scientific inspiration back home, they leave scientific inspiration behind just as often. Similarly, as foreign countries build advanced user facilities of their own, attracting top U.S. scientific talent to use them, these foreign nations are benefiting from the knowledge these researchers bring as part of conducting experiments at these facilities. In these times of budget stringencies, user facilities worldwide are attempting to avoid duplication and redundancy in services with other facilities. Sharing of resources through exchange of access also enables U.S.-based scientists to have use of additional resources not locally available. I truly do believe that U.S. companies, U.S. scientists, and U.S. citizens benefit substantially by the current system. It is very hard for me to imagine that any change to policy that serves to reduce the healthy, beneficial competition that currently exists would actually serve the intended purpose. Ultimately, adequate and sustained funding for basic research in the U.S., not only in supporting facilities but particularly in supporting individual primary investigator, is the best way of ensuring U.S. scientists and companies continue to lead in scientific discovery and innovation worldwide.

SLAC NATIONAL ACCELERATOR LABORATORY

**OFFICE OF THE DIRECTOR**

The Honorable Congressman Andy Harris
Chairman, Subcommittee on Energy & Environment
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Persis S. Drell
Professor and Director
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July 18, 2012

**RE: DEPARTMENT OF ENERGY USER FACILTIES: UTILIZING THE TOOLS OF SCIENCE TO DRIVE INNOVATION THROUGH FUNDAMENTAL RESEARCH**

Dear Chairman Harris,

I appreciate the opportunity to participate in the Committee on Science, Space, and Technology hearing on June 21, 2012. Transcript edits follow:

Line 404: 'actions' should read 'applications'
Line 405: 'virus' should read 'viruses.

My response to the questions submitted by the Members of the Committee follows on the next page.

Sincerely,

Persis S. Drell
Professor and Director

cc: Rep. Brad Miller
Ranking Member
Subcommittee on Energy & Environment

U.S. HOUSE OR REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON ENERGY & ENVIRONMENT

Questions for the Record
The Honorable Andy Harris

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

Dr. Persis Drell

1. In general, how do other countries manage intellectual property associated with user facility research conducted using government resources?

   *Based upon very limited data available to SLAC, it does not appear that research facilities around the world that are engaged in fundamental research have a consistent approach to the regulation or management of intellectual property created by guest users at their facilities. In some instances, our scientists have been able to conduct research at some of those facilities without executing any agreement regarding intellectual property rights. From this, we conclude that any inventions developed by our scientists at those facilities would belong to DOE or Stanford. However, SLAC is engaged primarily in fundamental research as opposed to applied research and are frequently collaborating with scientists from the host institution. This might not be the case if we were engaged in applied research at those facilities.*

   a. Please provide any recommendations regarding potential opportunities to improve DOE's current user facility IP structure.

      *I do not have any recommendations or proposed changes or suggested improvements to DOE's current IP structure for our user facilities. Congress has funded and DOE has constructed a variety of large research facilities that DOE makes available for use by others on a merit-based priority. As managers of government sponsored user facilities, we are mindful of our responsibilities to protect the government's interest in intellectual property generated using government funds and facilities. Similar to other DOE laboratories, our user agreements fall into one of two categories: (1) Non-proprietary agreements that allow the User free use of the facility for an approved experiment, which requires users to publish the results of the research undertaken at the facility and grants the U.S. Government a government use license in any intellectual property generated from the research performed at the facility or (2) a Proprietary User Agreement that allows the User to perform their approved experiment on a "full cost recovery" basis, delay or limit publishing of their research results, and grants the U.S. Government a very limited set of rights into any intellectual property generated through their experiment. In this way we ensure that the benefits of the research performed at no cost to the User remain available for U. S. Government use within the United States, and retain limited rights for the government even when the work is performed on a full cost basis.*

*I also wish to provide some additional background in response your hearing question on international users at SLAC.*

*In FY11, 2,031 scientists participated in experiments at SLAC's two major user facilities, the Linac Coherent Light Source and the Stanford Synchrotron Radiation Light Source. 75% of them represented US institutions (US universities, government labs, industry) and 25% percent represented institutions outside the US.*

*At the LCLS alone, 43 percent of users in FY11 represented US institutions. This roughly tracks the percentage of research proposals received from US institutions for that period. It also reflects the unique status of the LCLS. While there are many synchrotron light sources like our SSRL operating throughout the world, until recently the LCLS was the only operating free-electron X-ray laser facility, and so it has attracted strong, pent-up global demand from scientists who have been waiting for this chance to explore questions that were entirely out of reach before. After the US, the largest number of experimental proposals for the FY11 run came from Germany, France, the United Kingdom, Switzerland, Sweden, Italy, Denmark, Japan, South Korea and Australia. Many of these proposals from other countries include US scientists; LCLS proposals on average involve 15 collaborating researchers. Having the best scientists in the world come here to collaborate and share their expertise with our researchers has tremendous benefits for the American research enterprise.*

*The tradition of making user facilities available to the scientists with the best research proposals, regardless of where they come from, is based on decades of pragmatic experience: This is simply the way the best science gets done, and the way the quickest progress is made. Especially for research with no immediate economic application, the free exchange of information is generally viewed as to the benefit of everyone.*

*As an example, experiments at the LCLS have been testing a new technique called "self-seeding" that greatly improves the power and capabilities of the facility's X-ray laser beam. This idea originated with scientists at the German national laboratory, DESY, who published their findings in the open literature. People at other free-electron X-ray laser labs around the world are closely watching the SLAC experiments and are already planning to incorporate self-seeding into their own facilities. Meanwhile, SLAC scientists have been traveling to Japan to perform experiments at the new free-electron laser facility that recently opened there. In today's world, this fluid movement of people and ideas is essential for the development of groundbreaking technologies and for progress in every field of science.*

**Stephen R. Wasserman**

**Questions for the Record**

1) **In general, how do other countries manage intellectual property associated with user facility research conducted using government resources?**

Dr. Lanzirotti has provided a summary of intellectual property provisions at several international synchrotrons: the European Synchrotron Radiation Facility (France), the Canadian Light Source, the Diamond Light Source (UK), and the SPring-8 synchrotron facility (Japan). As a user of three of these facilities, we can confirm that the agreements between Lilly and the synchrotron incorporate the IP terms Dr. Lanzirotti described.

**a) Please provide any recommendations regarding potential opportunities to improve DOE's current user facility IP structure.**

As we noted in our original written testimony, Lilly covers all costs associated with its experiments at the Advanced Photon Source, including, through our support of the general user program, the original investment in constructing the APS. We believe that in cases where there is no financial support from the government for experiments at user facilities, ownership of intellectual property should automatically rest with the user. This simple framework is employed at the international synchrotrons with which our company has relationships. The current master user agreements from DOE laboratories have ambiguities in this area.

The uncertainties in ownership and rights to IP can be a disincentive for proprietary and possibly non-proprietary, users to interact with the National User Facilities. Indeed Lilly has designed its operations at the APS to avoid potential IP issues. Users would benefit from clarity in the terms on intellectual property within the user agreements. To our knowledge the DOE has never asserted its potential IP rights to inventions by users at National User Facilities. Consequently there appears to be little if any downside to creating an IP environment that is more welcoming to proprietary users.

We recognize the importance of demonstrating the effectiveness of DOE's support for the national user facilities. However, it is required that an invention covered by the user agreements be reported to DOE Patent Counsel within 6 months of conception or reduction to practice. This timeline is much too short for industry and could result in premature public disclosure. We suggest instead that inventions be reported immediately after publication of the relevant patent application.

2) **Your testimony notes the opportunity to improve user agreements for DOE's National Scientific User Facilities. Further, you mention Eli Lilly is working with Argonne National Laboratory to update the agreements for the use of the**

**Advanced Photon Source beamline. Please further elaborate on how user agreements could be improved.**

In recent years the Department of Energy has revised its user agreements. The new agreements have a distinct advantage over the previous versions. They now cover multiple user facilities within a single national laboratory, rather than each facility individually. A global agreement that covers all DOE user facilities remains a goal for the future.

The new agreements, an example of which is attached, focus on users who perform experiments on facility-owned and -operated beamlines. The management of the Advanced Photon Source agrees that these agreements can use improvement, especially for beamlines that are operated independently of the User Facility. Areas for development include indemnification for damage caused by general users to beamline equipment owned by non-DOE organizations, termination provisions, and, as discussed above, intellectual property. We are confident that DOE and its contractor laboratories, working with users such as ourselves, will be able to address these concerns to the benefit of both sides.

3) **It is longstanding policy for most research conducted at scientific user facilities to be transparent and published in the open literature. However, it seems concerning that the United States' top international competitors not only get access to and benefit from the research conducted at U.S. user facilities, they can even compete to use these machines themselves. Is there any way we can change policies to better benefit U.S. companies and citizens without disrupting longstanding practices of open scientific inquiry?**

The significant number of international users at National User Facilities is often a reflection of the high quality educational opportunities available in the United States. At the Advanced Photon Source, the great majority of international users are affiliated with academic institutions in America.

Because of the international reciprocity of science, Lilly is able to use X-ray synchrotrons in other countries. In this way we continue to obtain data of a quality similar to that from the APS when the light source has scheduled shutdowns for maintenance.

A goal of the DOE Office of Science is to leverage the capabilities of the National User Facilities to the greatest benefit for U.S. researchers, corporate and academic. Possibly the best way to do so is to match the needs of scientists and technologists with what the facilities offer. This approach requires the ongoing effort at many facilities to educate new users. Novice users can benefit from the great expertise of scientists employed by the facility. To encourage scientific discourse between facility and user, a new legal infrastructure that supports and enhances this type of interaction may be required.

**U.S. HOUSE OF REPRESENTATIVES**
**COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY**
**SUBCOMMITTEE ON ENERGY & ENVIRONMENT**

**Questions for the Record**
**The Honorable Andy Harris**

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

Ms. Suzy Tichenor

**How does Oak Ridge National Laboratory determine how much of its supercomputing capacity is available for industrial use? How is the remainder of the facility's computing capacity primarily allocated?**

In accordance with the Computational Facilities Allocation Policy[1] established by the Office of Advanced Scientific Computing Research (ASCR) in the Office of Science of the U.S. Department of Energy (DOE), time on the Jaguar high-performance computing system at the Oak Ridge Leadership Computing Facility (OLCF) is allocated through three programs. Industry is eligible to apply for time through any of these programs:

1. 60% of the system is allocated through the flagship Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program.[2] The mission of the INCITE program is to enable high-impact, grand-challenge research that could not otherwise be performed without access to the DOE's leadership-class systems. This program is open to all researchers across academia, industry, and government from around the world. Allocations are made through an annual peer review proposal process. For program year 2012, INCITE made awards totaling 940 million cpu hours on Jaguar with allocations generally ranging from 20 million to 100 million cpu hours. GE Global Research, Pratt & Whitney, Boeing, General Atomics, Shell, and Procter & Gamble (some in partnership with universities) have all received INCITE awards, proving that industry can win allocations based on merit and impact in this highly competitive program. INCITE has a "computational readiness" requirement to ensure that projects are, in fact, able to use a leadership-caliber supercomputer such as Jaguar. That requirement stipulates that projects typically must be able to use 20% of the system in their production runs.

2. 30% of the system is allocated through the ASCR Leadership Computing Challenge (ALCC).[3] The mission of the ALCC is to award time for special situations of interest to the DOE with an emphasis on high-risk, high-payoff simulations in areas directly related to the agency's energy mission, such as discovering and understanding new materials and chemical processes, advancing the clean energy agenda, and understanding the Earth's climate; for

[1] http://science.energy.gov/~/media/ascr/pdf/incite/docs/Allocation_process.pdf
[2] http://science.energy.gov/ascr/facilities/incite/
[3] http://science.energy.gov/ascr/facilities/alcc/

national emergencies; for exploration of new frontiers in physical and biological sciences; or for broadening the community of researchers capable of using leadership computing resources. This program is open to all researchers across academia, industry, and government from around the world. ALCC allocations are made through an annual peer review proposal process. For program year 2012, United Technologies Research Center, GE Global Research, semiconductor manufacturer Global Foundries, and Ramgen Power Systems, a small engineering firm in Seattle that is developing novel technology for carbon sequestration, received allocations of time on Jaguar ranging from 7 million to 40 million cpu hours. Ramgen Power Systems received the largest of these awards (40 million cpu hours), demonstrating that big problems are not the sole purview of big companies. Small companies, the backbone of the economy, also have complex, cutting-edge problems that can benefit from access to leadership class high performance computing systems like Jaguar.

3. The remaining 10% of the Jaguar system is allocated locally at the discretion of the OLCF Director. The principal goals of this Director's Discretion (DD) program are threefold: development of strategic partnerships; preparation for leadership computing (i.e., providing users the opportunity to configure their application codes for leadership-class capabilities); and application performance benchmarking, analysis, modeling, scaling and workflow studies, data analytics, and system software and tool development. Applications are accepted year-round and an internal Resource Utilization Council makes the final decision, using written input from subject matter experts. Grants are typically in the range of 1 million cpu hours but can be as large as 5 million cpu hours.

   OLCF also uses the DD allocations to grant time to industry, although there is not a specific set-aside for this purpose. This has been a terrific way for companies to "get their feet wet" with leadership computing environments. They are able to run much larger problems than they can run on their internal systems, work on scaling their software, and/or test government or university codes that already scale. And after several years of making DD grants to industry, we are seeing companies gain the experience needed to successfully compete for larger allocations through the ALCC program, and even the flagship INCITE program. Companies that have received DD allocations range from small to some of the largest in the nation. SmartTruck Systems, a small South Carolina engineering firm, used Jaguar to understand the airflow around long haul (18-wheel) trucks in order to design add-on parts that redirect that flow and thereby increase fuel efficiency. Access to Jaguar helped SmartTruck reduce the time from concept to a manufacture-ready design by 50%. At the other end of the spectrum, GM (#5 on the Fortune 500) and Ford (#9 on the Fortune 500) have also had DD projects on Jaguar.

**Please provide some additional examples of unsolved industrial problems that supercomputers could help answer. Would it be beneficial to increase the amount of time available at Oak Ridge Leadership Computing Facility for industrial users?**

Use of modeling and simulation with high-performance computing can have a dramatic impact across every industrial sector. For example, at present the auto and aerospace industries cannot do full-scale simulations of automobiles or aircraft; they can only simulate parts of these complex systems. Modeling and simulation can be applied across the manufacturing sector to replace or dramatically reduce the need to create physical prototypes. It can expedite the development of new and much-needed classes of catalysts, drugs, and lightweight materials for cars to increase fuel efficiency. Predictive simulation capability could also substantially improve the performance of internal combustion engines[4] and accelerate the development of advanced nuclear technologies.[5]

Although computing resources often fall short of demand across the OLCF application portfolio (the INCITE program generally receives three times as many requests for cpu hours as can be accommodated), a more critical issue for industrial projects is their need for support. Industrial users typically have less experience in using leadership systems than other users, as discussed below. Simply increasing the amount of time available at OLCF to industrial users might be beneficial for firms that have the in-house resources (talent and software) needed to make effective use of this time, but it would not address the need for the additional support that would be required to ensure productive use of leadership-class systems by less experienced users. OLCF is staffed to support principally the flagship INCITE program, and INCITE awardees are among the most experienced high-performance computing users in the world. Industrial users who access OLCF via the ALCC and DD pathways have equally complex problems to solve, but they generally do not have the same level of experience in using large-scale systems as INCITE users, and their software generally does not scale well. They often need much more assistance to have a successful experience.

**How does the Leadership Computing Facility make its resources available to small and mid-size industrial users? What are the biggest obstacles for those firms to achieve additional benefits derived from the use of supercomputing?**

OLCF makes its resources available to small and mid-size industrial users through the three programs outlined above: INCITE, ALCC, and the DD allocations. The availability of these resources is communicated to potential users through general announcements from ASCR and, for OLCF, through the outreach efforts of the Industrial Partnerships Program.

The biggest obstacles to effective use of supercomputing by small and mid-size industrial firms are lack of experience in using large-scale systems and lack of software that scales to the highly parallel architectures of these systems.

Many companies (particularly small to mid-size firms) are prevented from advancing in their application of modeling and simulation with high-performance computing by a lack of adequate in-house expertise. Even companies that are committed to using high-performance computing may not be able to maintain the in-house expertise, or enough of it, to apply the technology to their problems. And while almost no company can afford a system of the caliber of Jaguar, small and mid-size firms in particular often cannot afford to upgrade their small in-house systems to more powerful systems that could expand their use of modeling and simulation.

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[4] http://science.energy.gov/bes/news-and-resources/reports/abstracts/#Presice.
[5] http://science.energy.gov/bes/news-and-resources/reports/abstracts/#ACMS.

Other challenges impede broader industrial access to our systems. For example, most firms do not have extensive in-house software development capabilities, relying instead on commercially available software. Commercial software is generally not written to execute on highly parallel architectures, frequently scaling from only a few cores (processors) to a few hundred cores. In contrast, application software running on leadership computing systems often scales from several thousand to a hundred thousand or more cores. Until commercial software firms make the investments to scale their software, it will be difficult for many companies to take advantage of OLCF resources. And even when commercial codes do scale to several thousand cores, some firms using these codes are not taking advantage of this capability. Those firms must make the internal investment to scale up to at least the limits of their commercial software.

The OLCF plays a role in overcoming these obstacles by providing industrial users with access to high-performance computing tools (systems and government/university software that scales), talent (OLCF expertise), and training. Through these activities, the OLCF is increasing the impact of high-performance computing across the industrial sector. As we are successful in outreach and training to industry, industry should be better positioned to submit more well-qualified industrial proposals, resulting in increased allocations to industry and an increased return on the federal government's investment in the OLCF through more impactful science.

**U.S. HOUSE OF REPRESENTATIVES**
**COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY**
**SUBCOMMITTEE ON ENERGY & ENVIRONMENT**

**Questions for the Record**
**The Honorable Andy Harris**

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

Dr. Ernest Hall

1. It is longstanding policy for most research conducted at scientific user facilities to be transparent and published in the open literature. However, it seems concerning that the United States' top international competitors not only get access to and benefit from the research conducted at U.S. user facilities, they can even compete to use these machines themselves. Is there any way we can change policies to better benefit U.S. companies and citizens without disrupting longstanding practices of open scientific inquiry?

Response from Dr. Ernest Hall, GE Global Research:

I would like to address several aspects of this important question.

First, it is our impression that the use of the DOE Scientific User Facilities is at present dominated by university, government lab, and industrial users with US affiliations. We do not have concerns about either access or information security based on usage by non-US scientists.

At the same time, as a global company we benefit from access to similar user facilities, particularly synchrotron and neutron facilities, in other parts of the world including Canada, Europe, and Asia. We have used these facilities in the past for some very specialized experiments or to support our research efforts in other global locations, although the great majority of our research of this type occurs in the US. We support the open access of the world's scientific community to the world's best research facilities. However, it may be desirable to consider some priority or focus on specific US strategic goals and institutions (for example, small businesses). For example, the European Synchrotron Research Facility gives preference to proposals from contracting, or funding, countries, while maintaining some openness to all researchers (http://www.esrf.eu/UsersAndScience/UserGuide/Applying/Non-ContractingCountries).

Finally, we generally feel that the DOE policies of open access through the proposal system, plus the possibility of protecting intellectual property by doing proprietary research at a cost, is a good system.

We have argued in the past for adding national priorities, societal impact, and technological importance to the proposal evaluation process, in addition to the present criterion of scientific merit, and have seen some responsiveness from DOE on this topic. These criteria should also be used in the consideration of the construction of new facilities and the operation of existing facilities. Since the cost of doing research needs to be passed along to customers of US industries in the form of product prices, it is also important that all research at user facilities, including proprietary research, be available at the lowest cost possible.

In the final analysis, as I mentioned in my oral testimony, the DOE Scientific User Facilities are powerful tools that enable the advancement of science and the development of technological solutions to the world's most important issues. It is critically important that US scientists have access to the world's best tools, both for cutting-edge science and the less-glamorous robust technology development. In the end, this is best achieved by openness and participation by all of the world's leading scientists, while ensuring appropriate safeguards are in place to protect intellectual property in specific cases.

# Appendix 2

## Additional Material for the Record

PROPRIETARY USER AGREEMENT, UCHICAGO ARGONNE, LLC, OPERATOR OF ARGONNE NATIONAL LABORATORY

Lofgren

UNIVERSITY OF OXFORD • DEPARTMENT OF PHYSICS

Clarendon Laboratory • Parks Road • Oxford • OX1 3PU

Oxford Physics

April 24, 2012

Dr. Christopher Deeney
Assistant Deputy Administrator for Stockpile Stewardship
Defense Programs, National Nuclear Security Administration
US Department of Energy
1000 Independence Ave. SW
Washington, DC 20585

Dear Dr. Deeney:

I am writing regarding fundamental science at NIF, the recent NIF User Group meeting, and NIF shot allocations for FY2013. I will provide more detailed explanation below, but my main point is that I believe it essential for HED science on NNSA facilities, and the future of science on NIF in particular, that significant facility time (approximately 25 days) for fundamental science at NIF be provided in FY2013. I have heard that NNSA has provided draft guidance that only 5% of NIF time would be devoted to work outside the Stockpile Stewardship Program (SSP), of which only a fraction would be available to the fundamental science program. Proceeding with this allocation would have a very severe and enduring negative impact on the fundamental science community. I would appreciate the opportunity to discuss this with you personally in the near future.

As you are aware, the May 2011 joint NNSA/Office of Science workshop on "User Science at NIF" and subsequent workshop report were positively received by the fundamental science community and significantly increased the longstanding desire for access to NIF by academic users. The strong interest in NIF was further underscored by our recent NIF User Group meeting, held Feb. 12-15, 2012. This meeting, the first of its kind at LLNL, attracted a response larger than anticipated, with over 160 individuals representing 16 countries. The meeting had a strong attendance of early and mid-career scientists- in particular, over 30 students and postdocs attended. The talks were well received and a strong sense of scientific enthusiasm was present.

The major concern expressed at the meeting was the amount of NIF time available for fundamental science and the availability of target fabrication and other supporting resources. In the current fiscal year, 8 days have been allocated to fundamental science at NIF. Under the proposed guidance, approximately the same number of days would be available in FY2013- this would represent roughly just 3% of the available facility time. Under this scenario slow progress would be made on the set of experiments approved as a result of the 2009/2010 NIF call for proposals.

It is my firm view that this allocation would be a major setback to fundamental science at the NIF, including the building of the associated community and training of the next generation of scientists and engineers to support NNSA programs. DOE and laboratory management have both stated numerous times that approximately 15% of NIF time would be available to external users, and the groups who have been told they have been successful in their bids for access have been working to timetables based on this figure. DOE has also long stated the importance of fundamental science at NIF, and I believe this was most recently reiterated in a letter from Don Cook to Bill Brinkman prior to the May 2011 workshop. It has also been nearly two years since approval of the initial set of NIF fundamental science experiments.

With these DOE commitments, the demonstrated outstanding capabilities demonstrated by the facility, and the momentum from the 2011 workshop and the NIF User Group meeting, it is now time to move forward with a strong program of NIF fundamental science experiments in FY2013.

I would very much appreciate the opportunity to discuss this with you further, and will be in touch to set up a time. I look forward to working with you and your colleagues to realize the scientific opportunities provided by this unique, world-class facility.

Yours Sincerely,

Professor Justin Wark
University of Oxford
Chair of the NIF User Group

Cc:
D. Cook (NNSA)
J. Quintenz (NNSA)
K. Levedahl (NNSA)
E. Moses (LLNL)
C. Keane (LLNL)

***The Department of Energy has opted to utilize the following agreement for Designated Proprietary User Facilities transactions. Because these transactions are widespread across Departmental facilities, uniformity in agreement terms is desirable. Except for the *** provisions, minor modifications to the terms of this agreement may be made by CONTRACTOR, but any changes to the *** provisions or substantive changes to the non *** provisons will require approval by the DOE Contracting Officer, WHICH WILL LIKEY DELAY YOUR ACCESS TO THE USER FACILITY. In instances where DOE Contracting Officer approval for substantive changes cannot be obtained, Work for Others (WFOs) and Cooperative Research and Development Agreements (CRADAs) may be more appropriate due to the increased flexibility such agreements afford. Where this agreement is to be used as an umbrella agreement for multiple transactions it may be modified to reflect such usage.***

**Proprietary User Agreement**

BETWEEN

UChicago Argonne, LLC
("CONTRACTOR")
Operator of Argonne National Laboratory (hereinafter "Laboratory") under U.S. Department of Energy ("DOE") Contract No.DE-AC02-06CH11357

AND

______________________________
("USER")

(CONTRACTOR and USER are collectively, "the Parties")

The obligations of the Contractor may be transferred and shall apply to any successor in interest to said Contractor continuing the operation of the DOE facility involved in this Proprietary User Agreement.***

**ARTICLE I. <u>FACILITIES AND SCOPE OF WORK</u>**

Employee(s), consultant(s), and representative(s) of USER (hereinafter called "Participant(s)") shall be permitted to use certain Laboratory Proprietary User Facilities for the purpose of performing the experiment(s) accepted and approved for performance at the designated Proprietary User Facility. This Proprietary User Agreement shall be incorporated by reference and apply to all such experiments accepted and conducted at the designated Proprietary User Facilities which are totally funded by USER.

Upon request by USER and at the CONTRACTOR's discretion, limited non-collaborative support services may be provided to the USER by CONTRACTOR employees. CONTRACTOR will retain its employees assigned to this work on its payroll and will be reimbursed by USER for the account of DOE in accordance with DOE's pricing policy, which provides for full cost recovery.

**ARTICLE II. TERM OF THE AGREEMENT**

This Agreement shall have a term of five (5) years from the effective date. The term of this Agreement shall be effective as of the latter date of (1) the date on which it is signed by the last of the Parties, or (2) the receipt of any advance payment required under Article III. Unless terminated in accordance with the terms herein, this Agreement shall automatically renew on a year-to-year basis after the initial five year term.

**ARTICLE III. BILLING AND PAYMENT OF EXPENSES**

A. USER will coordinate with CONTRACTOR to prepare a cost estimate for USER's experiment at the User Facility, including potential limited non-collaborative support services from CONTRACTOR as requested by USER. All costs will be in accordance with DOE Order O 522.1, "Pricing of Departmental Materials and Services."

B. Full cost recovery rates are established at the beginning of each fiscal year and are subject to revision to reflect changing costs factors during the fiscal year. No work can begin until this advance payment is received by CONTRACTOR.

C. USER must set up and pre-fund the advance payment for the User Account as set forth in the CONTRACTOR Policy and Procedure for User Accounts before beginning an accepted and approved experiment. CONTRACTOR will invoice USER at the Billing Address provided by the USER, and USER will pay each such invoice in accordance with the instructions set forth in the CONTRACTOR Policy and Procedure for USER Accounts.

D. USER represents that the funding it brings to this Agreement does not include federal funds.

**ARTICLE IV. ADMISSION REQUIREMENTS**

USERs and Participants are subject to the administrative and technical supervision and control of CONTRACTOR; and will comply with all applicable rules of CONTRACTOR and DOE with regard to admission to and use of the User Facility, including safety, operating and health-physics procedures, environment protection, access to information, cyber-security, hours of work, and conduct. Participants shall execute any and all documents required by CONTRACTOR acknowledging and agreeing to comply with such applicable rules of CONTRACTOR and the terms of this Agreement. Participants will not be considered employees of CONTRACTOR for any purpose.

**ARTICLE V. PROPERTY AND MATERIALS****

USER may be permitted by the CONTRACTOR to furnish equipment, tooling, test apparatus, or materials necessary to assist in the performance of its experiment(s) at the User Facility. Such items shall remain the property of USER. Unless the Parties otherwise agree, all such property furnished by USER or equipment and test apparatus provided by USER will be removed by USER within sixty (60) days of termination or expiration of this Agreement or will be disposed of as directed by USER at USER's expense. Any equipment that becomes integrated into the User Facility shall be the property of the Government. USER acknowledges that any material supplied by USER may be damaged, consumed or lost. Materials (including residues and/or other contaminated material) remaining after performance of the work or analysis will be removed in their then condition by USER at USER's expense. USER will return User Facilities and equipment utilized in their original condition except for normal wear and tear.

CONTRACTOR shall have no responsibility for USER's property at the User Facility other than loss or damage caused by willful misconduct or gross negligence of CONTRACTOR or its employees.

Personal property produced or acquired during the course of this Agreement shall be disposed of as directed by the owner at the owner's expense.

**ARTICLE VI. <u>SCHEDULING</u>*****

USER understands that CONTRACTOR will have sole responsibility and discretion for allocating and scheduling usage of the User Facilities and equipment needed for or involved under this Agreement.

**ARTICLE VII. <u>INDEMNITY AND LIABILITY</u>*****

A. **Personnel Relationships** - USER shall be responsible for the acts or omissions of Participants.
B. **Product Liability** - To the extent permitted by US and US State law, if USER utilizes the work derived from this Agreement in the making, using, or selling of a product, process or service, then USER hereby agrees to hold harmless and indemnify CONTRACTOR and the United States Government, their officers, agents and employees from any and all liability, claims, damages, costs and expenses, including attorney fees, for injury to or death of persons, or damage to or destruction of property, as a result of or arising out of such utilization of the work by or on behalf of USER, its assignees or licensees.
C. **General Indemnity** - To the extent permitted by US and US State law, USER hereby agrees to indemnify and hold harmless CONTRACTOR and the United States Government, their officers, agents and employees from any and all liability, claims, damages, costs and expenses, including attorney fees, for injury to or death of persons, or damage to or destruction of property, to the extent such liability, claims, or damages is caused or contributed to by the negligence or intentional misconduct of USER or its employees or representatives during the performance of the work under this Agreement.
D. **Patent and Copyright Indemnity—Limited** - To the extent permitted by US and US State law, USER shall fully indemnify the Government and CONTRACTOR and their officers, agents, and employees for infringement of any United States patent or copyright arising out of any acts required or directed or performed by USER under the Agreement to the extent such acts are not normally performed at the facility.
E. The liability and indemnity provisions in paragraphs B, C and D above shall not apply unless USER shall have been informed as soon as practicable by CONTRACTOR or the Government of the suit or action alleging such liability or infringement, and such indemnity shall not apply to a claimed liability or infringement that is settled without the

consent of USER unless required by a court of competent jurisdiction.

**F. General Disclaimer -**

THE GOVERNMENT AND CONTRACTOR MAKE NO EXPRESS OR IMPLIED WARRANTY AS TO THE CONDITIONS OF THE USER FACILITY FURNISHED HEREUNDER. IN ADDITION, THE GOVERNMENT, CONTRACTOR AND USER MAKE NO EXPRESS OR IMPLIED WARRANTY AS TO THE RESEARCH OR ANY INTELLECTUAL PROPERTY, GENERATED INFORMATION, OR PRODUCT MADE OR DEVELOPED UNDER THIS AGREEMENT, OR THE OWNERSHIP, MERCHANTABILITY, OR FITNESS FOR A PARTICULAR PURPOSE OF THE RESEARCH OR RESULTING PRODUCT; THAT THE GOODS, SERVICES, MATERIALS, PRODUCTS, PROCESSES, INFORMATION, OR DATA TO BE FURNISHED HEREUNDER WILL ACCOMPLISH INTENDED RESULTS OR ARE SAFE FOR ANY PURPOSE INCLUDING THE INTENDED PURPOSE; OR THAT ANY OF THE ABOVE WILL NOT INTERFERE WITH PRIVATELY OWNED RIGHTS OF OTHERS. THE GOVERNMENT, CONTRACTOR AND/OR USER SHALL NOT BE LIABLE FOR SPECIAL, CONSEQUENTIAL, OR INCIDENTAL DAMAGES ATTRIBUTED TO USE OF SUCH FACILITIES, RESEARCH OR RESULTING PRODUCT, INTELLECTUAL PROPERTY, GENERATED INFORMATION, OR PRODUCT MADE OR DELIVERED UNDER THIS AGREEMENT.

**G. Notice and Assistance Regarding Patent and Copyright Infringement**

a. USER shall report to the Government, promptly and in reasonable written detail, each notice or claim of patent or copyright infringement based on the performance of this Agreement of which USER has knowledge.

b. In the event of any claim or suit against the Government on account of any alleged patent or copyright infringement arising out of the performance of this Agreement or out of the use of any supplies furnished or work or services performed hereunder, USER shall furnish to the Government when requested by the Government, all evidence and information in possession of USER pertaining to such suit or claim. Such evidence and information shall be furnished at the expense of the Government except where USER has agreed to indemnify the Government.

**ARTICLE VIII. <u>PATENT RIGHTS</u>*****

**A. Definitions**

**1.** "Subject Invention" means any invention or discovery of USER conceived or first actually reduced to practice in the course of or under this Agreement.

**2.** "Patent Counsel" means the DOE Patent Counsel assisting the Facility Operator.

**B. Rights of USER – Election to Retain Rights**

With respect to any Subject Invention reported and elected in accordance with paragraph (C) of this clause, USER may elect to obtain the entire right, title and interest in any patent application filed in any country on a Subject Invention and in any resulting patent secured by USER. Where appropriate, the filing of patent application by USER is subject to DOE security regulations and requirements.

**C. Invention Identification, Disclosures, and Reports**

USER shall furnish the Patent Counsel a written report concerning each USER Subject Invention within six months after conception or first actual reduction to practice, whichever occurs first. If USER wishes to elect title to the Subject Invention, a notice of election should be submitted with the report or within one year of such date of reporting of the Subject Invention.

**D. Facilities License**

USER agrees to and does hereby grant to the Government an irrevocable, nonexclusive paid-up license in and to any inventions or discoveries, regardless of when conceived or actually reduced to practice or acquired by USER, which at any time through completion of this Agreement are owned or controlled by USER and are incorporated in the User Facility as a result of this Agreement to such an extent that the User Facility is not restored to the condition existing prior to the Agreement (1) to practice or to have practiced by or for the Government at the user Facility, and (2) to transfer such licenses with the transfer of that User Facility. The acceptance or exercise by the Government of the aforesaid rights and license shall not prevent the Government at any time from contesting the enforceability, validity or scope of, or title to, any rights or patents herein licensed

**ARTICLE IX. <u>RIGHTS IN TECHNICAL DATA***</u>**

**A. Definitions**

1. "Technical Data" means recorded information, regardless of form or characteristic, of a scientific or technical nature. Technical data as used herein does not include financial reports, cost analyses, and other information incidental to Agreement administration.
2. "Proprietary Data" means technical data which embody trade secrets, developed at private expense, such as design procedures or techniques, chemical composition of materials, or manufacturing methods, processes or treatments, including minor modifications thereof, provided that such data:
   - **a.** are not generally known or available from other sources without obligation concerning their confidentiality,
   - **b.** have not been made available by the owner to others without obligation concerning their confidentiality,
   - **c.** are not already available to the Government without obligation concerning their confidentiality, and
   - **d.** are marked as "Proprietary Data."
3. "Unlimited Rights" means rights to use, duplicate or disclose technical data, in whole or in part, in any manner and for any purpose whatsoever, and to permit others to do so.

**B.** USER agrees to furnish to DOE or CONTRACTOR those data, if any, which are (1) essential to the performance of work by DOE or CONTRACTOR personnel or (2) necessary for the health and safety of such personnel in the performance of the work. Any data furnished to DOE or CONTRACTOR shall be deemed to have been delivered with unlimited rights unless marked as "Proprietary Data" of USER.

**C.** USER agrees that it shall have the sole responsibility for identifying and marking all documents containing Proprietary Data which are furnished by USER or produced under this Agreement. USER further agrees to mark each such document by or before termination of the Agreement by placing on the cover page thereof a legend identifying the document as Proprietary Data of USER and identifying each page and portion thereof to which the marking applies. The Government and CONTRACTOR shall not disclose properly marked Proprietary Data of USER outside the Government and CONTRACTOR. The Government and CONTRACTOR reserve the right to challenge the proprietary nature of any markings on data.

**D.** USER is solely responsible for the removal of all of its Proprietary Data from the facility by or before termination of this Agreement. The Government shall have unlimited rights in any Technical Data (including Proprietary Data) which are not removed from the facility by or before termination of the Agreement. The Government shall have unlimited rights in any Technical Data (including Proprietary Data) which are incorporated into the User Facility under the Agreement to such extent that the User Facility or equipment is not restored to the condition existing prior to such incorporation.

**E.** Upon completion or termination of the project, USER agrees to deliver to DOE and CONTRACTOR a non-proprietary report describing the work performed under the Agreement.

**ARTICLE X. <u>LABORATORY SITE ACCESS, SAFETY AND HEALTH</u>** ***

As a precondition to using CONTRACTOR User Facilities, Participants must complete all CONTRACTOR Site Access documents and requirements. USER and Participants shall take all reasonable precautions in activities carried out under this Agreement to protect the safety and health of others and to protect the environment. Participants must comply with all applicable safety, health, access to information, security and environmental regulations and the requirements of the Department and CONTRACTOR, including the specific requirements of the Proprietary User Facility covered by this Agreement. In the event that USER or Participant fails to comply with said regulations and requirements, CONTRACTOR may, without prejudice to any other legal or contractual rights, issue an order stopping all or any part of USER's or Participant's activities at the Designated Proprietary User Facility.

**ARTICLE XI. <u>PERSONNEL RELATIONSHIPS</u>** ***

Participants will remain employees or representatives of USER at all times during their participation in the work under this Agreement, and shall not be considered employees of CONTRACTOR or DOE for any purpose. Participants shall be subject to the administrative and technical supervision and control of CONTRACTOR during and in connection with the Participants' activities under this Agreement.

**ARTICLE XII. EXPORT CONTROLS*****

USER acknowledges that the export of goods or Technical Data may require some form of export control license from the U.S. Government and that failure to obtain such export control license may result in criminal liability under the laws of the United States.

**ARTICLE XIII. THIRD-PARTY CONTRACTS**

Contracts between USER and third parties for work on CONTRACTOR premises including, but not limited to, construction, installation, maintenance, and repair, will be subject to prior approval by the Department and CONTRACTOR. The Department and CONTRACTOR may require the insertion of specific terms and conditions into such contracts.

**ARTICLE XIV. DISPUTES *****

The parties will attempt to jointly resolve all disputes arising under this agreement. If the parties are unable to jointly resolve a dispute within a reasonable period of time, either party may contact the laboratory's Technology Transfer Ombudsman (TTO) to provide assistance. The TTO may work directly to resolve the dispute or, upon mutual agreement of the parties, contact a third party neutral mediator to assist the parties in coming to a resolution. The costs of the mediator's services will be shared equally by the parties. In the event that an agreement is not reached with the aid of the ombudsman or mediator, the parties may agree to have the dispute addressed by neutral evaluation. The decision rendered by the neutral evaluator shall be nonbinding on the parties, and any costs incurred there from shall be divided equally between the parties. Upon mutual agreement, the parties may request a final decision by the DOE Contracting Officer. Absent resolution, either party may seek relief in a court of competent jurisdiction.

**ARTICLE XV. CONFLICT OF TERMS*****

In the event of any conflict between the terms of this document and any other document issued by either Party, the terms of this document shall prevail.

**ARTICLE XVI. TERMINATION*****

Either Party may terminate this Agreement for any reason at any time by giving not less than thirty (30) days prior written notice to the other Party, provided that CONTRACTOR shall recover payment for the costs incurred by CONTRACTOR on behalf of USER prior to termination and for termination costs.

In witness whereof, the Parties hereto have executed this Agreement:

**AUTHORIZED SIGNATURES:**
By signing this Agreement, the signatories attest that they are legally authorized to commit their respective institutions to this Agreement.

**FOR THE CONTRACTOR: UChicago, Argonne LLC**

**BY:** G. Brian Stephenson
**(Name of Authorized Officer, typed)**

**SIGNATURE** ____________________

**TITLE:** **Interim Associate Laboratory Director for Photon Sciences**

**DATE:** ____________________

**FOR THE USER:**

**BY:** ____________________
**(Name of Authorized Officer, typed)**

**SIGNATURE** ____________________

**TITLE:** ____________________

**DATE:** ____________________

**ADDRESS:** ____________________

____________________

**TELEPHONE:** ____________________