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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.

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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.