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

HEARING CHARTER

America's Next Generation Supercomputer: The Exascale Challenge

Wednesday, May 22, 2013
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

PURPOSE

The Subcommittee on Energy will hold a hearing entitled *America's Next Generation Supercomputer: The Exascale Challenge* on Wednesday, May 22, at 10:00 a.m. in Room 2318 of the Rayburn House Office Building. The purpose of the hearing is to examine high-performance computing research and development challenges and opportunities, specifically as they relate to exascale computing. The hearing will also explore advanced scientific computing research. The hearing will additionally examine draft legislation[1] directing the Department of Energy (DOE) to develop an exascale computing system.

WITNESS LIST

- **Dr. Roscoe Giles**, Chairman, Advanced Scientific Computing Advisory Committee, Professor, Boston University.
- **Dr. Rick Stevens,** Associate Laboratory Director, Computing, Environment and Life Sciences, Argonne National Laboratory.
- **Ms. Dona Crawford,** Associate Director for Computation, Lawrence Livermore National Laboratory.
- **Dr. Daniel Reed,** Vice President for Research and Economic Development, University of Iowa.

BACKGROUND

Scientific research is traditionally conducted through theory or experimentation, both of which generate data that requires the capacity to be processed and analyzed. The invention of computers permitted this data to be examined with increased speed and complexity. As computational technology advanced, this capacity increased in pace and capability, while the data generated from various sensors and experiments also increased in volume. The advent of

[1] Legislation is appended.

scientific discovery in which large volumes of data is gathered and mined to exploit information, sometimes referred to as "big data,"[2] has transformed computing technology needs.

The greater availability and utilization of these high-speed supercomputers allows increasingly complex scientific research to be achieved. Medical research, energy and environment system simulations, computational chemistry, and innumerable other scientific problems directly benefit from high-performance computing (HPC).

Computing speed is measured in floating-point operations per second, or flops. In the 1970's, the first supercomputers had a capacity of about 100 megaflops, or 100 million flops. Through forty years of technology advancement, computing capacity climbed through gigaflops (10^9 calculations per second) and teraflops (10^{12}), to current HPC capacity of petaflops (10^{15}). Exascale computing refers to computing systems capable of a thousand-fold increase over current petascale computers, or the capability to do a quintillion, 10^{18}, calculations per second. To put this in context, there are currently about 1 sextillion (10^{21}) known stars in the universe – therefore "an exascale computer could count every star in the universe in 20 minutes."[3]

Currently, the fastest computer in the world is the Cray Titan, located at Oak Ridge National Lab, with a peak speed of 17.59 petaflops.[4] As of November 2012, the United States was home to five of the ten fastest supercomputers in the world (others include two from Germany and one each from Japan, China, and Italy).[5] Three of the top ten fastest supercomputers in the United States were developed and operated by the Department of Energy at Oak Ridge National Laboratory, Lawrence Livermore National Laboratory, and Argonne National Laboratory. The National Science Foundation also supports the development of supercomputers.

<u>Advanced Scientific Computing Research Program</u>

DOE's Office of Science administers the Advanced Scientific Computing Research (ASCR) program. ASCR is the leading supporter of non-military high-performance computing program within the Federal government. ASCR's mission is to:

> "advance applied mathematics and computer science; deliver, in partnership with disciplinary science, the most advanced computational scientific applications; advance

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[2] For more information on "Big Data" see April 24, 2013 House Science, Space, and Technology Subcommittees on Research and Technology hearing titled *"Next Generation Computing and Big Data Analytics*." http://science.house.gov/hearing/subcommittee-technology-and-subcommittee-research-joint-hearing-next-generation-computing

[3] Department of Energy, Advanced Scientific Computing Research "Leap to the extreme scale could break science boundaries," February 14, 2011. Accessible at: http://ascr-discovery.science.doe.gov/feature/exa_ov1.shtml

[4] http://wayback.archive.org/web/20130121075914/http://top500.org/blog/lists/2012/11/press-release/

[5] http://www.top500.org/lists/2012/11/

computing and networking capabilities; and develop, in partnership with the research community, including U.S. industry, future generations of computing hardware and tools for science."[6]

Department of Energy (DOE) Advanced Scientific Computing Research Spending

(dollars in millions)

Subprogram	FY12 Current	FY13 Annualized CR*	FY14 Request	FY14 Request versus FY12 Enacted	
				$	%
Mathematical, Computational, and Computer Sciences Research	*151.6*	--	*172.4*	*20.8*	*13.7*
High Performance Computing and Network Facilities	*276.7*	--	*293.1*	*16.4*	*5.9*
Total, Advanced Scientific Computing Research	***428.3***	***443.6***	***465.6***	***37.3***	***8.7***

*FY 2013 amounts shown reflect the P.L. 112-175 continuing resolution level annualized to a full year. These amounts are shown only at the "congressional control" level and above; below that level a dash (--) is shown.

In addition to high-performance computing activities, DOE's ASCR program also supports other activities in applied mathematics, computer science, next generation networks for science, and computational partnerships. For example, DOE is funding the development of the Energy Sciences Network (ESNet), to provide high-bandwidth connections to link national laboratories, universities, and other research institutions to allow those entities to collaborate on scientific research.

ASCR's primary scientific computing facility is the National Energy Research Scientific Computing Center (NERSC). NERSC, managed by Lawrence Berkeley National Laboratory, performs basic scientific research over a wide range of disciplines, such as material science, high energy physics data analysis, and chemistry simulations.[7]

DOE Exascale Strategy

The FY 2012 Consolidated Appropriations Act[8] expressed Congressional support for exascale computing, and specifically noted exascale is a "crucial component of long-term U.S. leadership." However, the accompanying Conference Report stressed the need for an "integrated

[6] DOE FY14 Detailed Budget Request, Volume 4, SC-21.
[7] National Energy Research Scientific Computing Center, "About NERSC," Last edited, April 4, 2013. Accessible at: http://www.nersc.gov/about/
[8] P.L. 112-74

strategy and program plan" from DOE. Accordingly, the Conference Report directed DOE to submit to the House and Senate Committees on Appropriations, not later than February 10, 2012, "a joint, integrated strategy and program plan for the crosscutting effort to develop exascale computing that includes:

- a target date for developing an operational exascale platform;
- interim milestones toward reaching that target;
- minimum requirements for an exascale supercomputer system, including power consumption efficiency goals;
- multi-year budget estimates for the exascale supercomputer initiative and costs of meeting each interim milestone;
- clear roles and responsibilities for each office involved in exascale supercomputer research and development; and
- a complete listing of exascale supercomputer activities included in the fiscal year 2013 budget request broken out by program, project and activity with comparisons to the current year's funding levels."[9]

Despite the directive, DOE has not yet reported its plan to Congress. In the absence of the DOE exascale supercomputer strategy, ASCR's FY14 budget request for High Performance Computing and Network Facilities subprogram still includes funding to "expand investments in critical technologies for exascale." However, no specific budget is requested.

Non-Civilian Exascale Uses

Should exascale computing be developed, a major beneficiary would be DOE's National Nuclear Security Administration (NNSA). NNSA supports a number of unclassified and classified computing activities to maintain the nuclear stockpile and develop new nuclear weapons. NNSA has previously held workshops in partnership with the Office of Science to examine research and development challenges to go from petascale to exascale computing systems.[10] ASCR is currently developing an exascale supercomputer development plan with the NNSA.[11]

Exascale Challenges

While exascale supercomputers would serve as a breakthrough leap above current computing capacity, important scientific and technical obstacles currently exist. For example, to facilitate increased computing speed, current computers can scale up to 250,000 parallel

[9] P.L. 112-74, Conference Report , p. 846
[10] Lawrence Livermore National Laboratory, "From Petascale to Exascale: R&D Challenges for HPC Simulation Environments," Last updated: October 24, 2012. Accessible at: https://asc.llnl.gov/exascale/
[11] DOE FY14 Detailed Budget Request, Volume 4, SC – 26.

processors, known as "parallelism." However, an exascale system would require parallelism up to one billion processors, which is an extremely complex and daunting task.[12] Additionally, using today's computing technology, an exascale system would consume more than a gigawatt of electricity.[13] One gigawatt of power is equivalent to power demands for roughly 700,000 to 1,000,000 homes, or the power output of a single, dedicated nuclear reactor. Obviously, the operating costs for such a exascale supercomputer could cost hundreds of millions of dollars per year in electricity costs alone if technological advancements are not made.

ASCAC Exascale Report on Synergistic Challenges

In March 2013, the Advanced Scientific Computing Advisory Committee (ASCAC) Data Subcommittee issued a report *Synergistic Challenges in Data-Intensive Science and Exascale Computing*.[14] The report reviewed challenges facing both "Big Data" and exascale computing systems and commented on the relationship between them. The report notes, "data-intensive research activities are increasing in all domains of science, and exascale computing is a key enabler of these activities."[15] ASCAC identified four findings and made three accompanying recommendations:

Findings:

1. There are opportunities for investments that can benefit both data-intensive science and exascale computing.
2. Integration of data analytics with exascale simulations represents a new kind of workflow that will impact both data-intensive science and exascale computing.
3. There is an urgent need to simplify the workflow for data-intensive science.
4. There is a need to increase the pool of computer and computational scientists trained in both exascale and data-intensive computing.

Recommendations:

1. The DOE Office of Science should give high priority to investments that can benefit both data-intensive science and exascale computing so as to leverage their synergies.
2. DOE ASCR should give high priority to research and other investments that simplify the science workflow and improve the productivity of scientists involved in exascale and data-intensive computing.

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[12] DOE ASCR "Leap to the extreme scale."
[13] DOE ASCR "Leap to the extreme scale."
[14] Department of Energy, Advanced Scientific Computing Advisory Committee, Data Subcommittee Report, "Synergistic Challenges in Data-Intensive Science and Exascale Computing," March, 2013. Accessible at: http://science.energy.gov/~/media/ascr/ascac/pdf/reports/2013/ASCAC_Data_Intensive_Computing_report_final.pdf
[15] ASCAC Data-Intensive Computing report.

3. DOE ASCR should adjust investments in programs such as fellowships, career awards, and funding grants, to increase the pool of computer and computational scientists trained in both exascale and data-intensive computing.

ADDITIONAL READING

DOE ASCAC Subcommittee Report: *The Opportunities and Challenges of Exascale Computing,* Fall 2010.
http://science.energy.gov/~/media/ascr/ascac/pdf/reports/exascale_subcommittee_report.pdf

DOE ASCAC Data Subcommittee Report: *Synergistic Challenges in Data-Intensive Science and Exascale Computing* , March 2012.
http://science.energy.gov/~/media/ascr/ascac/pdf/reports/2013/ASCAC_Data_Intensive_Computing_report_final.pdf

[~112H6454]

[DISCUSSION DRAFT]

MAY 13, 2013

113TH CONGRESS
1ST SESSION

H. R. ______

To amend the Department of Energy High-End Computing Revitalization Act of 2004 to improve the high-end computing research and development program of the Department of Energy, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

Mr. HULTGREN introduced the following bill; which was referred to the Committee on ______________________________

A BILL

To amend the Department of Energy High-End Computing Revitalization Act of 2004 to improve the high-end computing research and development program of the Department of Energy, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the ''American High-End Computing Leadership Act''.

SEC. 2. DEFINITIONS.

Section 2 of the Department of Energy High-End Computing Revitalization Act of 2004 (15 U.S.C. 5541) is amended by striking paragraphs (1) through (5) and inserting—

(1) CO-DESIGN.—The term ''co-design'' means the joint development of application algorithms, models, and codes with computer technology architectures and operating systems to maximize effective use of high-end computing systems.

(2) DEPARTMENT.—The term ''Department'' means the Department of Energy.

(3) EXASCALE.—The term ''exascale'' means computing system performance at or near 10 to the 18th power floating point operations per second.

(4) HIGH-END COMPUTING SYSTEM.—The term ''high-end computing system'' means a computing system with performance that substantially exceeds that of systems that are commonly available for advanced scientific and engineering applications.

(5) INSTITUTION OF HIGHER EDUCATION.—The term ''institution of higher education'' has the meaning given the term in section 101(a) of the Higher Education Act of 1965 (20 U.S.C. 1001(a)).

(6) NATIONAL LABORATORY.—The term ‘‘National Laboratory’’ means any one of the seventeen laboratories owned by the Department.

(7) SECRETARY.—The term ‘‘Secretary’’ means the Secretary of Energy.

SEC. 3. DEPARTMENT OF ENERGY HIGH-END COMPUTING RESEARCH AND DEVELOPMENT PROGRAM.

Section 3 of the Department of Energy High-End Computing Revitalization Act of 2004 (15 U.S.C. 5542) is amended—

(1) in subsection (a)(1), by striking ‘‘program’’ and inserting ‘‘coordinated program across the Department’’;

(2) in subsection (b)(2), by striking ‘‘vector’’ and all that follows through ‘‘architectures’’ and inserting ‘‘computer technologies that show promise of substantial reductions in power requirements and substantial gains in parallelism of multicore processors, concurrency, memory and storage, bandwidth, and reliability’’; and

(3) by striking subsection (d) and inserting the following:

‘‘(d) EXASCALE COMPUTING PROGRAM.—

‘‘(1) IN GENERAL.—The Secretary shall conduct a coordinated research program to develop exascale computing systems to advance the missions of the Department.

"(2) EXECUTION.—The Secretary shall through competitive merit review establish two or more National Laboratory-industry partnerships to conduct integrated research, development, and engineering of two or more prototype exascale systems, and—

"(A) conduct mission-related co-design activities in developing such prototype exascale platforms; and

"(B) develop those advancements in hardware and software technology required to fully realize the potential of an exascale production system in addressing Department target applications and solving scientific problems involving predictive modeling and simulation and large-scale data analytics and management.

"(3) ADMINISTRATION.—In carrying out this program, the Secretary shall—

"(A) provide, on a competitive, merit-reviewed basis, access for researchers in United States industry, institutions of higher education, National Laboratories, and other Federal agencies to these exascale systems, as appropriate; and

"(B) conduct outreach programs to increase the readiness for the use of such platforms by domestic industries, including manufacturers.

"(4) REPORTS.—

"(A) INTEGRATED STRATEGY AND PROGRAM MANAGEMENT PLAN.—The Secretary shall submit to Congress, not later than 90 days after the date of enactment of the American High-End Computing Leadership Act, a report outlining an integrated strategy and program management plan, including target dates for prototypical and production exascale platforms, interim milestones to reaching these targets, functional requirements, roles and responsibilities of National Laboratories and industry, acquisition strategy, and estimated resources required, to achieve this exascale system capability. The report shall include the Secretary's plan for Departmental organization to manage and execute the Exascale Computing Program, including definition of the roles and responsibilities within the Department to ensure an integrated program across the Department. The report shall also include a plan for ensuring balance and prioritizing across ASCR subprograms in a flat or slow-growth budget environment.

"(B) STATUS REPORTS.—At the time of the budget submission of the Department for each fiscal year, the Secretary shall submit a report to Congress that describes the status of milestones and costs in achieving the objectives of the exascale computing program.

"(C) EXASCALE MERIT REPORT.—At least 18 months prior to the initiation of construction or installation of any exascale-class computing facility, the Secretary shall transmit a plan to the Congress detailing—

"(i) the proposed facility's cost projections and capabilities to significantly accelerate the development of new energy technologies;

"(ii) technical risks and challenges that must be overcome to achieve successful completion and operation of the facility; and

"(iii) an assessment of the scientific and technological advances expected from such a facility relative to those expected from a comparable investment in expanded research and applications at terascale-class and petascale-class computing facilities.''.

SEC. 4. AUTHORIZATION OF APPROPRIATIONS.

Section 4 of the Department of Energy High-End Computing Revitalization Act of 2004 (15 U.S.C. 5543) is amended—

(1) by striking ''this Act'' and inserting ''section 3(d)''; and

(2) by striking paragraphs (1) through (3) and inserting the following:

''(1) $110,000,000 for fiscal year 2014; and

''(2) $110,000,000 for fiscal year 2015.''.