U.S. DEPARTMENT OF ENERGY | Office of Science

FY 2017 Budget Request to Congress for DOE's Office of Science

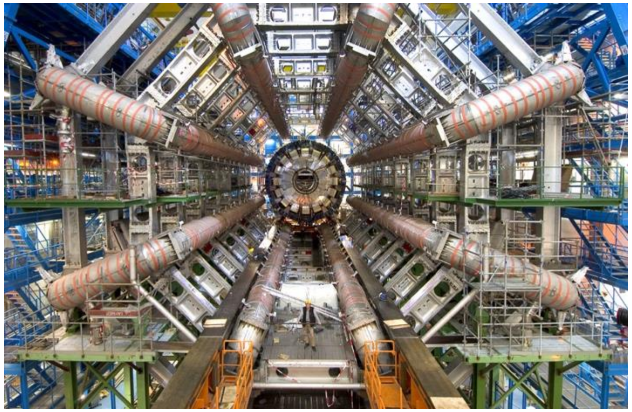
ASCAC Meeting, April 4, 2016

Cherry A. Murray
Director, Office of Science
www.science.energy.gov

Department of Energy Mission Areas

Energy

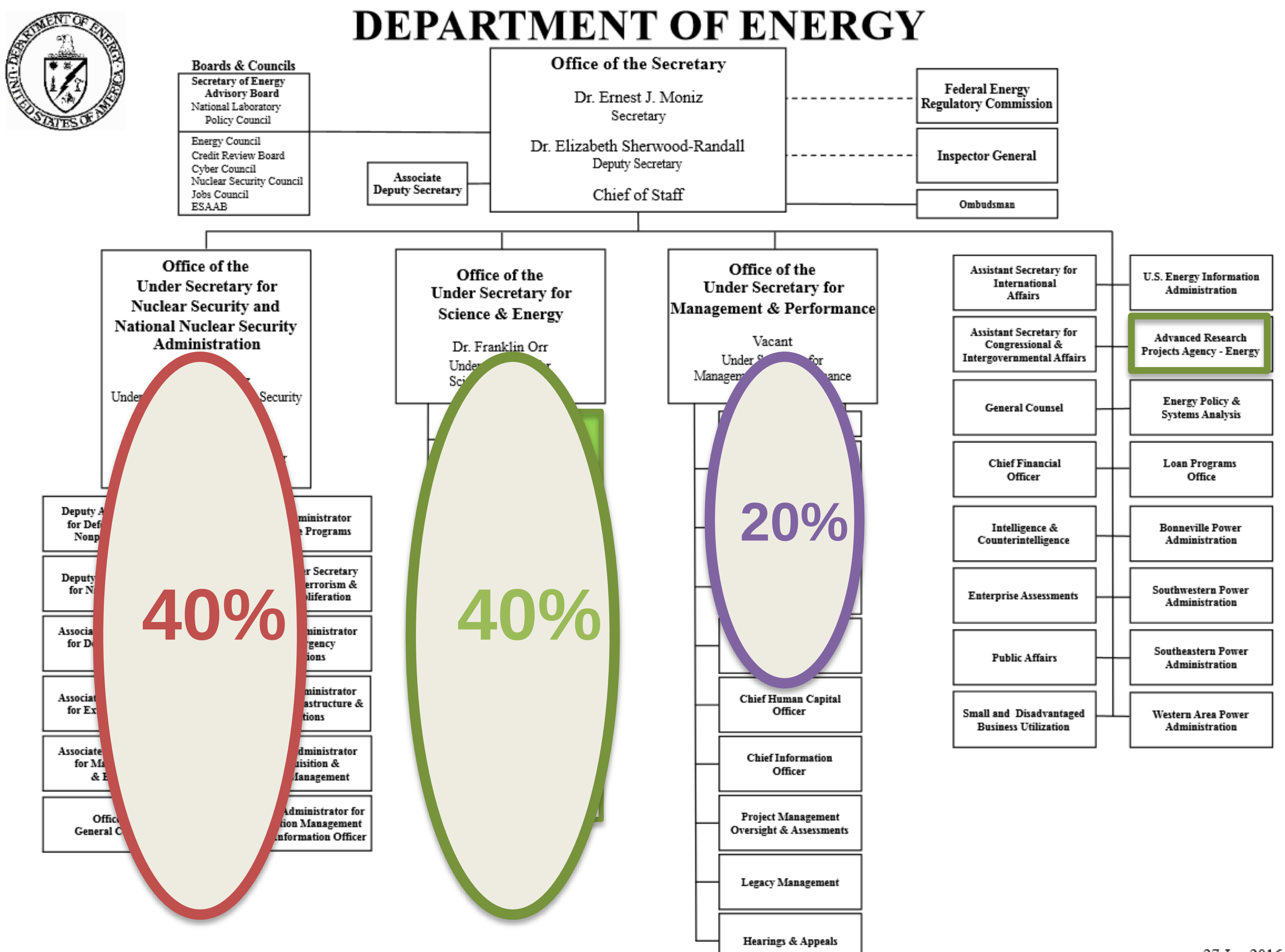
Science



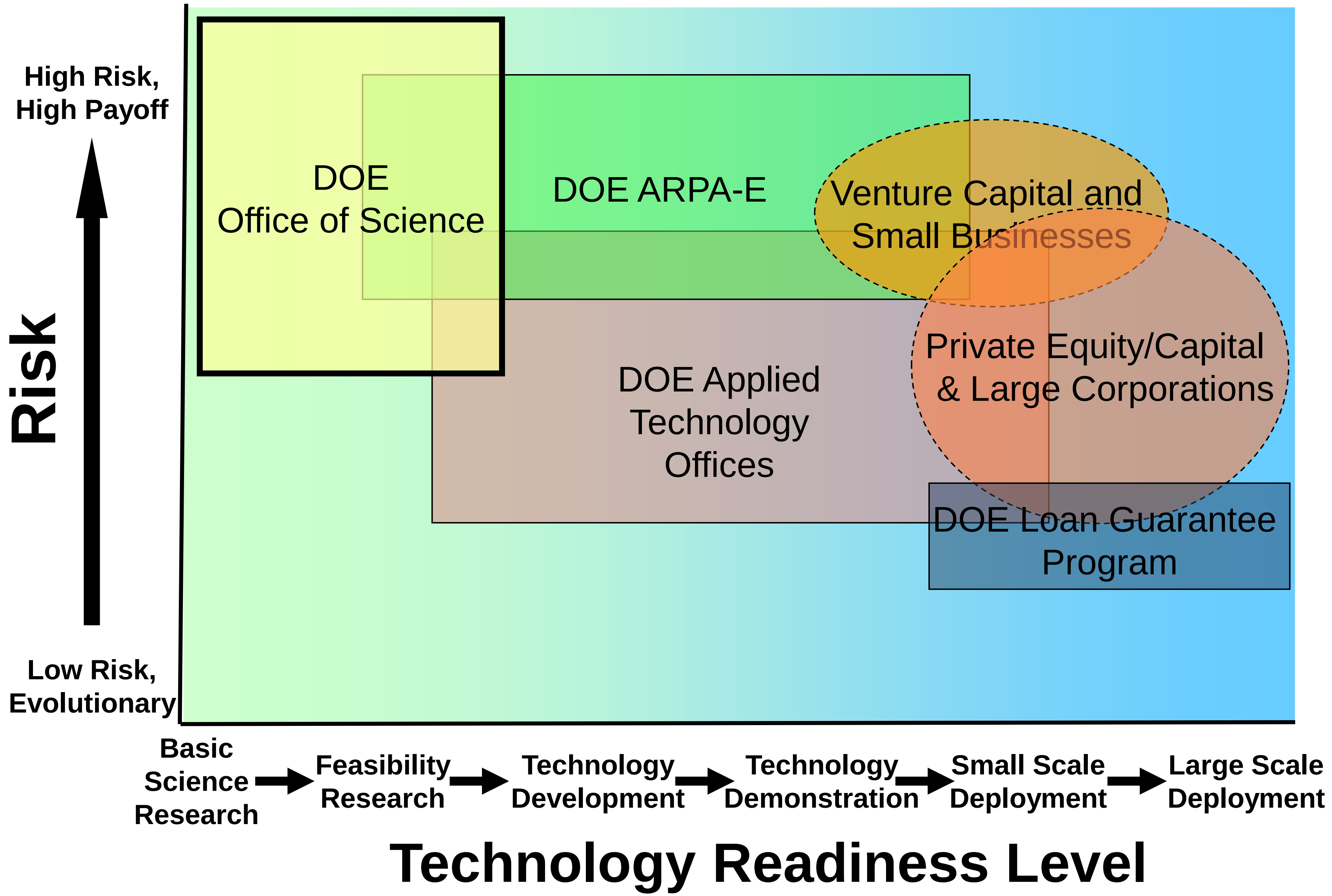
Nuclear Safety and Security

Environmental Cleanup

DOE Organization Chart 2016

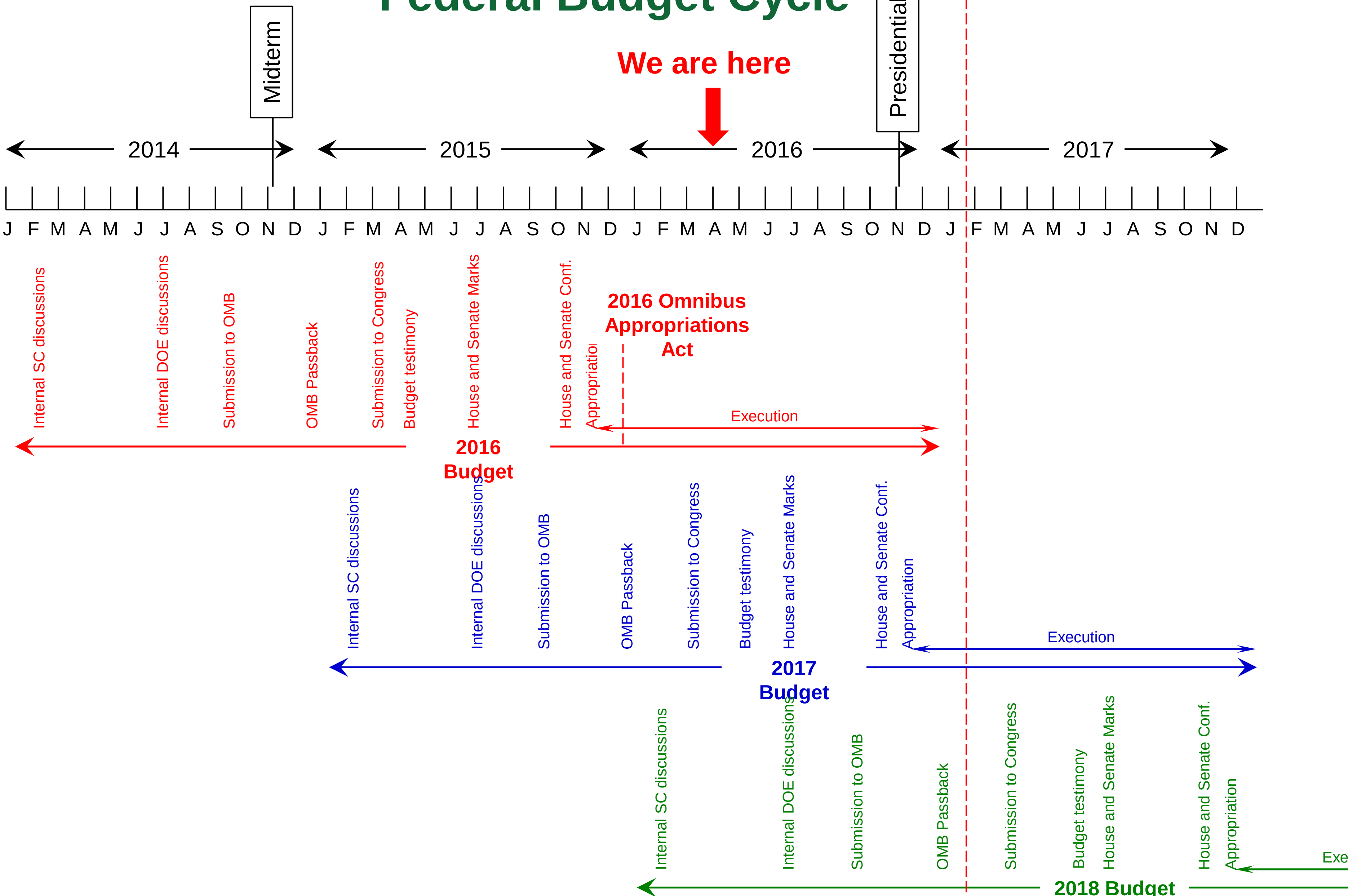


[1] The director of the Office of Technology Transitions also serves as DOE's Technology Transfer Coordinator who reports to the Secretary of Energy



High Risk, High Payoff
Risk
Low Risk, Evolutionary
DOE Office of Science
DOE ARPA-E
Venture Capital and Small Businesses
DOE Applied Technology Offices
Private Equity/Capital & Large Corporations
DOE Loan Guarantee Program
Basic Science Research
Feasibility Research
Technology Development
Technology Demonstration
Small Scale Deployment
Large Scale Deployment
Technology Readiness Level

Federal Budget Cycle



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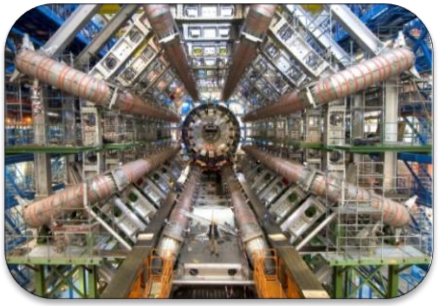
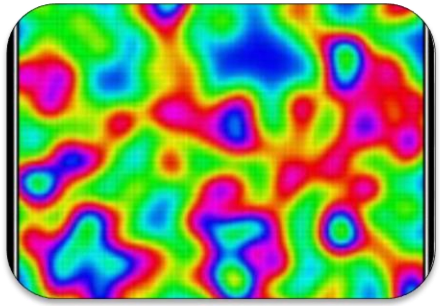
Office of Science FY16 - $5.35B



Largest Supporter of Physical Sciences in the U.S.

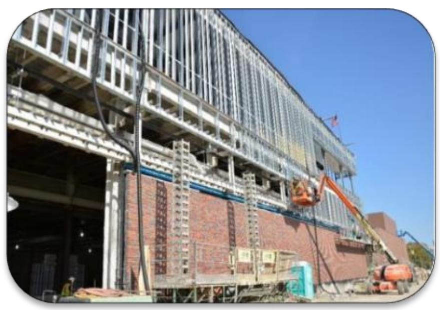


Research: 42%, $2.2B

~40% of Research to Universities

> 20,000 Scientists Supported

Funding at >300 Institutions including all 17 DOE Labs

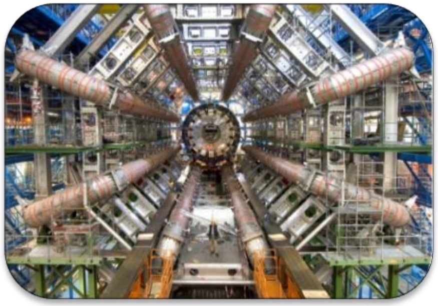


Construction: 13.5%, $723M

Facility Operations: 38%, $2.02B

>30,000 Scientific Facility Users

Office of Science FY17 Request: $5.67B, +6.1%



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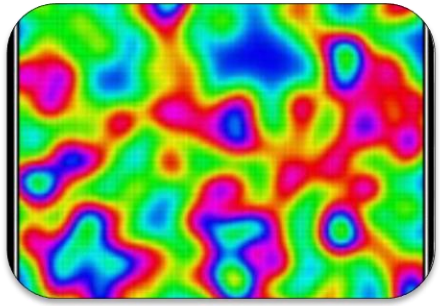
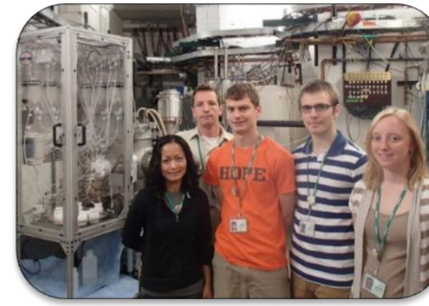


Research: 42%, $2.4B

~40% of Research to Universities



> 20,000 Scientists Supported

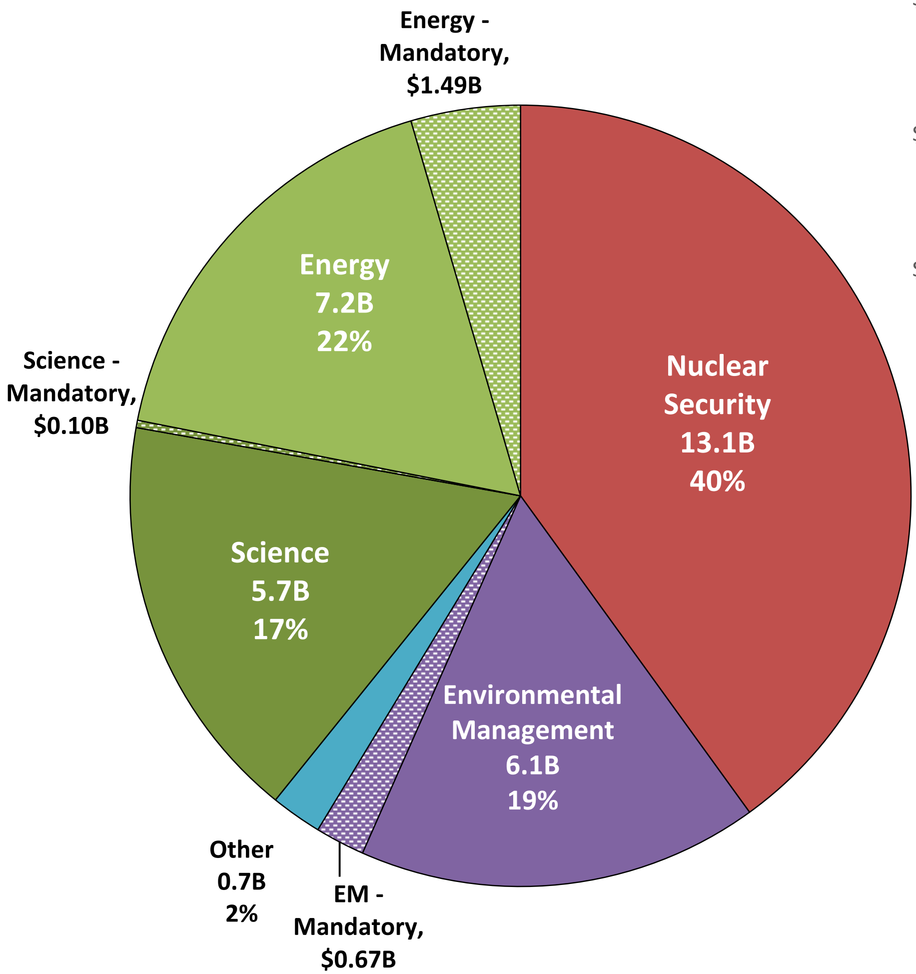
Funding at >300 Institutions including all 17 DOE Labs

Facility Operations: 36%, $2.06B

>30,000 Scientific Facility Users

$1.8B Mission Innovation

President's DOE FY 2017 Proposed Budget



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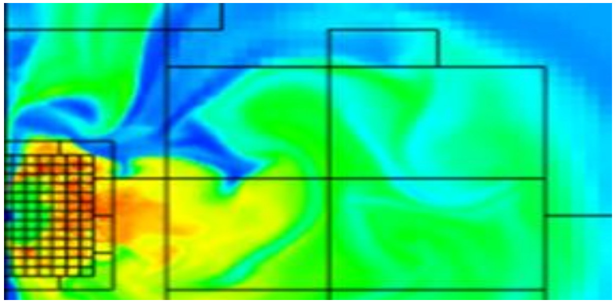
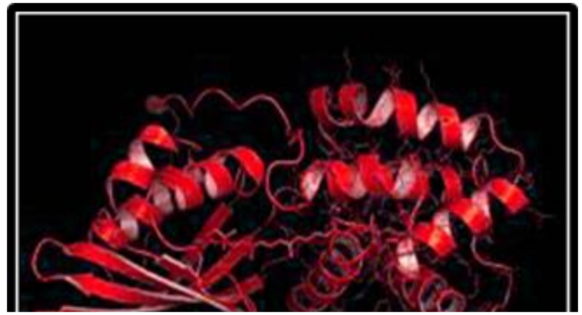
Office of Science Programs



Advanced Scientific Computing Research

FY2016 $621M

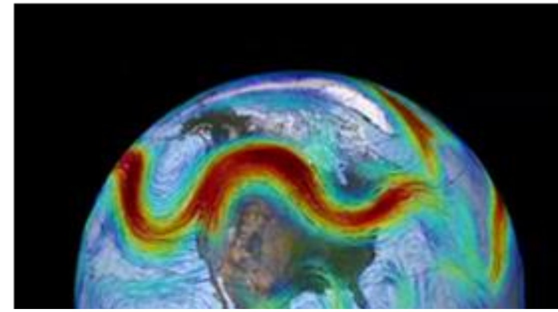
FY2017 Request +6.8%



Basic Energy Sciences

FY2016 $1849M

FY2017 Request +4.7%



Biological and Environmental Research

FY2016 $609M

FY2017 Request +8.7%

High Energy Physics

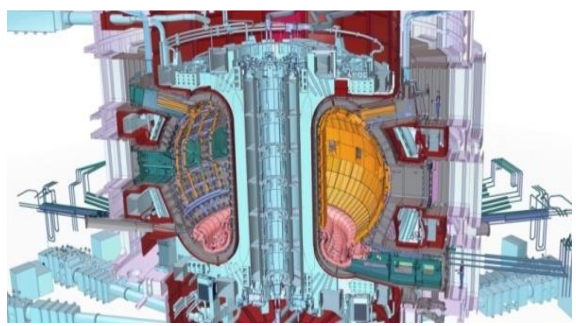
FY2016 $795M

FY2017 Request +2.9%

Fusion Energy Sciences

FY2016 $438M

FY2017 Request -9.1%



Nuclear Physics

FY2016 $617M

FY2017 Request +3.0%

Office of Science FY 2017 Budget Request to Congress

(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Science						
Advanced Scientific Computing Research	541,000	523,411	621,000	663,180	+42,180	+6.8%
Basic Energy Sciences	1,733,200	1,682,924	1,849,000	1,936,730	+87,730	+4.7%
Biological and Environmental Research	592,000	572,618	609,000	661,920	+52,920	+8.7%
Fusion Energy Sciences	467,500	457,366	438,000	398,178	-39,822	-9.1%
High Energy Physics	766,000	745,232	795,000	817,997	+22,997	+2.9%
Nuclear Physics	595,500	580,744	617,100	635,658	+18,558	+3.0%
Workforce Development for Teachers and Scientists	19,500	19,500	19,500	20,925	+1,425	+7.3%
Science Laboratories Infrastructure	79,600	79,600	113,600	130,000	+16,400	+14.4%
Safeguards and Security	93,000	93,000	103,000	103,000	......	......
Program Direction	183,700	183,700	185,000	204,481	+19,481	+10.5%
University Grants (Mandatory)	......	......	......	100,000	+100,000	......
Small Business Innovation/Technology Transfer Research (SC)	......	132,905	......	......	......	......
Subtotal, Science	5,071,000	5,071,000	5,350,200	5,672,069	+321,869	+6.0%
Small Business Innovation/Technology Transfer Research (DOE)	......	65,075	......	......	......	......
Rescission of Prior Year Balance	-3,262	-3,262	-3,200	......	+3,200	-100.0%
Total, Science	**5,067,738**	**5,132,813**	**5,347,000**	**5,672,069**	**+325,069**	**+6.1%**

SC Investments for Mission Innovation

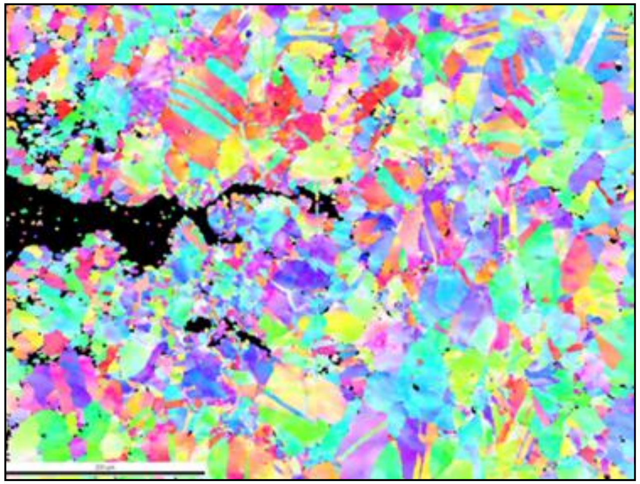
$100M in new funding in FY 2017

ASCR (+$10M)

- Computational Partnerships with EFRCs on solar, CO_2 reduction, catalysis, storage, subsurface, and biofuels; possibly new partnerships in wind and nuclear ($10M)

BES (+$51M)

- Energy Efficiency: Catalysts, modeled after nature's enzymes, that can operate at low-temperature and under ambient conditions; lightweight metallic materials; thermocaloric materials ($34.4M)
- Materials for Clean Energy: Self-healing materials for corrosive and high radiation environments (next-gen corrosive-resistant materials based on experiments and multi-scale modeling; chemistry under harsh or extreme environments) ($16.6M)



Analysis of cracks at the nanoscale

BER (+$35M)

- Biosystems design (computationally design and then bio-engineer biosystems) to introduce beneficial traits into plants and microbes for clean energy applications ($20M)
- Bioenergy Research Centers: New investments to translate 10 years of BRC research to industry ($15M, $5M per BRC)

FES (+4M)

- Whole-device fusion modeling and simulation using SciDAC partnerships ($4M)

SC Increases Academic Research by $100M (Mandatory) in FY 2017

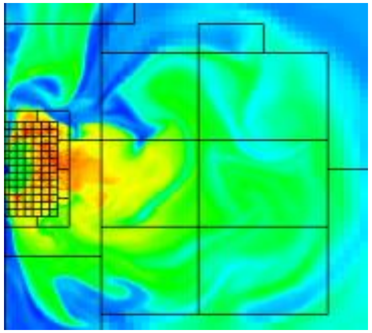
Investments are made in all of the SC programs, emphasizing emerging research areas, especially those recently identified by Federal Advisory Committees or other community activities. A few examples are:

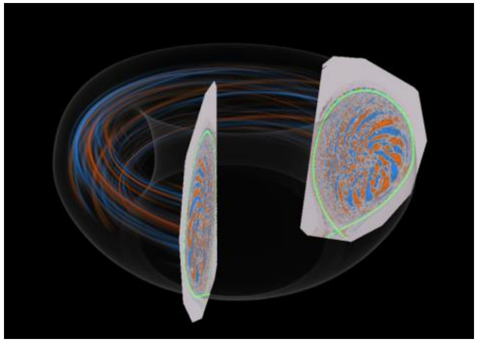
- **ASCR**: Applications software, applied mathematics, and computer science for capable exascale computing; mathematics for large-scale scientific data; neuromorphic computing architectures and information processing for extreme and self-reconfigurable computing architectures
- **BES**: Topics described in the 2015 BESAC Report *Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science*, including hierarchical architectures, non-equilibrium matter, non-ideal systems, coherence in light and matter, modeling & computation, and imaging across multiple scales.
- **BER**: New platform microbes for biofuels and bioproducts engineering; biofuel crop modeling for incorporation into a predictive framework.
- **FES**: Plasma/fusion research centers emphasizing the results of the 2015 community workshops, including for example low-temperature plasmas, plasma measurements, and verification & validation for magnetic fusion.
- **HEP**: Topics described in the 2014 HEPAP Long Range Plan and also topics that span multiple SC programs, including quantum information sciences/the entanglement frontier and quantum field theory across disciplines.
- **NP**: Topics described in the 2015 NSAC Long Range Plan, including research to accelerate discovery at FRIB, fundamental nuclear structure and nuclear astrophysics, fundamental symmetries, and super-heavy elements.

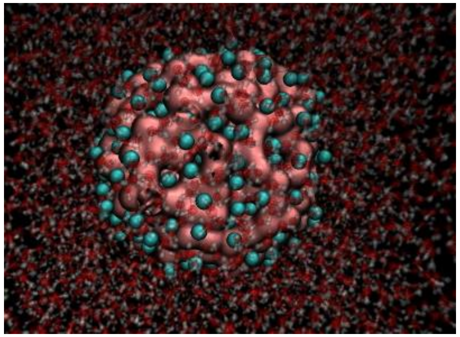
Advanced Scientific Computing Research

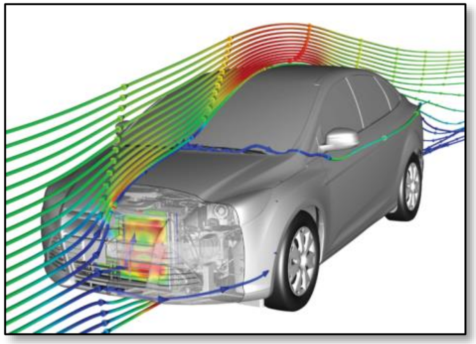
Computational and networking capabilities to extend the frontiers of science and technology

- **Exascale Computing Initiative (ECI) and Exascale Computing Project (ECP).** The ECP is initiated as a joint ASCR/NNSA partnership using DOE's formal project management processes. A new budget line is created for the ECP.
- **Facilities** operate optimally and with >90% availability; deployment of 10-40 petaflop upgrade at NERSC and site preparations for NERSC-9; upgrade of high traffic links on Esnet; and continued preparations for 180-200 petaflop upgrades at ALCF and OLCF.
- **SciDAC partnerships** will be recompeted in FY 2017 with new activities to include accelerating the development of clean energy technologies.
- **Applied Mathematics research** addresses challenges of increasing complexity and **Computer Science research** addresses exploration of "beyond Moore's law" architectures and supports data management, analysis, and visualization techniques.
- The **Computational Sciences Graduate Fellowship** is funded at $10,000K.









Components of the Exascale Program

- Exascale Computing Initiative (ECI)
  - The ECI was initiated in FY 2016 to support research, development, and computer-system procurements to deliver an exascale (10^{18} ops/sec) computing capability by the mid-2020s.
  - It is a partnership between SC and NNSA, addressing science and national security missions.
  - The Exascale Crosscut includes primary investments by SC/ASCR and NNSA/ASC and software application developments in both SC (BES and BER) and NNSA.

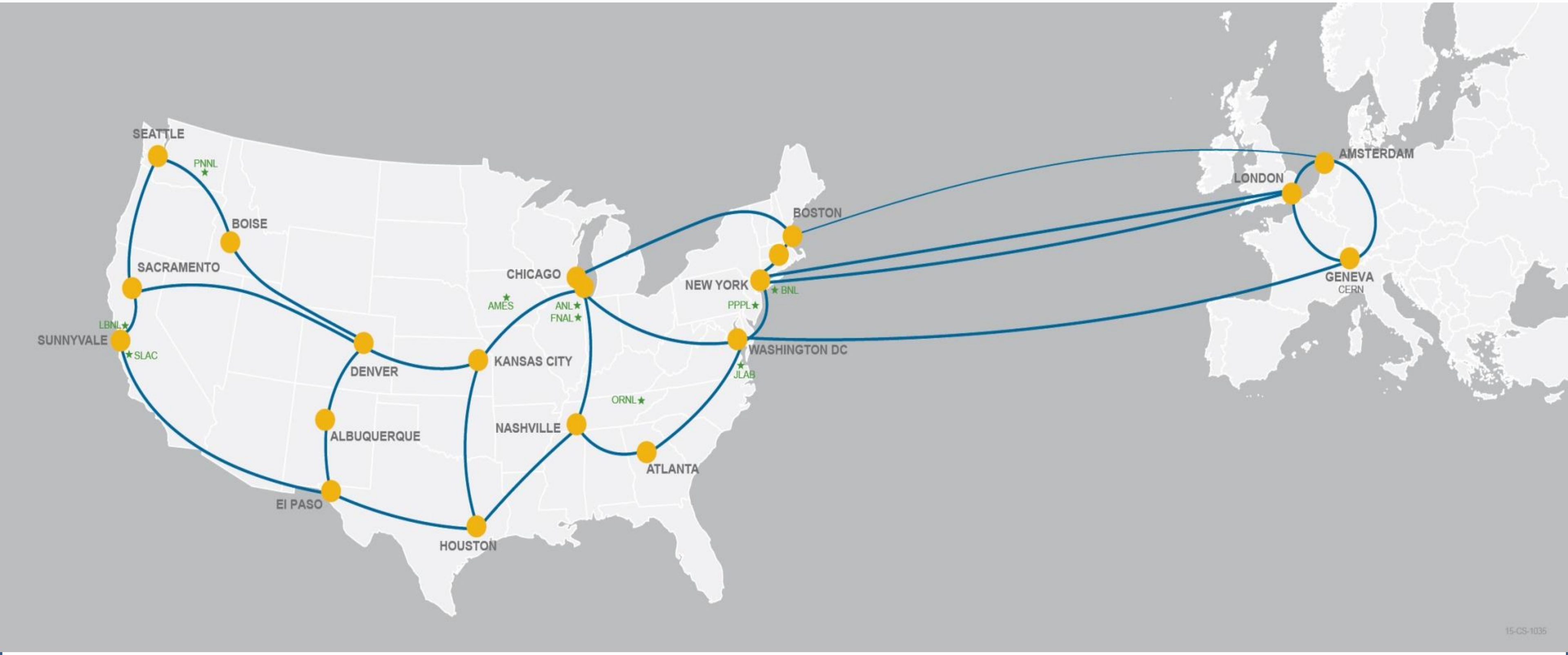
- Exascale Computing Project (ECP)
  - Beginning in FY 2017, the ASCR ECI funding is transitioned to the DOE project (the ECP), which is managed according to the principles of DOE Order 413.3b.
  - The new ECP subprogram in ASCR (SC-ECP) includes only activities required for the delivery of the exascale computers. An ECP Project Office has been established ORNL.
  - NNSA/ASC Advanced Technology Development and Mitigation (ATDM) supports activities for the delivery of exascale computers and the development of applications.

- Relationship of the ECI and ECP to the National Strategic Computing Initiative
  - On July 29, 2015, an executive order established the National Strategic Computing Initiative (NSCI) to ensure a coordinated Federal strategy in HPC research, development, and deployment.
  - DOE, along with the DoD and NSF, co-lead the NSCI. Within DOE, SC and NNSA execute the ECI and the ECP, which are the DOE contributions to the NSCI.

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	200	>8.5	180
Peak Power (MW)	2	9	4.8	< 3.7	13.3	1.7	13
Total system memory	357 TB	710TB	768TB	~1 PB DDR4 + High Bandwidth Memory (HBM)+1.5PB persistent memory	> 2.4 PB DDR4 + HBM + 3.7 PB persistent memory	676 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	~4,600 nodes	>3,200 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®

ESnet Addresses Data Growth



In FY 2017, the Energy Science Network (ESnet) will increase bandwidth to address the growing data requirements of SC facilities, such as the light sources, neutron sources, and particle accelerators at CERN. This includes upgrading high-traffic links to 400 gigabits per second (gbps). ESnet will also continue to extend science engagement efforts to solve the end-to-end network issues between DOE facilities and universities.

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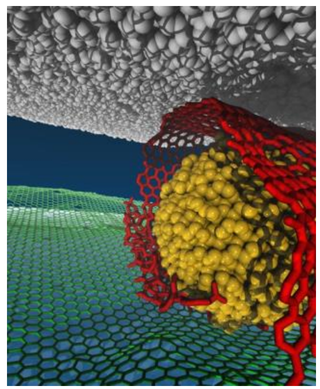
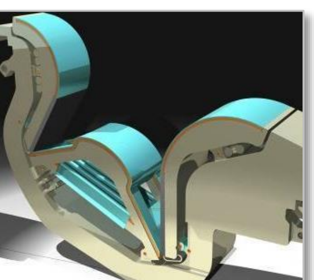
HPC Advancing Clean Energy

Materials for Nuclear Energy
Simulations at NERSC reveal structural defects from irradiation in nuclear power plants that can't be seen in experiments.
(R. Devanathan, PNNL)

Reducing Friction
A team of researchers used the ALCF to observe a mechanism for eliminating friction at the macroscale with potential to achieve superlubricity for a wide range of mechanical applications.
(S. Sankaranarayanan, ANL)

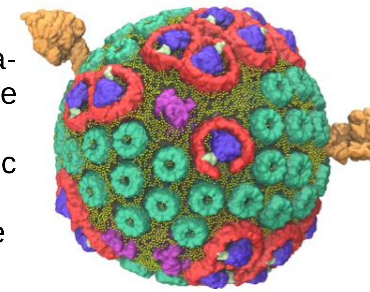


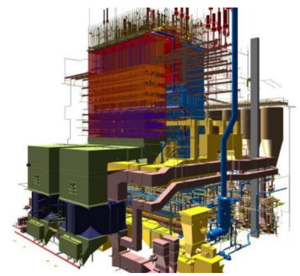


Materials for Fusion Energy
Researchers used the OLCF to obtain fundamental understanding of the plasma heat-load impinging on the Tokomak divertor and its dependence on the plasma current in present-day tokamak devices and in ITER. **(C.S. Chang, PPPL)**

Superconductivity
ALCF research is providing advanced calculations to identify the electronic mechanisms for high-temperature superconductivity in cuprates.
(L. Wagner, UI-UC)

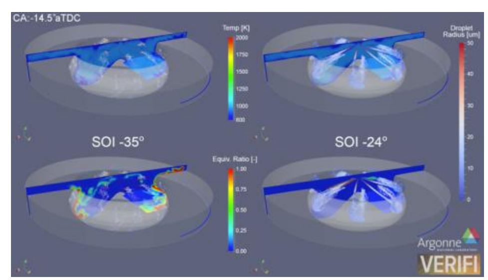
Photosynthesis
A team from the University of Illinois at Urbana-Champaign (UI-UC) used the OLCF to achieve a milestone in the field of biomolecular simulation, modeling a complete photosynthetic organelle of the bacteria Rhodobacter sphaeroides in atomic detail. The project is the first of its kind. **(C. Shulten, UI-UC)**





Clean Coal Combustion
Researchers at the University of Utah and its Carbon Capture Multi-Disciplinary Simulation Center (CCMSC) are using the OLCF to enable petascale simulations to guide the design of next-generation oxy-coal boilers for clean electric energy. **(M. Berzins, Utah)**

Cellulosic Ethanol
To understand barriers to biofuel production, researchers used the OLCF to develop detailed knowledge of lignin behavior that can guide genetic engineering of enzymes that produce bioethanol more efficiently.
(J. Smith, ORNL)



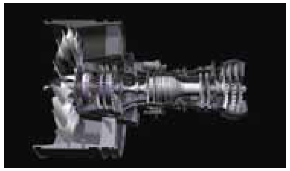
Better Engines
The ALCF is partnering with industry to develop simulation capabilities that can improve the fuel economy of vehicles.
(S. Som, ANL)

HPC Accelerating Energy Technology Development

General Motors
Increasing Fuel Efficiency of Cars

GM used the OLCF to accelerate, by at least a year, research to develop new thermoelectric materials that increase the fuel efficiency of cars. Typical car engines lose about 60 percent of fuel energy to waste heat. Access to DOE computers allowed GM to develop unique materials that convert some waste heat into electricity that can power various subsystems, removing a major burden from the car's main generator and lowering fuel consumption. GM also used the OLCF to optimize injector hole pattern design for desired in-cylinder fuel-air mixture distributions with a 4 - 40x improvement in workflow throughput via 100s of ensembles.

Pratt & Whitney
Accelerating Energy Efficient Jet Engine Design



Airlines are constantly seeking better fuel efficiency and lower emissions, but redesigning jet engines has traditionally involved many time-consuming, repetitive experiments. Pratt & Whitney has dramatically decreased problem-to-solution turnaround times by adding computer based virtual testing to the design process. Using the ALCF, Pratt & Whitney improved the fuel efficiency in its Pure Power engines by 12–15% with potential savings to airlines of nearly $1M per aircraft per year. The new design is also 75 percent quieter.

SmartTruck Systems
Reducing Truck Fuel Consumption

SmartTruck Systems of South Carolina used the OLCF to reduce by 50% the time to develop add-on parts that substantially improve the fuel efficiency - up to 12% - exceeding the EPA SmartWay requirements for long-haul Trucks. Add-on parts from SmartTruck can save each outfitted truck up to 3,700 gallons of fuel each year.

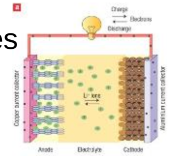
Royal Dutch Shell
Catalysis

Shell used the ALCF to improve the production of synthetic gas products by simulating the catalytic properties of cluster-based materials.

Ramgen Power Systems
Compressor Design Innovation

Ramgen Power Systems, a small firm in Bellevue, WA used the OLCF to accelerate the design of shock wave turbo compressors for carbon capture and sequestration and for energy production. Very high resolution computer models enabled the company to go from computer testing to cutting a titanium prototype in two months.

Bosch
Li-ion Batteries

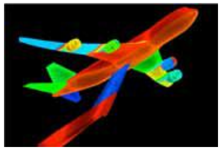


Bosch used OLCF resources to discover and optimize new classes of solid inorganic Li-ion electrolytes with high ionic and low electronic conductivity, and good electrochemical stability.

Fiat Chrysler Automobiles
Improving Pickup Aerodynamics

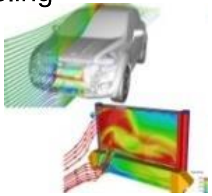
FCA has begun working with the OLCF to better understand the aerodynamics of a pickup truck. They will be doing large scale design of experiment studies to understand the influence of about 40 different geometric parameters on the aerodynamic behavior, specifically the drag coefficient, of pickup truck designs.

The Boeing Company
Aircraft Efficiency and Safety



Increasingly, aircraft manufacturers use predictive computational tools to take the place of expensive wind tunnel tests. Boeing used the OLCF to discover multiple solutions for steady RANS equations with separated flow to explain why numerical models sometimes fail to capture maximum lift.

Ford Motor Company
Underhood Cooling

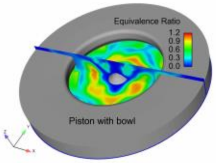


Ford used OLCF resources to develop a new, efficient and automatic analytical cooling package optimization process leading to one-of-a-kind design optimization of cooling systems. Ford also used the OLCF to develop a high-performance computational strategy for modeling engine Cycle-to-Cycle Variation (CCV) - the first such simulation at scale.

Caterpillar
Heavy Equipment Efficiency

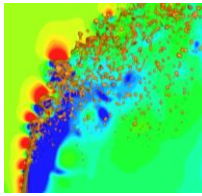
Caterpillar used ALCF resources to develop more powerful combustion engine simulation capabilities to allow shorter development times and reduce need for multi-cylinder test programs. CAT also used the OLCF for evaluating large-scale HPC and GPU capability of critical welding simulation software and further developing & testing weld optimization algorithm.

Convergent Science
Engine Design



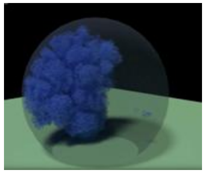
Convergent Science is an Independent Software Vendor specializing in Computational Fluid Dynamics tools. They used the ALCF to improve scaling of combustion simulations to allow unprecedented number of simultaneous jobs, providing a valuable design tool for engine manufacturers jobs, providing a valuable design tool for engine manufacturers.

United Technologies
Jet Efficiency & Catalysis



UTRC used the OLCF to conduct first-of-a-kind high-fidelity LES computations of flow in turbomachinery components for more fuel efficient, next-generation jet engines. They also used the OLCFs to Demonstrate biomass as a viable, sustainable feedstock for fuel cell hydrogen production; showed that nickel is a feasible catalytic alternative to platinum

General Electric
Advancing Wind Energy

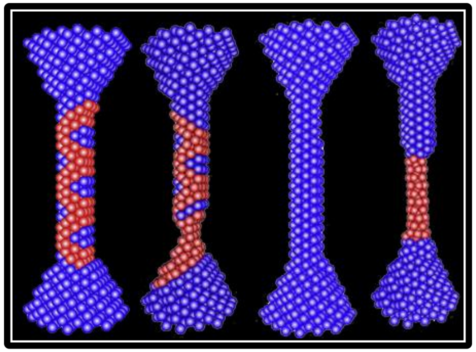


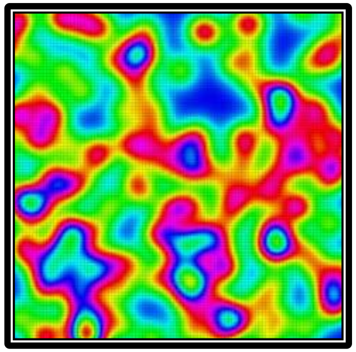
GE used ALCF resources to enable the design of quieter, more efficient wind turbines by accurate simulations of the complex behavior of air flows around wind turbine blades. GE also used the OLCF to conduct first time simulations of ice formation within million-molecule water droplets . This is expanding understanding of freezing at the molecular level to enhance wind turbine resilience in cold climates.

Basic Energy Sciences

Understanding, predicting, and controlling matter and energy at the electronic, atomic, and molecular levels

- Increased funding for **Energy Frontier Research Centers** (EFRCs) will fully fund up to five new awards in the area of subsurface science, with an emphasis on advanced imaging of geophysical and geochemical signals.
- A new activity in **Computational Chemical Sciences** will leverage U.S. leadership in computational chemistry community codes for petascale and in anticipation of exascale computing.
- Core research increases to advance the **Mission Innovation** agenda, targeting materials and chemistry for energy efficiency and for use in extreme environments.
- Both **Energy Innovation Hubs** continue. Joint Center for Energy Storage Research (JCESR) will be in its 5th year. Joint Center for Artificial Photosynthesis (JCAP) will be in its 3rd year of renewal.
- To maintain international competitiveness in discovery science, support continues for the **Linac Coherent Light Source-II (LCLS-II)** construction project and the **Advanced Photon Source Upgrade (APS-U)** major item of equipment project.
- BES **user facilities** operate at optimal levels.

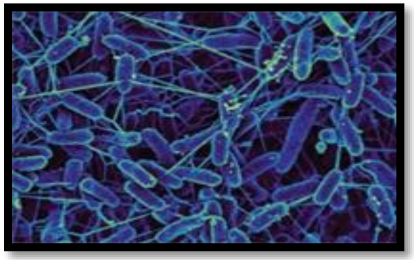



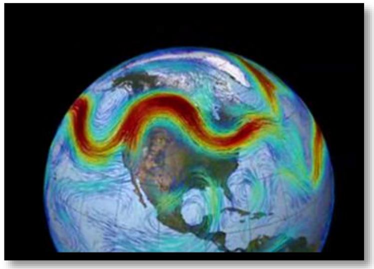


Biological and Environmental Research

Understanding complex biological, climatic, and environmental systems

- **Genomic sciences** supports the Bioenergy Research Centers, new microbiome research, and increases efforts in biosystems design for bioenergy and renewable bioproducts.
- **Mesoscale-to-molecules** research supports the development of enabling technology to visualize key metabolic processes in plant and microbial cells at the subcellular and mesoscale.
- **Climate and Earth System Modeling** supports development of physical, chemical, and biological model components to simulate climate variability and change at regional and global scales.
- **Atmospheric System Research (ASR)** addresses major uncertainties in climate change models: the role of clouds and the effects of aerosols on precipitation, and the atmospheric radiation balance.
- **Environmental System Science** supports research to provide a robust, predictive understanding of terrestrial surface and subsurface ecosystems. Includes Next Generation Ecosystem Experiments targeting climatically sensitive terrestrial ecosystems not well represented in models.
- **Climate and Environmental Data Analysis and Visualization** employs server side analysis to simplify analysis of large scale observations with model-generated data.
- **User facilities operate at optimal levels: ARM** continues measurements at fixed sites, and mobile facilities deploy to the Arctic, Antarctic, and the Atlantic Ocean. **JGI** provides genome sequence data, synthesis, and analysis. **EMSL** continues novel research using the High Resolution and Mass Accuracy Capability.





FY 2017 SC Contributions to DOE Crosscuts

	Adv Mat	ECI	Sub-surface	EWN	Cyber-security	Total
Advanced Scientific Computing Res.	0	154,000	0	0	0	154,000
Basic Energy Sciences	17,600	26,000	41,300	0	0	84,900
Biological and Environmental Research	0	10,000	0	24,300	0	34,300
Safeguards and Security	0	0	0	0	27,197	27,197
Total, SC Contribution Crosscuts	17,600	190,000	41,300	24,300	27,197	300,397

Adv Mat: Advanced Materials Crosscut
ECI: Exascale Computing Initiative Crosscut
Subsurface: Subsurface Technology and Engineering RD&D Crosscut
EWN: Energy-Water Nexus Crosscut
Cybersecurity: Cybersecurity Crosscut

SC Contributes to Five FY 2017 DOE Crosscuts

Advanced Materials (Adv Mat): Identified as a priority in both the 2015 QTR and the QER, activities in the Adv Mat crosscut address faster development of new materials and reductions in the cost of materials qualification in clean energy applications, from discovery through deployment. New activities emphasize DOE-wide efforts in (1) materials design and synthesis, (2) applied design, (3) process scale-up, (4) qualification, and (5) digital data and informatics.

Exascale Computing Initiative (ECI): Activities in the ECI crosscut, a partnership between SC and NNSA, address accelerating R&D to overcome key challenges in parallelism, energy efficiency, and reliability, leading to deployment of exascale systems in the mid-2020s. In addition to underpinning DOE's missions in science and national security, the computational capabilities developed in the ECI also will support R&D in DOE's applied energy technology areas, as described in the 2015 QTR.

Subsurface Technology and Engineering RD&D (Subsurface): Activities in the Subsurface crosscut address coordinated research in Wellbore Integrity, Stress State and Induced Seismicity, Permeability Manipulation, New Subsurface Signals, and Risk Assessment Tools. Over 80 percent of our total energy supply comes from the subsurface; the goals of this crosscut are enhanced energy security, reduced impact on climate change via CO_2 sequestration, and significantly mitigated environmental impacts from energy-related activities and operations.

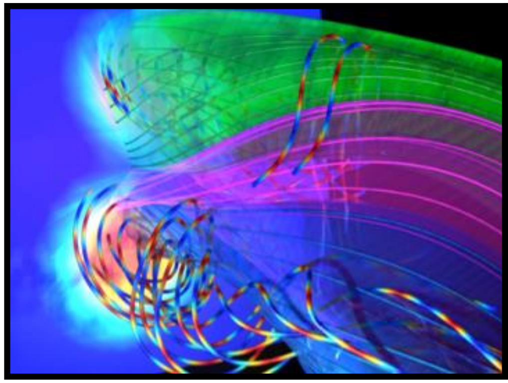
Energy-Water Nexus (EWN): The EWN crosscut addresses the transition to more resilient energy and coupled energy-water systems. The EWN crosscut supports: (1) an advanced, integrated data, modeling, and analysis platform to improve understanding and inform decision-making; (2) investments in targeted technology research offering the greatest potential for impact; and (3) policy analysis and stakeholder engagement designed to build from and strengthen the two preceding areas while motivating community involvement and response.

Cybersecurity: The Department of Energy (DOE) is engaged in two categories of cyber-related activities: protecting the DOE enterprise from a range of cyber threats that can adversely impact mission capabilities and improving cybersecurity in the electric power subsector and the oil and natural gas subsector. The cybersecurity crosscut supports central coordination of the strategic and operational aspects of cybersecurity and facilitates cooperative efforts such as the Joint Cybersecurity Coordination Center (JC3) for incident response and the implementation of Department-wide Identity Control and Access Management (ICAM).

Fusion Energy Sciences

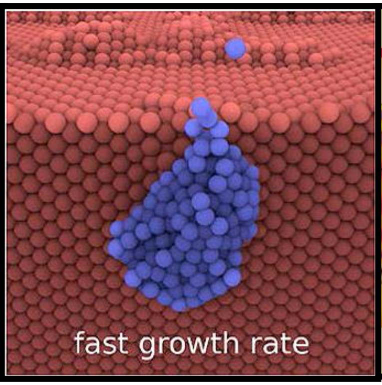
Matter at very high temperatures and densities and the scientific foundations for fusion

- Research is supported for the DIII-D and NSTX-U national programs.
- NSTX-U operates for 16 weeks; DIII-D operates for 14 weeks; Alcator C-Mod ceases operation as scheduled and MIT scientists collaborate full-time on domestic and international facilities.
- Support continues for U.S. research involvement on international machines EAST (China), KSTAR (Korea), and W7-X (Germany).
- HEDLP research is focused on the MEC instrument at LCLS.
- General plasma science activities continue, including the partnership with NSF for discovery-driven plasma science and engineering research.
- U.S. contributions to ITER support US ITER Project Office; the US direct contribution; and progress on hardware contributions, including fabrication of the central solenoid magnet modules and structures and the toroidal field magnet conductor.

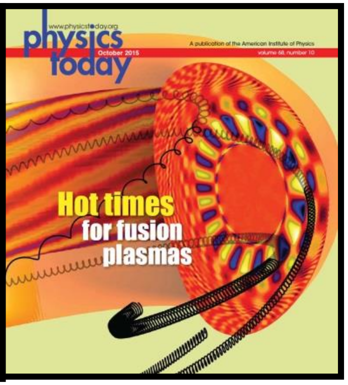


Magnetic reconnection driven by 3-D flux-rope interaction in the Large Plasma Device

New central solenoid magnet inside NSTX-Upgrade



Growth of helium bubbles that degrade tungsten performance



Gyrokinetic simulation of energetic ions in tokamak plasma

High Energy Physics

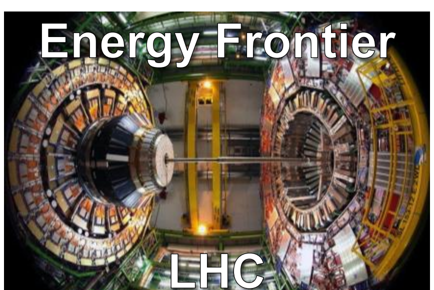
Understanding how the universe works at its most fundamental level

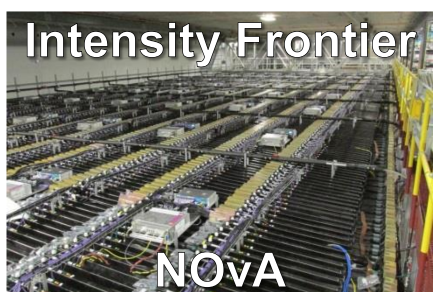
- The FY 2017 HEP budget reflects the way the P5 plan has evolved as the U.S. and international community have adopted and responded to it

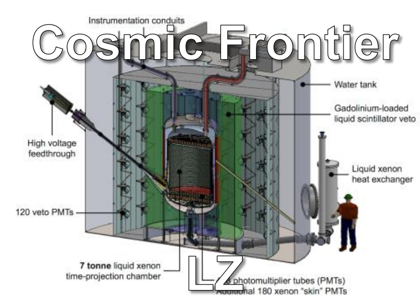
- **Energy Frontier:** Continue active engagement in highly successful LHC program
  - Initial LHC detector upgrade project funding ends in FY 2017
  - Scope being determined for high luminosity(HL)- LHC, P5’s highest priority near-term project; CD-0 in 2016
  - The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in LHC data analysis of world’s highest energy particle collider data, at 13 TeV

- **Intensity Frontier:** Solidify international partnerships for U.S.-hosted LBNF/DUNE
  - Rapid progress on LBNF/DUNE has attracted attention from interested international partners, and FY 2017 investments in site preparation and cavern excavation aim to solidify formal agreements
  - Fermilab will continue improvements to accelerator complex while serving high-intensity neutrino beams to short-and long-baseline experiments enabling full utilization of the FNAL facilities

- **Cosmic Frontier:** Advance our understanding of dark matter and dark energy
  - Fabrication funding ramp up in FY 17 supports key P5 recommended Cosmic Frontier projects to study dark matter and dark energy: LSSTcam, DESI, SuperCDMS-SNOLab, and LZ







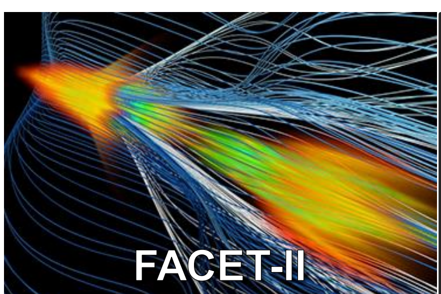
	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

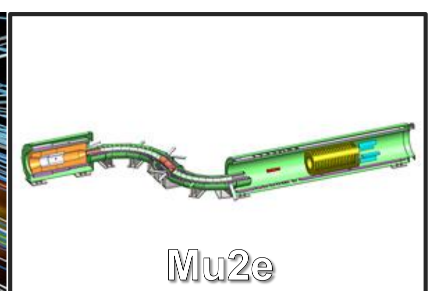
High Energy Physics

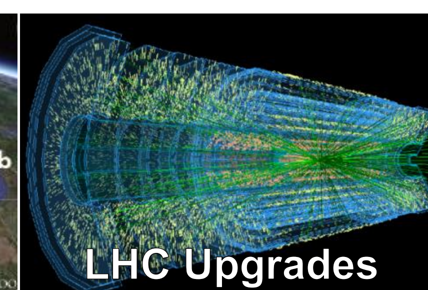
The technology and construction needed to pursue to physics

- Construction & project support increases to implement the P5 strategy:
  - LBNF/DUNE aims to solidify partnerships with FY 2017 investments in site preparation and excavation of caverns for the neutrino detectors and cryogenic infrastructure
  - LHC ATLAS and CMS Detector Upgrade projects continue fabrication; HL-LHC upgrades begin
  - Muon g-2 completes project funding profile and will begin receiving beam at Fermilab
  - Dark energy: LSSTcam and DESI fabrication support increase according to planned profiles
  - Dark matter: LZ will continue fabrication as SuperCDMS-SNOLab proceeds to final design
  - Construction continues for the Muon to Electron Conversion Experiment (Mu2e)
  - FACET-II support begins, in order to create a new facility that will enable accelerator R&D aimed at dramatically improved capability and cost-effectiveness in future high-energy colliders

- Accelerator Stewardship
  - AS works to make particle accelerator technology widely available to science and industry by supporting use-inspired basic research in accelerator science and technology
  - FY17 Request supports research activities at laboratories, universities, and in industry for technology R&D areas such as laser, ion-beam therapy, and accelerator technology for energy and environmental applications
  - FY17 Request supports Brookhaven Accelerator Test Facility (ATF) operations and the continuation of the Accelerator Stewardship Test Facility Pilot Program



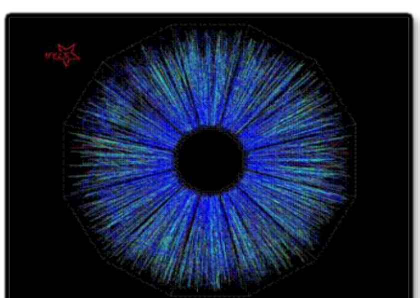
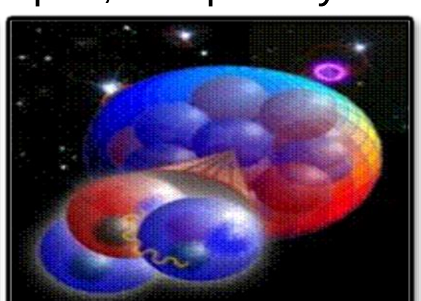
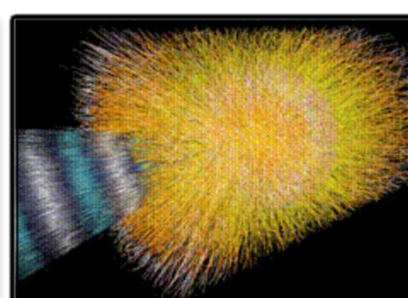
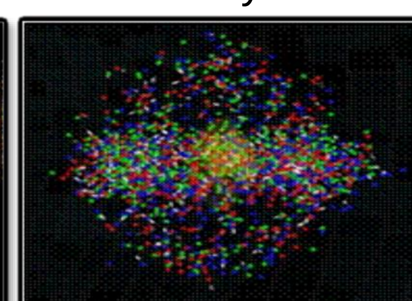




Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

- Funding for **research** increases to advance activities across the program, including R&D to develop new approaches for isotopes not currently available in sufficient quantities.
- A **graduate traineeship** is initiated in radiochemistry and nuclear chemistry with an emphasis in isotope production ($1M).
- Operations at **RHIC** increase to explore the properties of the quark gluon plasma first discovered there and to enable studies of spin physics.
- The **12 GeV CEBAF Upgrade** is completed in FY 2017 and the scientific program is initiated promising new discoveries and an improved understanding of quark confinement.
- Construction continues on the **Facility for Rare Isotope Beams.** The **Gamma-Ray Energy Tracking Array (GRETA)** MIE is initiated to exploit the scientific potential of FRIB.
- Fabrication begins for a **Stable Isotope Production Facility (SIPF)** to produce enriched stable isotopes, a capability not available in the U.S. for almost 20 years.

FY2017 Issues and Priorities

- **BALANCE - Discovery research vs science for clean energy and departmental crosscuts**
- **BALANCE - Research funding vs scientific user facilities construction vs operation**
- **Exascale computing project! National Strategic Computing Initiative**
- **International partnerships in Big Science**
  - **Defining moment in fusion sciences**
  - **LHC CMS, ATLAS upgrades at the same time as LBNF/DUNE**
- **Enhance communications with Congress and research universities**
- **Best practices in national lab management**

DOE Funding Modalities

Discovery Research

Use-Inspired Basic Research

Applied Research

Technology Maturation & Deployment

Office of Science

ARPA-E*

Applied Programs

Goal: new knowledge / understanding
Focus: phenomena
Metric: knowledge generation

Goal: practical targets
Focus: performance
Metric: milestone achievement

Consortia, Crosscuts

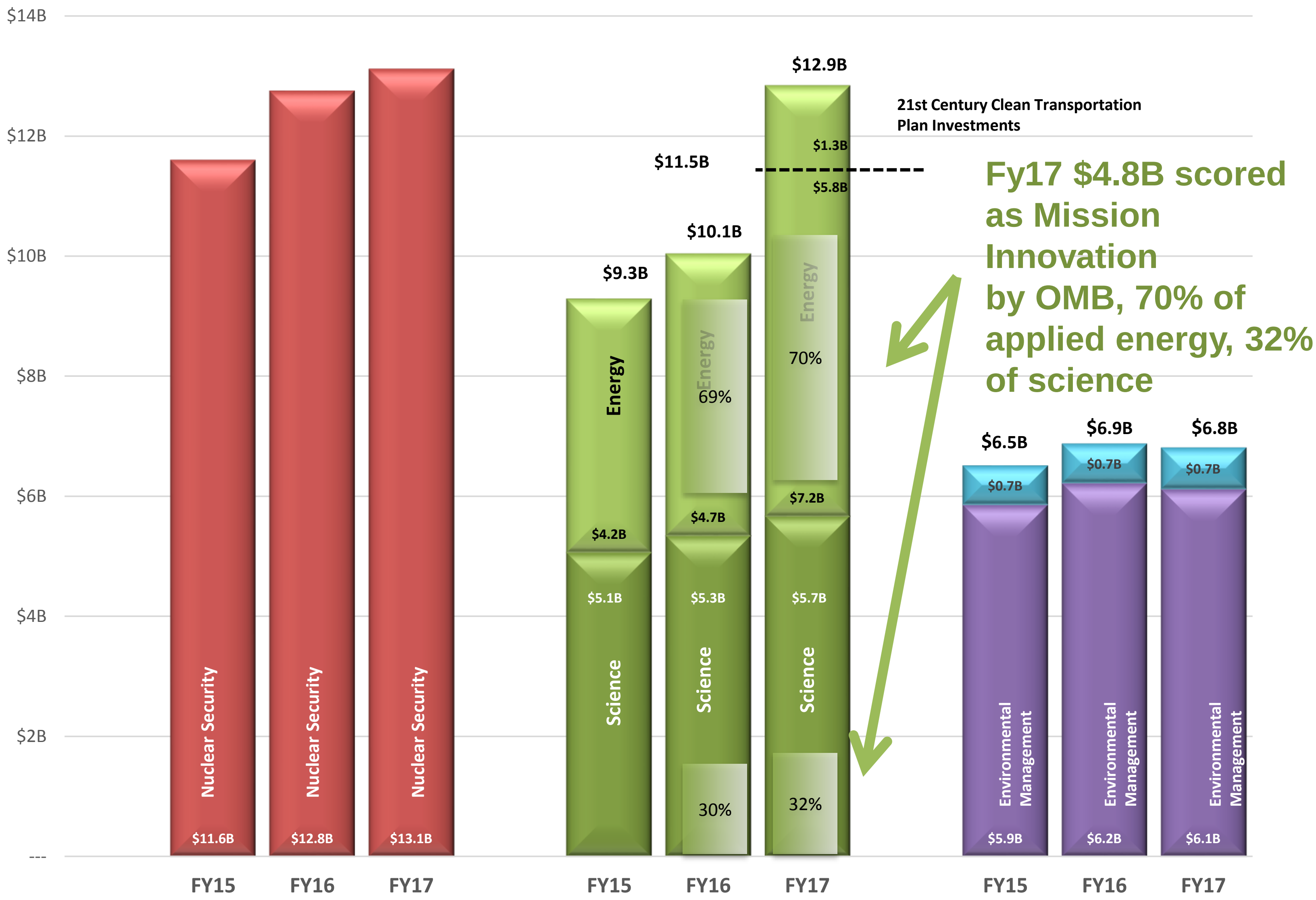
Bioenergy Research Centers, Hubs

Energy Frontier Research Centers

Core Research / Individual PIs

* ARPA-E targets technology gaps, high-risk concepts, aggressive delivery times

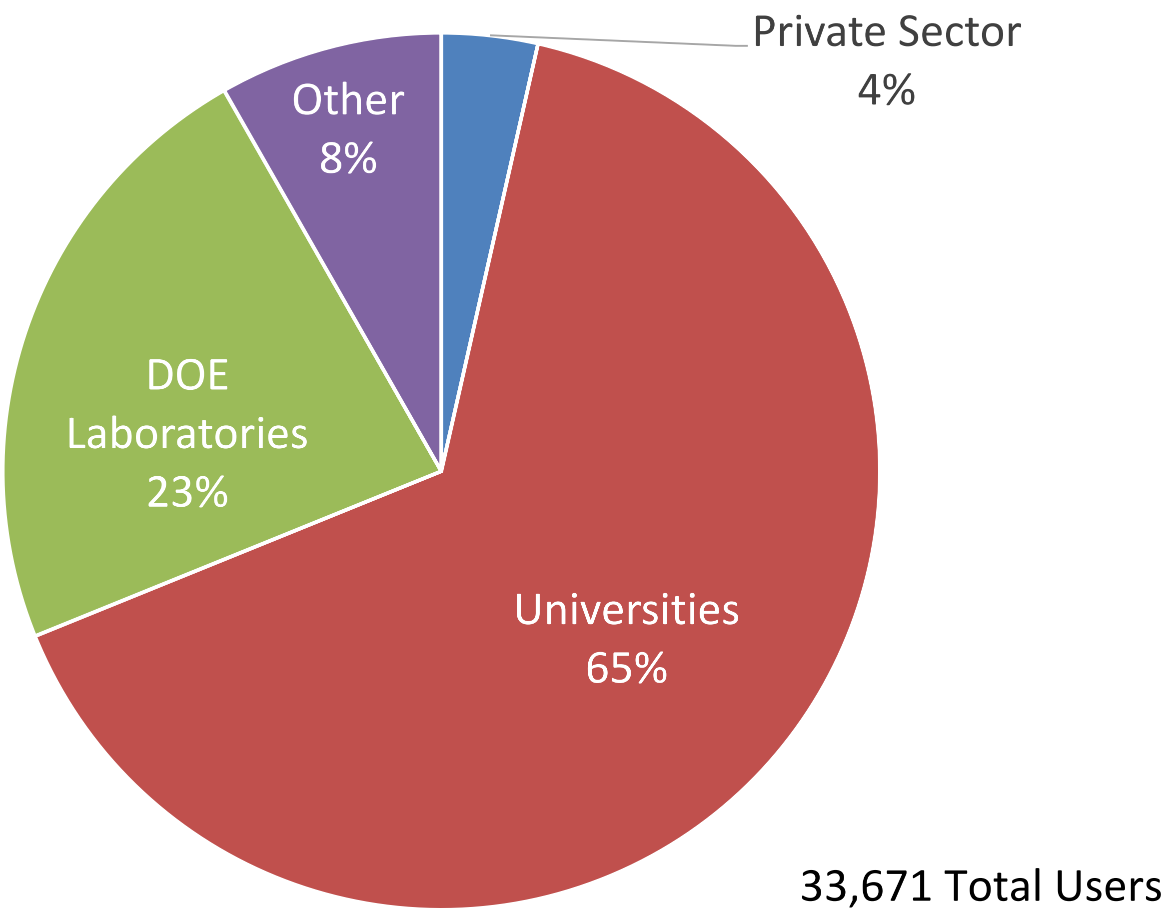
DOE Mission Innovation R&D, FY 16 and 17



FY 2016
28 user facilities

U.S. DEPARTMENT OF
ENERGY
Office of Science

Office of Science User Facility Statistics FY14



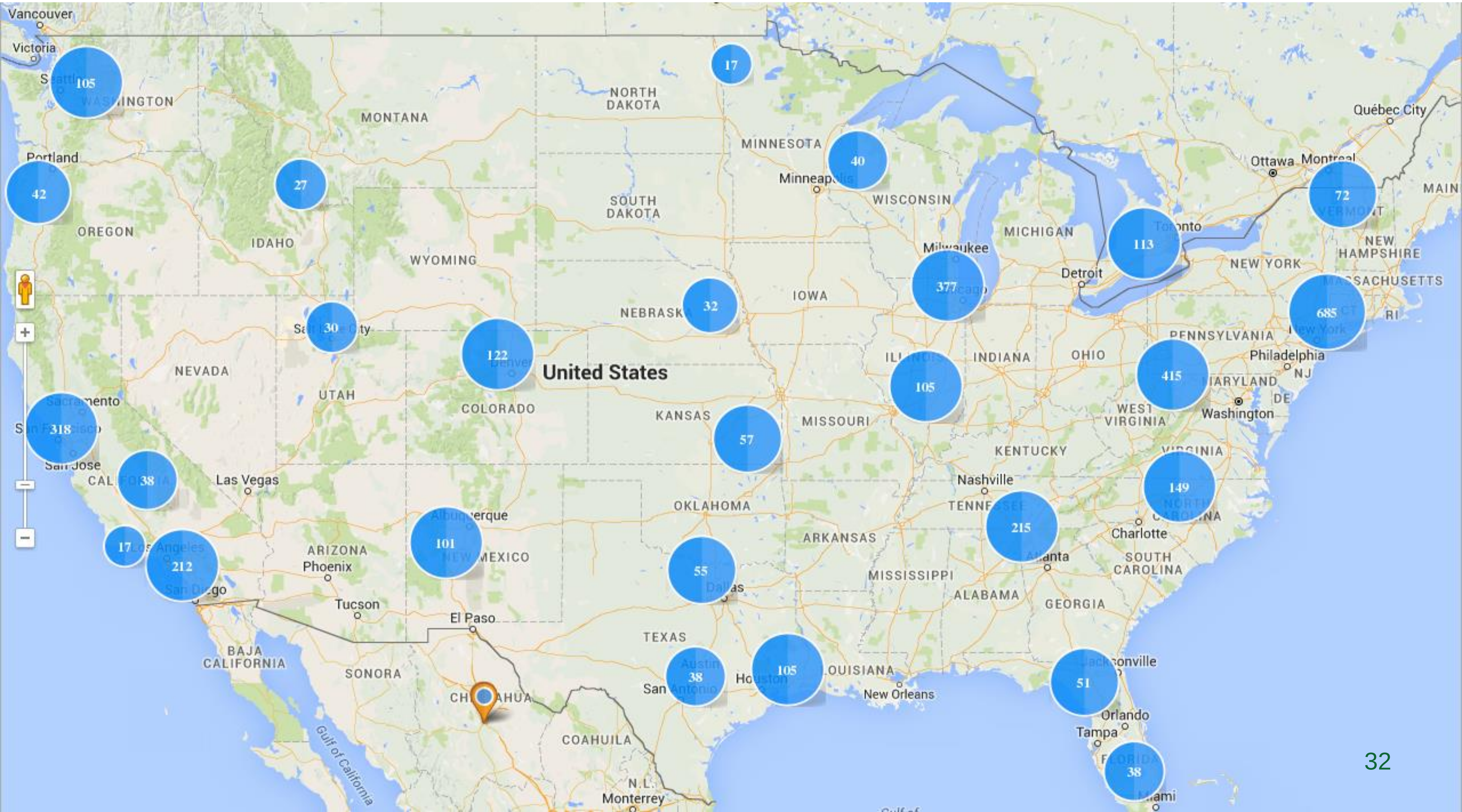
U.S. DEPARTMENT OF ENERGY | Office of Science

Other includes many institutions, such as: non-DOE labs, federal agencies, research hospitals, K-12 students, and international institutions

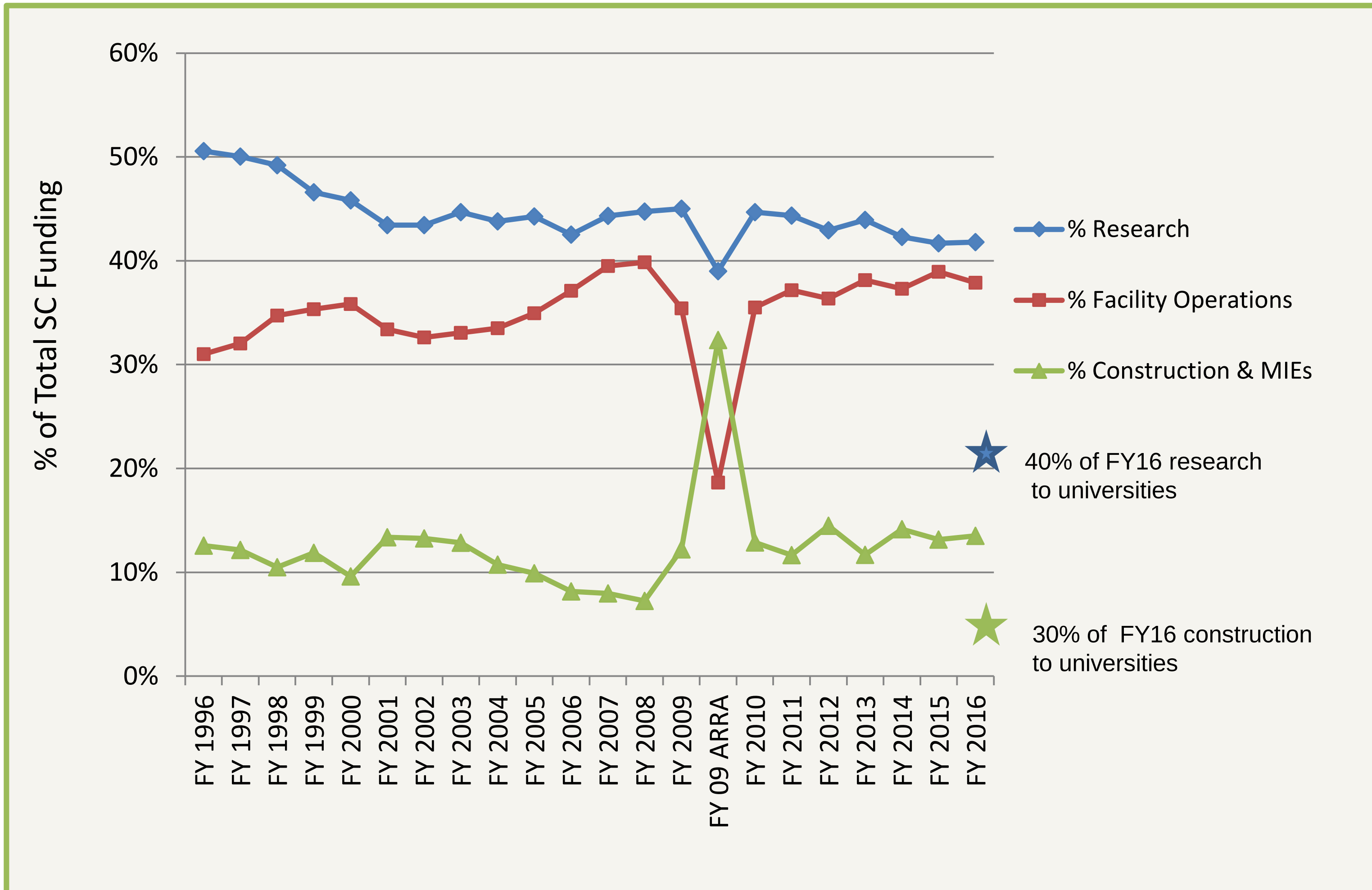
Data on University Grants and Users Across Country

http://science.energy.gov/universities/interactive-grants-map/

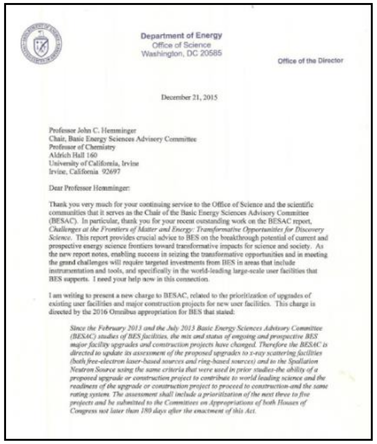
http://science.energy.gov/user-facilities/user-statistics/



SC Investments in Research, Facilities, and Construction



BESAC New Charge on Prioritization of Facility Upgrades



Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

December 21, 2015

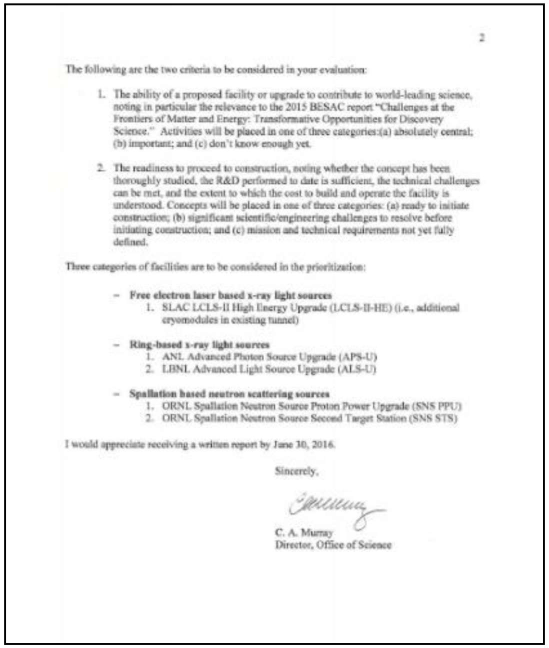
Professor John C. Hemminger
Chair, Basic Energy Sciences Advisory Committee
Professor of Chemistry
Aldrich Hall 160
University of California, Irvine
Irvine, California 92697

Dear Professor Hemminger:

Thank you very much for your continuing service to the Office of Science and the scientific communities that it serves as the Chair of the Basic Energy Sciences Advisory Committee (BESAC). In particular, thank you for your recent outstanding work on the BESAC report, *Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science*. This report provides crucial advice to BES on the breakthrough potential of current and prospective energy science frontiers toward transformative impacts for science and society. As the new report notes, enabling success in seizing the transformative opportunities and in meeting the grand challenges will require targeted investments from BES in areas that include instrumentation and tools, and specifically in the world-leading large-scale user facilities that BES supports. I need your help now in this connection.

I am writing to present a new charge to BESAC, related to the prioritization of upgrades of existing user facilities and major construction projects for new user facilities. This charge is directed by the 2016 Omnibus appropriation for BES that stated:

> *Since the February 2013 and the July 2013 Basic Energy Sciences Advisory Committee (BESAC) studies of BES facilities, the mix and status of ongoing and prospective BES major facility upgrades and construction projects have changed. Therefore the BESAC is directed to update its assessment of the proposed upgrades to x-ray scattering facilities (both free-electron laser-based sources and ring-based sources) and to the Spallation Neutron Source using the same criteria that were used in prior studies-the ability of a proposed upgrade or construction project to contribute to world leading science and the readiness of the upgrade or construction project to proceed to construction-and the same rating system. The assessment shall include a prioritization of the next three to five projects and be submitted to the Committees on Appropriations of both Houses of Congress not later than 180 days after the enactment of this Act.*



2

The following are the two criteria to be considered in your evaluation:

1. The ability of a proposed facility or upgrade to contribute to world-leading science, noting in particular the relevance to the 2015 BESAC report "Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science." Activities will be placed in one of three categories:(a) absolutely central; (b) important; and (c) don't know enough yet.

2. The readiness to proceed to construction, noting whether the concept has been thoroughly studied, the R&D performed to date is sufficient, the technical challenges can be met, and the extent to which the cost to build and operate the facility is understood. Concepts will be placed in one of three categories: (a) ready to initiate construction; (b) significant scientific/engineering challenges to resolve before initiating construction; and (c) mission and technical requirements not yet fully defined.

Three categories of facilities are to be considered in the prioritization:

- **Free electron laser based x-ray light sources**
  1. SLAC LCLS-II High Energy Upgrade (LCLS-II-HE) (i.e., additional cryomodules in existing tunnel)
- **Ring-based x-ray light sources**
  1. ANL Advanced Photon Source Upgrade (APS-U)
  2. LBNL Advanced Light Source Upgrade (ALS-U)
- **Spallation based neutron scattering sources**
  1. ORNL Spallation Neutron Source Proton Power Upgrade (SNS PPU)
  2. ORNL Spallation Neutron Source Second Target Station (SNS STS)

I would appreciate receiving a written report by June 30, 2016.

Sincerely,

C. A. Murray
Director, Office of Science

From: Dr. Cherry A. Murray (Director, Office of Science)

I am writing to present a new charge to BESAC, related to the prioritization of upgrades of existing user facilities and major construction projects for new user facilities.

The following are the two criteria to be considered in your evaluation:

1. The ability of a proposed facility or upgrade to contribute to world-leading science, noting in particular the relevance to the 2015 BESAC report "Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science." Activities will be placed in one of three categories:(a) absolutely central; (b) important; and (c) don't know enough yet.

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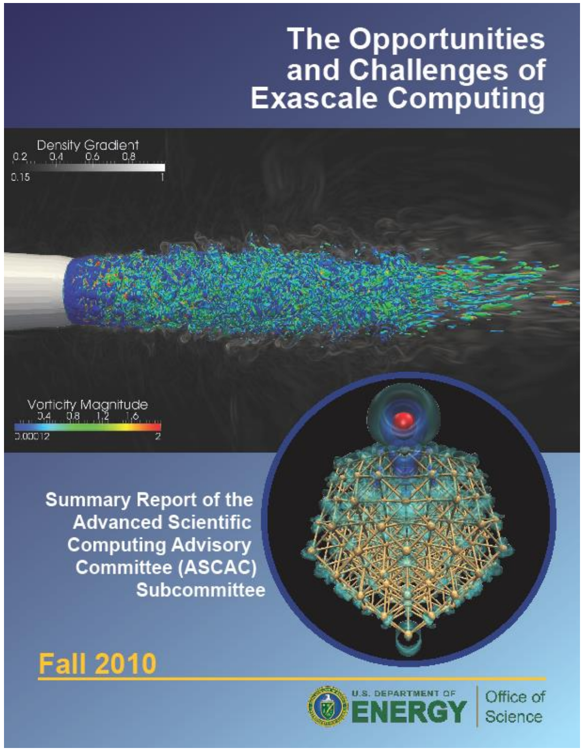
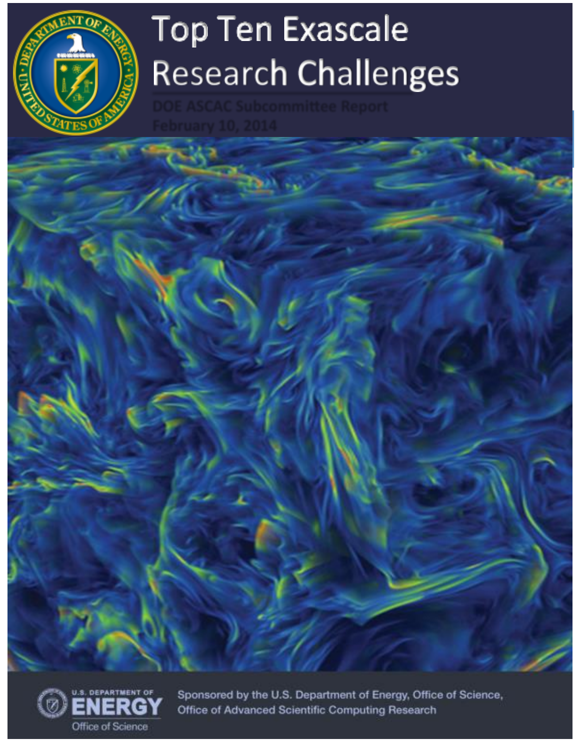
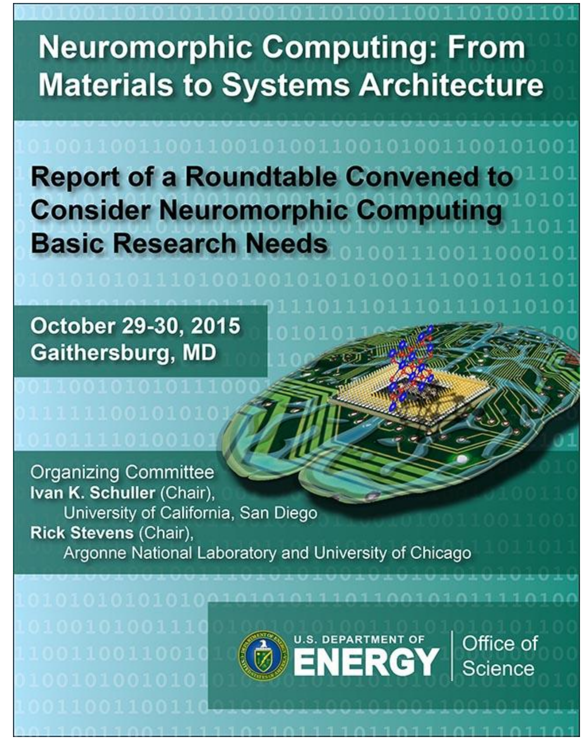
Exascale Computation Grand Challenge







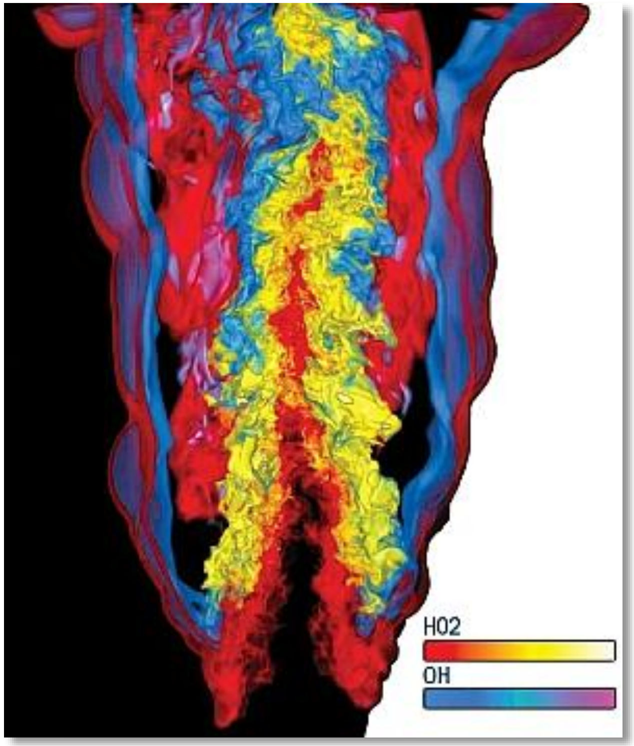
http://science.energy.gov/~/media/ascr/ascac/pdf/reports/Exascale_subcommittee_report.pdf

http://science.energy.gov/~/media/ascr/ascac/pdf/meetings/20140210/Top10reportFEB14.pdf

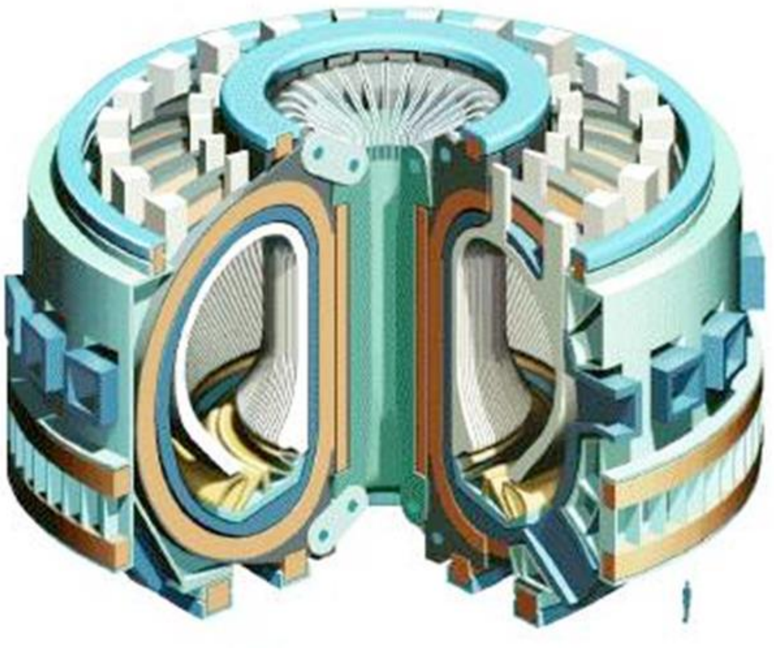
http://science.energy.gov/bes/community-resources/reports/abstracts/#NCFMtSA

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; chemical sciences**
  - 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



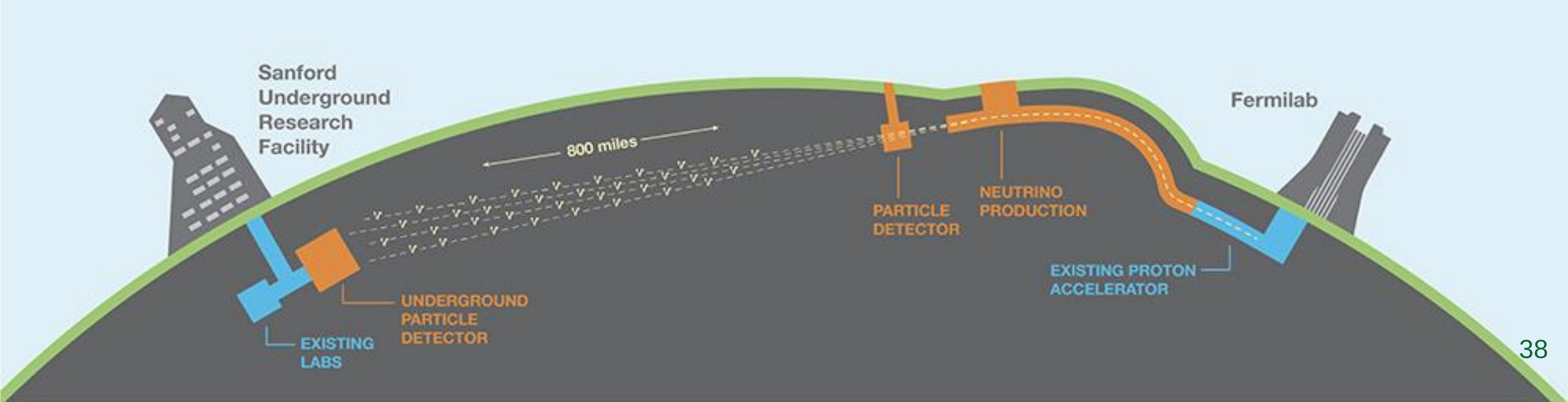
ITER Congressional Language



"…not later than May 2, 2016, the Secretary of Energy shall submit to the Committees on Appropriations of both Houses of Congress a report recommending either that the United States remain a partner in the ITER project after October 2017 or terminate participation, which shall include, as applicable, an estimate of either the full cost, by fiscal year, of all future Federal funding requirements for construction, operation, and maintenance of ITER or the cost of termination."

Long Baseline Neutrino Facility

- P5 recommended LBNF as the centerpiece of a U.S.-hosted world-leading neutrino program
  - the highest-priority large project in its timeframe
- The world's most intense neutrino beam will be produced at Fermilab and directed 800 miles through the earth to Lead, South Dakota
  - Fermilab will lead this effort with a few international partners, most notably CERN
- A very large (40 kiloton) liquid argon neutrino detector will be placed in the Homestake Mine in Lead, SD
  - An international collaboration has been established for the Deep Underground Neutrino Experiment (DUNE)
  - The U.S. will contribute to the detector as part of the LBNF project



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