U.S. DEPARTMENT OF ENERGY | Office of Science

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

BESAC Meeting, February 11, 2016

Cherry A. Murray, PhD
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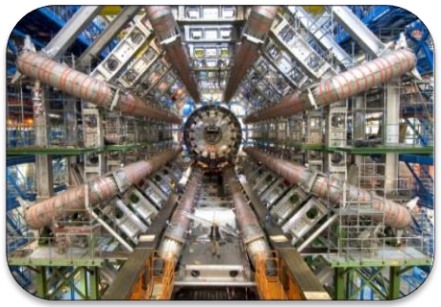
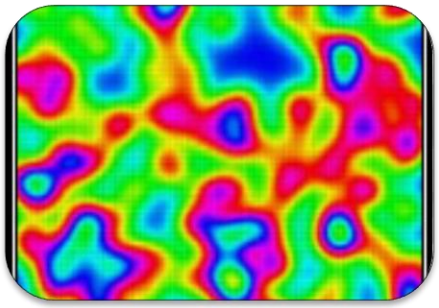
www.science.energy.gov

Office of Science FY16 - $5.35B

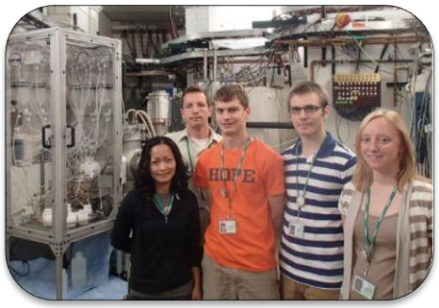


Largest Supporter of Physical Sciences in the U.S.



Research: 42%, $2.2B

~40% of Research to Universities



> 20,000 Scientists Supported

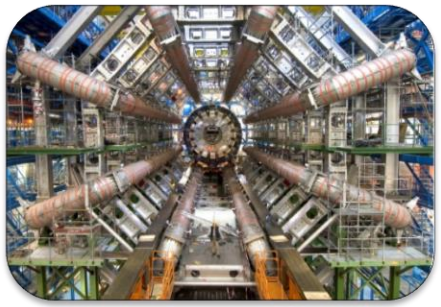
Funding at >300 Institutions including all 17 DOE Labs

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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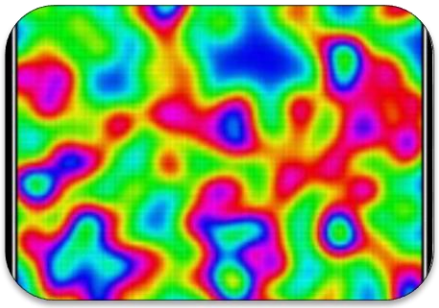
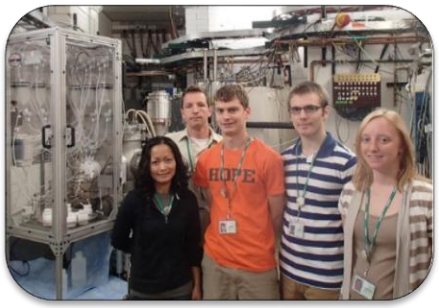


Research: 42%, $2.4B

~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

Office of Science FY 2017 Budget Request to Congress

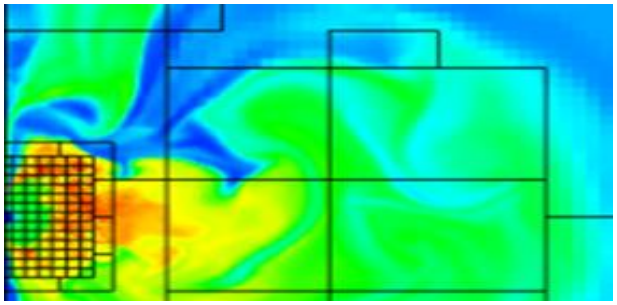
(Dollars in thousands)

	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%**

Priorities for FY 2017

- **Maintain strong support for discovery science and world-class science facilities**
  - **Maintain a healthy balance among PI research, groups and centers, and facility operations**
  - **Continue to use community priorities to make difficult choices and design, build, operate, and sunset world-class facilities**
  - **Lead and steward the US accelerator science R&D capabilities**
  - **Lead and steward the US computational R&D capabilities, in collaboration with NNSA – garner support for and execute the exascale initiative**
  - **Support partnerships and collaborations**
- **Be proactive in supporting science for clean energy**
  - **Basic research needs workshops – partner with DOE technology offices and industry**
  - **Science-based transformational energy technology in Mission Innovation**
- **Increase relationship building with Congress**
- **Increase relationship building with research universities**
- **Given the importance of the DOE national labs in US R&D, institutionalize best practices in national lab management**

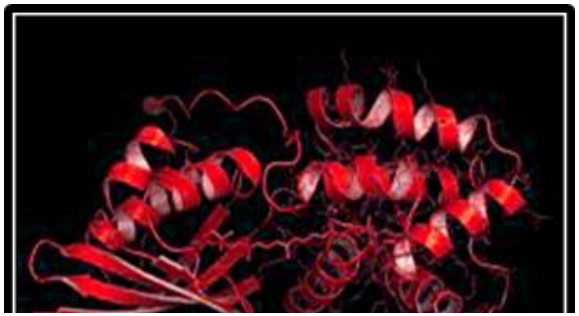
Office of Science Programs



Advanced Scientific Computing Research

FY2016 $621M

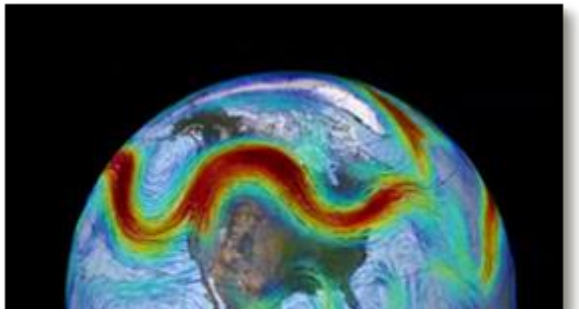
FY2017 Request +6.8%



Basic Energy Sciences

FY2016 $1849M

FY2017 Request +4.7%



Biological and Environmental Research

FY2016 $609M

FY2017 Request +8.7%

High Energy Physics

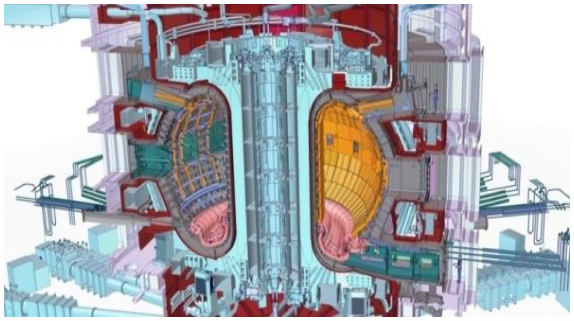
FY2016 $795M

FY2017 Request +2.9%

Fusion Energy Sciences

FY2016 $438M

FY2017 Request -9.1%



Nuclear Physics

FY2016 $617M

FY2017 Request +3.0%

SC Investments for Mission Innovation

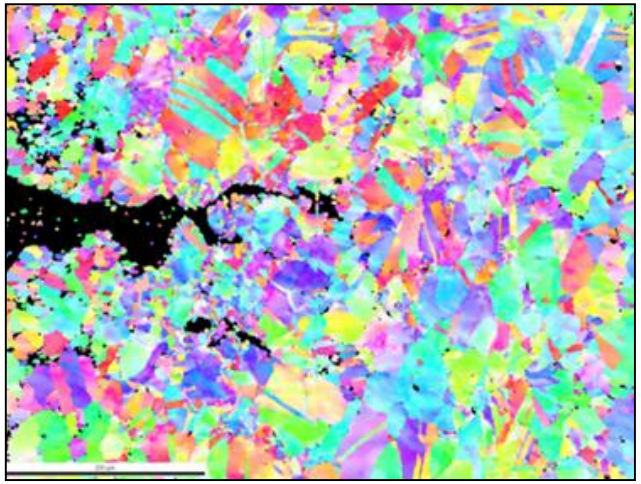
$100M in new funding in FY 2017

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

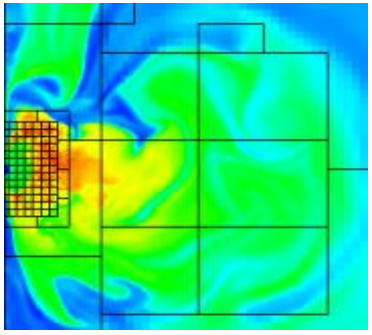
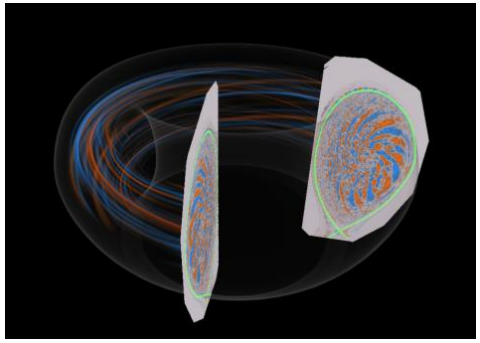
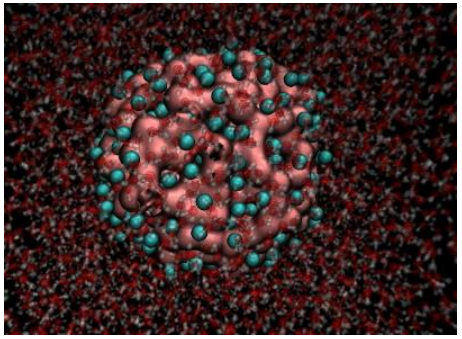
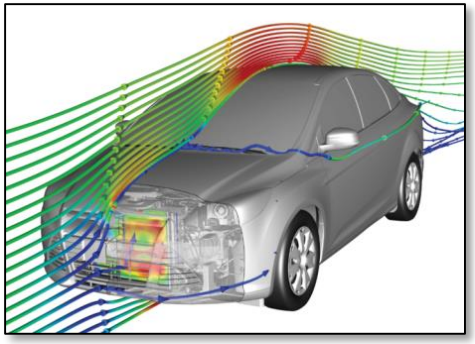
Investments are made in all of the SC programs, emphasizing emerging research areas, especially those recently identified by Federal Advisory Committees or other community activities. A few examples are:

- **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

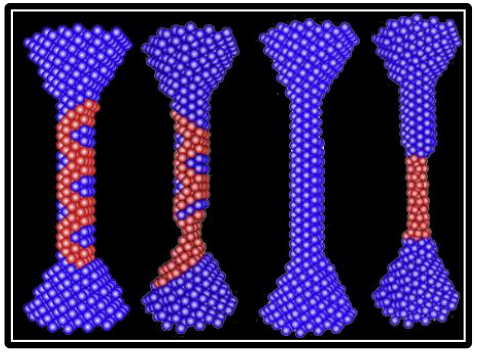
- **Exascale Computing Initiative (ECI) and Exascale Computing Project (ECP).** The ECP is initiated as a joint ASCR/NNSA partnership using DOE's formal project management processes. A new budget line is created for the ECP.
- **Facilities** operate optimally and with >90% availability; deployment of 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.

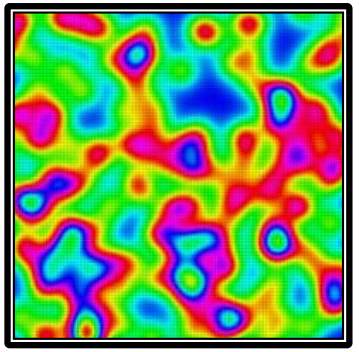





Basic Energy Sciences

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.



BES FY 2017 Budget Request to Congress

(Dollars in thousands)

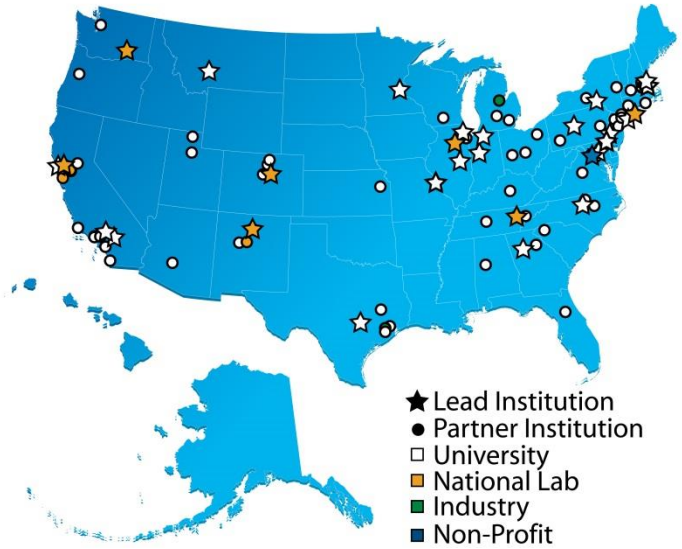
	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Materials Sciences and Engineering						
Research	258,951	259,209	250,319	280,989	+30,670	+12.3%
Experimental Program to Stimulate Competitive Research (EPSCoR)	9,951	9,951	14,776	8,520	-6,256	-42.3%
Energy Frontier Research Centers (EFRCs)	50,800	50,800	55,800	55,800	…	…
Energy Innovation Hubs—Batteries and Energy Storage	24,175	24,175	24,137	24,088	-49	-0.2%
Computational Materials Sciences	8,000	8,000	12,000	12,000	…	…
SBIR/STTR	12,008	…	12,758	14,448	+1,690	+13.2%
Total, Materials Sciences and Engineering	**363,885**	**352,135**	**369,790**	**395,845**	**+26,055**	**+7.0%**
Chemical Sciences, Geosciences, and Biosciences						
Research	239,086	238,164	231,129	256,853	+25,724	+11.1%
Energy Frontier Research Centers (EFRCs)	49,200	49,200	54,200	86,766	+32,566	+60.1%
Energy Innovation Hubs—Fuels from Sunlight	15,000	15,000	15,000	15,000	…	…
Computational Chemical Sciences	…	…	…	13,635	+13,635	…
General Plant Projects (GPP)	600	1,000	1,000	1,000	…	…
SBIR/STTR	10,350	…	10,732	14,102	+3,370	+31.4%
Total, Chemical Sciences, Geosciences, and Biosciences	**314,236**	**303,364**	**312,061**	**387,356**	**+75,295**	**+24.1%**
Scientific User Facilities						
Synchrotron Radiation Light Sources	447,186	450,103	481,906	489,059	+7,153	+1.5%
High-Flux Neutron Sources	244,113	245,050	264,645	261,177	-3,468	-1.3%
Nanoscale Science Research Centers	113,649	114,925	118,763	122,272	+3,509	+3.0%
Other Project Costs	9,300	9,300	…	…	…	…
Major Items of Equipment	42,500	42,500	35,500	20,000	-15,500	-43.7%
Research	31,713	26,847	34,853	37,537	+2,684	+7.7%
SBIR/STTR	27,918	…	31,182	33,484	+2,302	+7.4%
Total, Scientific User Facilities	**916,379**	**888,725**	**966,849**	**963,529**	**-3,320**	**-0.3%**
Subtotal, Basic Energy Sciences	**1,594,500**	**1,544,224**	**1,648,700**	**1,746,730**	**+98,030**	**+5.9%**
Construction						
13-SC-10 Linac Coherent Light Source-II (LCLS-II), SLAC	138,700	138,700	200,300	190,000	-10,300	-5.1%
Total, Basic Energy Sciences	**1,733,200**	**1,682,924**	**1,849,000**	**1,936,730**	**+87,730**	**+4.7%**

Energy Frontier Research Centers

FY 2016 = $110M; FY 2017 = $143M

Current EFRCs ($100M in FY 2015)

- 32 awards; $2-4M/year for 4 years (22 renewal, 10 new centers)
- Lead institutions by type: 23 universities; 8 DOE National Laboratories; 1 nonprofit organization
- Over 100 participating institutions, located in 33 states plus the District of Columbia



EFRCs 2009-14 ($100M/year+$277M ARRA)

- 46 EFRCs of $2-5M per year for 5 years

FY2016 Appropriation

- In 2016, there will be a Funding Opportunity Announcement (FOA) for up to five new EFRCs that focus on research directions under-represented in the current EFRC portfolio; included will be topics identified at the 2015 Basic Research Needs for Environmental Management Workshop.
- EFRC solicitations begin a two year FOA cycle.

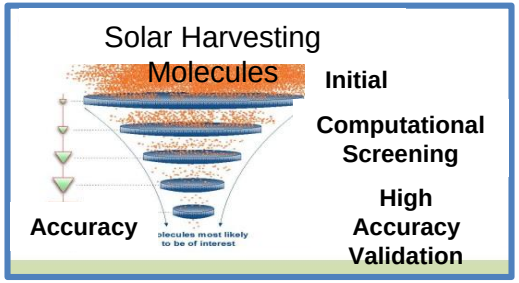
FY2017 Budget Request

- FY 2017 budget request includes an increase of $33M to fully fund up to 5 new EFRCs in subsurface science relevant to the Departmental Subsurface crosscut.
- The new EFRCs will support multidisciplinary teams to address the grand challenge identified in 2015 strategic planning activities: “Advanced imaging of geophysical and geochemical signals in the subsurface.”

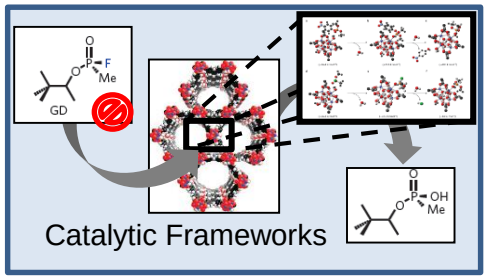
Computational Chemical Sciences
FY 2017 = $14M

Deliverable: Open-source modular chemistry codes and software packages that are automated, account for quantum/relativistic effects, and with sufficient accuracies for d- and f- electron systems

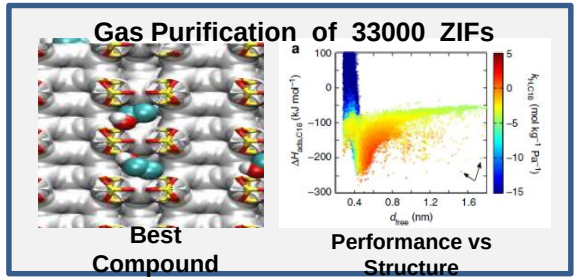
- A new activity -- $14M is requested to support 4-5 teams of researchers to capitalize on existing investments in quantum chemistry codes and upgrade them to be compatible with the current and future generations of high performance computers.
- Assemble teams of mathematical and computational chemists to develop open-source software with new algorithms to allow simulation of chemical processes of complex systems.
- Rewrite software and algorithms to fully realize the current and future gains in efficiency offered by massively parallel computing platforms.
- Deliver codes that treat electronic and spin effects in order to avoid case-by-case retooling of the model of electronic potential that is embedded in many current computational methods.



High-Accuracy Design of Catalysis



Artificial Photosynthesis

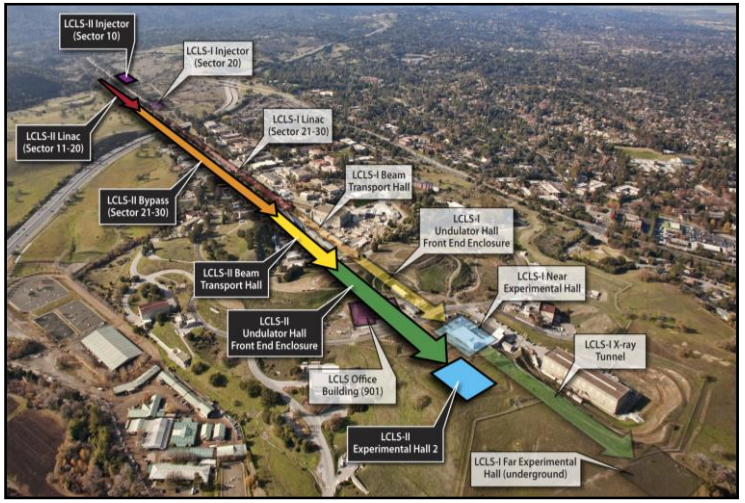


Field-Driven Chemical Rearrangements

LCLS-II and APS-U Underway

Linac Coherent Light Source-II (LCLS-II)

- FY 2016 = $200,300K; FY 2017 = $190,000K for R&D, design, prototyping, long lead procurement, and construction of technical systems.
- LCLS-II will provide high-rep-rate, ultra-bright, transform-limited femtosecond x-ray pulses with polarization control and pulse length control to ~1 femtosecond. The hard x-ray range will be expanded to 25 keV.
- Added are a 4 GeV superconducting linac; an electron injector; and two undulators to provide x-rays in the 0.2–5 keV energy range.



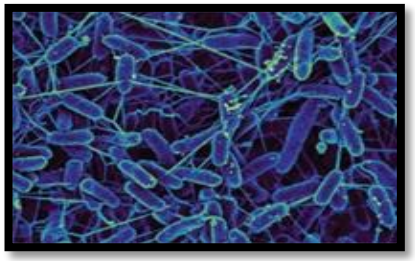
Advanced Photon Source Upgrade (APS-U)

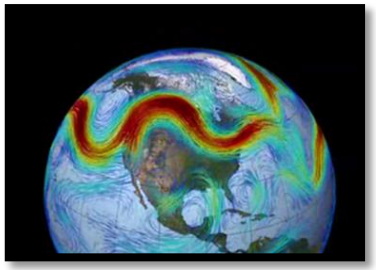
- FY 2016 = $20,000K; FY 2017 = $20,000K for R&D, design, and limited prototyping.
- APS-U will provide a multi-bend achromat lattice to provide extreme transverse coherence and brightness.
- Initial conceptual design for the new lattice completed; conducting R&D and key component prototyping in support of the new design. Key performance parameters are being defined for the project and the new storage ring.

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.

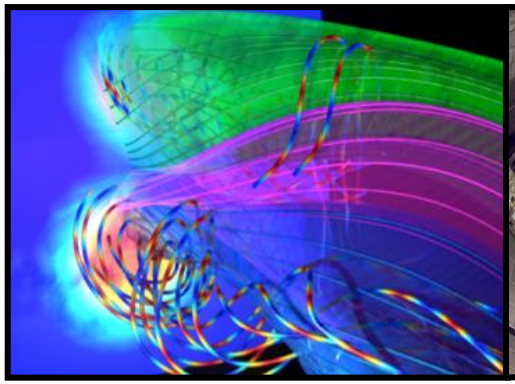
Energy-Water Nexus (EWN): The EWN crosscut addresses the transition to more resilient energy and coupled energy-water systems. The EWN crosscut supports: (1) an advanced, integrated data, modeling, and analysis platform to improve understanding and inform decision-making; (2) investments in targeted 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

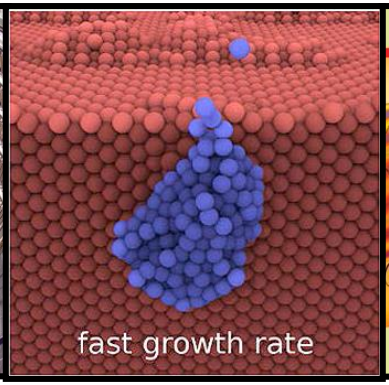
Matter at very high temperatures and densities and the scientific foundations for fusion

- 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.

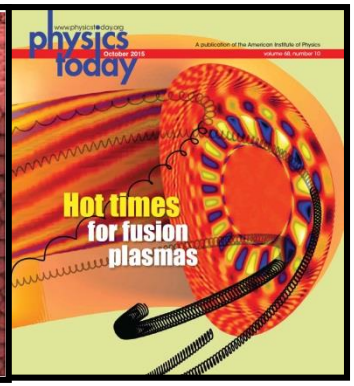


Magnetic reconnection driven by 3-D flux-rope interaction in the Large Plasma Device

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

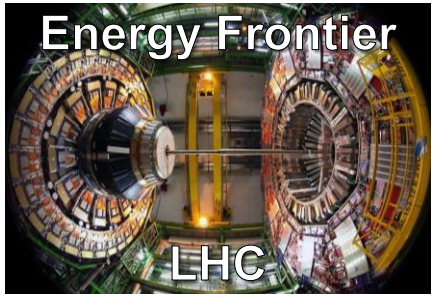
Understanding how the universe works at its most fundamental level

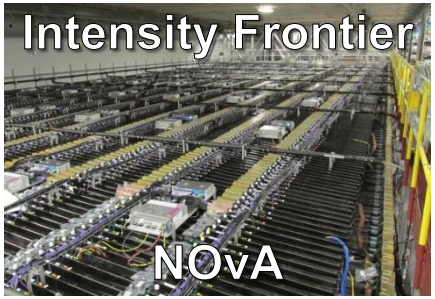
- The FY 2017 HEP budget reflects the way the P5 plan has evolved as the U.S. and international community have adopted and responded to it

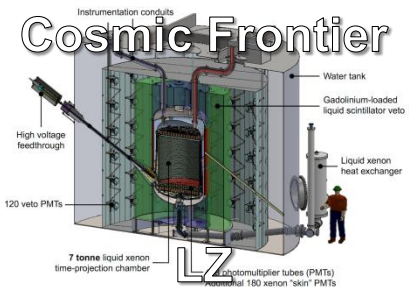
- Energy Frontier: Continue active engagement in highly successful LHC program
  - Initial LHC detector upgrade project funding ends in FY 2017
  - Scope being determined for high luminosity(HL)- LHC, P5's highest priority near-term project; CD-0 in 2016
  - The U.S. will continue to play a leadership 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





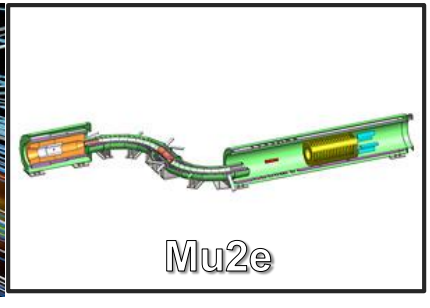


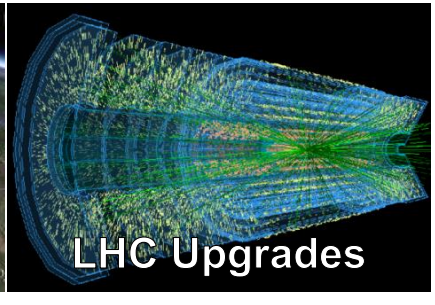
	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

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

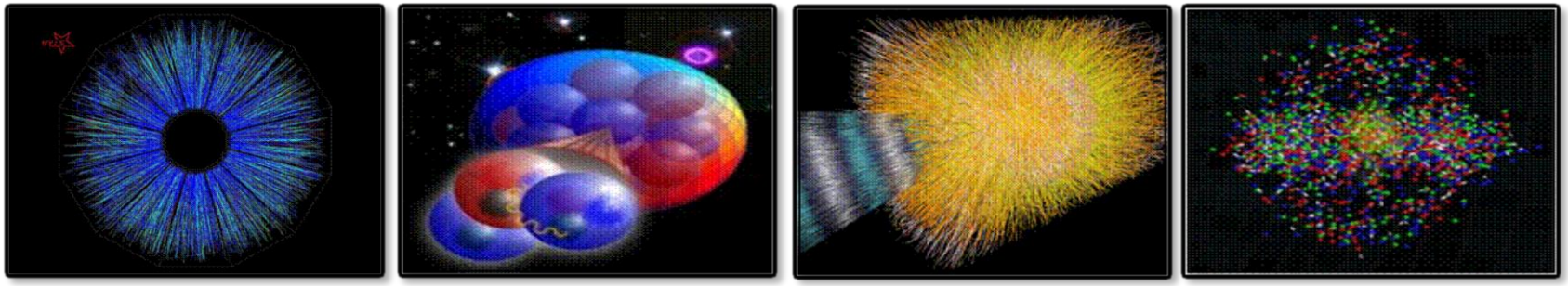




Nuclear Physics

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.



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