U.S. DEPARTMENT OF
ENERGY

DOE Office of Advanced Scientific Computing Research

Presented to the

Advanced Scientific Computing Advisory Committee

by

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Associate Director

December 9, 2015

Office of Science

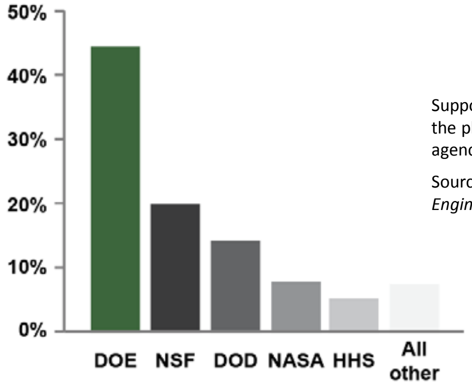
By the numbers

Shown is a portion of SLAC's two-mile-long linear accelerator (or linac), which provides the electron beam for the new Linac Coherent Light Source (LCLS) – the world's first hard x-ray, free-electron laser. For nearly 50 years, SLAC's linac had produced high-energy electrons for physics experiments. Now researchers use the very intense X-ray pulses (more than a billion times brighter than the most powerful existing sources) much like a high-speed camera to take stop-motion pictures of atoms and molecules in motion, examining fundamental processes on femtosecond timescales.

SC delivers scientific discoveries and tools to transform our understanding of nature and advance the energy, economic, and national security of the U.S.

Research

- Support for 47% of the U.S. Federal support of basic research in the physical sciences;
- ~22,000 Ph.D. scientists, grad students, engineers, and support staff at >300 institutions, including all 17 DOE labs;
- U.S. and world leadership in high-performance computing and computational sciences;
- Major U.S. supporter of physics, chemistry, materials sciences, and biology for discovery and for energy sciences.



Support for basic research in the physical sciences by agency.

Source: *NSF Science and Engineering Indicators 2012*

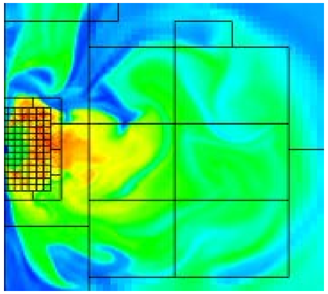
Scientific User Facilities

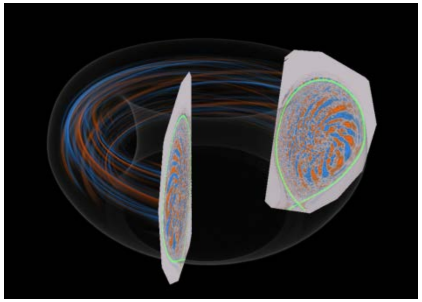
- The world's largest collection of scientific user facilities (aka research infrastructure) operated by a single organization in the world, used by 31,000 researchers each year.

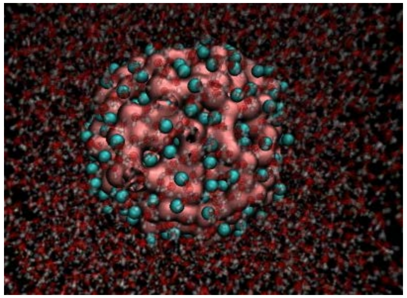
Advanced Scientific Computing Research

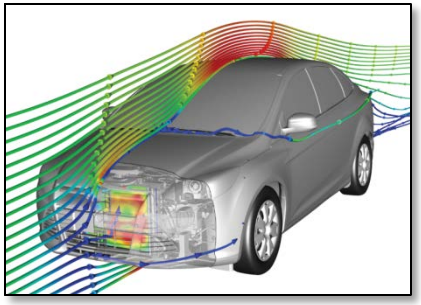
Computational and networking capabilities to extend the frontiers of science and technology

- **Mathematics research** to address challenges of increasing complexity within DOE's mission areas from a mathematical perspective. This requires integrated, iterative processes across multiple mathematical disciplines.
- **Computer science research** to increase the productivity and integrity of HPC systems and simulations, and support data management, analysis, and visualization techniques.
- **SciDAC partnerships** to dramatically accelerate progress in scientific computing that delivers breakthrough scientific results.
- **Exascale computing** research and development of capable exascale hardware architectures and system software, including the deployment of programming environments for energy-efficient, data-intensive applications, and engagement with HPC vendors to deliver systems that address the exascale challenges.
- **Facilities** operate with at least 90% availability while continuing planned upgrades – begin deployment of 10-40 petaflop upgrade at NERSC and continue preparations for 75-200 petaflop upgrades at each LCF.
- Continue a postdoctoral program at the ASCR facilities and provide funding for the Computational Science Graduate Fellowship to address DOE workforce needs.

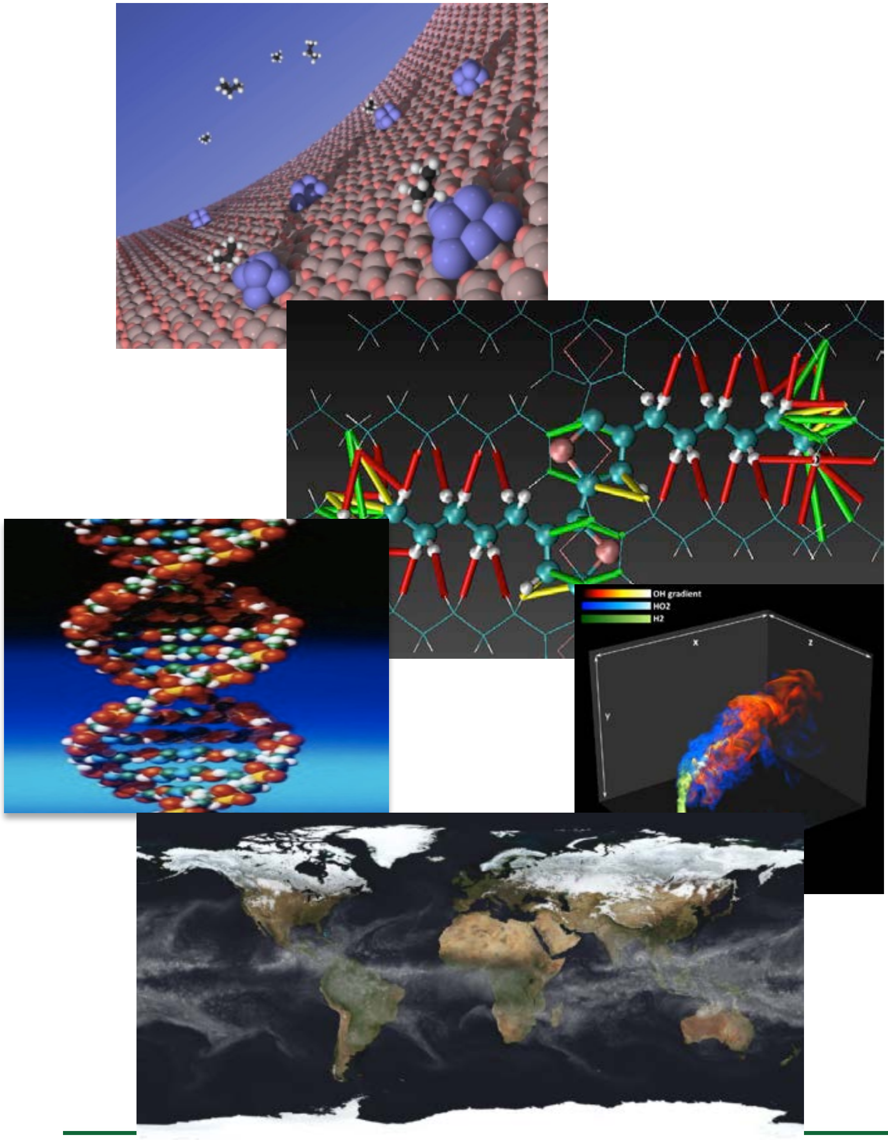








ASCR Investment Priorities



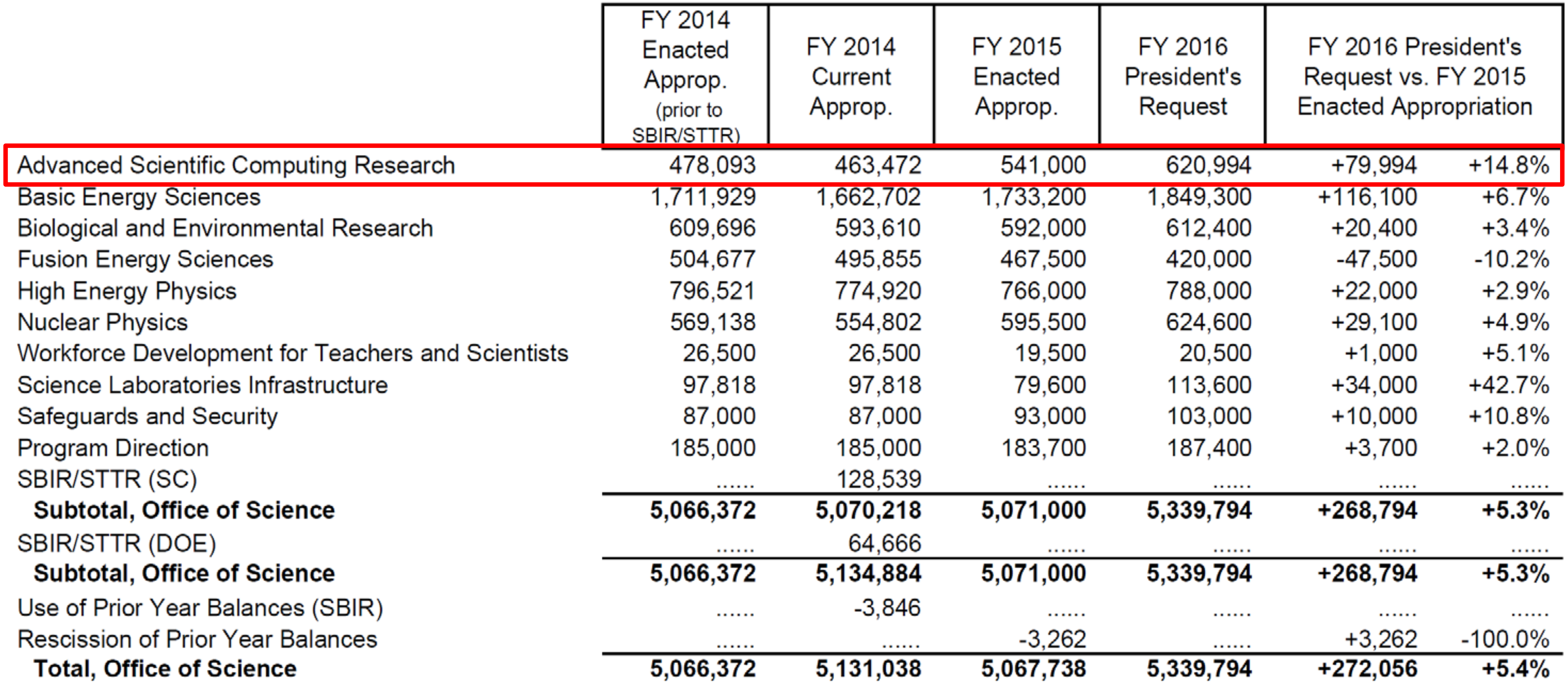
Investment Priorities:

- **Exascale –** conduct research and development, and design efforts in hardware software, and mathematical technologies that will produce exascale systems for science applications.
- **Facilities –** acquire and operate more capable computing systems, from multi-petaflop through exascale computing systems that incorporate technologies emerging from research investments.
- **Large Scientific Data –** prepare today's scientific and data-intensive computing applications to migrate to and take full advantage of emerging technologies from research, development and design efforts.

Budget

Office of Science FY 2016 Budget Request to Congress

(Dollars in thousands)



	FY 2014 Enacted Approp. (prior to SBIR/STTR)	FY 2014 Current Approp.	FY 2015 Enacted Approp.	FY 2016 President's Request	FY 2016 President's Request vs. FY 2015 Enacted Appropriation	
Advanced Scientific Computing Research	478,093	463,472	541,000	620,994	+79,994	+14.8%
Basic Energy Sciences	1,711,929	1,662,702	1,733,200	1,849,300	+116,100	+6.7%
Biological and Environmental Research	609,696	593,610	592,000	612,400	+20,400	+3.4%
Fusion Energy Sciences	504,677	495,855	467,500	420,000	-47,500	-10.2%
High Energy Physics	796,521	774,920	766,000	788,000	+22,000	+2.9%
Nuclear Physics	569,138	554,802	595,500	624,600	+29,100	+4.9%
Workforce Development for Teachers and Scientists	26,500	26,500	19,500	20,500	+1,000	+5.1%
Science Laboratories Infrastructure	97,818	97,818	79,600	113,600	+34,000	+42.7%
Safeguards and Security	87,000	87,000	93,000	103,000	+10,000	+10.8%
Program Direction	185,000	185,000	183,700	187,400	+3,700	+2.0%
SBIR/STTR (SC)	......	128,539	......	......	......	......
Subtotal, Office of Science	**5,066,372**	**5,070,218**	**5,071,000**	**5,339,794**	**+268,794**	**+5.3%**
SBIR/STTR (DOE)	......	64,666	......	......	......	......
Subtotal, Office of Science	**5,066,372**	**5,134,884**	**5,071,000**	**5,339,794**	**+268,794**	**+5.3%**
Use of Prior Year Balances (SBIR)	......	-3,846	......	......	......	......
Rescission of Prior Year Balances	......	......	-3,262	......	+3,262	-100.0%
Total, Office of Science	**5,066,372**	**5,131,038**	**5,067,738**	**5,339,794**	**+272,056**	**+5.4%**

ASCR Budget Overview

		FY 2014 Appropriation (w/o SBIR/STTR)	FY 2015 Current Approp.	FY 2016 President's Request	*FY 2016 House Mark*	*FY 2016 Senate Mark*
	Advanced Scientific Computing Research					
Exascale	Applied Mathematics	47,081	49,155	49,229	48,229	49,229
Exascale	Computer Science	55,835	55,767	56,842	56,042	56,842
Exascale	Computational Partnerships (SciDAC)	46,261	46,918	47,918	47,918	47,918
	Next Generation Networking for Science	17,852	19,000	19,000	17,281	19,000
	SBIR/STTR	0	5,830	6,181	6,055	6,181
	Total, Mathematical, Computational, and Computer Sciences Research	*167,029*	*176,670*	*179,170*	175,525	*179,170*
	High Performance Production Computing (NERSC)	67,105	75,605	76,000	76,000	86,000
	Leadership Computing Facilities	160,000	184,637	171,000	178,000	181,000
Exascale	Research and Evaluation Prototypes	36,284	57,329	141,788	57,800	121,788
	High Performance Network Facilities and Testbeds (ESnet)	33,054	35,000	38,000	38,000	38,000
	SBIR/STTR	0	11,759	15,036	12,214	15,036
	Total, High Performance Computing and Network Facilities	*296,443*	*364,330*	*441,824*	*362,014*	*441,484*
	Total, Advanced Scientific Computing Research	**463,472**	**541,000**	**620,994**	**537,539**	**620,994**

FY 2016 Exascale Crosscut

($K)

	FY 2015 Enacted	FY2016 Request	FY 2016 vs FY 2017	FY2016 House Mark	FY2016 Senate Mark
NNSA					
ASC: Advanced Technology Development and Mitigation	50,000	64,000	+14,000	64,000**	64,000
NNSA Total	**50,000**	**64,000**	**+14,000**	**64,000****	**64,000**
SC					
ASCR Total	91,000	177,894	+86,894	99,000	157,894
BER	0	18,730	+18,730	0	18,730
BES	8,000	12,000	+4,000	8,000	12,000
SC Total	**99,000**	**208,624**	**+109,624**	**107,000**	**188,624**
Exascale Total	**149,000**	**272,624**		**171,000**	**252,624**

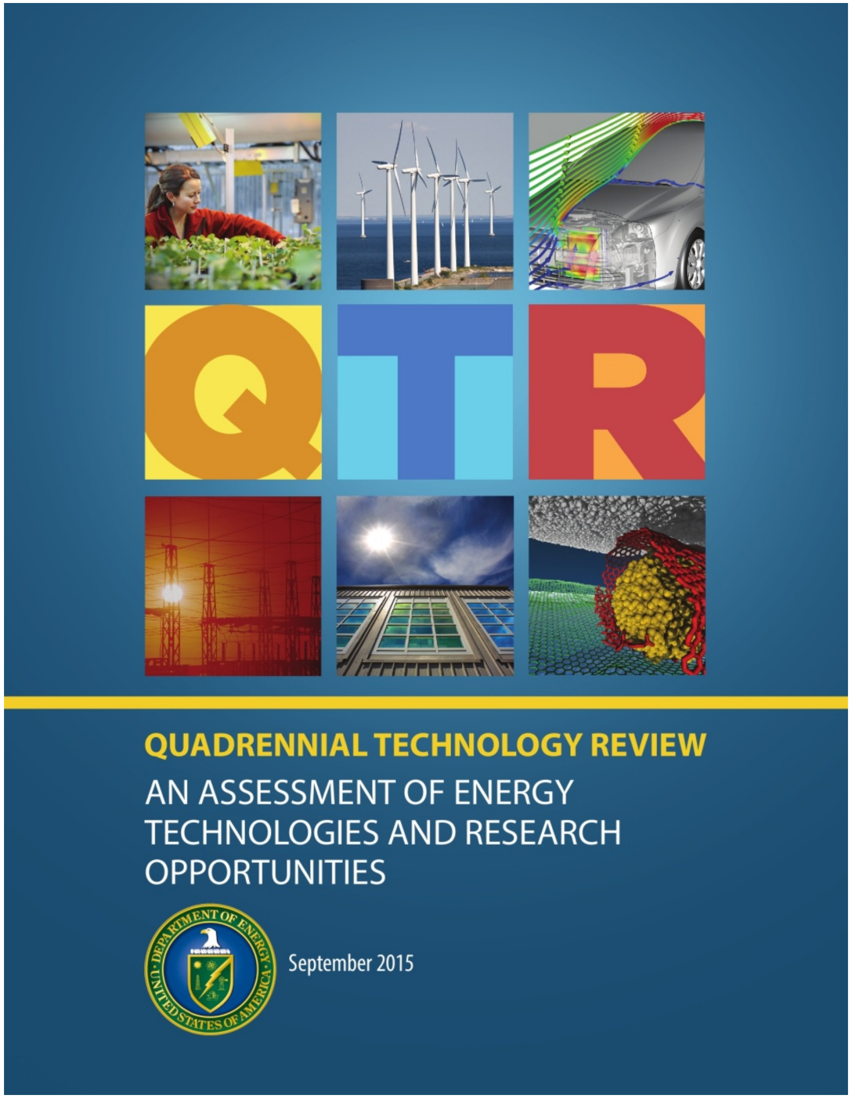
*** ATDM will be protected from an unspecified $ 18M reduction*

Updates

- DOE Quadrennial Technology Review
- Status of Key Appointees
- ASCR Personnel Changes
- Exascale (update)
- Recent workshop – Neuromorphic Computing
- National Strategic Computing Initiative (Erin Szulman)
- Requirements Gathering Process (update, Barb Helland)
- RFI Results (Barb Helland)
- Presentation by Ed Synakowski, FES
- Presentation by Alex Larzelere, NE

DOE Quadrennial Technology Review (QTR)

September 2015*



QTR

QUADRENNIAL TECHNOLOGY REVIEW

AN ASSESSMENT OF ENERGY TECHNOLOGIES AND RESEARCH OPPORTUNITIES

September 2015

- Examines the status of the science and technology that are the foundation of our energy system, together with the research, development, demonstration, and deployment (RDD&D) opportunities to advance them
- Focuses primarily on technologies with commercialization potential in the midterm and beyond
- Frames trade-offs that all energy technologies must balance across such dimensions as cost, security and reliability of supply, diversity, environmental impacts, land use, and materials use
- Provides data and analysis on RDD&D pathways to assist decision makers as they set priorities to develop more secure, affordable, and sustainable energy services
- Policies and regulations are examined separately by the Quadrennial Energy Review (QER)

*http://www.energy.gov/sites/prod/files/2015/09/f26/Quadrennial-Technology-Review-2015_0.pdf

DOE's Quadrennial Reviews

- Quadrennial Energy Review: Called for by the President to analyze government-wide energy policy, particularly focused on energy infrastructure.

- Quadrennial Technology Review: Secretary Moniz requested the second volume be published in parallel with the QER to provide analysis of the most promising RDD&D opportunities across energy technologies in working towards a clean energy economy.
  - The resulting analysis and recommendations of the QTR 2015 will ***inform the national energy enterprise*** and will ***guide the Department of Energy's*** programs and capabilities, budgetary priorities, industry interactions, and National Laboratory activities.

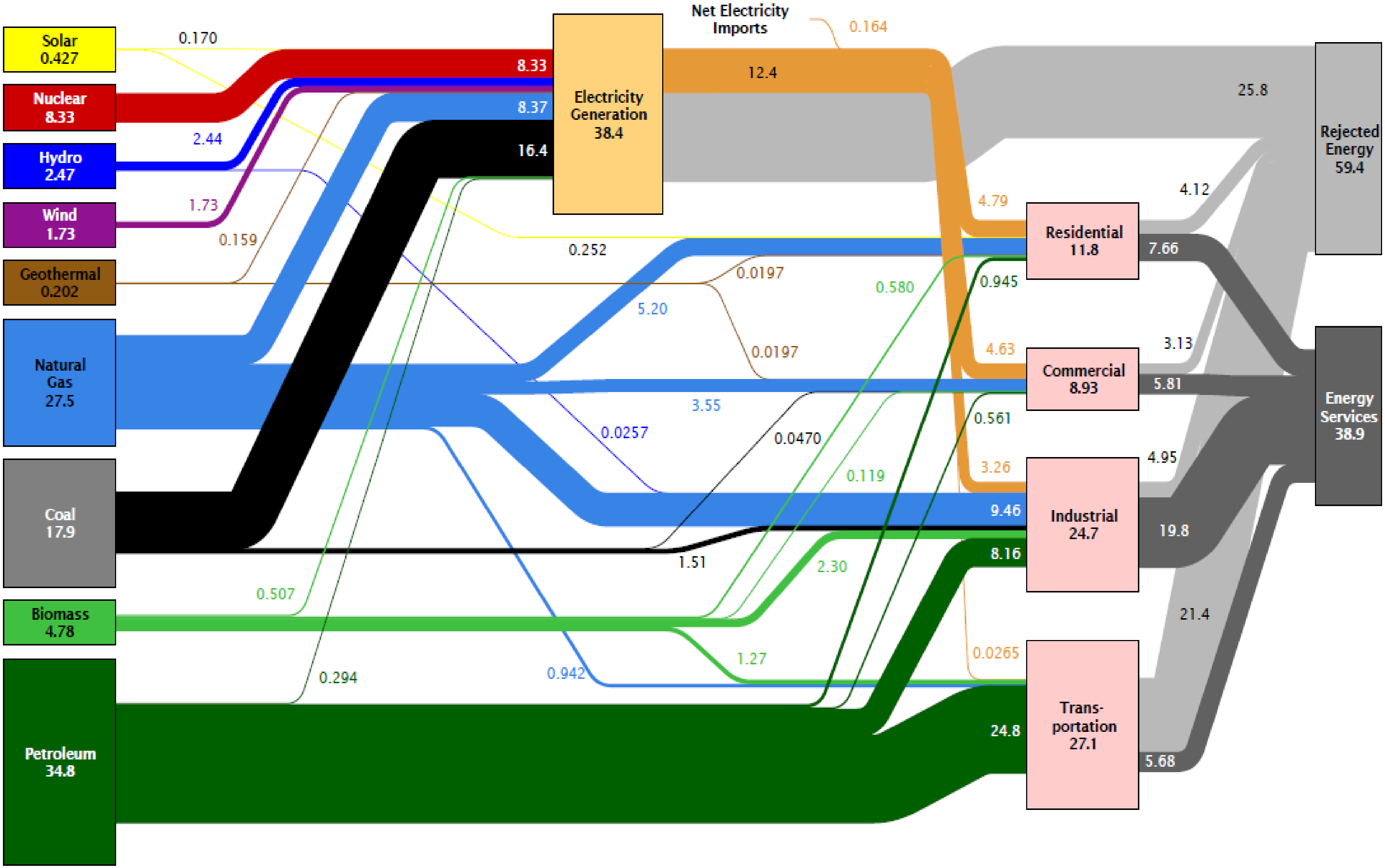
Changes since the 2011 QTR*

- Decreasing growth of gasoline consumption
- Increased vehicle gas mileage to record levels
- U.S. now world’s largest producer of oil and gas combined
- Newly dynamic nuclear power landscape
- Increased deployment of wind (1.65x) and solar energy (9x)
- Slowing growth of electricity consumption
- Increasing opportunities for U.S. manufacturing
- Growing market for electric vehicles
- Regionally constrained water availability
- Significant economic growth with flat greenhouse gas emissions

http://energy.gov/downloads/first-quadrennial-technology-review-qtr-2011

Estimated U.S. Energy Use in 2014: ~98.3 Quads

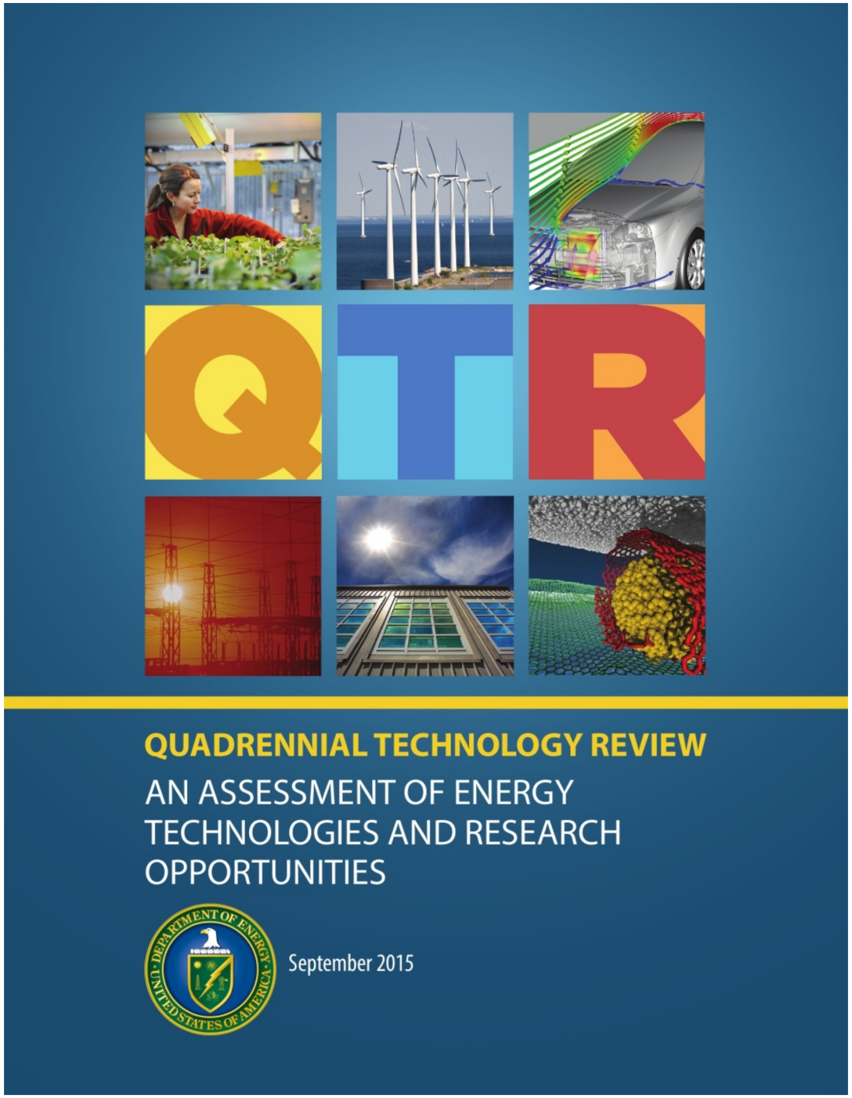
Lawrence Livermore National Laboratory



Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

DOE Quadrennial Technology Review (QTR)

September 2015*



QTR

QUADRENNIAL TECHNOLOGY REVIEW

AN ASSESSMENT OF ENERGY TECHNOLOGIES AND RESEARCH OPPORTUNITIES

September 2015

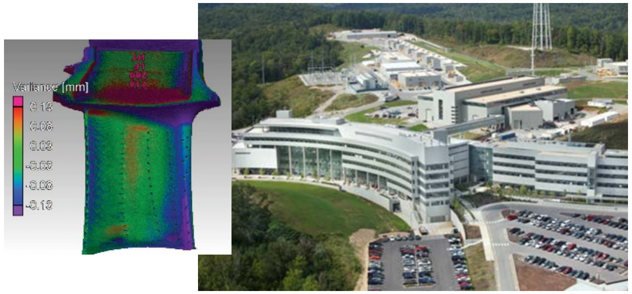
Chapter 1:	**Energy Challenges**
Chapter 2:	**Energy Sectors and Systems**
Chapter 3:	**Enabling Modernization of the Electric Power System**
Chapter 4:	**Advancing Clean Electric Power Technologies**
Chapter 5:	**Increasing Efficiency of Building Systems and Technologies**
Chapter 6:	**Innovating Clean Energy Technologies in Advanced Manufacturing**
Chapter 7:	**Advancing Systems and Technologies to Produce Cleaner Fuels**
Chapter 8:	**Advancing Clean Transportation and Vehicle Systems and Technologies**
Chapter 9:	**Enabling Capabilities for Science and Energy**
Chapter 10:	**Concepts in Integrated Analysis**
Chapter 11:	**Summary and Conclusions**

Enabling Science: Understanding and Controlling Matter at the Atomic Scale

Unique, cutting-edge experimental tools for characterization, discovery, and synthesis of novel materials and energy systems.

X-ray light sources provide a range of wavelengths capable of probing structures as small as atoms to whole cells and beyond.

- LCLS-II and APS-U will provide higher energy and brighter beams.
- Instrument development brings NSLS-II's world-leading beam brightness to more experiments.



Neutron sources are uniquely suited to non-destructive 3D structure determination of real systems.

- The SNS Second Target Station would enable new science in condensed matter, structural biology, and energy materials.

Nanoscale Science Research Centers integrate theory, synthesis, fabrication, and characterization of novel nanomaterials

- New capabilities in *in operando* electron microscopy and accelerator-based nanoscience.
- Novel fabrication techniques in combinatorics and self-assembly.

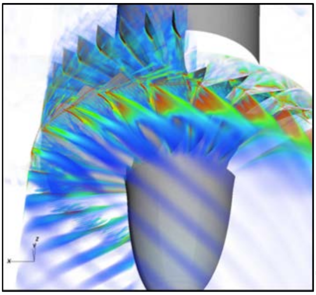
On-going research, development, and upgrades for facilities opens new frontiers in materials characterization (real systems in real time).

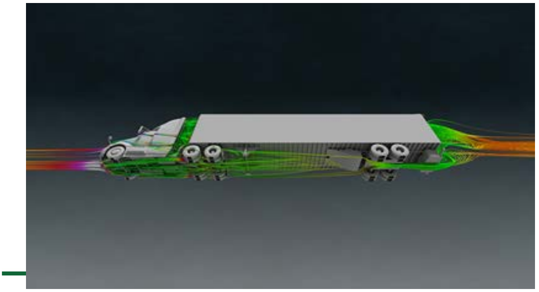
Enabling Science: Modeling and Simulation of Complex Phenomena

Accelerating discovery through modeling and simulation of real systems.

- DOE and SC supported supercomputers enable simulation of complex real-world phenomena, putting true "systems-by-design" in reach.
- The *Office of Advanced Scientific Computing Research* supports this push to modeling and simulation of real systems through parallel development of hardware, software, and skilled personnel.
    - *Leadership-class computers*
    - *Production-class computers*
    - *Energy Sciences Network*
- DOE computers - enabled through dedicated outreach from the laboratories - have an enormous impact across the engineering and manufacturing space.
- The development needs of *exascale* computing – hardware, software, and efficiency – are being supported through *co-design* centers.

Name	**Performance (pflops/s)**	**Laboratory**
Titan	17.6	Oak Ridge
Mira	8.60	Argonne
Cascade	2.53	Pacific Northwest
Edison	1.65	Lawrence Berkeley (NERSC)
Hopper	1.05	Lawrence Berkeley (NERSC)
Red Sky	0.43	NREL/Sandia





Appointees

Appointees

Cherry A. Murray nominated to senior role at U.S. Department of Energy

SELECTED TO LEAD OFFICE OF SCIENCE

August 6, 2015

Cambridge, Ma. – Aug. 6, 2015 – President Barack Obama has nominated former Harvard School of Engineering and Applied Sciences Dean Cherry A. Murray to be Director of the Office of Science in the United States Department of Energy, a key administration post.

The announcement was made at the White House on August 5. The nomination must be confirmed by the United States Senate.

Murray, who concluded her five-year tenure as dean at the end of 2014, is currently the Benjamin Pierce Professor of Technology and Public Policy at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS) and Professor of Physics. She came to Harvard in 2009, after a distinguished career as an experimental scientist and administrator in two of America’s leading basic and applied research organizations, Lawrence Livermore National Laboratory and Bell Laboratories.

HARVARD
John A. Paulson
School of Engineering
and Applied Sciences

ASCR Personnel Changes

ASCR Personnel Changes

- Ceren Susut-Bennett returned in July from a 4-month detail to National Science Foundation
- Karen Pao left federal service, August 2015
- Currently recruiting to fill two vacant applied-mathematics program manager positions
- Barb Helland has taken the lead for the Exascale Computing Initiative
- Bill Harrod leading effort to develop a long-range plan for ASCR research

Facilities Status

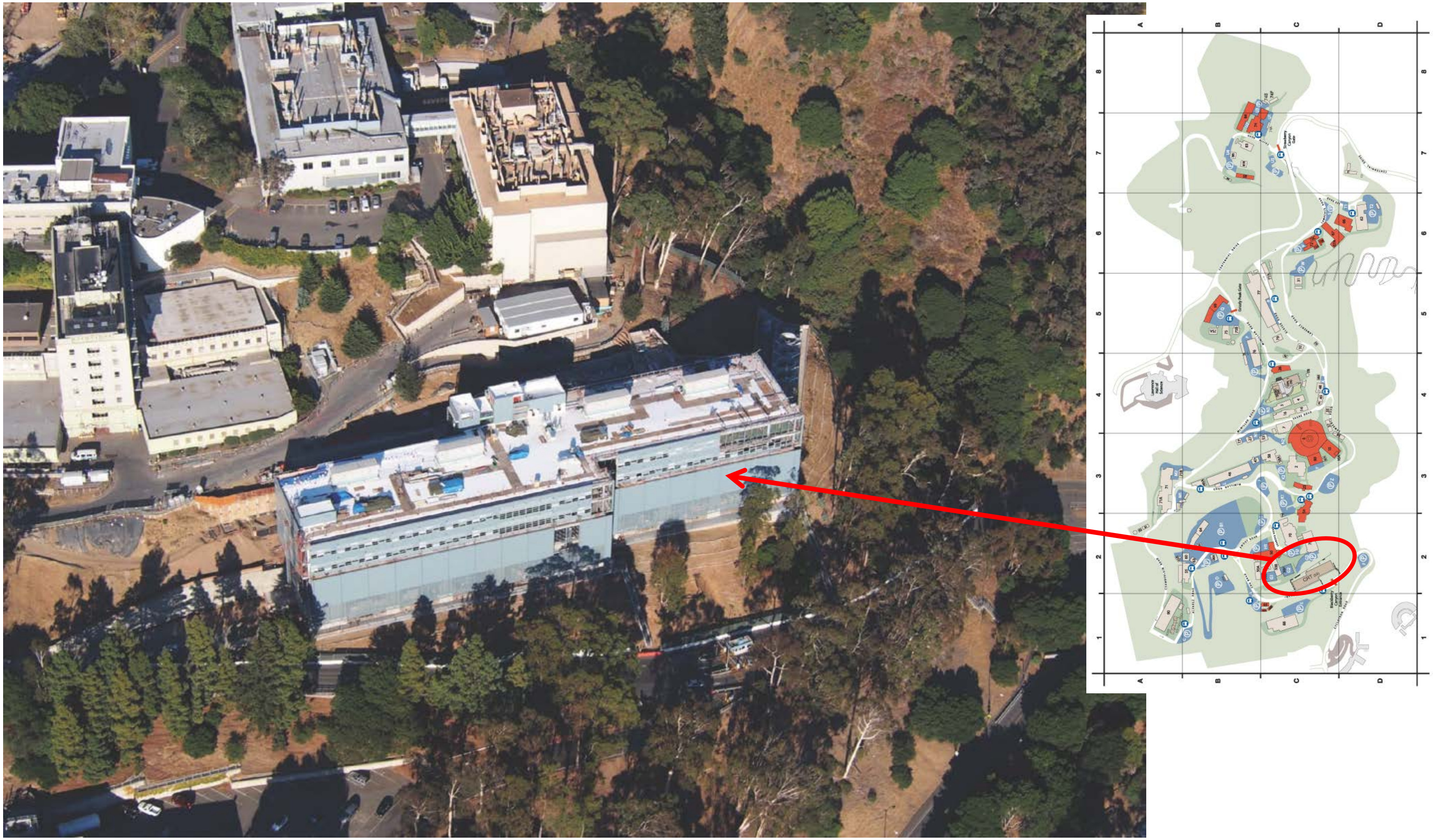
ASCR Computing Upgrades At a Glance

System attributes	NERSC Now	OLCF Now	ALCF Now	NERSC Upgrade	OLCF Upgrade	ALCF Upgrades	
Name Planned Installation	**Edison**	**TITAN**	**MIRA**	**Cori** **2016**	**Summit** **2017-2018**	**Theta** **2016**	**Aurora** **2018-2019**
System peak (PF)	2.6	27	10	> 30	150	>8.5	180
Peak Power (MW)	2	9	4.8	< 3.7	10	1.7	13
Total system memory	357 TB	710TB	768TB	~1 PB DDR4 + High Bandwidth Memory (HBM)+1.5PB persistent memory	> 1.74 PB DDR4 + HBM + 2.8 PB persistent memory	>480 TB DDR4 + High Bandwidth Memory (HBM)	> 7 PB High Bandwidth On-Package Memory Local Memory and Persistent Memory
Node performance (TF)	0.460	1.452	0.204	> 3	> 40	> 3	> 17 times Mira
Node processors	Intel Ivy Bridge	AMD Opteron Nvidia Kepler	64-bit PowerPC A2	Intel Knights Landing many core CPUs Intel Haswell CPU in data partition	Multiple IBM Power9 CPUs & multiple Nvidia Voltas GPUS	Intel Knights Landing Xeon Phi many core CPUs	Knights Hill Xeon Phi many core CPUs
System size (nodes)	5,600 nodes	18,688 nodes	49,152	9,300 nodes 1,900 nodes in data partition	~3,500 nodes	>2,500 nodes	>50,000 nodes
System Interconnect	Aries	Gemini	5D Torus	Aries	Dual Rail EDR-IB	Aries	2nd Generation Intel Omni-Path Architecture
File System	7.6 PB 168 GB/s, Lustre®	32 PB 1 TB/s, Lustre®	26 PB 300 GB/s GPFS™	28 PB 744 GB/s Lustre®	120 PB 1 TB/s GPFS™	10PB, 210 GB/s Lustre initial	150 PB 1 TB/s Lustre®

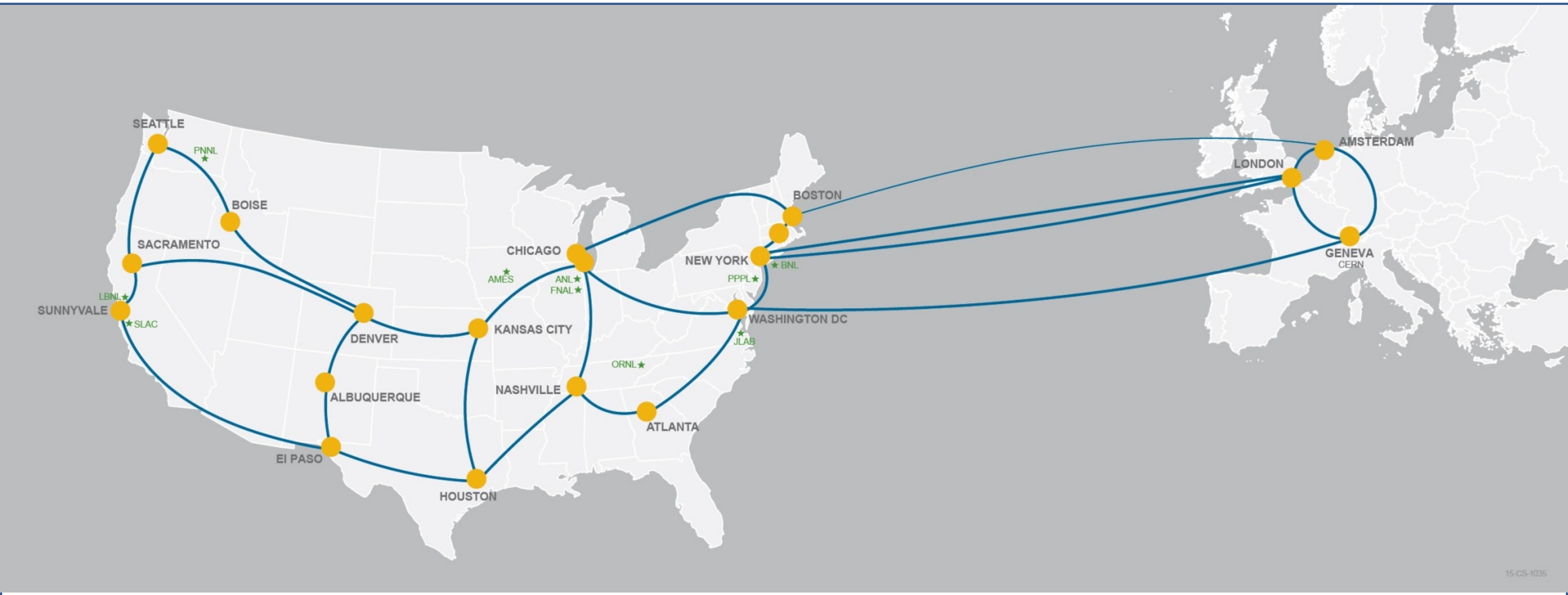
U.S. DEPARTMENT OF ENERGY

LBNL Computational Research and Theory Building

(Dedication November 12, 2015)



Esnet Makes a Broad Impact

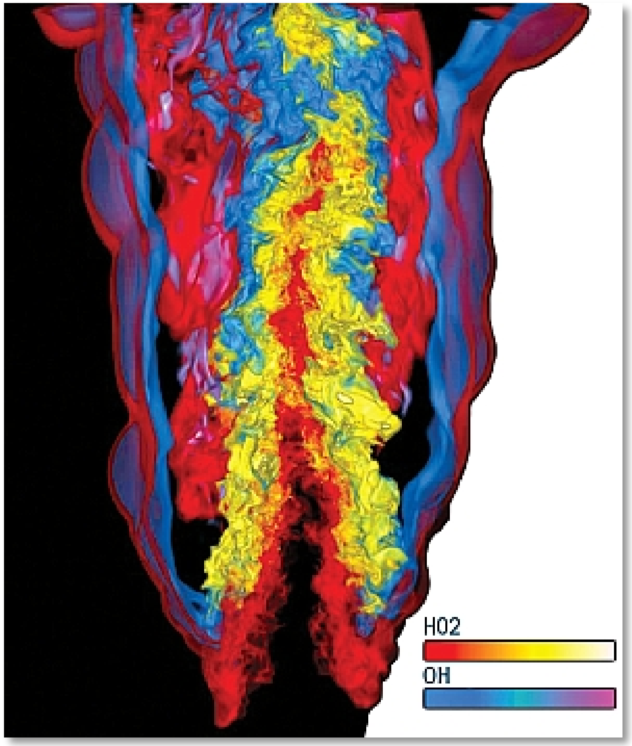


- European Extension supporting LHC run 2 since commencement in June, 2015
- NSF has made 130 awards for universities to implement ESnet's **Science DMZ** architecture
- NIH, USDA, also adopting Science DMZ - along with universities in Canada, Europe, Australia
- ESnet's new Science Engagement team working with DOE light sources to improve data mobility for beamline users
- Secretarial Award for OSCARS, software tool adopted by 50 organizations
- Lead multi-agency workshop on Software Defined Networking, sponsored by OSTP, NSF, DOE in 2014

Exascale

DOE's Exascale Computing Initiative: Next Generation of Scientific Innovation

- **Departmental Crosscut – In partnership with NNSA**
- **"All-in" approach: hardware, software, applications, large data, underpinning applied math and computer science**
- **Supports DOE's missions in national security and science:**
  - Stockpile stewardship – support annual assessment cycle
  - Discovery science – next-generation materials
  - Mission-focused basic science in energy – next-generation climate software
  - Use current Leadership Computing approach for users
- **The next generation of advancements will require Extreme Scale Computing**
  - 100-1,000X capabilities of today's computers with a similar physical size and power footprint
  - Significant challenges are power consumption, high parallelism, reliability
- **Extreme Scale Computing, cannot be achieved by a "business-as-usual," evolutionary approach**
  - Initiate partnerships with U.S. computer vendors to perform the required engineering, research and development for system architectures for capable exascale computing
  - Exascale systems will be based on marketable technology – Not a "one off" system
  - Productive system – Usable by scientists and engineers



Exascale Computing Initiative (ECI)
Key Performance Goals

Parameter	
Performance	Sustained 1 – 10 ExaOPS
Power	20 MW
Cabinets	200 - 300
System Memory	128 PB – 256 PB
Reliability	Consistent with current platforms
Productivity	Better than or consistent with current platforms
Scalable benchmarks	*Target speedup over "current" systems …*
Throughput benchmarks	*Target speedup over "current" systems …*

ExaOPS = 10^{18} Operations / sec

Exascale Target System Characteristics

- 20 pJ per average operation
- Billion-way concurrency (current systems have million-way)
- Ecosystem to support new application development and collaborative work, enable transparent portability, accommodate legacy applications
- High reliability and resilience through self-diagnostics and self-healing
- Programming environments (high-level languages, tools, …) to increase scientific productivity

Broadening the Reach of Exascale Science Applications

- **Initial call for input from all 17 DOE Laboratories released on May 31, 2015 to identify potential applications that could deliver new science capabilities on exascale systems. 126 application white papers received. Input will be used by ASCR/ASC to define/refine exascale applications**
  - to identify additional key scientific areas for exascale discovery, and specific opportunities for new and existing scientific applications.
  - to provide broad input on the kinds of partnerships and investments required to address technical challenges of exascale applications.

- **NIH-NSF-DOE Request for Information to identify scientific research topics that need High Performance Computing (HPC) capabilities that extend 100 times beyond today's performance on scientific applications. Released 9/15/15; Responses were due to NIH 11/13/15 – 114 responses received.**
  - Information will be used to assist agencies to construct the NSCI roadmap that will guide development of an exascale ecosystem to support scientific research, and to inform the research, engineering and development process. It is likely that a range of advanced capabilities will need to be developed to respond to the varied computing needs across science disciplines.

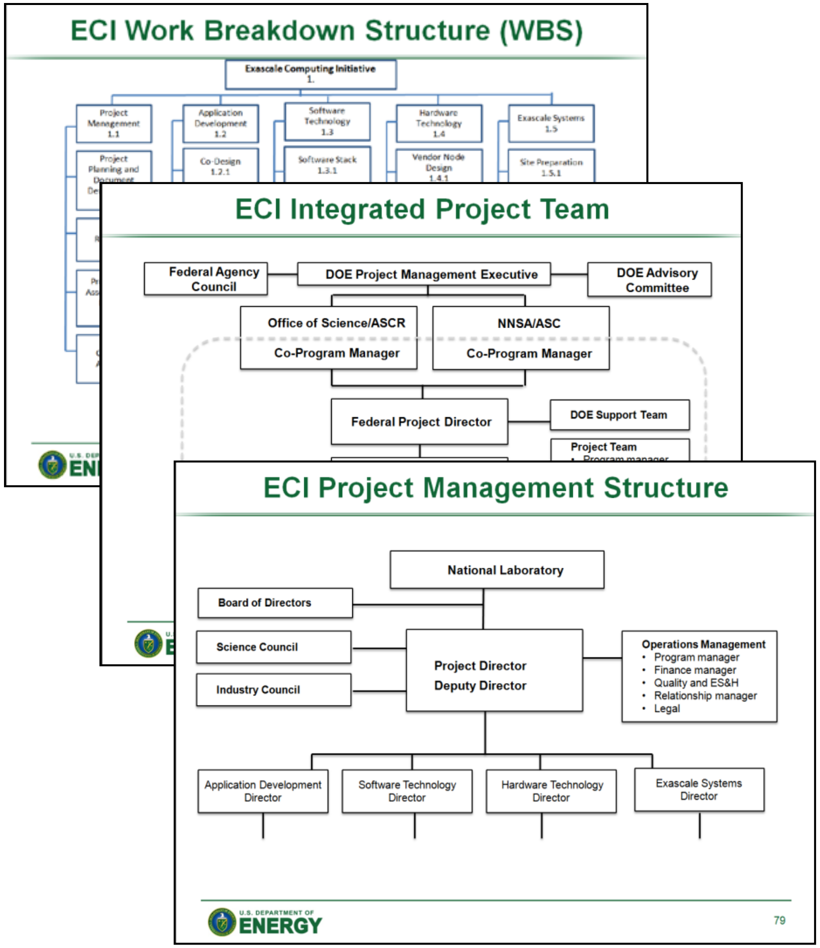
Top Ten Technical Challenges for Exascale

(Advanced Scientific Computing Advisory Committee Findings)

1. **Energy efficiency:** Creating more energy efficient circuit, power, and cooling technologies.
2. **Interconnect technology:** Increasing the performance and energy efficiency of data movement.
3. **Memory technology:** Integrating advanced memory technologies to improve both capacity and bandwidth.
4. **Scalable System Software:** Developing scalable system software that is power and resilience aware.
5. **Programming systems:** Inventing new programming environments that express massive parallelism, data locality, and resilience
6. **Data management:** Creating data management software that can handle the volume, velocity and diversity of data that is anticipated.
7. **Exascale algorithms:** Reformulating science problems and refactoring their solution algorithms for exascale systems.
8. **Algorithms for discovery, design, and decision:** Facilitating mathematical optimization and uncertainty quantification for exascale discovery, design, and decision making.
9. **Resilience and correctness:** Ensuring correct scientific computation in face of faults, reproducibility, and algorithm verification challenges.
10. **Scientific productivity:** Increasing the productivity of computational scientists with new software engineering tools and environments.

http://science.energy.gov/~/media/ascr/ascac/pdf/reports/2013/report.pdf

“Projectizing” the Exascale Initiative



ECI Work Breakdown Structure (WBS)

Exascale Computing Initiative 1.
Project Management 1.1
Project Planning and Document De
Application Development 1.2
Co-Design 1.2.1
Software Technology 1.3
Software Stack 1.3.1
Hardware Technology 1.4
Vendor Node Design 1.4.1
Exascale Systems 1.5
Site Preparation 1.5.1

ECI Integrated Project Team

Federal Agency Council
DOE Project Management Executive
DOE Advisory Committee
Office of Science/ASCR Co-Program Manager
NNSA/ASC Co-Program Manager
Federal Project Director
DOE Support Team
Project Team
- Program manager

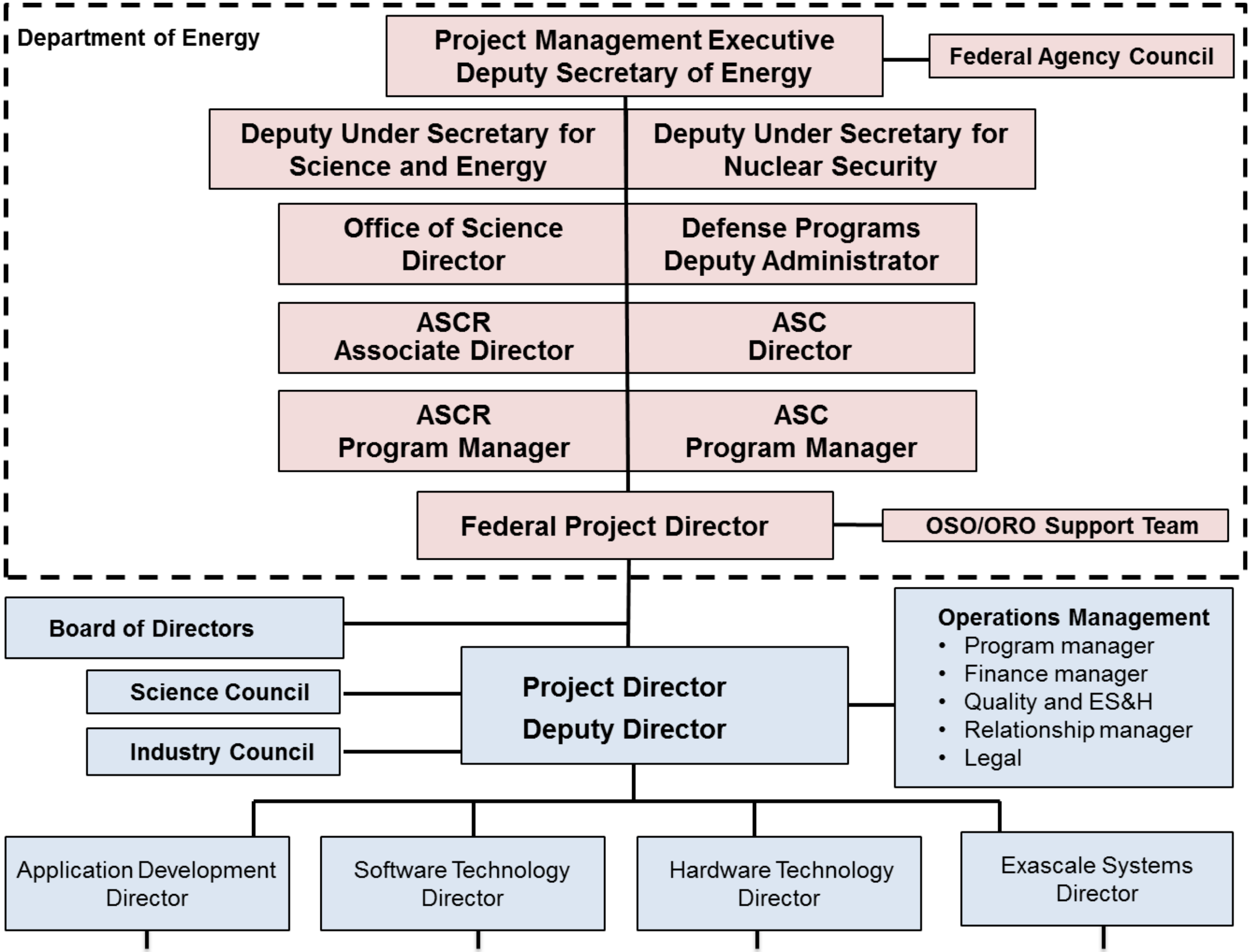
ECI Project Management Structure

National Laboratory
Board of Directors
Science Council
Industry Council
Project Director
Deputy Director
Operations Management
- Program manager
- Finance manager
- Quality and ES&H
- Relationship manager
- Legal

Application Development Director
Software Technology Director
Hardware Technology Director
Exascale Systems Director

- The exascale initiative will follow established DOE review and decision protocols for its execution
- A project office has been established at ORNL with representation from the major participating laboratories (ANL, LANL, LBNL, LLNL, ORNL, SNL)
- An Integrated Project Team (IPT) has been established, analogous to execution of previous, large, Office of Science projects
- The IPT is refining the work breakdown structure (WBS) and is preparing required project documentation (e.g., critical-decision packages, preliminary project execution plans, etc.)
- A top-level WBS activity has been established to develop and implement exascale applications, based on a labs-wide request for information

"Projectizing" the Exascale Initiative, cont'd



Department of Energy

Project Management Executive
Deputy Secretary of Energy

Federal Agency Council

Deputy Under Secretary for Science and Energy

Deputy Under Secretary for Nuclear Security

Office of Science Director

Defense Programs Deputy Administrator

ASCR Associate Director

ASC Director

ASCR Program Manager

ASC Program Manager

Federal Project Director

OSO/ORO Support Team

Board of Directors

Science Council

Industry Council

Project Director
Deputy Director

Operations Management
- Program manager
- Finance manager
- Quality and ES&H
- Relationship manager
- Legal

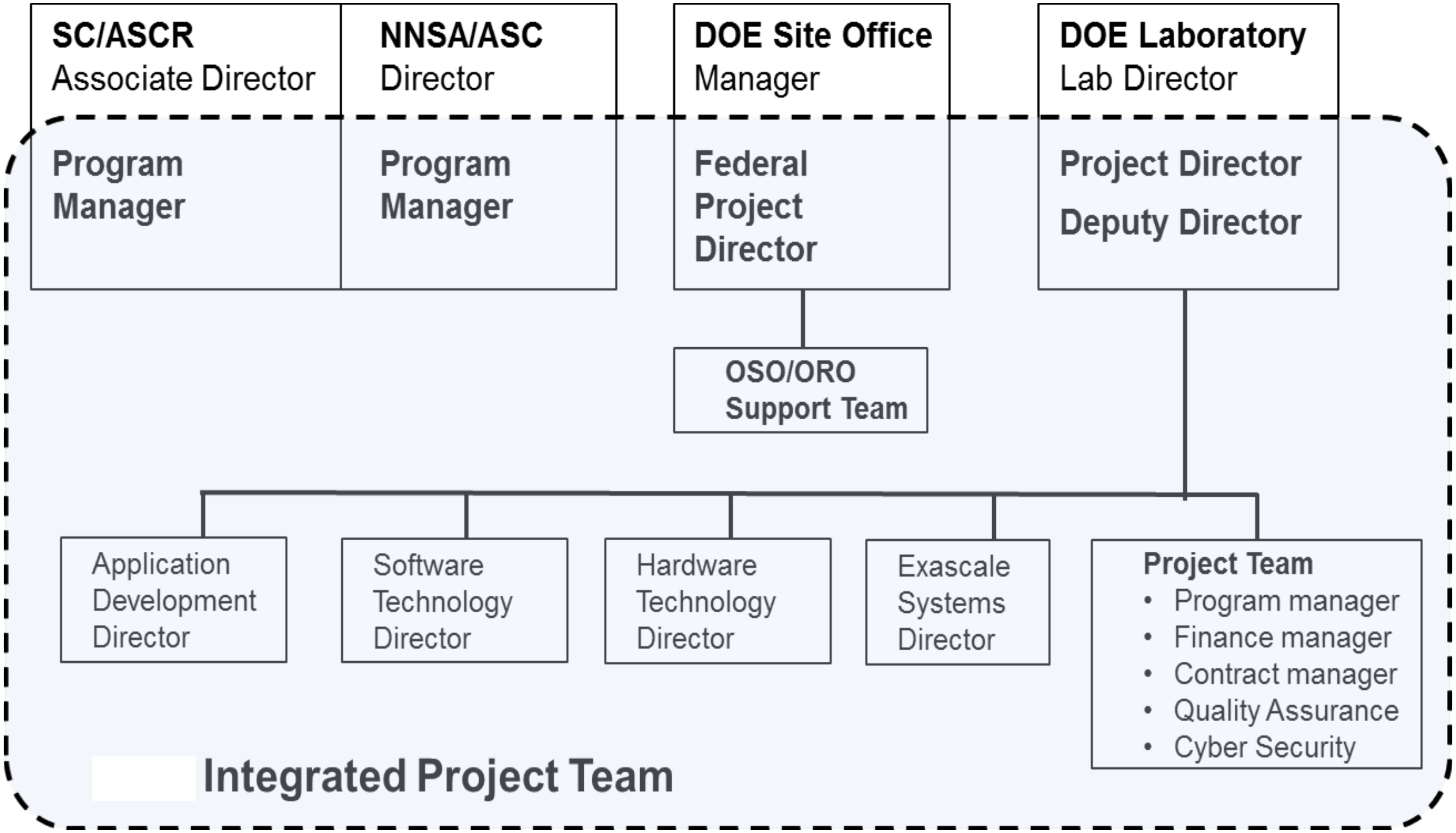
Application Development Director

Software Technology Director

Hardware Technology Director

Exascale Systems Director

“Projectizing” the Exascale Initiative, cont’d



SC/ASCR
Associate Director

Program Manager

NNSA/ASC
Director

Program Manager

DOE Site Office
Manager

Federal Project Director

OSO/ORO Support Team

DOE Laboratory
Lab Director

Project Director

Deputy Director

Application Development Director

Software Technology Director

Hardware Technology Director

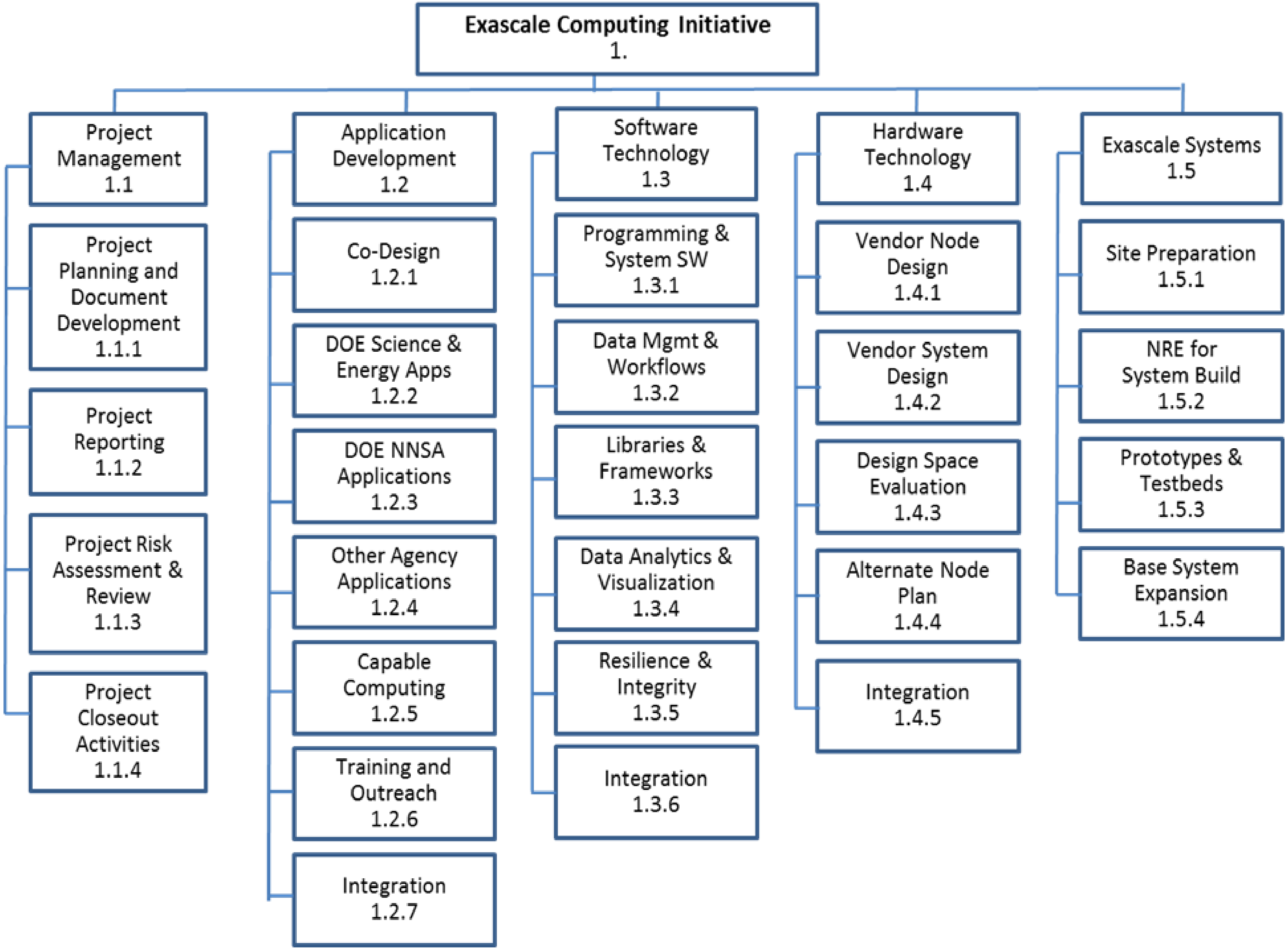
Exascale Systems Director

Project Team
- Program manager
- Finance manager
- Contract manager
- Quality Assurance
- Cyber Security

Integrated Project Team

“Projectizing” the Exascale Initiative, cont’d

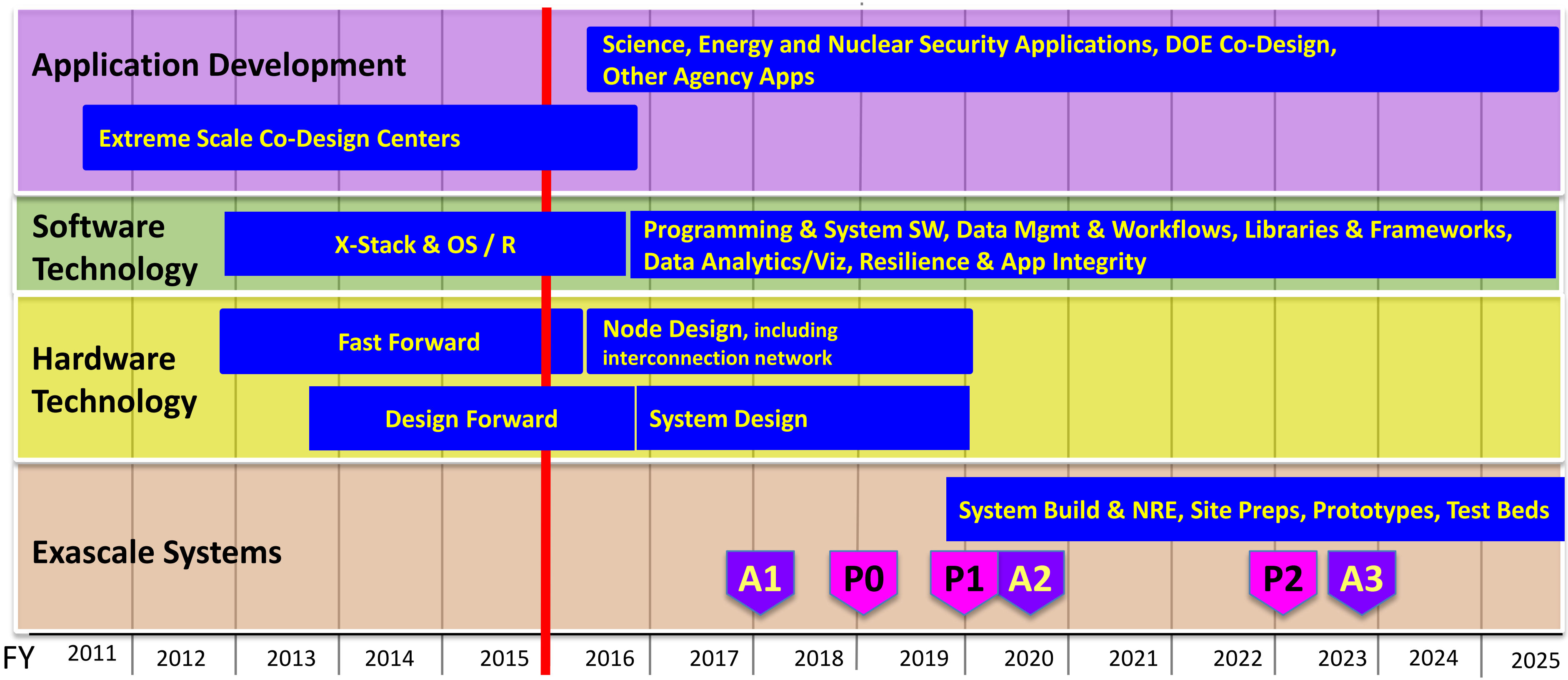
Work Breakdown Structure



- Exascale Computing Initiative 1.
  - Project Management 1.1
    - Project Planning and Document Development 1.1.1
    - Project Reporting 1.1.2
    - Project Risk Assessment & Review 1.1.3
    - Project Closeout Activities 1.1.4
  - Application Development 1.2
    - Co-Design 1.2.1
    - DOE Science & Energy Apps 1.2.2
    - DOE NNSA Applications 1.2.3
    - Other Agency Applications 1.2.4
    - Capable Computing 1.2.5
    - Training and Outreach 1.2.6
    - Integration 1.2.7
  - Software Technology 1.3
    - Programming & System SW 1.3.1
    - Data Mgmt & Workflows 1.3.2
    - Libraries & Frameworks 1.3.3
    - Data Analytics & Visualization 1.3.4
    - Resilience & Integrity 1.3.5
    - Integration 1.3.6
  - Hardware Technology 1.4
    - Vendor Node Design 1.4.1
    - Vendor System Design 1.4.2
    - Design Space Evaluation 1.4.3
    - Alternate Node Plan 1.4.4
    - Integration 1.4.5
  - Exascale Systems 1.5
    - Site Preparation 1.5.1
    - NRE for System Build 1.5.2
    - Prototypes & Testbeds 1.5.3
    - Base System Expansion 1.5.4

Exascale Computing Initiative

Timeline



Application Development

Science, Energy and Nuclear Security Applications, DOE Co-Design, Other Agency Apps

Extreme Scale Co-Design Centers

Software Technology

X-Stack & OS / R

Programming & System SW, Data Mgmt & Workflows, Libraries & Frameworks, Data Analytics/Viz, Resilience & App Integrity

Hardware Technology

Fast Forward

Node Design, including interconnection network

Design Forward

System Design

Exascale Systems

System Build & NRE, Site Preps, Prototypes, Test Beds

P0 Node Prototype

P1 Petascale Prototype

P2 Exascale Prototype

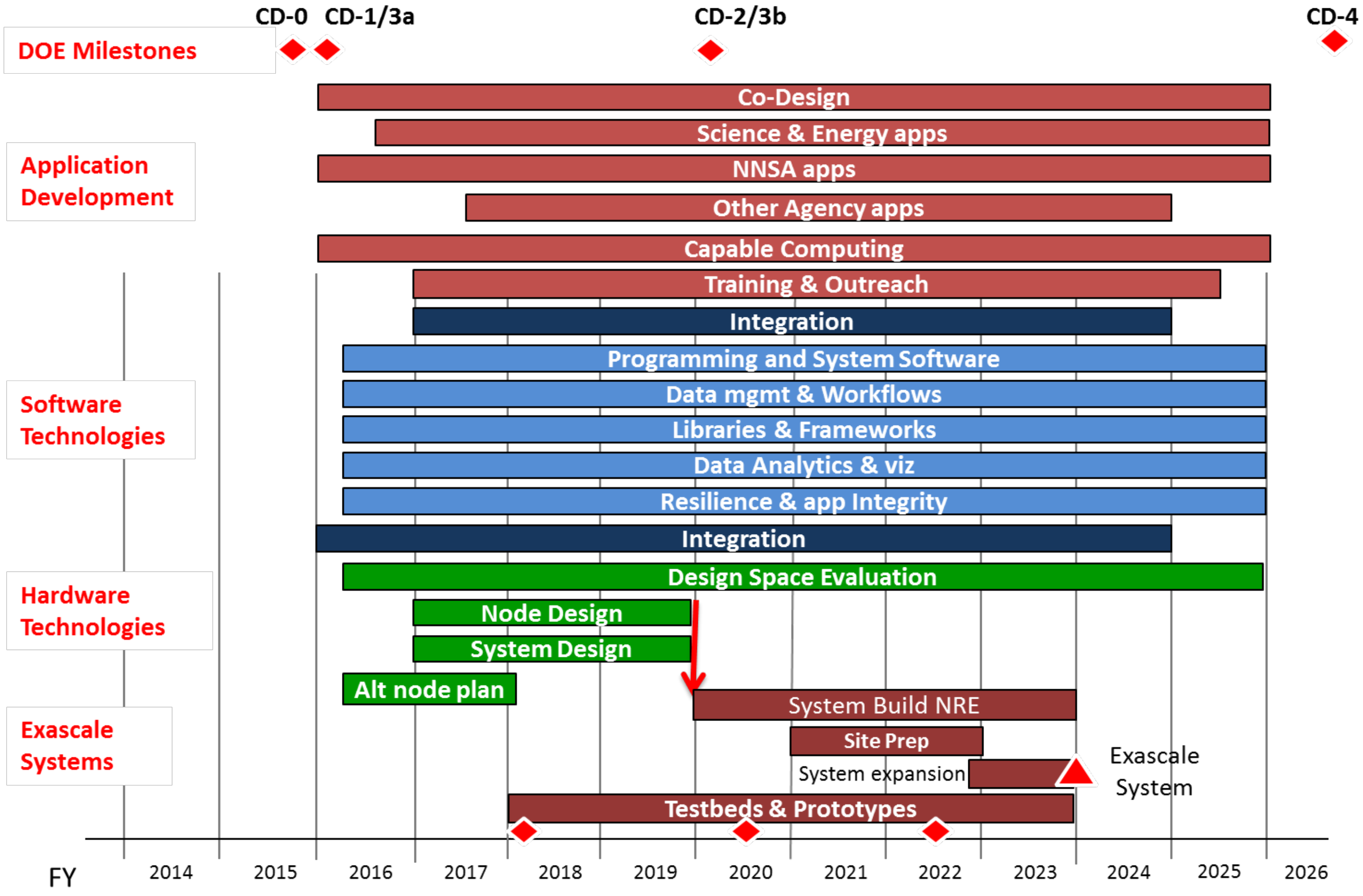
A1 CORAL Systems

A2 APEX Systems

A3 Exascale Systems

Procurement of A1, A2 and A3 are not executed, but are highly leverage, by the ECI Project

“Projectizing” the Exascale Initiative, cont’d



Department of Energy
Advanced Scientific Computing Advisory Committee
Exascale Computing Initiative Review

August 2015

Findings:

Like any ambitious undertaking, DOE’s proposed ECI involves some risks, as it seeks to develop and deploy advanced computing technologies and systems of unprecedented scale. Despite the risks, the benefits of the initiative to scientific discovery, national security and U.S. economic competitiveness are clear and compelling. The subcommittee strongly endorses the DOE plan for exascale computing development and deployment.

Given the centrality of advanced computing to scientific discovery, economic competitiveness, and national security, it is critical that the U.S. continue to maintain leadership in both enabling computing technologies and in their applications to problems of national importance. Thus, the subcommittee believes the proposed DOE ECI is an important element of ensuring the continued national security and economic competitiveness of the United States.

Response to ASCAC Review of ECI

Number	ASCAC Recommendation	ASCR Response
1	Develop a detailed management and execution plan that defines clear responsibilities and decision-making authority to manage resources, risks, and dependencies appropriately across vendors, DOE laboratories, and other participants. The present joint leadership structure spanning SC and NNSA has been effective in articulating a coherent vision for the future. For this high-level vision to be translated into a realizable and detailed execution plan, the subcommittee recommends that DOE establish a leadership structure that operates below and in concert with the present, high-level leadership at DOE headquarters. This leadership structure's sole focus should be the exascale program.	ASCR agrees; development of a detailed management and execution plan is in progress.
2	Given the scope, complexity, and potential impact of the ECI, conduct periodic external reviews by a carefully constituted advisory board. Such a board may also be useful in resolving complex resource issues and in assessing research and development risks when technology is changing quickly. It can also help define success metrics.	ASCR agrees and is implementing an advisory board, as well as Independent Project reviews, to perform periodic reviews.

Response to ASCAC Review of ECI

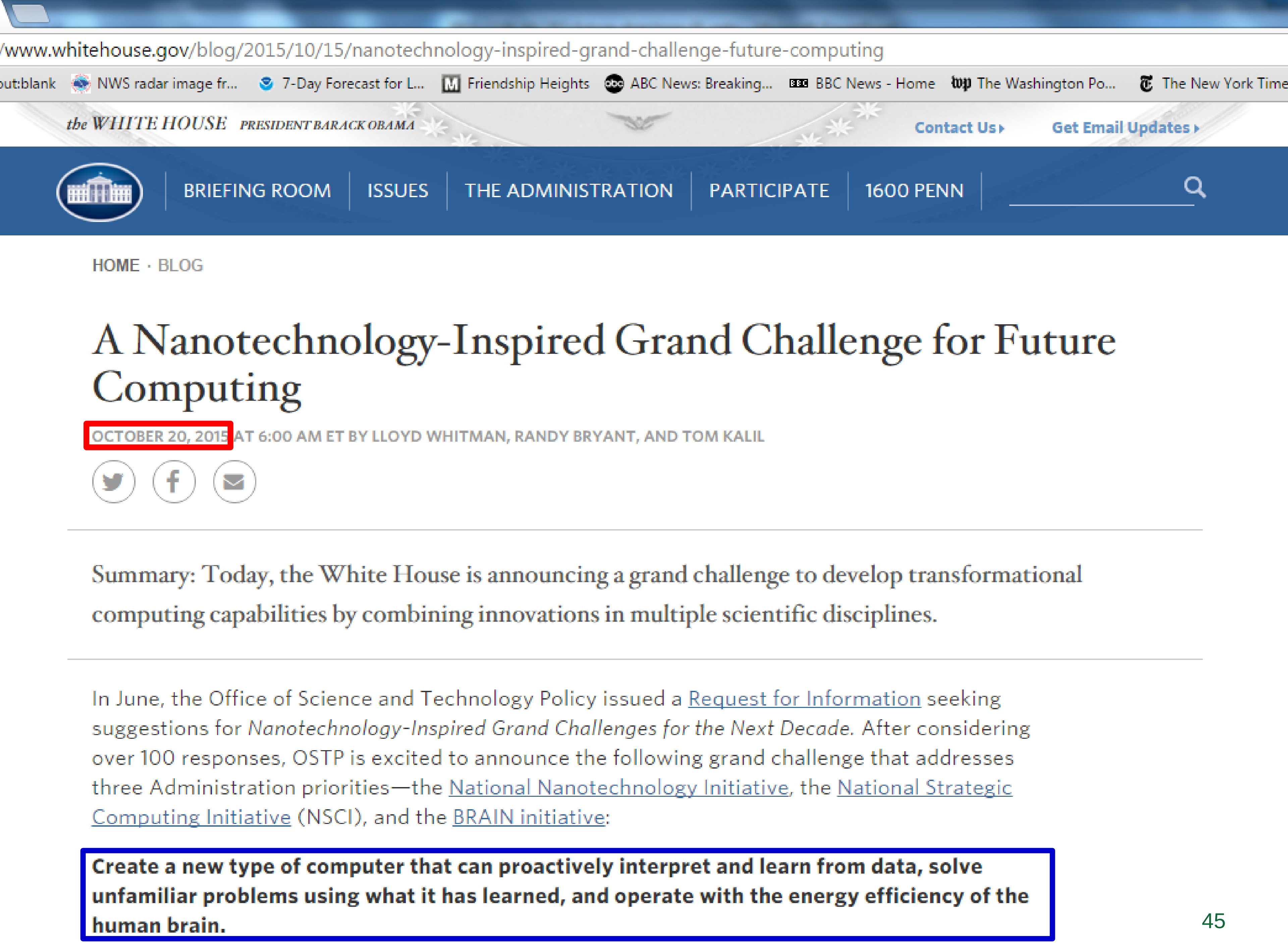
Number	ASCAC Recommendation	ASCR Response
3	Where appropriate, work with other federal research agencies and international partners on workforce development and long-term research needs, while not creating dependencies that could delay or imperil the execution plan.	ASCR agrees and is incorporating appropriate activities in the ECP and is pursuing collaborations with other federal agencies via NSCI.
4	Mitigate software risks by developing evolutionary alternatives to complement more innovative, but untested alternatives. This would ensure that applications have both an evolutionary and a revolutionary path to exascale execution.	ASCR agrees and is implementing this in the ECP conceptual design.
5	As part of the execution plan, clearly distinguish essential system attributes (e.g., sustained performance levels) from aspirational ones (e.g., specific energy consumption goals) and focus effort accordingly.	ASCR agrees and is implementing this in the ECP conceptual design.
6	Unlike other elements of the hardware/software ecosystem, application performance and stability are mission critical, necessitating continued focus on hardware/software co-design to meet application needs.	ASCR agrees and is implementing this in the ECP conceptual design.
7	Remain cognizant of the need for the ECI to support both data intensive and computation intensive workloads.	ASCR agrees and is implementing this in the ECP conceptual design.

Neuromorphic Computing

Neuromorphic Computing Community Engagement

- **2015 DOE Workshop Report: Neuro-Inspired Computational Elements (NICE) [February 23-25, 2015]**
  - Information Processing and Computation Systems beyond von Neumann/Turing Architecture and Moore’s Law Limits
  - A specific focus for this year’s Workshop was the value proposition for neuro-inspired/neuromorphic computing: what these systems offer, or may offer, that exceeds the current and forecasted capabilities of conventional computing approaches.
    - **Key Finding** – Neuromorphic systems could provide value in two, coupled tracks:
      1. Analysis, sense making, prediction and control
      2. Platform for understanding neural systems and testing hypotheses generated by neuroscience.
    - **Key Recommendation –** Coordinated effort across multiple disciplines and application areas is needed to:
      1. Establish appropriate metrics
      2. Develop performance parameters
      3. Support development of neuro-inspired/neuromorphic systems

http://science.energy.gov/~/media/ascr/pdf/programdocuments/docs/NICE2015_Workshop_Report.pdf



A Nanotechnology-Inspired Grand Challenge for Future Computing

OCTOBER 20, 2015 AT 6:00 AM ET BY LLOYD WHITMAN, RANDY BRYANT, AND TOM KALIL

Summary: Today, the White House is announcing a grand challenge to develop transformational computing capabilities by combining innovations in multiple scientific disciplines.

In June, the Office of Science and Technology Policy issued a Request for Information seeking suggestions for *Nanotechnology-Inspired Grand Challenges for the Next Decade.* After considering over 100 responses, OSTP is excited to announce the following grand challenge that addresses three Administration priorities—the National Nanotechnology Initiative, the National Strategic Computing Initiative (NSCI), and the BRAIN initiative:

Create a new type of computer that can proactively interpret and learn from data, solve unfamiliar problems using what it has learned, and operate with the energy efficiency of the human brain.

https://www.whitehouse.gov/blog/2015/10/15/nanotechnology-inspired-grand-challenge-future-computing

ASCR/BES Neuromorphic Computing Study Group Roundtable Discussion

October 29-30, 2015

Gaithersburg, MD

Jointly sponsored by ASCR and BES to evaluate both advanced materials and scientific computing research opportunities to support development of a new paradigm for extreme and self-reconfigurable computing architectures that go beyond Moore's Law and mimic neuro-biological architectures.

Approximately 15 experts in emerging computer architectures and related materials science research topics attended, along with observers from across DOE Labs.

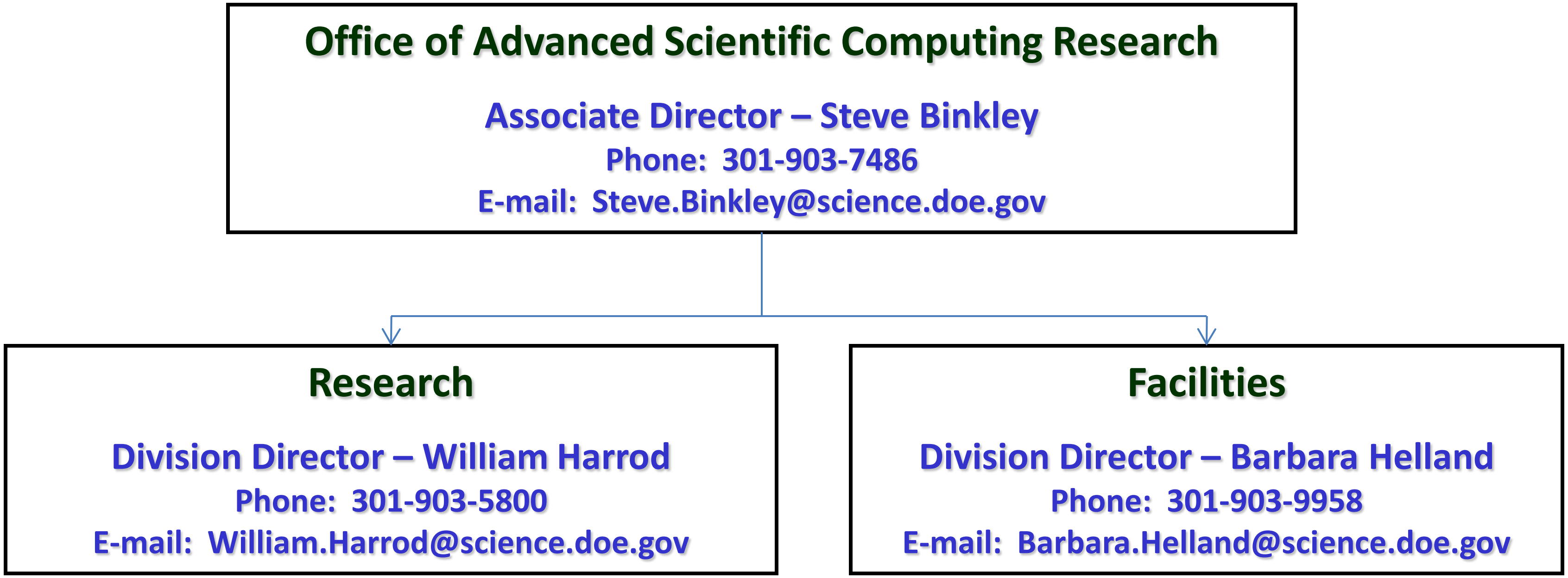
A summary report is being developed (expected in December 2015).

Organizing Committee:

Rick Stevens and Ivan Schuller (co-chairs)

Robinson Pino (ASCR) and Michael Pechan (BES)

ASCR at a Glance



Office of Advanced Scientific Computing Research

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Relevant Websites

ASCR: science.energy.gov/ascr/

ASCR Workshops and Conferences:
science.energy.gov/ascr/news-and-resources/workshops-and-conferences/

SciDAC: www.scidac.gov

INCITE: science.energy.gov/ascr/facilities/incite/

Questions?