DOE/CF-0110
Volume 4

Department of Energy
FY 2016 Congressional Budget Request

Science

Advanced Research Projects Agency−Energy

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FUNDING BY APPROPRIATION

(Discretionary dollars in thousands)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015 $	FY 2016 vs. FY 2015 %
Department of Energy Budget by Appropriation						
Energy and Water Development, and Related Agencies						
Energy Programs						
Energy Efficiency and Renewable Energy	1,900,641	1,824,876	1,914,195	2,722,987	+808,792	+42.3%
Electricity Delivery and Energy Reliability	147,242	144,205	146,975	270,100	+123,125	+83.8%
Nuclear Energy	888,376	877,620	833,379	907,574	+74,195	+8.9%
Fossil Energy Programs						
Clean Coal Technology	0	0	-6,600	0	+6,600	+100.0%
Fossil Energy Research and Development	561,931	550,630	560,587	560,000	-587	-0.1%
Naval Petroleum and Oil Shale Reserves	19,999	22,457	19,950	17,500	-2,450	-12.3%
Elk Hills School Lands Fund	0	0	15,580	0	-15,580	-100.0%
Strategic Petroleum Reserve	189,360	189,360	200,000	257,000	+57,000	+28.5%
Northeast Home Heating Oil Reserve	8,000	8,000	1,600	7,600	+6,000	+375.0%
Total, Fossil Energy Programs	**779,290**	**770,447**	**791,117**	**842,100**	**+50,983**	**+6.4%**
Uranium Enrichment Decontamination and Decommissioning Fund	598,574	598,574	625,000	542,289	-82,711	-13.2%
Energy Information Administration	116,999	116,999	117,000	131,000	+14,000	+12.0%
Non-Defense Environmental Cleanup	231,741	231,782	246,000	220,185	-25,815	-10.5%
Science	5,066,372	5,131,038	5,067,738	5,339,794	+272,056	+5.4%
Advanced Research Projects Agency - Energy	280,000	280,000	279,982	325,000	+45,018	+16.1%
Departmental Administration	126,449	126,449	125,130	153,511	+28,381	+22.7%
Indian Energy Programs	0	0	0	20,000	+20,000	N/A
Office of the Inspector General	42,120	42,120	40,500	46,424	+5,924	+14.6%
Title 17 - Innovative Technology Loan Guarantee Program	20,000	7,857	17,000	0	-17,000	-100.0%
Advanced Technology Vehicles Manufacturing Loan Program	6,000	6,000	4,000	6,000	+2,000	+50.0%
Tribal Indian Energy Loan Guarantee Program	0	0	0	11,000	+11,000	N/A
Total, Energy Programs	**10,203,804**	**10,157,967**	**10,208,016**	**11,537,964**	**+1,329,948**	**+13.0%**
Atomic Energy Defense Activities						
National Nuclear Security Administration						
Weapons Activities	7,781,000	7,790,197	8,180,359	8,846,948	+666,589	+8.1%
Defense Nuclear Nonproliferation	1,954,000	1,941,983	1,615,248	1,940,302	+325,054	+20.1%
Naval Reactors	1,095,000	1,101,500	1,233,840	1,375,496	+141,656	+11.5%
Office of the Administrator	377,000	370,500	0	0	0	N/A
Federal Salaries and Expenses	0	0	369,587	402,654	+33,067	+8.9%
Total, National Nuclear Security Administration	**11,207,000**	**11,204,180**	**11,399,034**	**12,565,400**	**+1,166,366**	**+10.2%**
Environmental and Other Defense Activities						
Defense Environmental Cleanup	5,000,000	4,999,293	5,453,017	5,527,347	+74,330	+1.4%
Other Defense Activities	755,000	755,000	753,449	774,425	+20,976	+2.8%
Total, Environmental and Other Defense Activities	**5,755,000**	**5,754,293**	**6,206,466**	**6,301,772**	**+95,306**	**+1.5%**
Total, Atomic Energy Defense Activities	**16,962,000**	**16,958,473**	**17,605,500**	**18,867,172**	**+1,261,672**	**+7.2%**
Power Marketing Administrations						
Southeastern Power Administration	0	0	0	0	0	N/A
Southwestern Power Administration	11,892	11,892	11,400	11,400	0	0
Western Area Power Administration	95,930	95,930	91,740	93,372	+1,632	+1.8%
Falcon and Amistad Operating and Maintenance Fund	420	420	228	228	0	0
Colorado River Basins Power Marketing Fund	-23,000	-23,000	-23,000	-23,000	0	0
Total, Power Marketing Administrations	**85,242**	**85,242**	**80,368**	**82,000**	**+1,632**	**+2.0%**
Federal Energy Regulatory Commission	0	0	0	0	0	N/A
Subtotal, Energy and Water Development and Related Agencies	**27,251,046**	**27,201,682**	**27,893,884**	**30,487,136**	**+2,593,252**	**+9.3%**
Uranium Enrichment Decontamination and Decommissioning Fund Discretionary Payments	0	0	-463,000	-471,797	-8,797	-1.9%
Excess Fees and Recoveries, FERC	-26,236	-19,686	-28,485	-23,587	+4,898	+17.2%
Title XVII Loan Guarantee Program Section 1703 Negative Credit Subsidy Receipt	0	0	0	-68,000	-68,000	N/A
Total, Discretionary Funding by Appropriation	**27,224,810**	**27,181,996**	**27,402,399**	**29,923,752**	**+2,521,353**	**+9.2%**

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Proposed Appropriation Language

For Department of Energy expenses including the purchase, construction, and acquisition of plant and capital equipment, and other expenses necessary for science activities in carrying out the purposes of the Department of Energy Organization Act (42 U.S.C. 7101 et seq.), including the acquisition or condemnation of any real property or facility or for plant or facility acquisition, construction, or expansion, and purchase of not more than 17 passenger motor vehicles for replacement only, including [two buses, $5,071,000,000,] *one ambulance and one bus*, *$5,339,794,000*, to remain available until expended[: *Provided*, That $183,700,000], *of which, $187,400,000,* shall be available until September 30, [2016] 2017, for program direction[: *Provided further*, That no funding may be made available for United States cash contributions to the International Thermonuclear Experimental Reactor project until its governing Council implements the recommendations of the Third Biennial International Organization Management Assessment Report: Provided further, That the Secretary of Energy may waive this requirement upon submission to the Committees on Appropriations of the House of Representatives and the Senate a determination that the Council is making satisfactory progress towards implementation of such recommendations].

Explanation of Change

Proposed appropriation language updates reflect the funding and replacement of passenger motor vehicle levels requested in FY 2016. In addition, the fiscal year 2015 restrictions on the obligation of funding for ITER cash contributions are proposed for elimination.

Public Law Authorizations

<u>Science:</u>

- Public Law 95-91, "Department of Energy Organization Act", 1977
- Public Law 102-468, "Energy Policy Act of 1992"
- Public Law 108-153, "21st Century Nanotechnology Research and Development Act 2003"
- Public Law 109-58, "Energy Policy Act of 2005"
- Public Law 110-69, "America COMPETES Act of 2007"
- Public Law 111-358, "America COMPETES Reauthorization Act of 2010"

<u>Nuclear Physics:</u>

- Public Law 101-101, "1990 Energy and Water Development Appropriations Act," establishing the Isotope Production and Distribution Program Fund
- Public Law 103-316, "1995 Energy and Water Development Appropriations Act," amending the Isotope Production and Distribution Program Fund to provide flexibility in pricing without regard to full-cost recovery

<u>Workforce Development for Teachers and Scientists:</u>

- Public Law 101-510, "DOE Science Education Enhancement Act of 1991"
- Public Law 103-382, "The Albert Einstein Distinguished Educator Fellowship Act of 1994"

Science

($K)

FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request
5,066,372	5,131,038	5,067,738	5,339,794

Overview

The Office of Science's (SC) mission is to deliver scientific discoveries and major scientific tools to transform our understanding of nature and advance the energy, economic, and national security of the United States. The SC is the Nation's largest Federal sponsor of basic research in the physical sciences and the lead Federal agency supporting fundamental scientific research for energy.

The SC accomplishes its mission and advances national goals by supporting:

- *The frontiers of science*—discovering nature's mysteries from the study of subatomic particles, atoms, and molecules that are the building blocks of the materials of our everyday world to the DNA, proteins, and cells that are the building blocks of entire biological systems; each of the programs in the SC supports research to probe the most fundamental questions of its disciplines.
- *The 21st Century tools of science*—providing the Nation's researchers with 26 state-of-the-art national scientific user facilities, the most advanced tools of modern science, enabling the U.S. to remain at the forefront of science, technology, and innovation.
- *Science for energy and the environment*—advancing a clean energy agenda through fundamental research on energy production, conversion, storage, transmission, and use and through advancing our understanding of the earth and its climate; targeted investments include the three DOE Bioenergy Research Centers (BRCs), the Energy Frontier Research Centers (EFRCs), two Energy Innovation Hubs, and atmospheric process and climate modeling research.

The SC has long been a leader of U.S. scientific discovery and innovation. Over the decades, SC investments and accomplishments in basic research have provided the foundations for new technologies, businesses, and industries, making significant contributions to our Nation's economy and quality of life. Select scientific accomplishments in FY 2014 enabled by the SC programs are described in the program budget narratives. Additional descriptions of recent science discoveries can be found at http://science.energy.gov/stories-of-discovery-and-innovation/.

Highlights and Major Changes in the FY 2016 Budget Request

The FY 2016 request for the SC is $5.340 billion, an increase of $272 million or 5.4 percent, relative to the FY 2015 enacted level. The FY 2016 request supports a balanced research portfolio that invests in discovery science—research that probes some of the most fundamental questions in high energy, nuclear, and plasma physics; materials and chemistry; biological systems and earth system components; and mathematics—as well as basic research that underpins advances in clean energy. The request supports about 22,000 investigators at over 300 U.S. academic institutions and at all of the DOE laboratories. The SC user facilities continue to offer capabilities unmatched anywhere in the world; nearly 31,000 researchers from universities, national laboratories, industry, and international partners are expected to use these facilities in FY 2016. The FY 2016 request supports the construction of new user facilities necessary to provide world class research capabilities in the United States and targeted research and development (R&D), such as accelerator R&D, necessary for future facilities and facility upgrades to deliver desired capabilities and maximize scientific potential.

- *Advanced Scientific Computing Research (ASCR)* supports research to discover, develop, and deploy computational and networking capabilities to analyze, model, simulate, and predict complex phenomena important to DOE. ASCR grows $80.0 million, or 14.8 percent, relative to the FY 2015 enacted level. The increase provides support for research that focuses on the linked challenges of capable exascale and data-intensive science, and computational partnerships under the Scientific Discovery through Advanced Computing (SciDAC) program. The request provides for significantly expanded investments in Research and Engineering Prototypes (REP) to develop critical technologies and system integration for exascale, including initiation of exascale node and system architecture design efforts. REP initiated partnerships with key vendors accelerates the R&D of critical technologies to advance the Department's exascale goals and reduce the economic and manufacturing barriers to their commercial production. The FY 2016 request supports preparations at the two Leadership Computing Facilities for 75–200 petaflop upgrades at each facility in the 2018–2019 timeframe. The National Energy Research Scientific Computing Center (NERSC) take delivery of the NERSC-8 supercomputer, which will expand the capacity of the facility to 10–40 petaflops to address growing demand.

- *Basic Energy Sciences (BES)* supports fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies. BES increases $116 million or 6.7 percent from the FY 2015 enacted level. The requests continues support for on-going core research at approximately the FY 2015 enacted level, including a small increase for the Energy Frontier Research Centers (EFRC) to support areas underrepresented in the current EFRC portfolio, and it continues support for the Batteries and Energy Storage Energy Innovation Hub. A renewal decision for the Fuels from Sunlight Energy Innovation Hub will be made in 2015. The Computational Materials Sciences activity is increased. The FY 2016 request provides for operations of five synchrotron light sources, five nanoscale research centers, and two neutron scattering centers. Funding to transition the Lujan Neutron Scattering Center to NNSA is also continued. No funds are requested in FY 2016 for National Synchrotron Light Source (NSLS) because the newly constructed National Synchrotron Light Source-II (NSLS II) is in operations. The request also provides for increases in construction for the Linac Coherent Light Source-II (LCLS-II), and it continues funding the Advanced Photon Source (APS) Upgrade and the NSLS-II Experimental Tools (NEXT) major items of equipment request.
- *Biological and Environmental Research (BER)* supports fundamental research and scientific user facilities to achieve a predictive understanding of complex biological, climatic, and environmental systems for a secure and sustainable energy future. BER increases by $20.4 million or 3.4 percent above the FY 2015 enacted level. The FY 2016 request continues support for core research in Genomic Science and the three DOE Bioenergy Research Centers (BRC), while funding for Radiological Sciences and Structural Biology Infrastructure is decreased as activities are completed. Increased support is requested in FY 2016 for research to understand the interdependencies of water, energy, and climate change. Operations are supported for BER's three scientific user facilities, the Joint Genome Institute (JGI), the Environmental Molecular Sciences Laboratory (EMSL), and the Atmospheric Radiation Measurement (ARM) Climate Research Facility.
- *Fusion Energy Sciences (FES)* supports research to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation for fusion energy. The FES FY 2016 request decreases by $47.5 million or 10.2 percent from the FY 2015 enacted level. Funding at the FY 2015 level is requested for key U.S. Contributions to ITER project, including important critical path items. Funding for the operations of the National Spherical Torus Experiment (NSTX), which completed a major upgrade in FY 2014, is increased to support 16 weeks of run time and to begin fabrication of two important facility enhancements. DIII-D research and operations are maintained at the FY 2015 request levels. The FY 2016 request supports five weeks of research operations of the Alcator C-Mod facility in its final year of operations.
- *High Energy Physics (HEP)* supports research to understand how the universe works at its most fundamental level by discovering the most elementary constituents of matter and energy, probing the interactions among them, and exploring the basic nature of space and time itself. HEP increases by $22.0 million or 2.9 percent above the FY 2015 enacted level. The request supports the planned construction funding profile for the Muon to Electron Conversion Experiment (Mu2e), and the MIEs for the Large Hadron Collider (LHC) upgrades to two detectors – the ATLAS (A Large Toroidal LHC Apparatus) and Compact Muon Solenoid (CMS) detectors. Optimal operations for the upgraded Neutrinos at the Main Injector (NuMI) beamline of NuMI Off-axis ν_e Appearance (NOvA) Experiment are provided. The FY 2016 request increases to support R&D and project engineering and design associated with the Long Baseline Neutrino Facility (LBNF), and initiation of the fabrication of three new MIEs for next–generation dark–energy and dark–matter experiments, consistent with the High Energy Physics Advisory Panel (HEPAP) (P5) report recommendations. Funding increases for the fabrication of the Large Synoptic Survey Telescope MIE according to the planned profile. Core research is decreased slightly to provide support for high priority efforts.
- *Nuclear Physics (NP)* supports research to discover, explore, and understand all forms of nuclear matter, supporting experimental and theoretical research to create, detect, and describe the widely varied forms of nuclear matter that exist in the universe, including those no longer found naturally. NP increases $29.1 million or 4.9 percent relative to the FY 2015 enacted level. Construction of the Facility for Rare Isotope Beams (FRIB) continues, consistent with the performance baseline profile approved in August 2013. Funding for the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) Upgrade decreases as accelerator commissioning is completed in FY 2015. The FY 2016 request also

provides for operation of the Relativistic Heavy Ion Collider (RHIC) for 22 weeks and for optimal operations at the Argonne Tandem Linac Accelerator System. Core research increases in FY 2016 to support high-priority research areas.

Basic and Applied R&D Coordination

Coordination between the Department's basic research and applied technology programs is a high priority within DOE and is facilitated through joint planning meetings, technical community workshops, annual contractor/awardee meetings, joint research solicitations, focused "tech teams" and working groups in targeted research areas, and collaborative program management of DOE's Small Business Innovation Research (SBIR) and Small Business Technology Transfer Research (STTR) programs. Co-funding of research activities and facilities at the DOE laboratories and funding mechanisms that encourage partnerships also facilitate research integration within the basic and applied research communities. Specific collaborative activities are highlighted in the "Basic and Applied R&D Coordination" sections of each individual SC program budget justification narrative.

High-Risk, High-Reward Research[a]

The SC incorporates high-risk, high-reward basic research elements in its research portfolios to drive innovation and challenge current thinking using a variety of mechanisms to develop topics: Federal advisory committees, triennial Committees of Visitors, program and topical workshops, interagency working groups, National Academies studies, and special SC program solicitations. Many of these topics are captured in formal reports, e.g., *Building for Discovery: Strategic Plan for U.S. Particle Physics in the Global* Context, by the High Energy Physics Advisory Panel (HEPAP-P5) (2014) [b]; *Top Ten Exascale Research Challenges*, by the Advanced Scientific Computing Advisory Committee (ASCAC) (2014) [c]; *Report of the BESAC Subcommittee on Future X-ray Light Sources,* by the Basic Energy Sciences Advisory Committee (BESAC) (2013) [d]; Synergistic *Challenges in Data-Intensive Science and Exascale*, ASCR workshop report (2012) [e]; *Biosystems Design*, BER workshop report (2012) [f]; and *Nuclear Physics: Exploring the Heart of the Matter*, by the National Research Council (2012) [g].

Scientific Workforce

The SC and its predecessors have more than a 50-year history in the training of a skilled scientific workforce. In addition to the undergraduate and graduate research internship programs supported through the SC's Office of Workforce Development for Teachers and Scientists (WDTS), the six SC research programs support the training of undergraduates, graduate students, and postdoctoral researchers through ongoing sponsored research awards at universities and the DOE national laboratories. The research program offices also support targeted graduate-level experimental training in areas associated with scientific user facilities, such as particle and accelerator physics, neutron and x-ray scattering, and nuclear physics. The SC coordinates with other DOE offices and other agencies on best practices for training programs and program evaluation through active participation in the National Science and Technology Council's (NSTC's) Committee on Science, Technology, Engineering, and Mathematics Education (CoSTEM). The SC also participates in the American Association for the Advancement of Science's (AAAS) Science & Technology Policy Fellowships program and the Presidential Management Fellows (PMF) Program to bring highly qualified scientists to DOE headquarters for 1–2 years.

Crosscuts

The FY 2016 Budget request continues crosscutting programs which coordinate across the Department to address our energy, environmental and national security challenges. These crosscutting initiatives, summarized below, are discussed in greater detail in the supporting programs' narratives.

Exascale Computing: Exascale systems are needed to support areas of research that are critical to national security objectives as well as applied research advances in areas such as climate models, combustion systems, and nuclear reactor design that are not within the capacities of today's systems. Exascale systems' computational power are needed for

[a] In compliance with the reporting requirements in the America COMPETES Act of 2007 (P.L. 110-69, section 1008).
[b] http://science.energy.gov/~/media/hep/hepap/pdf/May%202014/FINAL_P5_Report_Interactive_060214.pdf
[c] http://science.energy.gov/~/media/ascr/ascac/pdf/meetings/20140210/Top10reportFEB14.pdf
[d] http://science.energy.gov/~/media/bes/besac/pdf/Reports/Future_Light_Sources_report_BESAC_approved_72513.pdf
[e] http://science.energy.gov/~/media/ascr/ascac/pdf/reports/2013/ASCAC_Data_Intensive_Computing_report_final.pdf
[f] http://genomicscience.energy.gov/biosystemsdesign/index.shtml
[g] http://www.nap.edu/catalog.php?record_id=13438

increasing capable data-analytic and data-intense applications across the entire Federal complex. Exascale is a component of long-term collaboration between the SC's Advanced Scientific Computing Research (ASCR) program and the National Nuclear Security Administration's (NNSA) Advanced Simulation and Computing Campaign (ASC) program.

Subsurface Engineering: Over 80 percent of our total energy supply comes from the subsurface, and this importance is magnified by the ability to also use the subsurface to store and sequester fluids and waste products. The subsurface crosscut, SubTER, will address identified challenges in the subsurface through highly focused and coordinated research in Wellbore Integrity, Stress State and Induced Seismicity, Permeability Manipulation, and New Subsurface Signals to ensure enhanced energy security, material impact on climate change via CO2 sequestration, and significantly mitigated environmental impacts from energy-related activities and operations.

Energy-Water: The energy-water nexus crosscut is an integrated set of cross-program collaborations designed to accelerate the Nation's transition to more resilient energy and coupled energy-water systems. The crosscut supports: (1) an advanced, integrated data, modeling, and analysis platform to improve understanding and inform decision-making for a broad range of users and at multiple scales; (2) investments in targeted technology research opportunities within the system of water-energy flows that offer the greatest potential for positive impact; and (3) policy analysis and stakeholder engagement designed to build from and strengthen the two preceding areas while motivating more rapid community involvement and response.

Cyber Security: DOE is engaged in three categories of cyber-related activities: protecting the DOE enterprise from a range of cyber threats that can adversely impact mission capabilities; bolstering the U.S. Government's capabilities to address cyber threats; 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 for incident response and the implementation of Department-wide Identity Credential and Access Management.

FY 2016 Crosscuts ($K)

	Exascale Computing	Subsurface Engineering	Energy-Water	Cyber Security	Total
Advanced Scientific Computing Research	177,894	0	0	0	177,894
Basic Energy Sciences	12,000	5,000	0	0	17,000
Biological and Environmental Research	18,730	0	11,800	0	30,530
Safeguards and Security	0	0	0	33,156	33,156
Total, Crosscuts	208,624	5,000	11,800	33,156	258,580

Science
Funding by Congressional Control ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Advanced Scientific Computing Research	**478,093**	**463,472**	**541,000**	**620,994**	**+79,994**
Basic Energy Sciences					
Research	1,609,929	1,560,702	1,594,500	1,649,000	+54,500
Construction					
13-SC-10 Linac Coherent Light Source-II, SLAC	75,700	75,700	138,700	200,300	+61,600
07-SC-06 National Synchrotron Light Source (NSLS) II, BNL	26,300	26,300	0	0	0
Total, Construction	**102,000**	**102,000**	**138,700**	**200,300**	**+61,600**
Total, Basic Energy Sciences	**1,711,929**	**1,662,702**	**1,733,200**	**1,849,300**	**+116,100**
Biological and Environmental Research	**609,696**	**593,610**	**592,000**	**612,400**	**+20,400**
Fusion Energy Sciences					
Research	305,177	296,355	317,500	270,000	-47,500
Construction					
14-SC-60 ITER	199,500	199,500	150,000	150,000	0
Total, Fusion Energy Sciences	**504,677**	**495,855**	**467,500**	**420,000**	**-47,500**
High Energy Physics					
Research	745,521	723,920	729,000	731,900	+2,900
Construction					
11-SC-40 Long Baseline Neutrino Facility, FNAL	16,000	16,000	12,000	16,000	+4,000
11-SC-41 Muon to Electron Conversion Experiment, FNAL	35,000	35,000	25,000	40,100	+15,100
Total, Construction	**51,000**	**51,000**	**37,000**	**56,100**	**+19,100**
Total, High Energy Physics	**796,521**	**774,920**	**766,000**	**788,000**	**+22,000**

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Nuclear Physics					
Operation and Maintenance	488,638	474,302	489,000	517,100	+28,100
Construction					
14-SC-50 Facility for Rare Isotope Beams, Michigan State University	55,000	55,000	90,000	100,000	+10,000
06-SC-01 12 GeV CEBAF Upgrade, TJNAF	25,500	25,500	16,500	7,500	-9,000
Total, Construction	**80,500**	**80,500**	**106,500**	**107,500**	**+1,000**
Total, Nuclear Physics	**569,138**	**554,802**	**595,500**	**624,600**	**+29,100**
Workforce Development for Teachers and Scientists	**26,500**	**26,500**	**19,500**	**20,500**	**+1,000**
Science Laboratories Infrastructure					
Infrastructure Support					
Payment in Lieu of Taxes	1,385	1,385	1,713	1,713	0
Facilities and Infrastructure	900	900	6,100	30,977	+24,877
Oak Ridge Landlord	5,951	5,951	5,777	0	-5,777
Oak Ridge Nuclear Operations	0	0	0	12,000	+12,000
Total, Infrastructure Support	8,236	8,236	13,590	44,690	+31,100
Construction					
15-SC-75 Infrastructure and Operational Improvements at PPPL	0	0	25,000	0	-25,000
15-SC-76 Materials Design Laboratory at ANL	0	0	7,000	23,910	+16,910
15-SC-77 Photon Science Laboratory Building at SLAC	0	0	10,000	25,000	+15,000
15-SC-78 Integrative Genomics Building at LBNL	0	0	12,090	20,000	+7,910
13-SC-70 Utilities Upgrade, FNAL	34,900	34,900	0	0	0
13-SC-71 Utility Infrastructure Modernization, TJNAF	29,200	29,200	0	0	0
12-SC-70 Science and User Support Building, SLAC	25,482	25,482	11,920	0	-11,920
Total, Construction	**89,582**	**89,582**	**66,010**	**68,910**	**+2,900**
Total, Science Laboratories Infrastructure	**97,818**	**97,818**	**79,600**	**113,600**	**+34,000**
Safeguards and Security	**87,000**	**87,000**	**93,000**	**103,000**	**+10,000**
Program Direction	**185,000**	**185,000**	**183,700**	**187,400**	**+3,700**

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Small Business Innovation/Technology Transfer Research (SC portion)	**0**	**128,539**	**0**	**0**	**0**
Subtotal, Science	**5,066,372**	**5,070,218**	**5,071,000**	**5,339,794**	**+268,794**
Small Business Innovation/Technology Transfer Research (DOE transfer)	**0**	**64,666**	**0**	**0**	**0**
Use of prior year balances (SBIR)	**0**	**-3,846**[a]	**0**	**0**	**0**
Use of prior year balances (Rescission)	**0**	**0**	**-3,262**	**0**	**+3,262**
Total, Science Appropriation	**5,066,372**	**5,131,038**	**5,067,738**	**5,339,794**	**+272,056**
Federal FTEs	**956**	**929**	**940**	**945**	**+5**

SBIR/STTR:

- FY 2014 Current: SBIR: $112,472,000 (includes unobligated prior-year funds of $3,277,000 from BER and $569,000 from ASCR) was reprogrammed within SC and $57,066,000 was transferred from other DOE programs; STTR: $16,067,000 was reprogrammed within SC and $7,600,000 was transferred from other DOE programs.
- FY 2015 projected: SBIR: $116,876,000 and STTR: $16,119,000 (SC only).
- FY 2016 Request: SBIR: $124,644,000; STTR: $18,696,000 (SC Only).

[a] Reflects the use of prior-year unobligated balances ($3,846,000) in FY 2014 for SBIR.

Advanced Scientific Computing Research

Overview

The Advanced Scientific Computing Research (ASCR) program's mission is to advance applied mathematics and computer science; deliver the most advanced computational scientific applications in partnership with disciplinary science; advance computing and networking capabilities; and develop future generations of computing hardware and tools for science, in partnership with the research community, including U.S. industry. The strategy to accomplish this has two thrusts: developing and maintaining world-class computing and network facilities for science; and advancing research in applied mathematics, computer science and advanced networking.

U.S. private- and public-sector organizations are increasingly using supercomputers to achieve breakthroughs of major scientific or economic importance. These achievements have already advanced U. S. competitiveness[a] and were, in many cases, accomplished through access to very powerful supercomputers and High Performance Computing (HPC) experts at the Department of Energy (DOE) national laboratories using tools developed with support from ASCR. ASCR has a strong track record of supporting innovative scientific computing. Researchers using ASCR facilities have: made discoveries in functional materials, fundamental studies of turbulence in chemically reacting systems, climate change, and in the understanding of the physical properties of matter, such as the quark-gluon nature of nuclear matter; modeled 3-D full-core reactor neutron transport to predict the behavior of novel nuclear fuels in fission reactors; conducted 3-D turbulent combustion simulations of hydrocarbons to increase fuel efficiency; made U.S. airplane engines quieter, more fuel efficient, and less polluting; made long haul trucks more energy efficient in record time; simulated ice formation in million-molecule water droplets to reduce the wind turbine downtime in cold climates; and are identifying novel materials for use in extreme energy environments.

According to a recent study by the Council on Competitiveness[b], U.S. companies that use high performance computing to deliver a competitive edge, "…are confident their organizations could consume up to 1,000-fold increases in capability and capacity in a relatively short amount of time" but 92% see "scalability of software" as a significant barrier to delivering on that potential followed closely by the cost of the systems, the programmability of the systems, and the availability of expertise.

Numerous reports have documented the challenges of simply scaling existing computer designs to reach exascale. Drawing from these reports and experience, the Advanced Scientific Computing Advisory Committee (ASCAC) identified the top 10 computing technology advancements that are needed to achieve productive, economically viable exascale systems:

- create more energy efficient circuits, power and cooling technologies;
- increase the performance and energy efficiency of data movement through new interconnect technologies;
- integrate advanced memory technologies to dramatically improve capacity and bandwidth;
- develop scalable system software that is power- and resilience- aware;
- invent new programming environments that express massive parallelism, data locality, and resilience;
- create data management software that can handle the volume, velocity and diversity of data that is anticipated;
- reformulate science problems and redesign, or reinvent, their solution algorithms for exascale systems;
- facilitate mathematical optimization and uncertainty quantification for exascale discovery, design, and decision making; ensure correct scientific computation in the face of faults, reproducibility, and algorithm verification challenges; and
- increase the productivity of computational scientists with new software engineering tools and environments.[c]

The Office of Science, through ASCR, and the National Nuclear Security Administration (NNSA), have partnered to make strategic investments in hardware, methods, and critical technologies to address the exascale technical challenges and deliver an exascale system. Such a system will help scientists harness the thousand-fold increase in capability to address

[a] "*Real-World Examples of Supercomputers Used For Economic and Societal Benefits: A Prelude to What the Exascale Era Can Provide*", May 2014, International Data Corporation (IDC) #248647

[b] "*The Exascale Effect: Benefits of Supercomputing Investment for U.S. Industry*", September 2014, Council on Competitiveness and Intersect360 Research.

[c] *"Top Ten Exascale Research Challenges"*, Feb. 10, 2014, Advanced Scientific Computing Advisory Committee (ASCAC).

critical research challenges and will maintain U.S. competitiveness in high performance computing (HPC). These efforts are linked with investments to advance data-intensive science and to effectively use the massive scientific data generated by DOE's unparalleled suite of scientific user facilities and large-scale collaborations. By investing in both next-generation computing and data-intensive science, the ASCR program will enable the community of HPC users to improve and shorten industrial design processes; design advanced materials; better understand dark matter and dark energy; explore possibilities for dramatically increasing fuel efficiency while lowering emissions; design advanced nuclear reactors that are modular, safe, and affordable; improve accuracy of climate predictions; predict and investigate how to control the behavior of fusion plasmas; and calculate the subatomic interactions that determine nuclear structure.

Highlights of the FY 2016 Budget Request

The FY 2016 Budget Request for ASCR makes significant new investments in research and partnerships to advance the Department's goals for capable exascale computing. Capable exascale computing, with a thousand- fold increase in performance over today's systems as measured by science applications important to the DOE mission and HPC scientific community, is the next frontier of development in HPC, extending capability significantly beyond today's petascale computers to address the next generation of scientific, engineering, and large-data problems. The goal of the exascale computing effort in SC is to provide the forefront computing resources needed to meet and advance the Department's science missions into the next decade. This will require major advances in technology, the most important of which are increased parallelism, energy efficiency, and reliability, which are needed for scalable use of these computing systems. Because DOE partners with commercial vendors to accelerate development of commodity parts, its research investments will impact computing at all scales ranging from the largest scientific computers and data farms to department-scale computing to home computers and laptops.

The investment strategy has five components:

- Conduct research, development, and design efforts in hardware, software, and mathematical technologies leading toward capable exascale systems.
- Prepare today's scientific and data-intensive computing applications to exploit fully the capabilities of exascale systems by coordinating their development with the emerging technologies from the research, development, and design efforts.
- Partner with HPC vendors to accelerate the pace of implementation of technologies required for capable exascale computing.
- Acquire and operate increasingly capable computing systems, starting with multi-petaflop machines that incorporate emerging technologies from research investments.
- Collaborate with other Federal agencies to ensure broad applicability of capable exascale computing across the US Government.

<u>Mathematical, Computational, and Computer Sciences Research</u>

To ensure DOE applications can fully exploit an exascale system, this activity will support co-design centers that interact with the vendor partnerships to strengthen feedback loops between DOE applications, research and vendor technologies; research and development of software, tools, and middleware for capable exascale systems; applied mathematics methods that address the challenges from increased parallelism and reliability; software productivity to broaden the impact of capable exascale systems; and data management and advanced storage technologies that are focused on the energy and reliability challenges.

Experiments at several of SC's user facilities, such as the light and neutron sources, and experiments at the Large Hadron Collider (LHC), are migrating towards work flows that need near real-time interaction between instruments and simulations.[a] Experiments and simulations are often deeply intertwined as simulations become necessary in the design of large-scale experiments, and data from experiments are analyzed in simulations to inform and guide further experiments. The volume and complexity of data generated have increased such that a focused effort is required to develop theories, tools, and technologies to manage data–from generation through integration, transformation, analysis, and visualization, including collaborative environments; to capture the historic record of the data; and to archive and share it. This request

[a] http://science.energy.gov/~/media/ascr/ascac/pdf/reports/2013/ASCAC_Data_Intensive_Computing_report_final.pdf, http://science.energy.gov/~/media/ascr/pdf/research/scidac/ASCR_BES_Data_Report.pdf

supports ASCR efforts in data-intensive science for collaborations with applied mathematicians and computer scientists to address end-to-end data management challenges and develop new scientific workflows.

Software, tools, and methods from core research efforts will be used by the Scientific Discovery through Advanced Computing (SciDAC) partnerships to more effectively use the current and immediate next generation high performance computing facilities.

High Performance Computing and Network Facilities

The Research and Evaluation Prototypes (REP) activity has recently supported R&D partnerships with U.S. vendors to improve the energy efficiency and reliability of critical technologies such as memory, processors, network interfaces, and interconnects for use in next-generation, massively parallel supercomputers. The compute node is the basic building block of a high performance computer where all of these technologies come together. In FY 2016, REP will competitively select R&D partnerships with U.S. computer vendors to initiate the design and development of node and system designs suitable for exascale systems. These efforts will influence the development of prototypes that advance DOE goals and are based on the results of REP investments made in FY 2014-2015. This is an essential component of the Department's exascale computing plan and a key step in the vendor's productization efforts. Industry's full development costs for novel HPC systems are many billions of dollars and cover incorporated technologies that impact commercial offerings across their product line – from laptops and handheld devices to servers and HPC systems. HPC is a small fraction of the overall computing market and direct investment is critical in order to influence the trajectory of technology development. In addition, Industry roadmaps and past experience indicate that vendors will be slow to incorporate novel technologies, such as those developed by REP, in their commercial products. By forging a strong partnership with U.S. vendors with significant direct investment during the design phase, the Department can ensure cohesive development of hardware technologies and applications to deliver exascale capabilities to advance science and engineering.

The Leadership Computing Facilities (LCFs) will continue preparations for planned 75-200 petaflops (pf) upgrades at each site in the 2018-2019 timeframe. Because these upgrades represent technological advances in both hardware and software, funds are included in REP to continue supporting non-recurring engineering efforts for the ASCR facilities that incorporate custom features to meet the Department's mission requirements. REP will also expand efforts in exascale component technology research and development, system engineering, and integration, leading to the design and development of future HPC systems including prototype test beds for demonstrating the feasibility of building exascale systems, and the exascale systems themselves.

The National Energy Research Scientific Computing Center (NERSC) takes delivery of the NERSC-8 supercomputer in FY 2016, which will expand the capacity of the facility by 10-40 pf to address emerging scientific needs.

Experienced computational scientists who assist a wide range of users in taking effective advantage of the advanced computing resources are critical assets at both the LCFs and NERSC. To address this DOE mission need, support continues for a post-doctoral training program for high end computational science and engineering. In addition, the three NERSC sites will continue coordinating efforts to quantify scientist's computational requirements and prepare their users for future architectures.

According to the Advanced Scientific Computing Advisory Committee (ASCAC), the Computational Science Graduate Fellowship (CSGF) has been, according to the Advanced Scientific Computing Advisory Committee (ASCAC), "an exceptionally effective program that has had a significant impact on the national Computational Science infrastructure."[a] In July 2014, the ASCAC Workforce Subcommittee found that the CSGF "enables graduates to pursue a multidisciplinary program of education that is coupled with practical experience at the laboratories. The program is highly effective in both its educational goals and in its ability to supply talent to the laboratories. However, its current size and scope are too limited to solve the identified workforce problems. The committee felt strongly that this proven program should be extended to increase its ability to support the DOE mission."[b] Both the ASCR facilities and its exascale research efforts rely on the continued availability of highly skilled computational scientists such as those produced by the CSGF and face increasing competition for the limited supply of these workers. Therefore, the FY 2016 budget request includes $10,000,000 for the

[a] http://science.energy.gov/~/media/ascr/ascac/pdf/reports/ASCAC_CSGF_Report_2011-Final.pdf
[b] http://science.energy.gov/~/media/ascr/ascac/pdf/charges/ASCAC_Workforce_Letter_Report.pdf

CSGF within the Research and Evaluation Prototypes activity to expand the program and strengthen connections to both the ASCR facilities and to the challenges of exascale computing.

With the 100 gigabit per second (Gbps) expansion to support SC's collaborations in Europe complete, the Energy Science Network (ESnet) will explore, in coordination with the National Science Foundation, next generation optical networking technologies and global networking architectures for future upgrades. The outcomes of these efforts will help ESnet keep pace with the continuing growth of scientific traffic from DOE's scientific user facilities and experiments.

Within the FY 2016 Budget Request, ASCR supports the Department's Exascale Computing Departmental Crosscut. The Exascale Computing Initiative's goal is to significantly accelerate the development of capable exascale computing systems to meet national security needs. Exascale systems are needed to support areas of research that are critical to national security objectives as well as applied research advances in areas such as climate models, combustion systems, and nuclear reactor design that are not within the capacities of today's systems. Exascale systems' computational power are needed for increasing capable data-analytic and data-intense applications across the entire Federal complex. Exascale is a component of long-term collaboration between SC's Advanced Scientific Computing Research (ASCR) program and the National Nuclear Security Administration's (NNSA) Advanced Simulation and Computing Campaign (ASC) program.

FY 2016 Crosscuts ($K)

	Exascale Computing	Total
Advanced Scientific Computing Research	177,894	177,894

Advanced Scientific Computing Research
Funding ($K)

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Mathematical, Computational, and Computer Sciences Research					
Applied Mathematics	47,081	47,081	49,155	49,229	+74
Computer Science	55,835	55,835	55,767	56,842	+1,075
Computational Partnerships	46,261	46,261	46,918	47,918	+1,000
Next Generation Networking for Science	17,852	17,852	19,000	19,000	+0
SBIR/STTR	4,972	0	5,830	6,181	+351
Total, Mathematical, Computational, and Computer Sciences Research	**172,001**	**167,029**	**176,670**	**179,170**	**+2,500**
High Performance Computing and Network Facilities					
High Performance Production Computing	67,105	67,105	75,605	76,000	+395
Leadership Computing Facilities	160,000	160,000	184,637	171,000	-13,637
Research and Evaluation Prototypes	36,284	36,284	57,329	141,788	+84,459
High Performance Network Facilities and Testbeds	33,054	33,054	35,000	38,000	+3,000
SBIR/STTR	9,649	0	11,759	15,036	+3,277
Total, High Performance Computing and Network Facilities	**306,092**	**296,443**	**364,330**	**441,824**	**+77,494**
Total, Advanced Scientific Computing Research	**478,093**	**463,472**	**541,000**	**620,994**	**+79,994**

SBIR/STTR funding:

- FY 2014 transferred: SBIR $12,722,000 and STTR $1,899,000 of FY 2014 dollars, plus $569,000 in unobligated prior years dollars for SBIR
- FY 2015 Enacted: SBIR $15,457,000 and STTR $2,132,000
- FY 2016 Request: SBIR $18,450,000 and STTR $2,767,000

[1] Funding reflects the transfer of SBIR/STTR to the Office of Science.

Advanced Scientific Computing Research
Explanation of Major Changes ($K)

	FY 2016 vs. FY 2015
Mathematical, Computational, and Computer Sciences Research: Research will continue to focus on the linked challenges of capable exascale and data-intensive science.	+2,500
High Performance Computing and Network Facilities: Increase supports: Research and Development Prototypes, which will significantly expand efforts to support the initiation of R&D partnerships with U.S. vendors for the design and development of exascale node and systems prototypes building on the previous investments in critical technologies and conceptual designs; lease costs; increased power costs; the NERSC upgrade, which will expand the capacity of the facility by 10-40 pf to address emerging scientific needs; ESnet efforts, in coordination with NSF, to develop next generation optical networking and global networking architectures for future upgrades. LCF funding decreases as the majority of site preparations for planned upgrades will be completed in FY 2015.	+77,494
The Computational Sciences Graduate Fellowship is critically important to the ASCR facilities and to our exascale goals. The Research and Evaluation Prototypes activity will support the fellowship at $10,000,000 in FY 2016. Research and Evaluation Prototypes will also increase to support for non-recurring engineering efforts to ensure user facility upgrades meet the Department's mission requirements.	
Total, Advanced Scientific Computing Research	**+79,994**

Basic and Applied R&D Coordination

Coordination across disciplines and programs is a cornerstone of the ASCR program. Partnerships within SC are mature and continue to advance the use of high performance computing and scientific networks for science. Growing areas of collaboration will be in the area of data-intensive science and readying applications for exascale. ASCR continues to have a strong partnership with NNSA for achieving the Department's goals for exascale computing. In April 2011, ASCR and NNSA strengthened this partnership by signing a memorandum of understanding for collaboration and coordination of exascale research within the Department. Areas of mutual interest between ASCR and the DOE technology programs, particularly the Office of Electricity Delivery and Energy Reliability (OE) and the Office of Nuclear Energy (NE), are applied mathematics for the optimization of complex systems, control theory, and risk assessment. Through the National Information Technology Research and Development Subcommittee of the National Science and Technology Council's (NSTC) Committee on Technology, the interagency networking and information technology R&D coordination effort, ASCR also coordinates with programs across the Federal Government. In FY 2016, cross-agency interactions and collaborations will continue, fostered by the National Strategic Computing Initiative coordinated by OSTP.

Program Accomplishments

Hydrogen on Demand. As part of an INCITE project on Argonne's Leadership Computing Facility (ALCF), researchers performed a 16,611 atom Quantum Molecular Dynamics (QMD) simulation on Mira to study hydrogen production using the reaction of a lithium-aluminum (Li-Al) alloy particle with water for on-demand hydrogen gas production. Producing hydrogen from aluminum-water reactions has potential for many clean energy applications, including on-board fuel production for hydrogen-powered vehicles. However, the approach has been limited by production scalability issues due to poor yields using aluminum particles. The simulation performed on Mira revealed that alloying Al particles with Li results in orders-of-magnitude acceleration of the reaction rate as well as higher yields.

Advancing Next Generation Nuclear Energy. A team, led by Westinghouse and ORNL, received the International Data Corporation's HPC Excellence Award in June 2014 for their core physics simulations of the Westinghouse AP1000 pressurized water reactor (PWR) core using the Virtual Environment for Reactor Application (VERA) system developed by the Consortium for Advanced Simulation of Light-Water Reactors (CASL), DOE's Nuclear Energy hub. The simulations, performed on the Oak Ridge Leadership Computing Facility (OLCF), produced 3-D, high-fidelity power distributions representing conditions expected to occur during the AP1000 core start-up and used up to 240,000 computational units in parallel. The results included as many as one trillion particle histories per simulation to reduce statistical errors and provide insights that improve understanding of core conditions, helping to ensure safe startup of the AP1000 PWR core. Westinghouse is deploying the AP1000 worldwide with eight plants currently under construction in China and the United States.

Calming the Chaos Keeps Supercomputers Humming. Diagnosis Using the Chaos of Computing Systems, or DUCCS, was developed by ASCR researchers to quickly and nonintrusively detect a variety of hardware faults in processing units, accelerators, memory elements, and interconnects of large-scale high-performance computing systems such as supercomputers, clusters, and server farms. The software combines chaotic map theory with hardware details to detect component faults in systems that handle large computational problems such as scientific computations, weather predictions, and web data processing. DUCCS software provides critical diagnosis information that contributes to the resilience of computing systems in terms of error-free computations and sustained capacity. This work has been recognized as one of the year's top technological innovations with a 2014 "R&D 100 Award" presented by R&D Magazine.

Understanding Mercury Toxicity. Supercomputer simulations run at NERSC show for the first time how mercury, a toxic environmental pollutant, binds preferentially to sulfur-containing molecules rather than those with oxygen and other similar atoms. The simulations revealed that an interaction between mercury and water molecules is important to the process, a finding that establishes a basis for understanding the chemistry of mercury that is impossible from experimentation alone. These results are critical for understanding toxicity, bioavailability, transport, and environmental fate of this major global pollutant.

Advanced Mathematics Bring Nanocrystals Into Focus. X-ray crystallography gives scientists new insights in areas ranging from genomics to photosynthesis to bone disease. As light sources at SC user facilities become more powerful, the emerging technique of X-ray nanocrystallography offers great promise for studying objects that are the size of macromolecules within the membranes of cell walls. ASCR researchers recently developed an algorithmic framework and new mathematical tools for decoding and combining the diffraction patterns generated by X-ray experiments in order to understand the overall structure of the examined material. The multi-step mathematical process for nanocrystallography involves building up a 3-dimensional structure from 2-dimensional X-ray diffraction patterns from thousands of nanocrystals with different sizes and orientations. This new computational framework is a major development for enabling scientific advances from the analysis of the massive data from the Department's light sources.

Simulations Illuminate Path to Improve Understanding of Type 2 Diabetes. Computing resources at the ALCF have helped researchers determine how proteins misfold to create the tissue-damaging structures that lead to type 2 diabetes. The researchers combined experiments and computation to understand the chemical pathway. The simulations identified a missing intermediate step, in which transient rigid fibrils form, then morph into floppy protein loops, and finally take the form of tough fibrils and stack up to form the damaging amyloid fibril. With the new understanding and access to Mira, future work could target a possible treatment, such as designing an inhibitor to interfere with the harmful pathway. In addition, the research collaboration can apply the method to determine the intermediate steps in similar diseases such as Alzheimer's that are linked to the formation of amyloid fibrils.

Observations Validate SciDAC Supernova Simulations. One of the first terascale accomplishments in 2003 in the SciDAC program was a 3-D simulation that explored the mechanism responsible for the explosion of core-collapse supernovas, phenomena responsible for producing all of the elements in the periodic table. These pioneering simulations produced the theoretical SASI, or standing accretion shock instability, a sloshing of stellar material that destabilizes the expanding shock and helps lead to an explosion. Now, more than a decade later, researchers mapping radiation signatures from the Cassiopeia A supernova with NASA's NuSTAR high-energy x-ray telescope array have published observational evidence that supports the SASI model. During the same period the researchers have improved the initial 3-D simulation so that today, the team is using 85 million core hours and scaling to more than 60,000 cores to simulate a supernova in three dimensions with a fully physics-based model that could generate the most revealing supernova yet.

Beyond Remote Access - New Scientific Workflows. ESnet recently began to support complex scientific workflows requiring access to more than one DOE user facility simultaneously. In these 'coupled facility' experiments, scientific data is streamed at a very high rate from a DOE light source or other data generator, to a high performance computing facility for real-time analysis. The 'coupled facility' architecture was instrumental in facilitating a recent experimental result, in which a team of collaborators from LBNL and SLAC obtained 'snapshots' of photosynthetic water oxidation in Phytosystem-II, using femtosecond X-ray diffraction and spectroscopy.

Advanced Scientific Computing Research
Mathematical, Computational, and Computer Sciences Research

Description

The Mathematical, Computational, and Computer Sciences Research subprogram supports research activities that effectively use the current and future generations of DOE's computer and networking capabilities. Computational science is increasingly central to progress at the frontiers of science and to our most challenging engineering problems. Accordingly, the subprogram delivers:

- new mathematics required to more accurately model systems involving processes taking place across a wide range of time and length scales;
- software, tools, and middleware to efficiently and effectively harness the potential of today's high performance computing systems and advanced networks for science and engineering applications;
- operating systems, data management, analyses, representation model development, user interfaces, and other tools required to make effective use of future-generation supercomputers and the data sets from current and future scientific user facilities;
- computer science and algorithm innovations that increase the energy efficiency of future-generation supercomputers;
- networking and collaboration tools to make scientific resources readily available to scientists, in university, national laboratory, and industrial settings.

The research program will develop methods, software, and tools to use HPC systems for data-intensive and computational science at the exascale. This requires a focus on increased parallelism, energy efficiency, and reliability.

Deriving scientific insights from vast amounts of raw data will require a focused research effort to develop the necessary theories, tools, and technologies to manage the full data lifecycle from generation or collection through integration, transformation, analysis, and visualization, to capturing the historic record of the data and archiving, and sharing them.

Applied Mathematics

The Applied Mathematics activity supports the research and development of applied mathematical models, methods, and algorithms for understanding complex natural and engineered systems related to DOE's mission. These mathematical models, methods, and algorithms are the fundamental building blocks for describing physical and biological systems computationally. This activity's research underpins all of DOE's modeling and simulation efforts. Significant innovation in applied mathematics is needed to realize the potential of next generation high performance computing systems. High-fidelity modeling and simulation requires a number of new algorithmic techniques and strategies supported by this activity, including: advanced solvers for large linear and nonlinear systems, time integration schemes, multi-physics coupling, methods that use asynchrony or randomness, adaptively, algorithmic resilience, and strategies for reducing global communications.

Computer Science

The Computer Science activity supports research on extreme-scale computing and extreme-scale data. Reports from computer vendors indicate that because of power constraints, data movement, rather than computational operations, will be the constraining factor for future systems. Memory per core is expected to decline sharply due to power requirements and the performance growth of storage systems will continue to lag behind the computational capability of the systems. Multi-level storage architectures that span multiple types of hardware are anticipated and require research within this activity to develop new approaches to run-time data management and analysis.

Significant innovation in computer science is needed to realize the potential of next generation HPC systems and other scientific user facilities in a timeframe consistent with their anticipated availability. There will be continued emphasis on data-intensive science challenges with particular attention to the intersection with exascale computing challenges and the unique needs of DOE scientific user facilities including data management. There will also be significant efforts in tools, user interfaces, the high performance computing software stack that can dynamically deal with time-varying energy efficiency and reliability requirements–including operating systems, file systems, compilers, and performance tools–and visualization and analytics tools that scale to extremely massive datasets. These efforts are essential to ensure DOE mission applications are able to use commercially available HPC hardware.

Computational Partnerships

The Computational Partnerships activity supports the SciDAC program, which accelerates progress in scientific computing through partnerships among applied mathematicians, computer scientists, and scientists in other disciplines. These partnerships enable scientists to conduct complex scientific and engineering computations on leadership-class and high-end computing systems at a level of fidelity needed to simulate real-world conditions. SciDAC applications include climate science, fusion research, high energy physics, nuclear physics, astrophysics, materials science, chemistry, and accelerator physics.

SciDAC focuses on the high-end of high performance computational science and engineering and addresses two challenges: to broaden the community and thus the impact of high performance computing, particularly to address the Department's missions and to ensure that progress at the frontiers of science is enhanced rather than diminished by advances in computational technology, most pressingly, the emergence of hybrid, multi-core architectures.

Next Generation Networking for Science

ASCR has played a leading role in the development of the high-bandwidth networks connecting researchers to facilities, data, and one another. ASCR-supported researchers helped establish critical protocols on which the internet is based. Next Generation Networking for Science research makes possible international collaborations such as the Large Hadron Collider and underpins virtual meeting and other commercial collaboration tools. These research efforts build upon results from Computer Science and Applied Mathematics to develop integrated software tools and advanced network services to use new capabilities in ESnet to advance DOE missions.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Mathematical, Computational, and Computer Sciences Research $176,670,000	**$179,170,000**	**+$2,500,000**
Applied Mathematics ($49,155,000)	**($49,229,000)**	**(+$74,000)**
Research efforts support the Department's efforts in capable exascale and data-intensive science. These efforts develop scalable mathematical and statistical models, algorithms, and methods for the representation, analysis, and understanding of extreme-scale data from scientific simulations and experiments.	Applied Mathematics will continue efforts to develop new algorithmic techniques and strategies that extract scientific advances and engineering insights from massive data for DOE missions. Applied Mathematics will also address many of the challenges of exascale including: advanced solvers, uncertainty quantification, algorithmic resilience, and strategies for reducing global communications.	The slight increase will support priority research areas in capable exascale and data-intensive science.
Computer Science ($55,767,000)	**($56,842,000)**	**(+$1,075,000)**
To achieve the full potential of exascale computing, a software stack must be developed that includes new programming models and metrics for evaluating system status. This activity supports software efforts that span the spectrum from low-level, operational software to high-level, application development environments. More specifically, it includes operating systems, runtimes for scheduling, memory management, file systems, and performance monitoring. Power management and resilience strategies, computational libraries, compilers, programming models, and application frameworks are also included. Scalability, programmability, resilience, and code portability are emphasized to promote ease of use, reliability, accommodation of legacy code, and	Computer Science will continue efforts to develop an exascale software stack, new programming models and metrics for evaluating system status. This activity is primarily focused on addressing the challenges of exascale and data-intensive science. Emphasis will remain on efforts to promote ease of use; increase parallelism, energy efficiency, and reliability, and will ensure that research efforts are tightly coupled to application requirements and developments in industry, particularly those identified by the co-design centers and developed in partnerships supported by the Research and Evaluation Prototypes activity.	The slight increase will support priority research areas in capable exascale and data-intensive science.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
pathways to future development beyond exascale. Research efforts also support the Department's efforts in capable exascale and data-intensive science. These efforts focus on in situ data management, analysis and visualization, new I/O subsystems, and new multi-level storage system software.		
Computational Partnerships ($46,918,000)	**($47,918,000)**	**(+$1,000,000)**
The SciDAC institutes continue to play a key role in assisting DOE mission critical applications to effectively use the ASCR production and leadership computing facilities. The strategic partnerships with the other Office of Science programs continue to address their specific needs as they move toward larger data sets and more complex computing systems. The Scalable Data Management Analysis and Visualization (SDAV) Institute and data-intensive co-design center continue to support the Department's efforts in data-intensive science. The role of this activity is to develop robust tools and software to manage and analyze massive data with SDAV focused on the near term and co-design focused on emerging hardware. This activity focuses on the current set of co-design centers that partner DOE mission applications with forefront researchers and computing vendors. These efforts inform core research efforts in applied mathematics and computer science as well as the computing resources for the next generation of scientific user facilities.	The SciDAC Institutes will be recompeted in FY 2016. These Institutes will continue to provide the bridge between the core research program and the DOE science applications. The development of SciDAC tools and resources by the Institutes is primarily for use on computational systems, such as those existing and planned for at the Oak Ridge and Argonne Leadership Computing Facilities, the National Energy Research Scientific Computing Center, and similar world-class computing facilities over the following 5 years. In addition, the exascale Co-design centers will undergo a comprehensive external peer review in FY 2015 to document progress and impact, and to inform the recompetition of these efforts in FY 2016.	The increase will support a more robust infrastructure in anticipation of the challenges for the SciDAC applications.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Next Generation Networking for Science ($19,000,000)	**($19,000,000)**	**($0)**
With the production deployment of 100 gigabit per second (Gbps) technologies, research continues to focus on developing networking software, middleware, and hardware that delivers 99.999% reliability while allowing the successful products of prior research to transition into operation. These investments are increasingly important as ESnet expands production use of very high-throughput and optical technologies. Research focuses on the challenges of moving, sharing, and validating massive quantities of data from DOE scientific user facilities and large scale collaborations via high speed optical networks. This includes the challenges in building, operating, and maintaining the network infrastructure over which these data pass. Research supports the Department's efforts in exascale and data-intensive science. This activity focuses on integrating the SC facilities with computing resources and collaborations.	The Next Generation Networking for Science activity will continue to work closely with SC user facilities and applications, to develop the necessary tools – networking software, middleware and hardware - to address the challenges of moving, sharing and validating massive quantities of data via next generation optical networking technologies. This focus will allow DOE scientists to productively collaborate regardless of the geographical distance between scientists and user facilities or the size of the data.	No change
SBIR/STTR ($5,830,000)	**($6,181,000)**	**(+$351,000)**
In FY 2015, SBIR/STTR funding is set at 3.3% of non-capital funding.	In FY 2016, SBIR/STTR funding is set at 3.45% of non-capital funding.	

Description

The High Performance Computing and Network Facilities subprogram delivers forefront computational and networking capabilities. These include high performance production computing at the National Energy Research Scientific Computing Center (NERSC) at LBNL and Leadership Computing Facilities (LCFs) at ORNL and ANL. These computers and the other SC research facilities generate many petabytes of data each year. Moving data to the researchers who need them requires advanced scientific networks and related technologies provided through High Performance Network Facilities and Testbeds, which includes the Energy Science Network (ESnet). The Research and Evaluation Prototypes activity invests in research and development that will play a critical role in delivering world-leading capabilities and achieving the Department's exascale computing goals.

Allocations of computer time at ASCR facilities provide critical resources for the scientific community, including industry and other agencies, following the peer reviewed, public access model used by other SC scientific user facilities. ASCR facilities provide a testbed for U.S. industry to scale and then validate code performance to optimize in-house HPC investments.

The Research and Evaluation Prototypes activity addresses the challenges of next generation computing systems. By actively partnering with the research community, including industry, on the development of technologies that enables next-generation machines, ASCR ensures that commercially available architectures serve the needs of the scientific community. Coupling this activity to the co-design centers ensures that application and software researchers can gain a better understanding of future systems to get a head start in developing software and models to take advantage of the new capabilities. The Research and Evaluation Prototypes activity prepares researchers to effectively use the next generation of scientific computers and seeks to reduce risk for future major procurements.

High Performance Production Computing

This activity supports NERSC, which delivers high-end production computing services for the SC research community. Approximately 5,000 computational scientists in about 500 projects use NERSC annually to perform scientific research across a wide range of disciplines including astrophysics, chemistry, climate modeling, materials, high energy and nuclear physics, fusion, and biology. NERSC users come from nearly every state in the U.S., with about 65% based in universities, 25% in DOE laboratories, and 10% in other government laboratories and industry. NERSC's large and diverse user base requires an agile support staff to aid users entering the high performance computing arena for the first time, as well as those preparing codes to run on the largest machines available at NERSC and other SC computing facilities. In FY 2015, NERSC will complete its move into the new Computational Research and Theory building on the Lawrence Berkeley National Laboratory campus.

NERSC is a vital resource for the SC research community and it is consistently oversubscribed, with requests exceeding capacity by a factor of 3–10. This gap between demand and capacity exists despite upgrades to the primary computing systems approximately every three years. NERSC regularly gathers requirements from SC domain programs through a long-established, robust process and uses these requirements to inform upgrade plans. These requirements activities are also vital to planning for SciDAC and other ASCR efforts to prioritize research directions and inform the community of new computing trends, especially as the computing industry moves toward heterogeneous and multi-core computing.

Leadership Computing Facilities

The LCFs enable open scientific applications, including industry applications, to harness the potential of leadership computing to advance science and engineering. The success of this effort is built on the gains made in Research and Evaluation Prototypes and ASCR research efforts. Another LCF strength is the staff, who operate and maintain the forefront computing resources and provide support to Innovative and Novel Computational Impact on Theory and Experiment (INCITE) projects, ASCR Leadership Computing Challenge projects, scaling tests, early science applications, and tool and library developers. Support staff experience is critical to the success of industry partnerships to address the challenges of next-generation computing.

The Oak Ridge Leadership Computing Facility's (OLCF) 27 petaflop system is one of the most powerful computers in the world for scientific research, and is ranked number two on the November 2014 Top 500 list[a]. Through allocations on the OLCF, several applications, including combustion studies in diesel jet flame stabilization, simulations of neutron transport in fast-fission reactor cores, and earthquake simulations, are running at the multi-pf scale. OLCF staff is sharing its expertise with industry to broaden the benefits of petascale computing for the Nation. For example, OLCF continues to work with industry to significantly reduce the need for costly physical prototypes and physical tests in the development of high-technology products.

The Argonne Leadership Computing Facility (ALCF) operates a 10-pf IBM Blue Gene Q (Mira), developed through a joint research project with support from the NNSA, industry, and ASCR's Research and Evaluation Prototypes activity. This HPC system achieves high performance with relatively lower electrical power consumption than other current petascale computers.

The ALCF and OLCF systems are architecturally distinct, consistent with DOE's strategy to foster a diversity of capabilities that provides the Nation's HPC user community the most effective resources. ALCF supports many applications, including molecular dynamics and materials, for which it is better suited than OLCF or NERSC. Through INCITE, ALCF also transfers its expertise to industry, for example, helping engineers understand the fundamental physics of turbulent mixing to transform product design and to achieve improved performance, lifespan and efficiency.

The demand for 2014 INCITE allocations at the LCFs outpaced the available resources by a factor of three.

Research and Evaluation Prototypes

The next generation of computing hardware will present new challenges for science and engineering applications—most notably increased parallelism, energy efficiency, and reliability. This activity supports research and development partnerships with vendors to influence and accelerate critical technologies for next-generation systems, system integration research, and development and engineering efforts. These partnerships are coupled to application development to ensure Department applications are ready to make effective use of commercial offerings.

Research and Evaluation Prototypes (REP) initiated partnerships with key vendors to accelerate the R&D of critical technologies that advance the Department's exascale goals and reduce the economic and manufacturing barriers to their commercial production. This is an essential component in the Department's Exascale Computing Plan that has been developed during the previous three years. Recent REP efforts were focused on developing conceptual designs and investigating critical technologies. This allowed DOE researchers to work closely with the vendors to better understand requirements and capabilities of the emerging technology. The DOE mission applications, which will execute on exascale systems, force significant requirements on the system design. These requirements will result in systems that have performance and scalability characteristics that exceed those needed in the general commercial sector. Investment in early design and development will allow DOE to strongly influence the eventual products. These efforts will result in computers that will achieve the Department's exascale performance goals and, given current industry roadmaps, without this investment these goals will not be achieved. REP projects require the vendors to cost share at approximately 40% of the cost of each project. The full cost for industry to develop novel HPC systems is multiple billions of dollars per system.

In addition, this activity partners with the NNSA on the Computational Sciences Graduate Fellowship (CSGF) and to support research investments in non-recurring engineering, for near-term technology customization for the ASCR facilities.

High Performance Network Facilities and Testbeds

The Energy Sciences Network (ESnet) provides the national and international network and networking infrastructure connecting DOE science facilities, experiments, and SC laboratories with other institutions connected to peer academic or commercial networks. The costs for ESnet are dominated by operations, including maintaining the fiber optic backbone and refreshing switches and routers on the schedule needed to ensure the 99.999% reliability required for large-scale scientific data transmission. Additional funds are used to support the growth in science data traffic and for testing and evaluation of new 400 Gbps technologies and software-defined networking services that will be required to keep pace with the expected

[a] http://www.top500.org/lists/2014/11/

data volume. In FY14, ESnet achieved 75% completion of its European extension project. This project will increase transatlantic bandwidth available to DOE collaborations–including high-energy physics experiments at CERN–by a factor of ten.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
High Performance Computing and Network Facilities $364,330,000	**$441,824,000**	**+$77,494,000**
High Performance Production Computing ($75,605,000)	**($76,000,000)**	**(+$395,000)**
Funding continues to support operation of the NERSC high-end capability systems (NERSC-7) including power costs, lease payments, and user support and a post-doctoral training program for high-end computational science and engineering.	Will support installation, acceptance and operation of the NERSC high-end capability systems (NERSC-7 and NERSC-8) including increased power costs, lease payments, and user support and continuation of the post-doctoral training program for high-end computational science and engineering.	Additional funds will be provided to support operations of both NERSC-7 and NERSC-8 and to begin planning for NERSC-9 in the FY19-FY20 timeframe.
Leadership Computing Facilities ($184,637,000)	**($171,000,000)**	**(-$13,637,000)**
Funding continues to support operation and allocation, through INCITE and ALCC, of the 27 petaflop Titan system at the OLCF and 10 petaflop Mira system at the ALCF. This includes lease payments, power, and user support. Also supports preparations at the LCFs to support 75-200 petaflop upgrades at each facility and a post-doctoral training program for high-end computational science and engineering. Each LCF has achieved Critical Decision -2; established a project baseline and negotiated a contract with the selected vendor.	Will support operation and allocation of the 27 petaflop Titan system at the OLCF and 10 petaflop Mira system at the ALCF through INCITE and ALCC. This includes lease payments, power, and user support. Also supports preparations – such as power, cooling and cabling at the LCFs to support 75-200 petaflop upgrades at each facility and continuation of the post-doctoral training program for high-end computational science and engineering.	Funds continue to support the operation of current resources, preparing applications for the proposed upgrades, and the remaining site preparation work for the upgrade. The decrease in funding for both LCFs reflect that the majority of site preparation will be completed in FY 2015 and they are working with their selected vendor to finalize system specifications.
Leadership Computing Facility at ANL: $80,320,000	$77,000,000	-$3,320,000
Leadership Computing Facility at ORNL: $104,317,000	$94,000,000	-$10,317,000

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Research and Evaluation Prototypes ($57,329,000)	**($141,788,000)**	**(+$84,459,000)**
As follow-ons to the previous research efforts in critical technologies and system interconnect, REP will, in FY 2015, competitively select teams to develop system designs suitable for next-generation platforms. In addition, it will fund the development of prototypes based on the results from the *Fast Forward* program's investments in critical crosscutting technology research in areas such as processors, memory subsystems, network interfaces and the interconnection network. The Computational Science Graduate Fellowships is funded at $3,000,000.	REP has recently supported efforts to improve the energy efficiency and reliability of critical technologies such as memory, processors, network interfaces and interconnects. The compute node is the basic building block of a high performance computer and all of these technologies come together in the node. Therefore, REP will competitively select R&D partnerships with U.S. vendors to initiate the design and development of node and system designs suitable for exascale systems. These efforts will influence the development of prototypes that advance DOE goals and are based on the results of the *Fast Forward and Design Forward* investments. This is an essential component of the Department's exascale computing plan and a key step in the vendor's productization efforts. Support will also be provided for non-recurring engineering efforts in support of ASCR facilities. To emphasize the vital importance of the CSGF program to the ASCR facilities and to our exascale goals, Research and Evaluation Prototypes will support the program at $10,000,000 in FY 2016.	The increase supports the design and development of node and system prototypes. These efforts support the development of four exascale nodes and three system architecture teams. Multiple teams are necessary to adequately explore design options and to mitigate overall project risk. Overall industry investment in this area is significant, with billions of dollars in development costs for next generation HPC systems. To influence the trajectory of technology, the Department must partner early with U.S. vendors and support a significant share of these early design and development efforts. Increased funding is also provided for non-recurring engineering efforts. The Computational Science Graduate Fellowships increases from $3,000,000 to $10,000,000.
High Performance Network Facilities and Testbeds ($35,000,000)	**($38,000,000)**	**(+$3,000,000)**
ESnet operates the network infrastructure to support critical DOE science applications, SC facilities and scientific collaborations around the world through 100 Gbps production network and begin research on the 400 Gbps technologies.	ESnet will operate the national and international network infrastructure to support critical DOE science applications, SC facilities and scientific collaborations around the world through 100 Gbps production network and begin upgrade to 400 Gbps testbed for networking testing and research.	The requested increase supports the upgrade of the ESnet 100 Gbps testbed to 400 Gbps to allow researchers to identify technologies needed for production use to support increased data production at DOE scientific user facilities and experiments.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
SBIR/STTR ($11,759,000)	**($15,036,000)**	**(+$3,277,000)**
In FY 2015, SBIR/STTR funding is set at 3.3% of non-capital funding.	In FY 2016, SBIR/STTR funding is set at 3.45% of non-capital funding.	

Advanced Scientific Computing Research
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program. The following table shows the targets for FY 2014 through 2016.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**ASCR Facility Operations—Average achieved operation time of ASCR user facilities as a percentage of total scheduled annual operation time**		
Target	≥ 90%	≥ 90%	≥ 90%
Result	Met	TBD	TBD
Endpoint Target	Many of the research projects that are undertaken at the Office of Science's scientific user facilities take a great deal of time, money, and effort to prepare and regularly have a very short window of opportunity to run. If the facility is not operating as expected the experiment could be ruined or critically setback. In addition, taxpayers have invested millions or even hundreds of millions of dollars in these facilities. The greater the period of reliable operations, the greater the return on the taxpayers' investment.		
Performance Goal (Measure)	**ASCR Research—Discovery of new applied mathematics and computer science tools and methods that enable DOE applications to deliver scientific and engineering insights with a significantly higher degree of fidelity and predictive power**		
Target	Support at least two new teams to conduct fundamental computer science research and at least three applied mathematics research teams that address issues of fault tolerance or energy management for next-generation computing systems	Conduct an external peer review of the three original co-design centers to document progress, impact, and lessons learned.	Fund two teams to develop exascale node designs.
Result	Met	TBD	TBD
Endpoint Target	Develop and deploy high-performance computing hardware and software systems through exascale platforms.		

Advanced Scientific Computing Research
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Capital operating expenses							
Capital equipment	n/a	n/a	7,325	7,325	8,000	6,000	+2,000

Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	203,313	203,313	228,169	314,777	+86,608
Scientific user facility operations	260,159	260,159	295,242	285,000	-10,242
Other	14,621	0	17,589	21,217	+3,628
Total, Advanced Scientific Computing Research	**478,093**	**463,472**	**541,000**	**620,994**	**+79,994**

Advanced Scientific Computing Research
Scientific User Facility Operations ($K)

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

Definitions:

Achieved Operating Hours – The amount of time (in hours) the facility was available for users.

Planned Operating Hours –

- For Past Fiscal Year (PY), the amount of time (in hours) the facility was planned to be available for users.
- For Current Fiscal Year (CY), the amount of time (in hours) the facility is planned to be available for users.
- For the Budget Fiscal Year (BY), based on the proposed budget request the amount of time (in hours) the facility is anticipated to be available for users.

Optimal Hours – The amount of time (in hours) a facility would be available to satisfy the needs of the user community if unconstrained by funding levels.

Percent of Optimal Hours – An indication of utilization effectiveness in the context of available funding; it is not a direct indication of scientific or facility productivity.

- For BY and CY, Planned Operating Hours divided by Optimal Hours expressed as a percentage.
- For PY, Achieved Operating Hours divided by Optimal Hours.

Unscheduled Downtime Hours - The amount of time (in hours) the facility was unavailable to users due to unscheduled events. NOTE: For type "A" facilities, zero Unscheduled Downtime Hours indicates Achieved Operating Hours equals Planned Operating Hours.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
NERSC	**$67,105**	**$67,105**	**$75,605**	**76,000**	**+395**
Number of Users	5,608	5,608	5,608	5,608	0
Achieved operating hours	8,482	8,482	N/A	N/A	N/A
Planned operating hours	8,585	8,585	8,585	8,585	0
Optimal hours	8,585	8,585	8,585	8,585	0
Percent optimal hours	98.8%	98.8%	N/A	N/A	N/A
Unscheduled downtime hours	1.2%	1.2%	N/A	N/A	N/A

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
OLCF	**$93,000**	**$93,000**	**$104,317**	**$94,000**	**-10,317**
Number of Users	1,064	1,064	1,064	1,064	0
Achieved operating hours	6,637	6,637	N/A	N/A	N/A
Planned operating hours	7,008	7,008	7,008	7,008	0
Optimal hours	7,008	7,008	7,008	7,008	0
Percent optimal hours	94.7%	94.7%	N/A	N/A	N/A
Unscheduled downtime hours	5.3%	5.3%	N/A	N/A	N/A
ALCF	**$67,000**	**$67,000**	**$80,320**	**$77,000**	**-3,320**
Number of Users	1,434	1,434	1,434	1,434	0
Achieved operating hours	6,882	6,882	N/A	N/A	N/A
Planned operating hours	7,008	7,008	7,008	7,008	0
Optimal hours	7,008	7,008	7,008	7,008	0
Percent optimal hours	98.2%	98.2%	N/A	N/A	N/A
Unscheduled downtime hours	1.8%	1.8%	N/A	N/A	N/A
ESnet	**$33,054**	**$33,054**	**$35,000**	**$38,000**	**+3,000**
Number of users[a]	N/A	N/A	N/A	N/A	N/A
Achieved operating hours	8,760	8,760	N/A	N/A	N/A
Planned operating hours	8,760	8,760	8,760	8,760	0
Optimal hours	8,760	8,760	8,760	8,760	0
Percent optimal hours	100%	100%	N/A	N/A	N/A
Unscheduled downtime hours	0%	0%	N/A	N/A	N/A

[a] ESnet is a high performance scientific network connecting DOE facilities to researchers around the world; user statistics are not collected.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Total Facilities	**$260,159**	**$260,159**	**$295,242**	**$285,000**	**-10,242**
Number of Users[a]	8,106	8,106	8,106	8,106	0
Achieved operating hours	30,761	30,761	N/A	N/A	N/A
Planned operating hours	31,361	31,361	31,361	31,361	0
Optimal hours	31,361	31,361	31,361	31,361	0
Percent of optimal hours[b]	97.6%	97.6%	N/A	N/A	N/A
Unscheduled downtime hours	2.4%	2.4%	N/A	N/A	N/A

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Estimate	FY 2016 vs FY 2015
Number of permanent Ph.D.'s (FTEs)	520	520	548	584	+36
Number of postdoctoral associates (FTEs)	130	130	137	146	+9
Number of graduate students (FTEs)	400	400	428	460	+32
Other scientific employment (FTEs)[c]	220	220	234	247	+13

[a] Total users only for NERSC, OLCF, and ALCF.

[b] For total facilities only, this is a "funding weighted" calculation FOR ONLY TYPE A facilities: $\frac{\sum_1^n [(\%OH\ for\ facility\ n) \times (funding\ for\ facility\ n\ operations)]}{Total\ funding\ for\ all\ facility\ operations}$

[c] Includes technicians, engineers, computer professionals and other support staff.

Basic Energy Sciences

Overview

The mission of the Basic Energy Sciences (BES) program is to support fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels in order to provide the foundations for new energy technologies and to support DOE missions in energy, environment, and national security.

The research disciplines that BES supports—condensed matter and materials physics, chemistry, geosciences, and aspects of physical biosciences—are those that discover new materials and design new chemical processes that touch virtually every important aspect of energy resources, production, conversion, transmission, storage, efficiency, and waste mitigation. BES research provides a knowledge base to help understand, predict, and ultimately control the natural world and helps build the foundation to achieve the vision of a secure and sustainable energy future. BES also supports world-class, open-access scientific user facilities consisting of a complementary set of intense x-ray sources, neutron sources, and research centers for nanoscale science. BES facilities probe materials with ultrahigh spatial, temporal, and energy resolutions to investigate the critical functions of matter—transport, reactivity, fields, excitations, and motion—and answer some of the most challenging grand science questions. BES-supported activities are entering a new era in which materials can be built with atom-by-atom precision and computational models can predict the behavior of materials before they exist.

As history has shown, breakthroughs in clean energy technologies will likely be built on a foundation of basic research advances. Key to exploiting such discoveries is the ability to create new materials using sophisticated synthesis and processing techniques, precisely define the atomic arrangements in matter, and control physical and chemical transformations. The energy systems of the future—whether they tap sunlight, store electricity, or make fuel by splitting water or reducing carbon dioxide—will revolve around materials and chemical changes that convert energy from one form to another. Such materials will need to be more functional than today's energy materials. To control chemical reactions or to convert a solar photon to an electron requires coordination of multiple steps, each carried out by customized materials with designed nanoscale structures. Such advanced materials are not found in nature; they must be designed and fabricated to exacting standards using principles revealed by basic science.

Highlights of the FY 2016 Budget Request

The FY 2016 Request for BES will support ongoing core research activities at or above the FY 2015 level with few exceptions for transitioning programs. Funding for the Batteries and Energy Storage Energy Innovation Hub will continue as planned. The Fuels from Sunlight Energy Innovation Hub is undergoing a review for a possible renewal for a final term with a maximum duration of five years; a renewal decision will be made in January 2015. Additional funding is requested for the Energy Frontier Research Centers (EFRCs) to invest in strategic areas of basic energy sciences that are not represented or are underrepresented in the current EFRC portfolio. The EFRC program will transition to a biennial solicitation cycle starting in FY 2016. The Computational Materials Sciences activity supports the second year of research awards that will be issued in FY 2015, and funds are requested for underrepresented research topics in predictive design of functional materials. A new investment in midscale instrumentation is also requested to develop cutting-edge electron scattering tools to advance the forefront of ultrafast science.

In FY 2016, BES will support near optimal operations of five x-ray light source facilities, two neutron source facilities, and five Nanoscale Science Research Centers. FY 2016 will be the first full year of operations for the newly constructed National Synchrotron Light Source-II (NSLS-II). No funds are requested for the National Synchrotron Light Source. The Linac Coherent Light Source-II project will ramp up construction activities, reaching its peak year of funding in FY 2016. The Advanced Photon Source Upgrade and the NSLS-II Experimental Tools (NEXT) major item of equipment projects will be supported as planned. FY 2016 is the last year of funding for the NEXT project.

DOE's subsurface cross-program crosscut, SubTER, aims to address identified challenges in the subsurface through highly focused and coordinated research in Wellbore Integrity, Stress State and Induced Seismicity, Permeability Manipulation, and New Subsurface Signals to ensure enhanced energy security, material impact on climate change via CO_2 sequestration, and dramatically mitigated environmental impacts from energy-related activities and operations. The BES contribution to SubTER will focus on fundamental geochemistry and geophysics with an emphasis on subsurface chemistry and complex fluid flow.

Over 80 percent of our total energy supply comes from the subsurface, and this importance is magnified by the ability to also use the subsurface to store and sequester fluids and waste products. SubTER will address identified challenges in the subsurface through highly focused and coordinated research in Wellbore Integrity, Stress State and Induced Seismicity, Permeability Manipulation, and New Subsurface Signals to ensure enhanced energy security, material impact on climate change via CO2 sequestration, and significantly mitigated environmental impacts from energy-related activities and operations.

As part of the Exascale Crossscut, BES will be responsible for the Computational Materials Sciences activities that will support basic research resulting in computer codes to predictively design functional materials, including codes that take full advantage of the future generation of exascale leadership computing capabilities. The report from the foundational workshop for this activity, Computational Materials, Science and Chemistry identified a number of applications that would take full advantage of future computing resources, including: 1) new catalysts to improve the efficiency of industrial processes, make effective use of bioenergy, and drive energy conversion and environment mitigation processes; 2) developing better models of photovoltaic processes and improving the efficiency of photovoltaic devices; and 3) next generation electronic and magnetic materials whose properties are governed by the strong interactions of electrons and have totally new functionalities.

Exascale systems are needed to support areas of research that are critical to national security objectives as well as applied research advances in areas such as climate models, combustion systems, and nuclear reactor design that are not within the capacities of today's systems. Exascale systems' computational power are needed for increasing capable data-analytic and data-intense applications across the entire Federal complex. Exascale is a component of long-term collaboration between the SC's Advanced Scientific Computing Research (ASCR) program and the National Nuclear Security Administration's (NNSA) Advanced Simulation and Computing Campaign (ASC) program.

FY 2016 Crosscuts ($K)

	Subsurface Engineering	Exascale Computing	Total
Basic Energy Sciences	5,000	12,000	17,000

Basic Energy Sciences
Funding ($K)

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Materials Sciences and Engineering					
Scattering and Instrumentation Sciences Research	64,421	64,421	64,407	67,303	+2,896
Condensed Matter and Materials Physics Research	122,120	122,120	122,120	122,120	0
Materials Discovery, Design, and Synthesis Research	72,424	72,424	72,424	72,424	0
Experimental Program to Stimulate Competitive Research (EPSCoR)	9,953	9,953	9,951	8,520	-1,431
Energy Frontier Research Centers (EFRCs)	50,800	50,800	50,800	55,800	+5,000
Energy Innovation Hubs—Batteries and Energy Storage	24,237	24,237	24,175	24,137	-38
Computational Materials Sciences	0	0	8,000	12,000	+4,000
SBIR/STTR	11,594	0	12,008	12,946	+938
Total, Materials Sciences and Engineering	**355,549**	**343,955**	**363,885**	**375,250**	**+11,365**
Chemical Sciences, Geosciences, and Biosciences					
Fundamental Interactions Research	76,794	76,794	76,796	78,726	+1,930
Chemical Transformations Research	93,693	93,693	93,493	93,493	0
Photochemistry and Biochemistry Research	68,599	68,599	68,797	68,797	0
Energy Frontier Research Centers (EFRCs)	49,200	49,200	49,200	54,200	+5,000
Energy Innovation Hubs—Fuels from Sunlight	24,237	24,237	15,000	15,000	0
General Plant Projects (GPP)	600	600	600	600	0
SBIR/STTR	10,093	0	10,350	11,085	+735
Total, Chemical Sciences, Geosciences, and Biosciences	**323,216**	**313,123**	**314,236**	**321,901**	**+7,665**
Scientific User Facilities					
Synchrotron Radiation Light Sources	433,050	433,050	447,186	477,079	+29,893
High-Flux Neutron Sources	247,250	247,250	244,113	254,990	+10,877
Nanoscale Science Research Centers (NSRCs)	100,392	100,392	113,649	118,763	+5,114
Other Project Costs	37,400	37,400	9,300	0	-9,300
Major Items of Equipment	45,000	45,000	42,500	35,500	-7,000
Research	40,532	40,532	31,713	34,853	+3,140

[1] Funding reflects the transfer of SBIR/STTR to the Office of Science.

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
SBIR/STTR	27,540	0	27,918	30,664	+2,746
Total, Scientific User Facilities	**931,164**	**903,624**	**916,379**	**951,849**	**+35,470**
Subtotal, Basic Energy Sciences	**1,609,929**	**1,560,702**	**1,594,500**	**1,649,000**	**+54,500**
Construction					
Linac Coherent Light Source-II (LCLS-II), SLAC	75,700	75,700	138,700	200,300	+61,600
National Synchrotron Light Source-II (NSLS-II), BNL	26,300	26,300	0	0	0
Total, Construction	**102,000**	**102,000**	**138,700**	**200,300**	**+61,600**
Total, Basic Energy Sciences	**1,711,929**	**1,662,702**	**1,733,200**	**1,849,300**	**+116,100**

SBIR/STTR Funding:

- FY 2014 transferred: SBIR $43,074,000 and STTR $6,153,000 (transferred out of BES in FY 2014 Current column)
- FY 2015 projected: SBIR $44,182,000 and STTR $6,094,000
- FY 2016 Request: SBIR $47,561,000 and STTR $7,134,000

Basic Energy Sciences
Explanation of Major Changes ($K)

	FY 2016 vs. FY 2015
Materials Sciences and Engineering: Additional funds are requested for the Energy Frontier Research Centers to support new centers in strategic areas of material science research that are not represented or are underrepresented in the current EFRC portfolio. The Computational Materials Sciences activity will increase to support additional research that will enable predictive design of functional materials. The Scattering and Instrumentation Sciences Research will increase to support a new investment in midscale instrumentation in the area of ultrafast electron scattering in support of related core research activities.	+11,365
Chemical Sciences, Geosciences, and Biosciences: Additional funds are requested for the Energy Frontier Research Centers to support new centers in strategic areas of chemical science, geoscience, and bioscience research that are not represented or are underrepresented in the current EFRC portfolio. The Fuels from Sunlight Energy Innovation Hub is considered for renewal for one final 5-year term starting in September 2015. If the Hub is renewed its scope will be narrowed compared to the first five year period to focus on carbon dioxide reduction. The Fundamental Interactions Research activity will increase to support a new investment in midscale instrumentation in the area of ultrafast electron scattering in support of related core research activities.	+7,665
Scientific User Facilities: BES will support near optimal operations of five light sources, including the first full year of operations for the newly constructed National Synchrotron Light Source-II (NSLS-II), five Nanoscale Science Research Centers, and two neutron sources. No funds are requested for the National Synchrotron Light Source. Funding for the Advanced Photon Source Upgrade and NSLS-II Experimental Tools (NEXT) major item of equipment projects will continue per the project plans. FY 2016 is the last year of funding for the NEXT project. No funds are requested for Other Project Costs for the Linac Coherent Light Source-II (LCLS-II) construction project per the project plan.	+35,470
Construction: Funding for the LCLS-II construction project will increase per the project plan.	+61,600
Total, Basic Energy Sciences	**+116,100**

Basic and Applied R&D Coordination

As a fundamental research program within the Department of Energy, BES strives to build and maintain close connections with other DOE program offices. The Department facilitates coordination between DOE R&D programs through a variety of Departmental activities, including joint participation in research workshops, strategic planning activities, solicitation development, and program review meetings. For example, the DOE Hub Working Group meets regularly to coordinate programmatic oversight and promote commonality across the DOE Energy Innovation Hubs. BES also coordinates with DOE technology offices on the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program, including the topical area planning, solicitations, reviews, and award selections.

BES program managers regularly participate in intra-departmental meetings for information exchange and coordination on solicitations, program reviews, and project selections in the research areas of biofuels derived from biomass; solar energy utilization; building technologies, including solid-state lighting; advanced nuclear energy systems and advanced fuel cycle technologies; vehicle technologies; improving efficiencies in industrial processes; and superconductivity for grid applications. These activities facilitate cooperation and coordination between BES and the DOE technology offices and defense programs. DOE program managers have also established formal technical coordination working groups that meet on a regular basis to discuss R&D programs with wide applications for basic and applied programs including the Office of Environmental Management. Additionally, DOE technology office personnel participate in reviews of BES research, and BES personnel participate in reviews of research funded by the technology offices and ARPA-E.

Co-funding and co-siting of research by BES and DOE technology programs at the same institutions has proven to be a valuable approach to facilitate close integration of basic and applied research. In these cases, teams of researchers benefit by sharing expertise and knowledge of research breakthroughs and program needs. The Department's national laboratory system plays a particularly important role in achieving integration of basic and applied research.

Program Accomplishments

Advances in fundamental science for superior batteries. Through the use of sophisticated modeling and experiments, the basic processes that are foundational to the complex systems that comprise batteries are being unraveled to aid in the development of new, superior ways to store energy.

- Atomistic calculations allowed the tailored design of a new binder for lithium-sulfur batteries that resulted in record breaking performance in capacity and lifetime.
- Over 1,500 molecules have been calculated as part of the electrolyte genome with high-throughput, theoretical calculations; these data will be combined with calculations of additional properties, such as their ability to form a solution with metal ions, to select potential high-performance electrolytes for experimental evaluation.
- Analytical characterization of operating batteries demonstrated that the superior charge/discharge rate observed in lithium iron phosphate electrodes is related to the formation of a series of unexpected non-equilibrium compounds during the charge/discharge cycle, opening up the potential composition space for future cathode materials for lithium ion batteries.
- Nanoscale materials continue to provide avenues for improved batteries; highly porous and conductive multi-walled carbon nanotubes were shown to trap polysulfide species and prevent them from forming insoluble compounds, which limit the service life of lithium-sulfur batteries. Trapping the polysulfides would potentially eliminate a major cause for performance degradation.

Discovery of Novel Porous Materials. Metal-organic framework (MOF) and related materials are porous structures made up of metal atoms "linked" by rigid organic molecules. Basic research is expanding the potential uses of these versatile materials for gas separations, storage of carbon dioxide and natural gas, and electrical conductors for energy storage applications.

- Using theoretical calculations coupled with characterization with neutron scattering and controlled synthesis, the capture of carbon dioxide was found to increase with chemical tuning and removal of linkers from the molecular MOF framework, providing a new design strategy to optimize carbon dioxide storage and separation.
- MOFs are normally insulators, but by incorporating electrically active organic linkers, MOFs have been designed with electrical conductivities that rival state-of-the-art organic semiconductors currently used in organic photovoltaics. These new porous, conductors have potential uses in novel energy applications such as batteries, supercapacitors, and fuel cells.
- A flexible MOF cage structure was created with a specially designed flexible, organic linker molecule allowing contraction/expansion of the cage by up to 33%. The modified MOF can selectively bind multiple metal ions, a property that could be used for selective recovery of toxic and/or rare earth metal ions and in energy storage applications.

Fundamental Science Enables Advanced Engine and Fuel Modeling. Fundamental understanding of chemical reactivity enables validated theories, models and computational tools for predicting rates, products, and dynamics of the chemical processes underlying clean and efficient energy utilization by combustion devices.

- Scientists have produced, observed, and directly measured reaction kinetics of key intermediates (hydroperoxyalkyl radicals) for initiating the combustion process. Such measurements provided deep insights for predictive modeling of the chemistry of autoignition processes in engines.
- Quantum chemical calculations were used for the first time to obtain molecular reaction rates for surrogate biodiesel in combustion reactions. The results revealed that by including tunneling reactions in high-fidelity engine models, predicted engine performance was noticeably impacted. Such calculations significantly improve the fidelity of engine modeling and will assist in the design and optimization of compression-ignition engines.
- Scientists established a new, fundamental theory to predict and model combustion reactions at high pressures and temperatures typical of advanced internal combustion engines. In the new model, mixing is dominated by diffusion of the fuel in a supercritical state, where there is no liquid/gas phase boundary. Experimental evidence at actual operating pressures validates the new theory and further challenges the current classical view of spray atomization in typical diesel engines.

Atomic-Level Understanding Enables Catalysis by Design. Fundamental understanding of how atoms bind to surfaces and to molecular targets provides the ability to design ideal catalysts by computer, optimizing reaction efficiency and specificity, before synthesizing them in the laboratory.

- Single palladium atoms were demonstrated for the first time to convert the inert surface of copper into an ultraselective catalyst. Binding single metal atoms to a different metal allows for a general strategy to design novel bifunctional heterogeneous catalysts that can be fine-tuned for catalyst selectivity and activity.
- A layered structure of cobalt-molybdenum nitride was discovered to have unexpected catalytic activity and stability similar to that of platinum. The structural knowledge as revealed by x-ray and neutron scattering will aid in the computational search for novel inexpensive compounds with optimal hydrogen electrocatalytic production.
- Using “catalysis by design” principles, scientists predicted novel compositions of nickel-gallium catalysts that experimentally reduce carbon dioxide to methanol at ambient conditions with long-term stability and with higher activity and selectivity than industrial catalysts.

New devices advance the capabilities at the light source facilities. Researchers developed improved optics and new detectors to enhance data quality and enable new user experiments.

- At the Stanford Synchrotron Radiation Lightsource, researchers developed a new fabrication method to produce advanced x-ray diffractive nanostructured devices for high resolution, high efficiency manipulation of hard x-rays. At the Advanced Photon Source, scientists developed a new multilayer grating interferometer that was used to produce high x-ray phase-contrast images. These new optical devices have significantly enhanced the imaging quality at the BES light sources.

- A new tool developed for the Linac Coherent Light Source x-ray laser provides a powerful pulse-by-pulse diagnostic with femtosecond (one quadrillionth of a second) resolution. The new device pinpoints the duration of x-ray pulses to within a few femtoseconds, giving scientists a much more detailed view of the individual pulses that interact with their samples. For the first time scientists can directly measure the x-ray power profile on a shot-by-shot basis with femtosecond resolution, providing a noninvasive diagnostic tool for photon experiments and new insight into lasing dynamics.
- A prototype three-dimensional detector was successfully demonstrated that allowed x-ray data to be taken at the high frame rates needed to explore scientifically challenging problems such as x-ray time-correlation spectroscopy, which require time information on the microsecond scale or better. The breakthrough comprises a two-level microchip that provides twice the area per pixel and allows more on-detector processing than conventional detectors.

BES user facilities assist industry to advance the frontiers of science and technology. Researchers from industry use the unique capabilities at the BES scientific user facilities to develop new technologies and new drugs that impact lives.

- Partnering with a leading chip manufacturer, Molecular Foundry researchers developed a new type of extreme ultraviolet photoresist that can be used to manufacture 10 nanometer (nm) node electronic chips, providing a pathway to the next generation technology after the current 14 nm chips. The concept was validated via systematic chemical characterization and could be incorporated into manufacturing lines as early as 2017.
- BES x-ray light source facilities have helped advance the fundamental understanding of how diseases function and how to design drugs to treat them. Recently, scientists used structural information from the Advance Light Source to understand the binding mechanism of a unique antibody that targets multiple cancer types. This led to the development of a unique one-armed antibody that is now in late-stage clinical trials.
- Neutron imaging was used to measure the texture and integrity of internal surfaces of a turbine blade, while parallel residual stress measurements revealed the effects of local heating during the manufacturing process. Collectively, these experiments can help to improve the turbine blade design and enable low cost, energy efficient manufacturing.

Description

Materials are critical to nearly every aspect of energy generation and end-use. Materials limitations are often the barrier to improved energy efficiencies, longer lifetimes of infrastructure and devices, or the introduction of new energy technologies. The *Materials Sciences and Engineering* subprogram supports research to provide the understanding of materials synthesis, behavior, and performance that will enable solutions to these wide-ranging challenges as well as opening new directions that are not foreseen based on existing knowledge. The research explores the origin of macroscopic material behaviors; their fundamental connections to atomic, molecular, and electronic structures; and their evolution as materials move from nanoscale building blocks to mesoscale systems. At the core of the subprogram is experimental, computational, and tool development research that will enable the predictive design and discovery of new materials with novel structures, functions, and properties. Such understanding and control are critical to science-guided design of highly efficient energy conversion processes, such as the conversion of sunlight to electricity, new electromagnetic pathways for enhanced light emission in solid-state lighting, and multi-functional nanoporous and mesoporous structures for optimum ionic and electronic transport in batteries and fuel cells.

To accomplish these goals, the portfolio includes three integrated research activities:

- **Scattering and Instrumentation Sciences**—Advancing science using new tools and techniques to characterize materials structure across multiple length scales and materials dynamics across multiple time scales, and to correlate this data with materials performance under real world conditions.
- **Condensed Matter and Materials Physics**—Understanding the foundations of material functionality and behavior.
- **Materials Discovery, Design, and Synthesis**—Developing the knowledge base and synthesis strategies to design and precisely assemble structures in order to control materials properties, enabling discovery of new materials with unprecedented functionalities.

The portfolio emphasizes understanding of how to direct and control energy flow in materials systems over multiple time and length scales, with increasing emphasis on the mesoscale. The research will enable prediction of materials behavior, transformations, and processes in challenging real-world systems—for example, for materials with many atomic constituents, complex structures, and a broad range of defects that are exposed to extreme environments. To maintain leadership in materials discovery, the research explores new frontiers and unpredicted, emergent materials behavior in materials systems, utilization of nanoscale control, and systems that are metastable or far from equilibrium. Finally, the research includes investigation of the interfaces between physical and biological sciences to explore bio-mimetic and bio-inspired processes as new approaches to novel materials design. This subprogram is also the home of the DOE Experimental Program to Stimulate Competitive Research (EPSCoR) that supports research spanning the broad range of DOE's science and technology programs in states that have historically received relatively less Federal research funding in the university sector.

In addition to single-investigator and small-group research, the subprogram supports Energy Frontier Research Centers (EFRCs), the Batteries and Energy Storage Energy Innovation Hub, and Computational Materials Sciences activities. These research modalities support multi-investigator, multidisciplinary research and focus on forefront energy technology challenges. The EFRCs support teams of investigators to perform basic research to accelerate transformative solutions for a wide range of energy technologies. The Batteries and Energy Storage Hub supports a large, tightly integrated team and research that spans basic and applied regimes with the goal of providing the scientific understanding that will enable the next generation of electrochemical energy storage for vehicles and the electrical grid. The Computational Materials Sciences activity, initiated in FY 2015, supports integrated, multidisciplinary teams of theorists and experimentalists who focus on development of validated community codes for predictive design of functional materials. This activity will include new approaches to better use the large data sets derived from advanced characterization of materials synthesis, processing, and properties assessments and the parallel data generated by large scale computational efforts on theory and modeling of materials phenomena.

Scattering and Instrumentation Sciences Research

Advanced characterization tools with very high precision in space and time are essential to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels. These capabilities provide the foundation for research central to DOE missions in energy, environment, and national security. Research in Scattering and Instrumentation Science supports innovative science, techniques, and instrumentation for scattering, spectroscopy, and imaging using electrons, neutrons, and x-rays. These tools provide precise information on the atomic structure and dynamics in materials. DOE's longstanding investments in world-leading electron, neutron, and synchrotron x-ray scattering facilities and the large associated user communities are a testament to the importance of this activity to the DOE mission. Revolutionary advances in these techniques will enable transformational research on advanced materials to address energy challenges.

The unique interactions of electrons, neutrons and x-rays with matter enable a range of complementary tools with different sensitivities and resolution for the characterization of materials at length- and time-scales spanning several orders of magnitude. A distinct aspect of this activity is the development of innovative instrumentation concepts and techniques for neutron scattering and imaging needed to correlate the microscopic and macroscopic properties of energy materials. Characterization for mesoscale phenomena is a growing aspect of this research as is the use of combined scattering techniques to extract heretofore unattainable information on multiple length and time scales.

Recent advances in investigations of materials dynamics are providing a new window into material functions under real world conditions. Ultrafast electron scattering, including diffraction, imaging, and spectroscopy, offers a unique opportunity for understanding structural dynamics and the behavior of matter under conditions far away from equilibrium. Gaining knowledge of the dynamical behavior of materials systems requires characterization tools that can observe structural details in relevant space scales (micron to angstrom) and time scales (femtosecond to microsecond). A new investment in midscale instrumentation funding is requested to support instrumental solutions to enable the development of electron optics and sources, sample environments, and enhanced detectors, to revolutionize our ability to capture and characterize dynamic processes at sub-angstrom spatial resolution and nanosecond temporal resolution. Time-resolved electron probes are complementary to that of x-ray free electron lasers due to the difference in the nature of electron and x-ray scattering. Collectively, these tools provide deeper insight into the dynamic nature of emergent behavior in materials and chemical processes.

Condensed Matter and Materials Physics Research

Understanding the foundations of how to control and change the properties of materials is critical to improving their functionality on every level and is essential to fulfilling DOE's energy mission. The Condensed Matter and Materials Physics activity supports experimental and theoretical research to advance our current understanding of phenomena in condensed matter—solids with structures that vary in size from the nanoscale to the mesoscale, the materials that make-up the infrastructure for energy technologies, including electronic, magnetic, optical, thermal, and structural materials.

A central focus is research to characterize and understand materials whose properties are derived from the strong interactions of the electrons in their structure, such as superconductors and magnetic materials. An emphasis is placed on investigating low-dimensional systems, including nanostructures, and studies of the electronic properties of materials under extreme conditions such as ultra-low temperatures and extremely high magnetic fields. The research is relevant to energy technologies and advances the fundamental understanding of the elementary energy conversion steps related to photovoltaics and solid state lighting, the energetics of hydrogen storage, and electron spin-phenomena and basic semiconductor physics relevant to next generation information technologies and electronics. Fundamental studies of the quantum mechanical behavior of electrons in materials will lead to an improved understanding of electrical and thermal conduction in a wide range of material systems. There is a critical need to couple theories that describe properties at the atomic scale to properties at the macroscale where the influence of size, shape, and composition is not adequately understood. Theoretical research also includes development of computational and data-oriented techniques for materials discovery.

The activity also emphasizes understanding how materials respond to their environments, including temperature, electromagnetic fields, radiation, and chemical environments. This includes the defects in materials and their effects on materials' electronic properties, strength, structure, deformation, and failure over a wide range of length and time scales that will enable the design of materials with superior properties and resistance to change under the influence of radiation.

Materials Discovery, Design, and Synthesis Research

The discovery and development of new materials has long been recognized as the engine that drives science frontiers and technology innovations. Predictive design and discovery of new forms of matter with desired properties is still a significant challenge for materials sciences. A strong, vibrant research enterprise in the discovery of new materials is critical to world leadership—scientifically, technologically and economically. One of the goals of this activity is to grow and maintain U.S. leadership in materials discovery by investing in advanced synthesis capabilities and by coupling these with state-of-the-art user facilities and advanced computational capabilities at DOE national laboratories.

A key part of this portfolio is bio-mimetic and bio-inspired materials research—translating biological processes into impactful approaches to design and synthesize materials with the remarkable properties found in nature, e.g., self-repair and adaptability to the changing environment. Synthesis science and materials chemistry research underpin many energy-related technological areas such as batteries and fuel cells, catalysis and electrocatalysis, solar energy conversion and storage, friction and lubrication, and novel membranes and porous architectures for advanced separations, efficient ion transport, and highly selective gas separation and storage.

Major research directions include the controlled synthesis of nanoscale materials and their assembly into functional materials with desired properties; porous materials with tailored reactivities and porosities; mimicking the energy-efficient, low temperature synthesis approaches of biology to produce semiconductor and magnetic materials under mild conditions; bio-inspired materials that assemble autonomously and, in response to external stimuli, dynamically assemble and disassemble; and adaptive and resilient materials that also possess self-repairing capabilities. Synthesis science supports fundamental research in solid state chemistry to enable discovery of new functional materials and the development of new crystal growth methods and thin film deposition techniques to create complex materials with targeted structure and properties. An important element of this activity is the development of real-time monitoring tools, diagnostic techniques, and instrumentation that can provide information on the progression of structure and properties as a material is formed, in order to understand the underlying physical mechanisms and to gain atomic level control of material synthesis and processing.

Experimental Program to Stimulate Competitive Research (EPSCoR)

DOE's Experimental Program to Stimulate Competitive Research (EPSCoR) is a Federal-State partnership program designed to enhance the capabilities and research infrastructure of designated states and territories to conduct sustainable and nationally competitive research. This activity supports basic research spanning the broad range of science and technology related to DOE mission areas in states and territories that have historically received relatively less Federal research funding than other states. EPSCoR supports research in these states that will develop their scientific capabilities and advance their ability to successfully compete for research funding through open research solicitations. The EPSCoR program supports materials sciences, chemical sciences, physics, energy-relevant biological sciences, geological and environmental sciences, high energy physics, nuclear physics, fusion energy sciences, advanced computing, and the basic sciences underpinning fossil energy, electricity delivery and reliability, nuclear energy, and energy efficiency and renewable energy.

EPSCoR promotes strong research collaboration between scientists/engineers in the designated states/territories and the world-class national laboratories, leveraging national user facilities and taking advantage of opportunities for intellectual collaboration across the DOE system. DOE EPSCoR supports Implementation Grants (large grants that promote development of infrastructure and research teams) and State-Laboratory partnership grants (individual university-based principal investigators teaming with national laboratories). EPSCoR also supports early career researchers in the designated states and territories. EPSCoR is science-driven and supports the most meritorious proposals based on peer review and programmatic priorities.

Energy Frontier Research Centers (EFRCs)

The EFRC program, initiated in FY 2009, is a unique research modality, bringing together the skills and talents of teams of investigators to perform energy-relevant, basic research with a scope and complexity beyond that possible in standard single-investigator or small-group awards. These multi-investigator, multi-disciplinary centers foster, encourage, and accelerate basic research to provide the basis for transformative energy technologies. The EFRCs are funded on a continuing basis through annual appropriations through this subprogram and the Chemical Sciences, Geosciences, and Biosciences subprogram. The EFRCs supported in this subprogram are focused on: the design, discovery, synthesis, and characterization of novel, solid-state materials that improve the conversion of solar energy and heat into electricity and that enhance the conversion of electricity to light; the development of the understanding of materials and processes required to enable improved electrical energy storage, efficient separation of gases for carbon capture, and control of defect evolution in radiation environments; and the exploration of phenomena such as superconductivity and spintronics that can optimize energy flow and boost the efficiency of energy transmission. After five years of research activity, the original cohort of 46 EFRCs produced an impressive breadth of accomplishments, including over 5,950 peer-reviewed journal papers, over 275 patent applications and an additional 100 patent/invention disclosures.

BES's active management of the EFRCs continues to be an important feature of the program. A variety of methods are used to regularly assess the progress of the EFRCs, including annual progress reports, monthly phone calls with the EFRC Directors, periodic Directors' meetings, and on-site visits by program managers. BES also conducts in-person reviews by outside experts. Each EFRC undergoes a review of its management structure and approach in the first year of the award and a midterm assessment of scientific program and progress compared to its scientific goals. To facilitate communication of results to other EFRCs and interactions with DOE technology programs, meetings of the EFRC principal investigators are held on an approximately biennial frequency.

An open recompetition of the EFRC program took place in FY 2014, culminating in the selection of 10 new and 22 renewed EFRCs, based on peer review by external experts. These 32 EFRCs continue to emphasize both grand challenge science and energy use-inspired research. Compared to the original 46 awards, which were 5 year awards, these EFRCs are 4-year awards with funding for the final two years contingent upon successful outcome of a mid-term review. The request for new funding in FY 2016 and the potential recovery of funds from terminations of poorly performing activities after the mid-term review will allow for a new focused EFRC solicitation in FY 2016.

Energy Innovation Hubs—Batteries and Energy Storage

Advanced energy storage solutions have become increasingly critical to the Nation with the expanded deployment of renewable energy sources coupled with growth in the numbers of hybrid and electric vehicles. For the electric grid, new approaches to electrochemical energy storage can provide enhanced grid stability and enable intermittent renewable energy sources to meet continuous electricity demand. For vehicles, new batteries with improved lifetimes, safety, and storage capacity are needed to expand the range of electric vehicles from a single charge while simultaneously decreasing the volume, manufacturing cost and weight. Today's electrical energy storage approaches suffer from limited energy and power capacities, lower-than-desired rates of charge and discharge, life-cycle limitations, low abuse tolerance, high cost, and decreased performance at high or low temperatures.

The Batteries and Energy Storage Hub, established in December 2012, focuses on understanding the fundamental performance limitations for electrochemical energy storage to launch the next generation, beyond lithium-ion energy storage technologies relevant to both the electric grid and transportation. The Hub, the Joint Center for Energy Storage Research (JCESR), is led by Argonne National Laboratory joined by four other national laboratories, five universities, and four industrial partners. JCESR's core task is basic research—using a new generation of nanoscience tools that enable observation, characterization, and control of matter down to the atomic and molecular scales to understand materials and chemical processes that are at the core of battery performance. The participation of industrial partners will facilitate efforts to ensure that the outcome of basic research leads toward practical solutions that are competitive in the marketplace.

JCESR focuses on systems beyond lithium-ion and discovery of new energy storage chemistries through the development of an atomic-level understanding of reaction pathways and development of universal design rules for electrolyte function. The overarching goals driving the scientific and engineering research towards next-generation energy storage technologies are summarized by JCESR as 5/5/5—five times the energy density of current systems at one-fifth the cost within five years, the award period for the Hub. As part of their internal evaluation of progress and potential for each research direction to meet the Hub goals, in consultation with BES, JCESR has made shifts in the research thrusts to maximize the impact of resources used in pursuit of these goals. JCESR will also deliver two additional legacies to the broader energy storage community:

creation of a library of fundamental scientific knowledge of the phenomena and materials of energy storage at the atomic and molecular level and demonstration of a new paradigm for battery R&D—integrating discovery science, battery design and computation, and research prototyping in a single highly interactive organization. Success in achieving these legacies will be measured by the rate, quality, and impact of JCESR's scientific publications, patents, and interactions across its discovery science, battery design and computation, and research prototyping functions. Progress against milestones is evaluated by quarterly/annual reports and annual performance reviews by external panels of science and management experts to verify and validate performance. JCESR underwent a management and early operations review in October 2013, and a science-focused review in July 2014. In both cases the review panels provided positive input and recommendations for furthering the JCESR research goals. BES continues to monitor progress closely.

Computational Materials Sciences

Recent major strides in materials synthesis, processing, and characterization, combined with concurrent advances in computational science—enabled by improvements in high performance computing capabilities—have opened an unprecedented opportunity to design new materials with specific function and properties. The opportunity is to leap beyond simple extensions of current theory and models of materials towards a paradigm shift in which specialized computational codes and software enable the design, discovery, and development of new materials, and in turn, create new advanced, innovative technologies. Given the importance of materials to virtually all technologies, computational materials sciences is a critical area in which the United States needs to be competitive.

If successful, this paradigm shift would significantly accelerate the design of revolutionary materials to meet the Nation's energy goals and enhance economic competitiveness. Development of fundamentally new design principles could enable stand-alone research codes and software packages to address multiple length and time scales for prediction of the total functionality of materials over a lifetime of use. Scientific workshops and National Research Council studies have identified enticing scientific challenges that would advance these goals.[a] Examples include dynamics and strongly correlated matter, conversion of solar energy to electricity, design of new catalysts for a wide range of industrial uses, and transport in materials for improved electronics. Success will require extensive research and development with the goal of creating experimentally validated, robust community codes that will enable functional materials innovation.

Research and development to create the computational codes requires a fully integrated team approach, combining the skills of experts in materials theory, modeling, computation, synthesis, characterization, and processing/fabrication. The range of the research includes development of new ab initio theory, mining the data from both experimental and theoretical databases, performing advanced in situ/in operando characterization to generate the specific parameters needed for computational models, and well controlled synthesis to confirm the predictions of the codes. Many of the underlying phenomena require understanding the material dynamics at ultrafast time scales and with near atomic resolution—requiring effective use of the unique world leading tools and instruments at DOE's user facilities, from ultrafast free electron lasers to aberration corrected electron microscopes to the best tools for atomically controlled synthesis. This is also an important topic for U.S. international scientific competitiveness as many of the codes currently used for materials research and engineering were developed outside of the U.S.

To facilitate U.S. leadership in this competitive field, FY 2016 funding will continue support of teams of scientists and engineers who received multi-year awards in FY 2015 to perform the basic research and develop/deliver codes and associated experimental/computational data for the design of functional materials. Additional FY 2016 funding is requested to support research for functional material topics not supported in FY 2015. Each research team will focus on a different area of functional materials. BES management and coordination among the teams would further leverage activities and accelerate key foundational research. An ideal end product for this research is open source, robust, validated, user friendly software that captures the essential physics and chemistry of relevant systems and can be used by the broader research community and by industry to dramatically accelerate the design of new functional materials. Following the effective management approach employed with other large team research activities, BES will actively manage the project through

[a] U.S. DOE. *Computational Materials Science and Chemistry for Innovation*. U.S. Department of Energy Office of Science, 2010. National Research Council. Integrated Computational Materials Engineering: A Transformational Discipline for Improved Competitiveness and National Security. Washington, DC: The National Academies Press, 2008.

annual peer reviews to assess progress towards planned scientific goals. Early in the award period, each funded research team will be reviewed, with a focus on management and early research activities.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Materials Sciences and Engineering $363,885,000	**$375,250,000**	**+$11,365,000**
Scattering and Instrumentation Sciences Research ($64,407,000)	**($67,303,000)**	**(+$2,896,000)**
Time domain, energy spectroscopy, and *in situ* instrumentation continues to improve, allowing advanced investigations of excitation and transport with high spatial resolution across relevant length scales for energy systems. Integration of multiple sources and detection schemes is emphasized to provide more complete assessment of spatial structures and excitation levels with high time resolution. Quantitative pictures of complex materials as they evolve in time under realistic environmental boundary conditions will validate theory and increase phenomenological understanding. Spatial resolution will span atoms to microstructure, including the mesoscale. Time scales to be investigated involve electronic motion in the ultra-fast regime, cooperative modes at atomic vibration and diffusion time scales, and degradation time scales across mesoscale structures.	Ultrafast science will continue to be a priority research area. Midscale instrumentation will support development of electron optics and sources, sample environments, and enhanced detectors to revolutionize our ability to capture and characterize dynamic processes at sub-angstrom spatial resolution and nanosecond temporal resolution. For x-rays, vacuum ultraviolet, and other lower frequency sources however, future investments will emphasize hypothesis-driven research with existing ultrafast science capabilities to establish a more complete understanding of materials properties and behaviors. Neutron scattering sciences will stress innovative time-of-flight scattering and imaging and their effective use in transformational research. New advances in spectroscopy, high-resolution analyses of energy-relevant soft matter, and quantitative *in situ* analysis capabilities under perturbing parameters such as temperature, stress, chemical environment, and magnetic and electric fields will be pursued.	Increased funding will be used to support midscale instrumentation related to ultrafast electron diffraction. For the balance of the research program, areas of increased emphasis involve hypothesis-driven ultrafast science and time-resolved imaging and energy excitation spectroscopy with high spatial resolution. A strong focus will be directed towards understanding scientific phenomena on real systems under realistic operating conditions. Research with traditional microscopy and x-ray techniques will be deemphasized.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Condensed Matter and Materials Physics Research ($122,120,000)	**($122,120,000)**	**($0)**
Research continues to support experimental and theoretical materials research emphasizing correlation effects, including phenomena observed in topological surface states. The program emphasizes the development of understanding of matter at atomistic length scales expanding to include properties at the mesoscale. This includes research on cold atom clusters to determine if these systems can provide new insights into the evolution of condensed matter behavior from atomic constituents. The program supports research on phenomena that occur as a consequence of interfaces and reduced dimensionality. Research continues to include assessments of the phenomena related to the structural, optical, and electrical properties of materials; and the control of material functionality in response to external stimuli including temperature, pressure, magnetic and electric fields, and radiation. The program continues to grow research on new theoretical tools and validated software for materials discovery. The research continues to advance fundamental understanding of defects to extend the lifetime and enhance performance of materials in energy generation and energy end-use applications.	The program will continue to support fundamental experimental and theoretical research on the properties of materials. It will focus on structural, optical, and electrical properties and control of material functionality in response to external stimuli including temperature, pressure, magnetic and electric fields, and radiation. Phenomena in materials will be investigated from atomistic through nanoscale to mesoscale length scales. The research supported will continue to address defect structures in materials and how these influence materials properties, especially in energy relevant materials. There is an ongoing emphasis on understanding the relationship between electronic structure and properties in materials that exhibit correlation effects. Research on spin physics, focusing on coupling across heterogeneous boundaries through spin orbit and exchange interactions and studies involving novel magneto-dynamics, will be continued. Research involving theory and computational data coupled to experimental characterization of material properties will continue to grow.	Research support is level compared to FY 2015. The FY 2016 program will enhance research understanding of matter at atomistic length scales expanding to include properties at the mesoscale. Research on granular materials, conventional superconductivity, high strain rate, high dose radiation effects, and cold atom physics will be de-emphasized.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Materials Discovery, Design, and Synthesis Research ($72,424,000)	**($72,424,000)**	**($0)**
Research continues to focus on the predictive design and synthesis of materials across multiple length scales, with a particular emphasis on the mesoscale. This will be enabled by more effective coupling of computational tools to experimental research on biology-inspired, physical, and chemical synthesis and processing techniques. Synthesis pathways may be better understood and precisely controlled by use of in situ diagnostic tools and characterization techniques, developed in the laboratory and at BES user facilities. This will create viable approaches for atom- and energy-efficient syntheses of new forms of matter with tailored properties. A key challenge will be to realize the complexity and functionality of biological systems, but with the use of inorganic earth-abundant materials. Research on novel materials for gas separations and storage will continue to take advantage of novel chemistries and concepts, including those inspired by biology.	Research on the predictive design and synthesis of materials across multiple length scales will continue with a particular emphasis on the mesoscale, where functionalities begin to emerge. Within this framework, a fundamental understanding of assembly, both self and directed, and interfacial phenomena, ubiquitous in all materials, will be developed. Additionally, synthesis pathways will be better understood by use of *in situ* diagnostics and characterization so that they can be controlled more precisely and dynamically. This research will help realize the visionary goals of atom- and energy-efficient syntheses of new forms of matter. Research on recent energy materials on the scene, such as perovskite photovoltaic materials and those with 2D topologies, will be strengthened to take advantage of the opportunities to realize a more thorough understanding and their potential for bringing about transformational advances in energy and information technologies.	Research support is level compared to FY 2015. The program will explore a new direction-dissipative assembly of active matter, i.e., material systems capable of transducing, storing and/or harvesting energy, emulating those found in nature. This will entail experimental materials synthesis research to be integrated even more closely with computational tools and resources. Research on developing synthesis methods for nanomaterials, e.g., nanoparticles, nanorods, etc. will be deemphasized.
Experimental Program to Stimulate Competitive Research (EPSCoR) ($9,951,000)	**($8,520,000)**	**(-$1,431,000)**
Research strengthens capabilities to advance DOE mission needs across energy science and technology in the EPSCoR states. Implementation grant and investment in early career research staff from EPSCoR states are sustained.	Efforts will continue to span science in support of the DOE mission, with continued emphasis on science that underpins DOE energy technology programs. Implementation grant, state-laboratory partnerships, and investment in early career research staff from EPSCoR states will be sustained.	The request is lower than the FY 2015 appropriation. The additional funding provided in FY 2015 is being used to minimize outyear mortgages for implementation grants.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Energy Frontier Research Centers (EFRCs) ($50,800,000)	**($55,800,000)**	**(+$5,000,000)**
The EFRCs that were started in FY 2014 are performing the first year of research of the award period as outlined in their proposals. This multidisciplinary research continues to provide accelerated progress in fundamental, energy-use inspired research. The research in these new EFRCs includes investigations of mesoscale science and utilization of computational research to predictably design new materials and processes. BES will hold a peer review to assess management and early operations.	The EFRCs will continue to perform fundamental multi-disciplinary research aimed at accelerating scientific innovation. All EFRCs will undergo a mid-term review in FY 2016 to assess progress toward meeting scientific research goals. DOE will issue a Funding Opportunity Announcement for up to five new EFRC awards in FY 2016.	The total BES EFRC program is increased by $10,000,000 compared to FY 2015, which is split equally between Materials Sciences and Engineering and Chemical Sciences, Geosciences, and Biosciences. New EFRCs funded through this subprogram will focus on strategic areas of material science research that are not represented or are underrepresented in the current EFRC portfolio.
Energy Innovation Hubs—Batteries and Energy Storage ($24,175,000)	**($24,137,000)**	**(-$38,000)**
Research continues to follow the established project plan for thrusts on multivalent intercalation, chemical transformations, and non-aqueous redox flow, as well as cross-cutting research on materials characterization, theory, and modeling. Systems analysis and translation activities include techno-economic modeling, cell design, and preliminary prototype development. Research includes a focus on the electrolyte genome, demonstrating the utility of this computational framework for designing new electrolytes using structure-chemical trends extracted from >10,000 first-principles calculated molecular motifs, modifications and mutations.	The Hub, in its fourth year, will continue to follow its project plan with an increasing focus on developing lab-scale prototypes to supplement the ongoing fundamental research science underpinning batteries for transportation and the grid, as well as cross-cutting research on materials characterization, theory, and modeling. JCESR will complete self-consistent system analyses using techno-economic modeling of three electrochemical couples identified through materials discovery, including output from the electrolyte genome, that have the potential to meet technical performance and cost criteria.	The funding is approximately level compared to FY 2015, following the planned funding profile.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Computational Materials Sciences ($8,000,000)	**($12,000,000)**	**(+$4,000,000)**
Coupling today's computational capabilities with world leading experimental instrumentation, the Computational Materials Sciences activity enhances U.S. leadership in the development of experimentally validated, robust computational codes that will enable materials discovery and innovation to meet the Nation's energy goals and enhance economic competitiveness. Funding supports up to four large teams of experts in materials theory, modeling, computation, synthesis, characterization, and processing/fabrication to perform the basic research required to develop and deliver research-oriented software and associated databases for predictive design of functional materials. In FY 2015, a competitive, peer review process will select the best research proposals, with each of the selected proposal teams focused on a different type of functional material. FY 2015 funding supports the first year of multi-year awards.	Computational Materials Sciences will advance U.S. leadership in the development of computational codes for materials sciences and engineering. The research activities involve teams of theorists, computational experts, and experimentalists with expertise in synthesis, characterization, and processing/fabrication of materials. The computational materials sciences teams that will start in FY 2015 will perform the first year of research as outlined in their proposals. This research will focus on basic science necessary to develop research-oriented, open-source, experimentally validated software and the associated databases required to predictively design materials with specific functionality. Funding will support additional multi-year awards for research teams focused on functional materials topics not supported by the FY 2015 awards. Early in the award period, each team will be peer reviewed to assess management and early research activities.	In addition to supporting the ongoing research for the FY 2015 awards, the FY 2016 request will broaden the technical breadth of the research to include new awards to teams focused on additional types of materials functionality.

Description

The transformation of energy between types (optical, electrical, chemical, heat, etc.) and the rearrangement of matter at the atomic, molecular, and nano-scales are critically important in every energy technology. The *Chemical Sciences, Geosciences, and Biosciences* subprogram supports research that explores fundamental aspects of chemical reactivity and energy transduction in order to develop a broad spectrum of new chemical processes, such as catalysis, that can contribute significantly to the advancement of new energy technologies. Research addresses the challenge of understanding physical and chemical phenomena over a tremendous range of spatial and temporal scales, from molecular through nanoscale and on to mesoscale, and at multiple levels of complexity, including the transition from quantum to classical behavior.

At the heart of this research lies the quest to understand and control chemical processes and the transformation of energy at the molecular scale in systems spanning simple atoms and molecules, active catalysts, and larger biochemical or geochemical systems. At the most fundamental level, the development and understanding of the quantum mechanical behavior of electrons, atoms, and molecules is rapidly evolving into the ability to control and direct such behavior to achieve desired results in meso- and macro-scale energy conversion systems.

This subprogram seeks to extend this new era of control science to include the capability to tailor chemical transformations with atomic and molecular precision. Here, the challenge is to achieve fully predictive assembly and manipulation of larger, more complex chemical, geochemical, and biochemical systems at the same level of detail now known for simple molecular systems.

To address these challenges, the portfolio includes coordinated research activities in three areas:

- **Fundamental Interactions**—Structural and dynamical studies of atoms, molecules, and nanostructures with the aim of providing a complete understanding of atomic and molecular interactions in the gas phase, condensed phase, and at interfaces.
- **Chemical Transformations**—Design, synthesis, characterization, and optimization of chemical processes that underpin advanced energy technologies, including catalytic production of fuels, nuclear energy, and geological sequestration of carbon dioxide.
- **Photochemistry and Biochemistry**—Research on the molecular mechanisms involved in the capture of light energy and its conversion into chemical and electrical energy through biological and chemical pathways.

The portfolio of this subprogram includes several unique efforts that enable these overall research themes. Novel sources of photons, electrons, and ions are developed to probe and control atomic, molecular, nanoscale, and mesoscale matter, particularly ultrafast optical and x-ray techniques to study and direct molecular, dynamics, and chemical reactions. This subprogram supports the nation's largest Federal effort in catalysis science for the design of new catalytic methods and materials for the clean and efficient production of fuels and chemicals. It also contains a unique effort in the fundamental chemistry of the heavy elements, with complementary research on chemical separations and analysis. Research in geosciences emphasizes analytical and physical geochemistry, rock-fluid interactions, and flow/transport phenomena that are critical to a scientific understanding of carbon sequestration. Natural photosynthetic systems are studied to create robust artificial and bio-hybrid systems that exhibit the biological traits of self-assembly, regulation, and self-repair. Complementary research on artificial systems includes organic and inorganic photochemistry, photo-induced electron and energy transfer, photo electrochemistry, and molecular assemblies for artificial photosynthesis.

In addition to single-investigator and small-group research, the subprogram supports EFRCs and the Fuels from Sunlight Energy Innovation Hub. These research modalities support multi-investigator, multidisciplinary research and focus on forefront energy technology challenges. The Hub supports a large, tightly integrated team and research that spans basic and applied regimes with the goal of providing the scientific understanding that will enable the next generation of technologies for the direct conversion of sunlight to chemical fuels.

Fundamental Interactions Research

This activity builds the fundamental science basis essential for technological advances in a diverse range of energy processes. Research encompasses structural and dynamical studies of atoms, molecules, and nanostructures, and the description of their interactions in full quantum detail. The ultimate objective, often gained through studies of model systems, is a complete understanding of reactive chemistry in the gas phase, condensed phase, and at interfaces. This activity also supports development of novel experimental and theoretical tools. New sources of photons, electrons, and ions are used to probe and control atomic, molecular, nanoscale, and mesoscale matter and processes on ultrafast time scales. New algorithms for computational chemistry are developed and applied in close coordination with experiment. Areas of emphasis are use-inspired, with relevance, for example, to combustion and catalysis, but the knowledge and techniques produced by this activity form a science base to underpin numerous aspects of the DOE mission.

The principal research thrusts are in atomic, molecular, and optical (AMO) sciences and chemical physics. AMO research emphasizes the interactions of atoms, molecules, and nanostructures with photons, particularly those from BES light sources, to characterize and control their behavior. AMO research examines energy transfer within isolated molecules that provides the foundation for understanding the making and breaking of chemical bonds. The FY 2016 request includes support for a new investment in midscale instrumentation to support development of ultrafast electron scattering probes. This activity will focus on achieving time-resolved mapping of structural molecular changes during chemical reactions. In time-resolved electron diffraction, very short electron pulses are applied to monitor chemical transformations in real time. The technique has been demonstrated for simple reactions in the condensed phase, but the challenge is even greater for reactions in the gas phase. Developments are underway that allow the pinning of gas molecules using laser pulses but have only been demonstrated for simple molecules. The development of innovative instrumentation for ultrafast electron scattering will help address these challenges. Time-resolved electron probes are complementary to that of x-ray free electron lasers due to the difference in the nature of electron and x-ray scattering. Collectively, these tools provide deeper insight into the dynamic nature of emergent behavior in materials and chemical processes.

Chemical physics research builds from the AMO research foundation by examining reactive chemistry of molecules that are not isolated, but whose chemistry is profoundly affected by the environment. It explores the transition from molecular-scale chemistry to collective phenomena in complex systems, such as the effects of solvation or interfaces on chemical structure and reactivity. This transition is often accompanied by a parallel transition from quantum mechanical behavior to classical or continuum behavior. Understanding such collective behavior is critical in a wide range of energy and environmental applications, from solar energy conversion to improved methods for handling radiolytic effects in context of advanced nuclear fuel or waste remediation. Gas-phase chemical physics emphasizes the incredibly rich chemistry of combustion—burning diesel fuel involves thousands of chemical reactions and hundreds of distinct species. Combustion simulation and diagnostic studies address the subtle interplay between combustion chemistry and the turbulent flow that characterizes all real combustion devices. This activity includes support for the Combustion Research Facility, a multi-investigator research laboratory at the Sandia National Laboratories campus in Livermore, California, for the study of combustion science.

Chemical Transformations Research

Chemical Transformation Research emphasizes the design, synthesis, characterization, and optimization of chemical processes that underpin advanced energy technologies including the catalytic production of fuels, the chemistry of actinides important to nuclear energy, and geological sequestration of carbon dioxide. A tremendous breadth of novel chemistry is covered: inorganic, organic, and hybrid molecular complexes; nanostructured surfaces; electrochemistry; nanoscale membranes; bio-inspired chemistry; and analytical and physical geochemistry. This activity develops unique tools for chemical analysis, using laser-based and ionization techniques for molecular detection, with an emphasis on imaging chemically distinct species.

This activity has a leadership role in the application of basic science to unravel the principles that define how catalysts work—how they accelerate and direct chemistry. Such knowledge enables the rational synthesis of novel catalysts, designed at the nanoscale but operating at the mesoscale, which will lead to increased energy efficiency and chemical selectivity. Because so many processes for the production of fuels and chemicals rely on catalysts, improving catalytic efficiency and selectivity has enormous economic and energy consequences. Advanced gas separation schemes for the removal of carbon dioxide from post-combustion streams are explored—these are essential to making carbon capture an economic reality.

Fundamental studies of the structure and reactivity of actinide-containing molecules provides the basis for their potential use in advanced nuclear energy systems. Geosciences research emphasizes a greater understanding of the consequences of deliberate storage, or accidental discharges, of energy related products (carbon dioxide or waste effluents), which require ever more refined knowledge of how such species react and move in the subsurface environment.

Photochemistry and Biochemistry Research

This activity supports research on the molecular mechanisms that capture light energy and convert it into electrical and chemical energy in both natural and man-made systems. The work is of critical importance for the effective use of our most abundant and durable energy source—the sun.

Natural photosynthesis is studied to provide roadmaps for the creation of robust artificial and bio-hybrid systems that exhibit the biological traits of self-assembly, regulation, and self-repair and that span from the atomic scale through the mesoscale. Physical science tools are extensively used to elucidate the molecular and chemical mechanisms of biological energy transduction, including processes beyond primary photosynthesis such as carbon dioxide reduction and subsequent deposition of the reduced carbon into energy-dense carbohydrates and lipids. Complementary research on artificial systems encompasses organic and inorganic photochemistry, light-driven energy and electron transfer processes, as well as photo-electrochemical mechanisms and molecular assemblies for artificial photosynthetic fuel production.

Energy Frontier Research Centers (EFRCs)

The EFRC program, initiated in FY 2009, is a unique research modality, bringing together the skills and talents of teams of investigators to perform energy-relevant, basic research with a scope and complexity beyond that possible in standard single-investigator or small-group awards. These multi-investigator, multi-disciplinary centers foster, encourage, and accelerate basic research to provide the basis for transformative energy technologies. The EFRCs are funded on a continuing basis through annual appropriations through this subprogram and the Materials Sciences and Engineering subprogram. The EFRCs supported in this subprogram are focused on the following topics: the design, discovery, control, and characterization of the chemical, biochemical, and geological moieties and processes for the advanced conversion of solar energy into chemical fuels; for improved electrochemical storage of energy; for the creation of next-generation biofuels via catalytic chemistry and biochemistry; and for science-based carbon capture and geological sequestration. After five years of research activity, the original cohort of 46 EFRCs produced an impressive breadth of accomplishments, including over 5,950 peer-reviewed journal papers, over 275 patent applications, and an additional 100 patent/invention disclosures.

BES's active management of the EFRCs continues to be an important feature of the program. A variety of methods are used to regularly assess the progress of the EFRCs, including annual progress reports, monthly phone calls with the EFRC Directors, periodic Directors' meetings, and on-site visits by program managers. BES also conducts in-person reviews by outside experts. Each EFRC undergoes a review of its management structure and approach in the first year of the award and a midterm assessment of scientific program and progress compared to its scientific goals. To facilitate communication of results to other EFRCs and interactions with DOE technology programs, meetings of the EFRC principal investigators are held on an approximately biennial frequency.

An open recompetition of the EFRC program took place in FY 2014, culminating in the selection of 10 new and 22 renewed EFRCs, based on peer review by external experts. These 32 EFRCs continue to emphasize both grand challenge science and energy use-inspired research. Compared to the original 46 awards, which were 5-year awards, these EFRCs are 4-year awards with funding for the final two years contingent upon the successful outcome of a mid-term review. The request for new funding in FY 2016 and the potential recovery of funds from terminations of poorly performing activities after the mid-term review will allow for a new, focused EFRC solicitation in FY 2016.

Energy Innovation Hubs—Fuels from Sunlight

Solar energy is a significant yet largely untapped clean energy resource. More energy from the sun strikes the earth in one hour than is consumed by all humans on the planet in a year. Through the process of photosynthesis, plants can effectively convert energy from the sun into energy-rich chemical fuels using the abundant feedstocks of water and carbon dioxide. If a human-made artificial photosynthesis system can be developed that can generate usable fuels directly from sunlight, carbon dioxide, and water, the potential energy benefits for the Nation would be substantial, reducing dependence on fossil fuels through use of fuels generated directly by sunlight. Due to the significant scientific and engineering challenges associated with developing such a system, however, there are no commercially-available fuels generated via artificial photosynthesis. For this reason, the Basic Energy Sciences Advisory Committee report, New Science for Secure and Sustainable Energy Future,[a] listed the production of fuels directly from sunlight as one of three strategic goals for which transformational science breakthroughs are most urgently needed.

Established in September 2010, the Fuels from Sunlight Hub, called the Joint Center for Artificial Photosynthesis (JCAP), is a multi-disciplinary, multi-investigator, multi-institutional effort to create critical transformative advances in the development of artificial photosynthetic systems for converting sunlight, water, and carbon dioxide into a range of commercially useful fuels. The Hub is targeted towards understanding and designing catalytic complexes or solids that generate chemical fuel from carbon dioxide and/or water; integrating all essential elements, from light capture to fuel formation components, into an effective solar fuel generation system; and providing a pragmatic evaluation of the solar fuel system under development. JCAP is led by the California Institute of Technology (Caltech) in primary partnership with Lawrence Berkeley National Laboratory (LBNL). Other partners include the SLAC National Accelerator Laboratory and several University of California institutions. JCAP is composed of internationally renowned scientists and engineers who seek to integrate decades of research community efforts and address critical research and development gaps; its visionary goal is the construction of an artificial photosynthetic system for robustly producing fuel from the sun ten times more efficiently than current crops.

Research in JCAP ranges from fundamental discovery of new materials to science-based design and testing of fully functional prototypes. JCAP has eight major parallel research and development projects: light capture and conversion; heterogeneous catalysis; molecular catalysis; high throughput experimentation; catalyst and photochemical benchmarking; molecular-nanoscale interfaces; membrane and mesoscale assembly; and prototyping. The projects' efforts are synergistically split between JCAP-South on the campus of Caltech and JCAP-North located near LBNL, with the exception of the benchmarking and high-throughput experimentation projects that are consolidated at JCAP-South. JCAP also makes use of state-of-the-art facilities at LBNL and SLAC as part of their efforts to examine, understand, and manipulate matter at the nanoscale. Despite the different geographic locations, JCAP is designed to operate as a single scientific entity. Its current efforts consist of discovery research to identify robust, Earth-abundant light absorbers, catalysts, linkers, and membranes that are required components of a complete system and scale-up science for design and development of prototypes. By studying the science of scale-up and by benchmarking both components (catalysts) and systems (device prototypes), JCAP seeks to move bench-top discovery to proof-of-concept prototyping and thus accelerate the transition from laboratory discovery to industrial use.

The Fuels from Sunlight Hub received the final year of funding for its initial five-year award term at the planned level in FY 2014. As part of BES oversight of this Hub, JCAP has been evaluated via peer review on an annual basis since the initiation of the project. Following the latest scientific and technical review conducted in April 2014, BES determined that JCAP was on target to satisfy both its five-year goal as originally proposed and the performance milestones set forth as renewal criteria in the 2012 Energy Innovation Hubs Report to Congress. Given the latest review results, JCAP's overall scientific and technological progress, and the distinct role of this Hub in the BES research portfolio, JCAP is being considered for a final term of renewal with a maximum duration of five years. A renewal would allow JCAP to capitalize on its achievements during the initial funding period and to further advance research efforts addressing critical needs in solar fuels development. The Department will make a renewal determination based on the outcome of an external peer review. If the Department recommends renewal, JCAP will be directed to initiate a restructured research and development plan focused primarily on discovery science for efficient solar-driven production of carbon-based fuels. The reduced funding level for a potential renewal award term compared to the first award term reflects a de-emphasized research scope both on water oxidation and on design and development of prototypes. This renewal plan is consistent with options suggested in the 2014 report from the Secretary of Energy Advisory Board, *Task Force Report to Support the Evaluation of New Funding Constructs for Energy R&D in the DOE*.

[a] U.S. DOE Basic Energy Sciences Advisory Committee. *New Science for a Secure and Sustainable Energy Future*. U.S. Department of Energy Office of Science, 2008.

General Plant Projects (GPP)

GPP funding is provided for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems at the Ames Laboratory. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and for meeting requirements for safe and reliable facilities operation. The total estimated cost of each GPP project will not exceed $10,000,000.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Chemical Sciences, Geosciences, and Biosciences $314,236,000	**$321,901,000**	**+$7,665,000**
Fundamental Interactions Research ($76,796,000)	**($78,726,000)**	**(+$1,930,000)**
Research continues to develop and apply forefront ultrafast x-ray and optical probes of matter, utilizing the LCLS, BES synchrotron light sources, and table-top laser-based ultrafast light sources, all aimed to advance fundamental understanding. Concomitant advances in theoretical methods are sought to guide and interpret ultrafast measurements and for predicting ultrafast phenomena. Increased emphasis is placed on time-resolved x-ray probes of matter at unprecedented short time scales and in systems of substantial complexity. These include non-linear x-ray phenomena, structural determinations for individual molecules and particles, and time-resolved imaging to record complex chemical and biochemical phenomena. Computational efforts stress improved methods for electronically excited states in molecules and extended mesoscale systems, which are key to the efficient design of energy conversion processes and materials. Work continues on advanced combustion research to accelerate the predictive simulation of highly efficient and clean internal combustion engines. Increased emphasis is placed on investigating properties of combustion in high-pressure or multiphase systems.	Research will continue to develop and apply forefront ultrafast x-ray and optical probes of matter, utilizing the LCLS, BES synchrotron light sources, and table-top laser-based ultrafast light sources, to probe and control atomic, molecular, nanoscale and mesoscale matter. New efforts in mid-scale instrumentation will support development of electron scattering techniques that enable the probing of intermediate molecular states in chemical reaction dynamics. The current limitation in gas phase experiments is the velocity mismatch in timescale between electron and laser pulses that limit such investigations to the picosecond timescale. Advanced theoretical methods will be developed to guide and interpret ultrafast measurements and to design new experiments. Emphasis will continue to be placed on time-resolved electron and x-ray probes of matter at unprecedented short time scales and in systems of increasing complexity. Computational efforts will stress the development of improved methods to calculate electronically excited states in molecules and extended mesoscale systems. Work will continue on advanced combustion research to accelerate the predictive simulation of highly efficient and clean internal combustion engines. Increased emphasis will be on investigating properties of combustion in high-	Research support increases compared to FY 2015 for investments in mid-scale instrumentation for chemical imaging at the limits of temporal and spatial resolution. Emphasis will be placed on diffraction induced by femtosecond electron pulses that reveals time resolved dynamics of chemical processes. Efforts in predictive theory and modeling will be enhanced due to importance of such methods to guide and interpret increasingly complex measurements, and for predictive modeling of chemical processes. Studies of ultrafast phenomena will be enhanced, and research on ultra cold molecules will be deemphasized. Well-developed research topics in molecular and particle spectroscopy may be redirected to evolving forefront areas, such as energy transfer in molecular systems, and the effects of solvation and interfaces on chemical structure and reactivity.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
	pressure or multiphase systems.	
Chemical Transformations Research ($93,493,000)	**($93,493,000)**	**($0)**
Research continues in the development of computational and complementary synthesis and atomic-level characterization for discovery of catalytic mechanisms enabling design of materials at the nanoscale for new or enhanced photo-catalytic and fuel-forming chemistries. The catalytic conversion of biomass to fuels and other energy related chemical products is emphasized. The discovery and design of novel separation approaches to carbon dioxide capture from post-combustion gas streams and oxygen from air prior to oxy-combustion continue with added integration with computational methods. Research continues on the multi-scale dynamics of reactive flow and plume migration in subsurface reservoirs, which can lead to improved models and risk assessment for carbon sequestration and other subsurface applications. Actinide research in support of advanced nuclear energy systems continues, with emphasis on new insights in actinides chemical bonding enabling new chemistry for separation and related nuclear fuels and waste form processes. In support of the departmental emphasis on subsurface engineering, aspects of the separations and the geosciences portfolios support new efforts in carbon capture and sequestration as well as research in geophysical characterization and monitoring techniques.	Synthesis, guided by theory and computation, will continue to explore novel catalytic materials at the nano- and mesoscale for the efficient conversion of traditional and new feedstocks into higher-value fuels and other chemicals. The catalytic conversion of biomass to fuels and other energy related chemical products will be emphasized. Likewise, coupled predictive theory and synthesis of designer mesoporous membranes and filter materials will seek more efficient separation of carbon dioxide from conventional power plant effluents or of oxygen from air relevant to oxycombustion approaches. Subsurface geochemistry and geophysics will seek to provide data and mechanistic interpretation for models of reactive flow and transport important for carbon sequestration and extraction of tight gas and oil. Actinide research will continue to emphasize new insights in actinides chemical bonding enabling new chemistry for separation and related nuclear fuels and waste form processes especially using ionic liquids. Fundamental research activities in geochemistry and geophysics of the subsurface will continue in FY 2016 in parallel with efforts in other offices as coordinated by the Subsurface Technology and Engineering RD&D (SubTER) technology integration team.	Research support is level compared to FY 2015. Areas of increased emphasis include integration of computational and theoretical modeling methods with energy-relevant catalytic chemistries and subsurface imaging. Some mature areas of research in polymer synthesis, liquid-liquid extraction techniques, and surface geophysics may be decreased.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Photochemistry and Biochemistry Research ($68,797,000)	**($68,797,000)**	**($0)**
Research on fundamental aspects of light energy capture and conversion in non-biological and biological (photosynthetic) systems continues to be emphasized, providing a critical foundation for direct conversion of solar energy to electricity, fuels, and high-value chemicals. Enhanced support for computational and modeling studies enables the design and fabrication of novel semiconductor/ polymer interfaces, dye-sensitized solar cells, inorganic-organic molecular complexes, and biohybrid light harvesting complexes. Greater emphases on understanding the mechanisms of water-splitting, redox, and other energy-relevant biological (enzymatic) reactions, from the nano- to the mesoscale, provides new insights important for development of novel bio-inspired catalysts based on earth-abundant materials, while biosynthetic and structural studies of the plant cell wall helps inform catalytic strategies for the direct conversion of biomass to fuels and other products.	Research will continue to emphasize a fundamental understanding of light energy capture and conversion in non-biological and biological (photosynthetic) systems. These studies will establish a foundation for direct conversion of solar energy to electricity, fuels, and high value chemicals. Efforts in computation and modeling will continue to be supported as such approaches can facilitate design and fabrication of semiconductor/polymer interfaces, dye-sensitized solar cells, inorganic-organic molecular complexes, and bio-inspired/biohybrid light harvesting complexes. Research to understand the fundamental mechanisms of water-splitting, redox, cell wall biosynthesis, and other energy-relevant biological (enzymatic) reactions, from the nano- to the mesoscale, will continue to be emphasized. These studies will provide new insights for developing novel bio-inspired catalysts based on earth-abundant materials and for controlling and optimizing chemical reactions important for energy capture, conversion, and storage.	Research support is level compared to FY 2015. Efforts in the study of plant hormones, biotic stress and on the development of genetic systems will be de-emphasized. Greater emphasis will be placed on understanding the structure, function, and mechanism of enzymes that mediate the flow of electrons in biological systems.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Energy Frontier Research Centers (EFRCs) ($49,200,000)	**($54,200,000)**	**(+$5,000,000)**
The EFRCs that were started in FY 2014 are performing the first year of research of the award period as outlined in their proposals. This multidisciplinary research continues to provide accelerated progress in fundamental, energy-use inspired research. The research in these new EFRCs includes investigations of mesoscale science and utilization of computational research to predictably design new materials and processes. BES will hold a peer review to assess management and early operations.	The EFRCs will continue to perform fundamental multi-disciplinary research aimed at accelerating scientific innovation. All EFRCs will undergo a mid-term review in FY 2016 to assess progress toward meeting scientific research goals. DOE will issue a Funding Opportunity Announcement for up to five new EFRC awards in FY 2016.	The total BES EFRC program is increased by $10,000,000 compared to FY 2015, which is split equally between Materials Sciences and Engineering and Chemical Sciences, Geosciences, and Biosciences. New EFRCs funded through this subprogram will focus on strategic areas of chemical science, geoscience, and bioscience that are not represented or are underrepresented in the current EFRC portfolio.
Energy Innovation Hubs—Fuels From Sunlight ($15,000,000)	**($15,000,000)**	**($0)**
The Fuels from Sunlight Hub completes its 5-year award at the planned level. Decision for continued funding beyond the 5 year term, which ends in September 2015, will be made in January 2015.	The Fuels from Sunlight Hub will be considered for the final term of renewal for up to 5 years starting in September 2015. The renewal would allow JCAP to capitalize on its achievements during the initial funding period and to further advance research efforts addressing critical needs in solar fuels development. The Department will base its renewal decision on the outcome of an external peer review.	If a renewal is awarded, the research scope of the renewal project will build on the accomplishments of the first phase of the JCAP award in hydrogen production and expand to CO_2 reduction for carbon-based fuel formation. JCAP will support a restructured research and development plan focused primarily on discovery science for efficient solar-driven production of carbon-based fuels. The reduced funding level compared to the first award term reflects a de-emphasized research scope on water oxidation and on design and development of prototypes.
General Plant Projects ($600,000)	**($600,000)**	**($0)**
Funding supports minor facility improvements at Ames Laboratory.	Funding will support minor facility improvements at Ames Laboratory.	General Plant Projects is level compared to FY 2015.

Basic Energy Sciences
Scientific User Facilities

Description

The Scientific User Facilities subprogram supports the operation of a geographically diverse suite of major research facilities that provide thousands of researchers from universities, industry, and government laboratories unique tools to advance a wide range of sciences. These user facilities are operated on an open access, competitive merit review basis, enabling scientists from every state and many disciplines from academia, national laboratories, and industry to utilize the facilities' unique capabilities and sophisticated instrumentation.

Studying matter at the level of atoms and molecules requires instruments that can probe structures that are one thousand times smaller than those detectable by the most advanced light microscopes. Thus, to characterize structures with atomic detail, we must use probes such as x-rays, electrons, and neutrons that are at least as small as the structures being investigated. The BES large-scale user facilities portfolio consists of a complementary set of intense x-ray sources, neutron scattering centers, and research centers for nanoscale science. These facilities allow researchers to probe materials in space, time, and energy with the appropriate resolutions that can interrogate the inner workings of matter to answer some of the most challenging grand science questions. By taking advantage of the intrinsic charge, mass, and magnetic characteristics of x-rays, neutrons, and electrons, these tools offer unique capabilities to help understand the fundamental aspects of the natural world.

Advances in tools and instruments often drive scientific discovery. The continual development and upgrade of the instrumental capabilities include new x-ray and neutron experimental stations, improved core facilities, and new stand-alone instruments. The subprogram also supports research in accelerator and detector development to explore technology options for the next generations of x-ray and neutron sources.

Annually, the BES scientific facilities are used by more than 15,000 scientists and engineers in many fields of science and technology. These facilities provide unique capabilities to the scientific community and are a critical component of maintaining U.S. leadership in the physical sciences. Collectively, these user facilities and enabling tools contribute to important research results that span the continuum from basic to applied research and embrace the full range of scientific and technological endeavors, including chemistry, physics, geology, materials science, environmental science, biology, and biomedical science. These capabilities enable scientific insights that can lead to the discovery and design of advanced materials and novel chemical processes with broad societal impacts, from energy applications to information technologies and biopharmaceutical discoveries. The advances enabled by these facilities extend from energy-efficient catalysts for clean energy production to spin-based electronics and new drugs for cancer therapy. For approved, peer-reviewed projects, operating time is available without charge to researchers who intend to publish their results in the open literature.

<u>Synchrotron Radiation Light Sources</u>

X-rays are an essential tool for studying the structure of matter and have long been used to peer into material through which visible light cannot penetrate. Today's synchrotron light source facilities produce x-rays that are billions of times brighter than medical x-rays. Scientists use these highly focused, intense beams of x-rays to reveal the identity and arrangement of atoms in a wide range of materials. The tiny wavelength of x-rays allows us to see things that visible light cannot resolve, such as the arrangement of atoms in metals, semiconductors, biological molecules, and other materials. The fundamental tenet of materials research is that structure determines function. The practical corollary that converts materials research from an intellectual exercise into a foundation of our modern technology-driven economy is that structure can be manipulated to construct materials with particular desired behaviors. To this end, synchrotron radiation has transformed the role of x-rays as a mainline tool for probing the atomic and electronic structure of materials internally and on their surfaces.

From its first systematic use as an experimental tool in the 1960s, synchrotron radiation has vastly enhanced the utility of pre-existing and contemporary techniques, such as x-ray diffraction, x-ray spectroscopy, and imaging and has given rise to scores of new ways to do experiments that would not otherwise be feasible with conventional x-ray machines. Moreover, the wavelength can be selected over a broad range (from the infrared to hard x-rays) to match the needs of particular experiments. Together with additional features, such as controllable polarization, coherence, and ultrafast pulsed time structure, these characteristics make synchrotron radiation the x-ray source of choice for a wide range of materials research. The wavelengths of the emitted photons span a range of dimensions from the atom to biological cells, thereby providing incisive probes for advanced research in a wide range of areas, including materials science, physical and chemical sciences, metrology, geosciences, environmental sciences, biosciences, medical sciences, and pharmaceutical sciences.

BES operates a suite of five light sources, including a free electron laser, the Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory (SLAC) and four storage ring based light sources—the Advanced Light Source (ALS) at Lawrence Berkeley National Laboratory (LBNL), Advanced Photon Source (APS) at Argonne National Laboratory (ANL), Stanford Synchrotron Radiation Lightsource (SSRL) at SLAC, and the newly constructed National Synchrotron Light Source-II (NSLS-II) at Brookhaven National Laboratory (BNL). Funds are provided to support facility operations, enable cutting-edge research and technical support, and to administer a robust user program at these facilities, which are made available to all researchers with access determined via peer review of user proposals.

<u>High Flux Neutron Sources</u>

One of the goals of modern materials science is to understand the factors that determine the properties of matter on the atomic scale and to use this knowledge to optimize those properties or to develop new materials and functionality. This process regularly involves the discovery of fascinating new physics, which itself may lead to previously unexpected applications. Among the different probes used to investigate atomic-scale structure and dynamics in scattering experiments, thermal neutrons have unique advantages:

- they have a wavelength similar to the spacing between atoms, allowing atomic resolution studies of structure and have an energy similar to the elementary excitations of atoms and magnetic spins in materials, thus allowing an investigation of material dynamics;
- they have no charge, allowing deep penetration into a bulk material;
- they are scattered to a similar extent by both light and heavy atoms but differently by different isotopes of the same element, so that different chemical sites can be distinguished via isotope substitution experiments, for example in organic and biological materials;
- they have a magnetic moment, and thus can probe magnetism in condensed matter systems; and
- their scattering cross-section is precisely measurable on an absolute scale, facilitating straightforward comparison with theory and computer modeling.

The High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) generates neutrons via fission in a research reactor. HFIR operates at 85 megawatts and provides state-of-the-art facilities for neutron scattering, materials irradiation, and neutron activation analysis. It is the world's leading production source of elements heavier than plutonium for medical, industrial and research applications. There are 13 neutron scattering instruments installed in the reactor hall at HFIR and the adjacent cold neutron beam guide hall and include world-class inelastic scattering spectrometers, small angle scattering, powder and single crystal diffractometers, neutron imaging, and an engineering diffraction machine.

Another approach for generating neutron beams is to use an accelerator to generate protons that strike a heavy-metal target. As a result of the impact, neutrons are produced in a process known as spallation. The Spallation Neutron Source (SNS) at ORNL is the world's brightest pulsed neutron facility and presently includes 19 instruments. These instruments include very high resolution inelastic and quasi-elastic scattering capabilities, powder and single crystal diffraction, polarized and unpolarized beam reflectometry, spin echo and small angle scattering spectrometers. A full suite of high and low temperature, high magnetic field, and high pressure sample environment equipment is available on each instrument. The final three instruments were completed in 2014 from the SNS Instrumentation Next Generation-II (SING-II) major item of equipment project: the ultra-small angle diffractometer, the elastic diffuse scattering spectrometer, and the macromolecular neutron diffractometer. All the SNS instruments are in high demand by researchers world-wide in a range of disciplines from biology to materials sciences and condensed matter physics.

<u>Nanoscale Science Research Centers (NSRCs)</u>

Nanoscience is the study of materials and their behaviors at the nanometer scale—probing and assembling single atoms, clusters of atoms, and molecular structures. The scientific quest is to design new nanoscale materials and structures, and observe and understand how they function, including how they interact with their environment. Developments at the nanoscale and mesoscale have the potential to make major contributions to delivering remarkable scientific discoveries that transform our understanding of energy and matter and advance national, economic, and energy security.

The NSRCs are DOE's premier user facilities for interdisciplinary research at the nanoscale, serving as the basis for a national program that encompasses new science, new tools, and new computing capabilities. The five NSRCs are the Center for Nanoscale Materials at ANL, Center for Functional Nanomaterials at BNL, Molecular Foundry at LBNL, Center for Nanophase Materials Sciences at ORNL, and Center for Integrated Nanotechnologies at SNL and LANL. Each center has particular expertise and capabilities, such as synthesis and assembly of nanomaterials; theory, modeling and simulation; imaging and spectroscopy including electron microscopy; and nanoscale integration. Selected thematic areas include catalysis, electronic materials, nanoscale photonics, and soft and biological materials. The centers are housed in custom-designed laboratory buildings near one or more other major BES facilities for x-ray, neutron, or electron scattering, which complement and leverage the capabilities of the NSRCs. These laboratories contain clean rooms, nanofabrication resources, one-of-a-kind signature instruments, and other instruments not generally available except at major user facilities. Operating funds are provided to enable cutting-edge research and technical support and to administer a robust user program at these facilities, which are made available to all researchers with access determined through external peer review of user proposals.

In FY 2015, the three electron-beam microcharacterization centers (EBMCs) will be merged administratively with their respective neighboring NSRCs. The three centers that will be merged are the Electron Microscopy Center for Materials Research at ANL, the National Center for Electron Microscopy at LBNL, and the Shared Research Equipment user facility at ORNL. The EBMCs provide superior atomic-scale spatial resolution and the ability to simultaneously obtain structural, chemical, and other types of information from sub-nanometer regions.

Other Project Costs

The total project cost (TPC) of DOE's construction projects comprises two major components—the total estimated cost (TEC) and other project costs (OPC). The TEC includes project costs incurred after Critical Decision-1, such as costs associated with all engineering design and inspection, the acquisition of land and land rights; direct and indirect construction/fabrication; and the initial equipment necessary to place the facility or installation in operation; and facility construction costs and other costs specifically related to those construction efforts. OPC represents all other costs related to the projects that are not included in the TEC. Generally, other project costs are incurred during the project's initiation and definition phase for planning, conceptual design, research, and development, and during the execution phase for research and development, startup, and commissioning. OPC is always funded via operating funds.

Major Items of Equipment

BES supports major item of equipment (MIE) projects to ensure the continual development and upgrade of major scientific instrument capabilities, including fabricating new x-ray and neutron experimental stations, improving core facilities, and providing new stand-alone instruments. In general, each MIE with a total project cost greater than $5,000,000 and all line item construction projects follow the DOE Project Management Order 413.3B, which requires formal reviews to obtain critical decisions that advance the development stages of a project. Additional reviews may be required depending on the complexity and needs of the projects in question. BES MIE projects are in two main categories: Synchrotron Radiation Light Sources and High Flux Neutron Sources.

Research

This activity supports targeted basic research in accelerator physics, x-ray and neutron detectors, and developments of advanced x-ray optics. Accelerator research is the cornerstone for the development of new technologies that will improve performance of accelerator-based light sources and neutron scattering facilities. Research areas include ultrashort pulse free electron lasers (FELs), new seeding techniques and other optical manipulation to reduce the cost and complexity and improve performance of next generation FELs, and very high frequency laser photoinjectors that can influence the design of linac-based FELs with high repetition rates. Detector research is a crucial component to enable the optimal utilization of user facilities, together with the development of innovative optics instrumentation to advance photon-based sciences, and data management techniques. The emphasis of the detector activity is on research leading to new and more efficient photon and neutron detectors. Research includes studies on creating, manipulating, transporting, and performing diagnostics of ultrahigh brightness beams and developing ultrafast electron diffraction systems that complement the capabilities of x-ray FELs. This activity also includes research in sophisticated data management tools to address the vastly accelerated pace and volume of data generated by faster, higher resolution detectors and brighter light sources.

This activity also supports long term surveillance and maintenance (LTS&M) responsibilities and legacy cleanup work at Brookhaven National Laboratory and SLAC National Accelerator Laboratory. Prior to FY 2014, this activity was funded by the DOE Environmental Management (EM) program.

This activity historically supported the three electron-beam microcharacterization centers (EBMCs). Starting in FY 2015, each EBMC is merged administratively with its respective neighboring NSRCs.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Scientific User Facilities $916,379,000	**$951,849,000**	**+$35,470,000**
Synchrotron Radiation Light Sources ($447,186,000)	**($477, 079,000)**	**(+$29,893,000)**
The FY 2015 appropriation supports operations of the BES light source facilities, including early operations for the newly constructed NSLS-II, at below optimal levels. NSLS ceases operations and transitions to a safe storage condition in FY 2015.	In FY 2016, funding is requested for near optimal operations of the five BES light sources, including the first full year of operations for the newly constructed NSLS-II. No funding is requested for NSLS.	The funding increase will support operations at near optimal levels for the light sources. It will allow the facilities to proceed with the most critical deferred repairs and replacements of outdated instruments, essential accelerator improvements, and limited staff hires or replacements. The request will also support the increased cost of power and user support.
High-Flux Neutron Sources ($244,113,000)	**($254,990,000)**	**(+$10,877,000)**
Funding is provided to continue the operation of HFIR and SNS at below optimal levels. BES operations at the Lujan Neutron Scattering Center cease and the facility transitions to a safe storage condition.	Funding is requested to continue the operation of HFIR and SNS at near optimal levels. Limited funding is requested for the Lujan Neutron Scattering Center for the removal of hazardous materials and planning of the disposition of unused equipment.	The funding increase will support operations at near optimal levels for HFIR and SNS. It will allow the facilities to proceed with the most critical deferred repairs and replacements of outdated instruments, essential machine improvements, and limited staff hires or replacements. The request will also support the increased cost of power and user support.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Nanoscale Science Research Centers ($113,649,000)	**($118,763,000)**	**(+$5,114,000)**
Funding supports continuing operations and support of users at the NSRCs at below optimal level. The electron-beam microcharacterization centers (EBMCs) merge with the NSRCs in FY 2015. Continued program emphasis cultivates and expands the user base from universities, national laboratories, and industry. Efforts include planning for future electron scattering needs that address scientific roadblocks toward observing ultrafast chemical and physical phenomena at ultra-small size scales in different sample environments.	Funding is requested to continue operations and support of users at the NSRCs at near optimal levels. Program emphasis will continue to cultivate and expand the user base from universities, national laboratories, and industry. Planning efforts will continue to advance the cutting-edge nanostructure characterization capabilities, with an emphasis on coupling multi-probes of photon, neutron, and electron, and planning for future electron scattering needs that could address scientific roadblocks toward observing ultrafast chemical and physical phenomena at ultra-small size scales in different sample environments.	The funding increase will support operations at near optimal levels for the NSRCs.
Other Project Costs ($9,300,000)	**($0)**	**(-$9,300,000)**
Funds for Other Project Costs are associated with the LCLS-II project at SLAC and follow the project plan.	No funds are requested for Other Project Costs in FY 2016.	Other Project Costs decreases according to the LCLS-II project plan.
Major Items of Equipment ($42,500,000)	**($35,500,000)**	**(-$7,000,000)**
APS-U continues with planning and design, magnet prototyping, and research and development related to implementation of the multi-bend achromat lattice during FY 2015.	APS-U will continue with planning and facility design, magnet prototyping, and research and development related to implementation of the multi-bend achromat lattice during FY 2016.	APS-U funding is level with FY 2015.
NEXT continues with the design, procurements, construction/fabrication, installation, testing and commissioning of equipment during FY 2015.	NEXT will continue with the design, procurements, construction/fabrication, installation, testing and commissioning of equipment during FY 2016.	NEXT funding decreases according to the project profile. FY 2016 is the final year of funding for this project.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Research ($31,713,000)	**($34,853,000)**	**(+$3,140,000)**
The research funding for the scientific user facilities supports efforts in x-ray optics developments and data management techniques, and continues to support seminal advances in accelerator and detector research cognizant of the DOE mission needs and instrumentation relevant to neutron and photon based science. FY 2015 funding for the three Electron Beam Microcharacterization Centers (EBMCs) merges with the Nanoscale Science Research Centers (NSRCs) budget. Funding to continue the long term surveillance and maintenance responsibilities at BNL and SLAC is also included in this portion of the budget.	The research funding for the scientific user facilities will continue to support selected, high-priority research activities. This funding will support activities to ensure that the scientific user facilities continue to demonstrate performance excellence, with focused efforts to address next generation facilities research needs. Emphasis will also be placed on detectors and optics instrumentation to allow full utilization of neutron and photon beams. Funding to continue the long term surveillance and maintenance responsibilities at BNL and SLAC is also included in this portion of the budget.	The increase in funding will allow expansion of research activities addressing new accelerator needs, detector and optics instrumentation, and the growing demands for data management tools by a wide spectrum of users.

Basic Energy Sciences
Construction

Description

Reactor-based neutron sources, accelerator-based x-ray light sources, and accelerator-based pulsed neutron sources are essential user facilities that enable critical DOE mission-driven science. These user facilities provide the academic, laboratory, and industrial research communities with the tools to fabricate, characterize, and develop new materials and chemical processes to advance basic and applied research, advancing chemistry, physics, earth science, materials science, environmental science, biology, and biomedical science. Regular investments in construction of new user facilities and upgrades to existing user facilities are essential to maintaining U.S. leadership in these research areas.

Taking the findings and recommendations of the July 25, 2013 BES Advisory Committee report into account, the Linac Coherent Light Source-II (LCLS-II) project was modified to include the addition of a superconducting linear accelerator and additional undulators to generate an unprecedented high-repetition-rate free-electron laser. This new, world-leading, high-repetition-rate x-ray source will solidify the LCLS complex as the world leader in ultrafast x-ray science for decades to come.

All BES construction projects are conceived and planned with the scientific community and, during construction, adhere to the highest standards of safety and are executed on schedule and within cost through dogged project management. In accordance with DOE Order 413.3B, each project is closely monitored and must perform within 10% of the cost and schedule performance baselines, established at Critical Decision 2, Approve Performance Baseline, and which are reproduced in the construction project data sheet.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Construction $138,700,000	**$200,300,000**	**+$61,600,000**
Linac Coherent Light Source-II (LCLS-II) ($138,700,000)	**($200,300,000)**	**(+$61,600,000)**
The project continues with facility design, initiates critical long-lead procurements of technical materials and cryogenic systems, continues research and development and prototyping activities, and fabrication of technical equipment during FY 2015.	The project will complete facility design, and continue research and development, prototyping, construction, and fabrication and installation of technical equipment during FY 2016.	LCLS-II funding is increased according to the project profile. The increased funding supports continuation of construction and installation activities.

Basic Energy Sciences
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**BES Facility Operations—Average achieved operation time of BES user facilities as a percentage of total scheduled annual operation time**		
Target	≥ 90%	≥ 90%	≥ 90%
Result	Met	TBD	TBD
Endpoint Target	Many of the research projects that are undertaken at the Office of Science's scientific user facilities take a great deal of time, money, and effort to prepare and regularly have a very short window of opportunity to run. If the facility is not operating as expected, the experiment could be ruined or critically setback. In addition, taxpayers have invested millions or even hundreds of millions of dollars in these facilities. The greater the period of reliable operations, the greater the return on the taxpayers' investment.		
Performance Goal (Measure)	**BES Facility Construction/MIE Cost & Schedule—Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.**		
Target	< 10%	< 10%	< 10%
Result	Met	TBD	TBD
Endpoint Target	Adhering to the cost and schedule baselines for a complex, large scale, science project is critical to meeting the scientific requirements for the project and for being good stewards of the taxpayers' investment in the project.		
Performance Goal (Measure)	**BES Solar Fuels—Demonstrate a scalable solar-fuels generator using Earth-abundant elements that produces fuel (without wires) from the sun 10 times more efficiently than current agriculturally produced plants**		
Target	Design first prototype device for testing components, such as catalysts, light harvesters, membranes, and interfaces, as an integrated system	N/A	N/A
Result	Met	N/A	N/A
Endpoint Target	Demonstration of a scalable solar-fuels generator using Earth-abundant elements that produces fuel (without wires) from the sun 10 times more efficiently than current agriculturally produced plants. The performance goal will be achieved by the *Fuels from Sunlight* Energy Innovation Hub.		

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**BES Energy Storage—Deliver two high-performance research energy storage prototypes for transportation and the grid that project at the battery pack level to be five times the energy density at 1/5 the cost of the 2011 commercial baseline.**		
Target	N/A	Through the "electrolyte genome," demonstrate a framework for designing new electrolytes using structure-chemical trends extracted from >10,000 first-principles calculated molecular motifs, modifications and mutations.	Complete self-consistent system analyses using techno-economic modeling of three electrochemical couples, identified through materials discovery including output from the electrolyte genome, that have the potential to meet technical performance and cost criteria.
Result	N/A	TBD	TBD
Endpoint Target	Deliver two high-performance research prototypes for transportation and the grid that project at the battery pack level to be five times the energy density at 1/5 the cost of the 2011 commercial baseline. The performance goal will be achieved by the *Batteries and Energy Storage* Energy Innovation Hub.		

Basic Energy Science
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Capital Operating Expenses Summary							
Capital Equipment	n/a	n/a	63,068	63,068	48,100	41,000	-7,100
General Plant Projects (GPP)	n/a	n/a	600	600	600	600	0
Accelerator Improvement Projects (AIP)	n/a	n/a	13,000	13,000	9,925	9,425	-500
Total, Capital Operating Expenses	**n/a**	**n/a**	**76,668**	**76,668**	**58,625**	**51,025**	**-7,600**
Capital Equipment							
Major Items of Equipment							
Advanced Photon Source Upgrade (APS-U), ANL (TPC TBD)[a]	TBD	40,000	20,000	20,000	20,000	20,000	0
Linac Coherent Light Source-II (LCLS-II), SLAC[b,c,]	—	67,000	0	0	0	0	0
NSLS-II Experimental Tools (NEXT), BNL (TPC $90,000)	90,000	27,000	25,000	25,000	22,500	15,500	-7,000
Total, Major Items of Equipment	n/a	n/a	45,000	45,000	42,500	35,500	-7,000
Other capital equipment projects under $2 million TEC	n/a	n/a	18,068	18,068	5,600	5,500	-100
Total, Capital equipment	**n/a**	**n/a**	**63,068**	**63,068**	**48,100**	**41,000**	**-7,100**
General Plant Projects (GPP)							
Other general plant projects under $5 million TEC	n/a	n/a	600	600	600	600	0
Total, General Plant Projects	**n/a**	**n/a**	**600**	**600**	**600**	**600**	**0**
Accelerator Improvement Projects (AIP)							
Accelerator improvement projects under $5 million TEC	n/a	n/a	13,000	13,000	9,925	9,425	-500

[a] Following the July 2013 BESAC report on Future X-Ray Light Sources, the APS-U project has been rescoped and a revised Mission Need Statement is in preparation.
[b] LCLS-II is requested as a line item construction project beginning in FY 2014.
[c] LCLS-II received $85,600,000 in FY 2010-FY 2013 as an MIE.

Major Items of Equipment Descriptions

Advanced Photon Source Upgrade (APS-U)

The Advanced Photon Source Upgrade (APS-U) MIE supports activities to design, build, install, and test the equipment necessary to upgrade an existing third-generation synchrotron light source facility, the Advanced Photon Source (APS). The APS is one of the Nation's most productive x-ray light source facilities, serving over 4,000 users annually and providing key capabilities to enable forefront scientific research in a broad range of fields of physical and biological sciences. The APS is the only hard x-ray 7 GeV source in the U.S. and only one of four in the world, along with the European Synchrotron Radiation Facility (ESRF) in France, PETRA-III in Germany, and Spring-8 in Japan. High-energy penetrating x-rays are especially critical for probing materials under real working environments, such as a battery or fuel cell under load conditions. All three foreign facilities are well into campaigns of major upgrades of beamlines and are also incorporating technological advancements in accelerator science to enhance performance. With the ever increasing demand for higher penetration power for probing real-world materials and applications, the higher energy hard x-rays (20 keV and above) produced at APS provide unique capabilities in the U.S. x-ray arsenal that are a pre-requisite for tackling the grand science and energy challenges of the 21^{st} Century. In response to the findings and recommendations of the July 25, 2013 BES Advisory Committee report, the APS-U Project will upgrade the existing APS to provide scientists with an x-ray source possessing world-leading transverse coherence and extreme brightness. The magnetic lattice of the APS storage ring will be upgraded to a multi-bend achromat configuration to provide 100-1000 times increased brightness. The APS upgrade will ensure that the APS remains a world leader in hard x-ray science. The high-energy penetrating x-rays will provide a unique scientific capability directly relevant to problems in energy, the environment, new and improved materials, and biological studies. The upgraded APS will complement the capabilities of x-ray free electron lasers (e.g., the Linac Coherent Light Source and Linac Coherent Light Source-II), which occupy different spectral, flux, and temporal range of technical specifications. The project is managed by Argonne National Laboratory.

NSLS-II Experimental Tools (NEXT)

The NSLS-II Experimental Tools (NEXT) MIE supports activities to add beamlines to the National Synchrotron Light Source-II (NSLS-II) Project. The NEXT Project will provide NSLS-II with complementary best-in-class beamlines that support the identified needs of the U.S. research community and the DOE energy mission. Implementation of this state-of-the-art instrumentation will significantly increase the scientific quality and productivity of NSLS-II. In addition, the NEXT project will enable and enhance more efficient operation of NSLS-II. The project is managed by Brookhaven National Laboratory.

Construction Projects Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
13-SC-10, Linac Coherent Light Source-II (LCLS-II), SLAC							
TEC	916,400	67,000	75,700	75,700	138,700	200,300	+61,600
OPC	48,600	18,600	10,000	10,000	9,300	0	-9,300
TPC	**965,000**	**85,600**[a]	**85,700**	**85,700**	**148,000**	**200,300**	**+52,300**
07-SC-06, National Synchrotron Light Source-II, BNL							
TEC	791,200	764,900	26,300	26,300	0	0	+/-0,000
OPC	120,800	93,400	27,400	27,400	0	0	+/-0,000
TPC	**912,000**	**858,300**	**53,700**	**53,700**	**0**	**0**	**+/-0,000**
Total, Construction							
TEC	n/a	n/a	102,000	102,000	138,700	200,300	+61,600
OPC	n/a	n/a	37,400	37,400	9,300	0	-9,300
TPC	**n/a**	**n/a**	**139,400**	**139,400**	**148,000**	**200,300**	**+52,300**

Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	697,010	697,010	686,876	707,373	+20,497
Scientific User Facilities Operations	780,692	780,692	804,948	850,832	+45,884
Major Items of Equipment	45,000	45,000	42,500	35,500	-7,000
Construction Projects (includes OPC)	139,400	139,400	148,000	200,300	+52,300
Other[b]	49,827	600	50,876	55,295	+4,419
Total, Basic Energy Sciences	**1,711,929**	**1,662,702**	**1,733,200**	**1,849,300**	**+116,100**

[a] LCLS-II received $85,600,000 in FY 2010-FY 2013 as an MIE.
[b] Includes SBIR/STTR funding and non-Facility related GPP.

Facility Operations ($K)

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

Definitions:

Achieved Operating Hours – The amount of time (in hours) the facility was available for users.

Planned Operating Hours –

- For Past Fiscal Year (PY), the amount of time (in hours) the facility was planned to be available for users.
- For Current Fiscal Year (CY), the amount of time (in hours) the facility is planned to be available for users.
- For the Budget Fiscal Year (BY), based on the proposed budget request the amount of time (in hours) the facility is anticipated to be available for users.

Optimal Hours – The amount of time (in hours) a facility would be available to satisfy the needs of the user community if unconstrained by funding levels.

Percent of Optimal Hours – An indication of utilization effectiveness in the context of available funding; it is not a direct indication of scientific or facility productivity.

- For BY and CY, Planned Operating Hours divided by Optimal Hours expressed as a percentage.
- For PY, Achieved Operating Hours divided by Optimal Hours.

Unscheduled Downtime Hours - The amount of time (in hours) the facility was unavailable to users due to unscheduled events. NOTE: For type "A" facilities, zero Unscheduled Downtime Hours indicates Achieved Operating Hours equals Planned Operating Hours.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
Advanced Light Source	**$60,000**	**$60,000**	**$60,500**	**$63,223**	**+2,723**
Number of Users	2,443	2,443	2,400	2,450	+50
Achieved operating hours	4,838	4,838	N/A	N/A	
Planned operating hours	5,100	5,100	5,000	5,200	+200
Optimal hours	5,300	5,300	5,300	5,300	0
Percent optimal hours	91.3%	91.3%	94.3%	98.1%	
Unscheduled downtime hours	<10%	<10%	<10%	<10%	

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Advanced Photon Source	**$122,800**	**$122,800**	**$124,815**	**$130,432**	**+5,617**
Number of Users	5,017	5,017	5,000	5,100	+100
Achieved operating hours	4,901	4,901	N/A	N/A	
Planned operating hours	5,000	5,000	5,000	5,000	0
Optimal hours	5,000	5,000	5,000	5,000	0
Percent optimal hours	98.0%	98.0%	100%	100%	
Unscheduled downtime hours	<10%	<10%	<10%	<10%	
National Synchrotron Light Source, BNL	**$29,900**	**$29,900**	**$5,500**	**$0**	**-5,500**
Number of Users	2,372	2,372	0	0	0
Achieved operating hours	5,848	5,848	N/A	N/A	
Planned operating hours	4,400	4,400	0	0	0
Optimal hours	4,500	4,500	0	0	0
Percent optimal hours	130.0%	130.0%	N/A	N/A	
Unscheduled downtime hours	<10%	<10%	N/A	N/A	
National Synchrotron Light Source-II, BNL	**$56,900**	**$56,900**	**$90,415**	**$110,000**	**+19,585**
Number of Users	0	0	200	700	+500
Achieved operating hours	N/A	N/A	N/A	N/A	
Planned operating hours	0	0	2,100	3,250	+1,150
Optimal hours	0	0	2,300	3,300	+1,000
Percent optimal hours	N/A	N/A	91.3%	98.5%	
Unscheduled downtime hours	N/A	N/A	<10%	N/A	
Stanford Synchrotron Radiation Lightsource	**$38,400**	**$38,400**	**$39,000**	**$40,755**	**+1,755**
Number of Users	1,556	1,556	1,500	1,550	+50
Achieved operating hours	5,176	5,176	N/A	N/A	
Planned operating hours	5,400	5,400	5,200	5,300	+100
Optimal hours	5,400	5,400	5,400	5,400	0
Percent optimal hours	95.9%	95.9%	96.3%	98.1%	
Unscheduled downtime hours	<10%	<10%	<10%	<10%	

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Linac Coherent Light Source	**$125,050**	**$125,050**	**$126,956**	**$132,669**	**+5,713**
Number of Users	612	612	580	580	0
Achieved operating hours	4,380	4,380	N/A	N/A	
Planned operating hours	4,400	4,400	4,700	4,600	-100
Optimal hours	4,500	4,500	4,700	4,700	0
Percent optimal hours	97.3%	97.3%	100%	97.9%	
Unscheduled downtime hours	<10%	<10%	<10%	<10%	
High Flux Isotope Reactor	**$59,750**	**$59,750**	**$60,688**	**$63,419**	**+2,731**
Number of Users	453	453	450	450	0
Achieved operating hours	3,682	3,682	N/A	N/A	
Planned operating hours	3,400	3,400	3,400	3,450	+50
Optimal hours	3,500	3,500	3,500	3,500	0
Percent optimal hours	105.2%	105.2%	97.1%	98.6%	
Unscheduled downtime hours	<10%	<10%	<10%	<10%	
Lujan Neutron Scattering Center	**$8,900**	**$8,900**	**$2,000**	**$2,000**	**0**
Number of Users	187	187	0	0	0
Achieved operating hours	1,683	1,683	N/A	N/A	
Planned operating hours	1,300	1,300	0	0	0
Optimal hours	2,000	2,000	0	0	0
Percent optimal hours	84.2%	84.2%	N/A	N/A	
Unscheduled downtime hours	<10%	<10%	N/A	N/A	
Spallation Neutron Source	**$178,600**	**$178,600**	**$181,425**	**$189,571**	**+8,146**
Number of Users	866	866	800	850	+50
Achieved operating hours	4,424	4,424	N/A	N/A	
Planned operating hours	4,400	4,400	4,700	4,650	-50
Optimal hours	4,500	4,500	4,700	4,700	0
Percent optimal hours	98.3%	98.3%	100%	98.9%	
Unscheduled downtime hours	<10%	<10%	<10%	<10%	

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE B FACILITIES[a]					
Center for Nanoscale Materials	**$20,100**	**$20,100**	**$23,427**	**$24,481**	**+1,054**
Number of users	451	451	470	500	+30
Center for Functional Nanomaterials	**$19,600**	**$19,600**	**$19,908**	**$20,804**	**+896**
Number of users	473	473	400	420	+20
Molecular Foundry	**$20,150**	**$20,150**	**$26,403**	**$27,591**	**+1,188**
Number of users	433	433	470	500	+30
Center for Nanophase Materials Sciences	**$19,857**	**$19,857**	**$22,901**	**$23,932**	**+1,031**
Number of users	421	421	440	450	+10
Center for Integrated Nanotechnologies	**$20,685**	**$20,685**	**$21,010**	**$21,955**	**+945**
Number of users	465	465	400	420	+20
Total, All Facilities	**$780,692**	**$780,692**	**$804,948**	**$850,832**	**+45,884**
Number of Users	15,749	15,749	13,110	13,970	+860
Achieved operating hours	34,932	34,932	N/A	N/A	
Planned operating hours	33,400	33,400	30,100	31,450	+1,350
Optimal hours	34,700	34,700	30,900	31,900	+1,000
Percent of optimal hours[b]	99.2%	99.2%	97.9%	98.7%	
Unscheduled downtime hours	<10%	<10%	<10%	<10%	

[a] Facility operating hours are not measured at user facilities that do not rely on one central machine

[b] For total facilities only, this is a "funding weighted" calculation FOR ONLY TYPE A facilities: $\frac{\sum_1^n [(\%OH\ for\ facility\ n) \times (funding\ for\ facility\ n\ operations)]}{Total\ funding\ for\ all\ facility\ operations}$

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Estimate	FY 2016 vs. FY 2015
Number of permanent Ph.D.'s (FTEs)	4,440	4,440	4,300	4,370	+70
Number of postdoctoral associates (FTEs)	1,160	1,160	1,110	1,130	+20
Number of graduate students (FTEs)	1,730	1,730	1,670	1,690	+20
Other[a]	2,930	2,930	2,840	2,890	+50

[a] Includes technicians, support staff, and similar positions.

13-SC-10, Linac Coherent Light Source-II
SLAC National Accelerator Laboratory, Menlo Park, California
Project is for Design and Construction

1. Significant Changes and Summary

Significant Changes

This Construction Project Data Sheet (CPDS) is an update of the FY 2015 CPDS and does not include a new start for the budget year.

In February 2014, the Office of Science conducted an external Independent Project Review (IPR) as part of the CD-1 development and re-approval process. The IPR committee endorsed the CD-1 cost range of $750,000,000-$1,200,000,000, but noted that the project contingency level is lower than that of other comparably scaled projects. Since then, Basic Energy Sciences (BES) has worked with the project to further evaluate the project work scope and cost estimate in response to the IPR. In July 2014, BES revised the preliminary TPC point estimate from $895,000,000 to $965,000,000 to include the cost of removing the existing linac in the first kilometer of the tunnel, utility and equipment upgrades needed to support the new superconducting linac and high repetition rate operation, and additional project contingency to reduce risk. Long-lead procurement items will be executed under CD-3B. The milestone dates have been adjusted to reflect this change, which will increase efficiency and further reduce risk.

Summary

The most recent DOE 413.3B approved Critical Decision (CD) is a revised CD-1 (Approve Alternative Selection and Cost Range) that was approved on August 22, 2014, with a preliminary TPC range of $750,000,000-$1,200,000,000.

A Federal Project Director has been assigned to this project and has approved this CPDS.

The revised LCLS-II project will construct a new high repetition rate electron injector and replace the first kilometer of the existing linac with a 4 GeV superconducting linac to create the electron beam required for x-ray production in the 0.2–5 keV range with a repetition rate near 1 MHz. The new electron beam will be transported to the existing undulator hall and will be capable of feeding either of the two new variable gap undulators. At the completion of the LCLS-II project, the facility will operate two independent electron linacs and two independent x-ray sources, supporting up to six experiment stations. The revised project will require a cryogenic plant to cool the linac to superconducting temperatures. A 10,000 square foot building will be constructed to house the cryogenic equipment.

An updated Acquisition Strategy was prepared in support of reapproval of CD-1. FY 2014 funding continued design work, R&D, prototyping activities, and fabrication of technical equipment. FY 2015 activities include design, long lead procurements of cryogenic systems, advance procurements of technical materials (primarily niobium), R&D, prototyping, fabrication, and installation activities. FY 2016 funding will continue activities for design, R&D, prototyping, fabrication, and installation, and initiate construction activities.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2013	4/22/2010		10/14/2011	1Q FY 2013	4Q FY 2016	3Q FY 2013	N/A	4Q FY 2019
FY 2014	4/22/2010		10/14/2011	4Q FY 2013	4Q FY 2016	4Q FY 2013	N/A	4Q FY 2019
FY 2015[a]	4/22/2010		10/14/2011	4Q FY 2015	4Q FY 2017	4Q FY 2016	N/A	4Q FY 2021
FY 2016	4/22/2010	1/21/2014	8/22/2014	2Q FY 2016	4Q FY 2017	2Q FY 2016	N/A	4Q FY 2021

[a] This project is pre-CD-2; the estimated cost and schedule are preliminary. Construction will not be executed without appropriate CD approvals.

CD-0 – Approve Mission Need for a construction project with a conceptual scope and cost range
Conceptual Design Complete – Actual date the conceptual design was completed (if applicable)
CD-1 – Approve Design Scope and Project Costs and Schedule Ranges
CD-2 – Approve Project Performance Baseline
Final Design Complete – Estimated/Actual date the project design will be/was complete (d)
CD-3 – Approve Start of Construction
D&D Complete – Completion of D&D work
CD-4 – Approve Start of Operations or Project Closeout

	Performance Baseline Validation	CD-3A	CD-3B
FY 2013	1Q FY 2013	3/14/2012	
FY 2014	4Q FY 2013	3/14/2012	
FY 2015	4Q FY 2015	3/14/2012	
FY 2016	2Q FY 2016	3/14/2012[a]	3Q FY 2015

CD-3A – Approve Long-Lead Procurements, Original Scope
CD-3B – Approve Long-Lead Procurements, Revised Scope

3. Project Cost History

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC, Except D&D	OPC, D&D	OPC, Total	TPC
FY 2013	18,000	367,000	385,000	20,000	N/A	20,000	405,000
FY 2014	18,000	367,000	385,000	20,000	N/A	20,000	405,000
FY 2015[b,c]	47,000	799,400	846,400	48,600	N/A	48,600	895,000
FY 2016[c,d]	47,000	869,400	916,400	48,600	N/A	48,600	965,000

4. Project Scope and Justification

Scope

SLAC's advances in the creation, compression, transport, and monitoring of bright electron beams have spawned a new generation of x-ray radiation sources based on linear accelerators rather than on storage rings. The Linac Coherent Light Source (LCLS) produces a high-brightness x-ray beam with properties vastly exceeding those of current x-ray sources in three key areas: peak brightness, coherence, and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons, providing up to 10^{12} x-ray photons in a pulse with duration in the range of 3–500 femtoseconds. These characteristics of the LCLS have opened new realms of research in the chemical, material, and biological sciences. LCLS-II will build on the success of LCLS by expanding the spectral range of hard x-rays produced at the facility by adding a new high repetition rate, spectrally tunable x-ray source. The repetition rate for x-ray production in the 0.2–5 keV range will be increased by at least a factor of 1,000 to yield unprecedented high average brightness x-rays that will be unique worldwide.

[a] CD-3A was approved as part of the original project scope prior to the July 2013 BESAC recommendation. All original project scope long lead procurement work was suspended.
[b] This project is pre-CD-2; the estimated cost and schedule are preliminary. Construction will not be executed without appropriate CD approvals.
[c] Includes MIE funding of $7,000,000 for the design phase and $60,000,000 for the construction phase, which results in $67,000,000 of TEC funding, as well as $18,600,000 of OPC funding, for a total of $85,600,000 of MIE funding in the TPC.

LCLS is based on the existing SLAC linear accelerator (linac), which is not a superconducting linac. The linac was originally designed to accelerate electrons and positrons to 50 GeV for colliding beam experiments and for nuclear and high energy physics experiments on fixed targets. It was later adapted for use as a FEL (the LCLS facility) and for advanced accelerator research. At present, the last third of the 3 kilometer linac is being used to operate the LCLS facility, and the first 2 kilometers are used for advanced accelerator research.

The revised LCLS-II project based on the July 2013 Basic Energy Sciences Advisory Committee (BESAC) report will construct a new high repetition rate electron injector and replace the first kilometer of the linac with a 4 GeV superconducting linac to create the electron beam required for x-ray production in the 0.2–5 keV range with a repetition rate near 1 MHz. The new electron beam will be transported to the existing undulator hall and will be capable of feeding either of the two new variable gap undulators. The revised project will require a cryogenic plant to cool the linac to superconducting temperatures. A 10,000 square foot building will be constructed to house the cryogenic equipment.

The third kilometer of the linac will continue to produce 14 GeV electron bunches for hard x-ray production at a 120 Hz repetition rate. The electron bunches will be sent to both of the new undulators to produce two simultaneous x-ray beams. The x-ray beams will span a tunable photon energy range of 1 to 25 keV, beyond the range of the existing LCLS facility, and they will incorporate "self-seeding sections" to greatly enhance the longitudinal coherence of the x-ray beams. The middle kilometer of the existing linac will not be used as part of LCLS-II but will continue to be used for advanced accelerator research. It would be available for future expansion of the LCLS-II capabilities.

At the completion of the LCLS-II project, the facility will operate two independent electron linacs and two independent x-ray sources, supporting up to six experiment stations. Both the capability and capacity of the facility will be significantly enhanced. The combined characteristics (spectral content, peak power, average brightness, pulse duration, and coherence) of the new x-ray sources will surpass the present capabilities of the LCLS beam in spectral tuning range and brightness. The high repetition rate will accommodate more experiments. Furthermore, the two new undulators will be independently controlled to enable more experiments to be conducted simultaneously.

Experience with LCLS has, for the first time, provided data on performance of the x-ray instrumentation and optics required for scientific experiments with the LCLS. The LCLS-II project will take advantage of this knowledge base to design LCLS-II x-ray transport, optics, and diagnostics matched to the characteristics of these sources. The LCLS-II project scope is able to leverage the existing suite of LCLS instrumentation for characterization of the x-ray sources with moderate upgrades primarily to address the higher repetition rate operation.

The existing LCLS Beam Transport and Undulator Hall will be modified as necessary to house the new undulators, electron beam dumps, and x-ray optics. The existing experimental stations will be updated as necessary for the exploitation of the new x-ray sources. In contrast to the initial version of the project, construction of a new undulator tunnel and a new instrument suite will not be required.

The LCLS-II project developed strategic partnerships with other SC laboratories for the design, fabrication, installation, and commissioning of the new superconducting linear accelerator, the high repetition rate electron injector and the new variable gap undulators.

Prior to implementing the revised LCLS-II project, the original LCLS-II scope included construction of the Sector 10 Annex with a total cost of $8.2M. The construction costs are included in the preliminary Total Project Cost of $965M.

<u>Justification</u>

The LCLS-II project's purpose is to expand the x-ray spectral operating range and the user capacity of the existing LCLS facility. The expanded spectral range will enable researchers to tackle new research frontiers. The capacity increase is critically needed as the demand for LCLS capabilities far exceeds the available time allocation to users. The revised LCLS-II presented here is informed by 2013 BESAC recommendations to provide "high repetition rate, ultra-bright, transform limited, femtosecond x-ray pulses over a broad photon energy (about 0.2–5 keV) with full spatial and temporal coherence" and the "linac should feed multiple independently tunable undulators each of which could have multiple endstations." Collectively, the project will enable groundbreaking research in a wide range of scientific disciplines in chemical, material and biological sciences.

Based on the factors described above, the most effective and timely approach for DOE to meet the Mission Need and realize the full potential of the LCLS is upgrading the existing x-ray free electron laser at SLAC with a new superconducting accelerator and x-ray sources.

The project has an exemption from the project management requirements in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets; however, the project is being conducted in accordance with the project management requirements in DOE O 413.3B, and all appropriate project management requirements have been met.

Key Performance Parameters (KPPs)

The Threshold KPPs, which will define the official performance baseline at CD-2, represent the minimum acceptable performance that the project must achieve. Achievement of the Threshold KPPs will be a prerequisite for approval of CD-4, Project Completion. The Objective KPPs represent the desired project performance. If project performance is sustained and funds are available, the project will strive to attain the Objective KPPs. The KPPs presented here are preliminary, pre-baseline values. The final key parameters will be established as part of CD-2, Performance Baseline.

Preliminary LCLS-II Key Performance Parameters

Performance Measure	Threshold	Objective
Variable gap undulators	2 (soft and hard x-ray)	2 (soft and hard x-ray)
Superconducting linac-based FEL system		
Superconducting linac electron beam energy	3 GeV	≥ 4 GeV
Superconducting linac repetition rate	50 kHz	1,000 kHz
Superconducting linac charge per bunch	0.02 nC	0.1 nC
Photon beam energy range	250–2,800 eV	200–5,000 eV
High repetition rate capable end stations	≥ 1	≥ 2
FEL photon quantity (10^{-3} BW[a])	10^{9} (10x spontaneous @ 2.5 keV)	> 10^{11} @ 2.5 keV
Normal conducting linac-based system		
Normal conducting linac electron beam energy	13 GeV	15 GeV
Normal conducting linac repetition rate	120 Hz	120 Hz
Normal conducting linac charge per bunch	0.1 nC	0.25 nC
Photon beam energy range	1–13,000 eV	1–25,000 eV
Low repetition rate capable end stations	≥ 2	≥ 3
FEL photon quantity (10^{-3} BW[a])	10^{10} (10x spontaneous @ 13 keV)	> 10^{12} @ 13 keV

[a] Fractional bandwidth. The specified KPPs are the number of photons with an energy within 0.1% of the specified central value.

5. Financial Schedule

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Design phase			
MIE funding			
FY 2012	2,000	2,000	2,000
FY 2013[a]	5,000	5,000	5,000
Total, MIE funding	7,000	7,000	7,000
Line item construction funding			
FY 2014	4,000	4,000	3,500
FY 2015	21,000	21,000	20,000
FY 2016	15,000	15,000	14,500
FY 2017	0	0	2,000
Total, Line item construction funding	40,000	40,000	40,000
Total, Design phase	47,000	47,000	47,000
Construction phase			
MIE funding			
FY 2012	42,500[b]	20,000	13,862
FY 2013[f]	17,500	40,000	27,285
FY 2014	0	0	12,256
FY 2015	0	0	6,597
Total, MIE funding	60,000	60,000	60,000
Line item construction funding			
FY 2014	71,700	71,700	18,713
FY 2015	117,700	117,700	136,387
FY 2016	185,300	185,300	180,300
FY 2017	189,100	189,100	176,000
FY 2018	176,000	176,000	186,000
FY 2019	69,600	69,600	68,700
FY 2020	0	0	43,300
Total, Line item construction funding	809,400	809,400	809,400
Total, Construction phase	869,400	869,400	869,400

[a] FY 2013 funding was requested as a line item, but due to a Continuing Resolution, FY 2013 funds were executed as an MIE.
[b] FY 2012 funding shown includes $22,500,000 of prior year balances from FY 2012 that was reallocated to the LCLS-II project during FY 2013.

	(dollars in thousands)		
	Appropriations	Obligations	Costs
TEC			
MIE funding			
FY 2012	44,500[b]	22,000	15,862
FY 2013[a]	22,500	45,000	32,285
FY 2014	0	0	12,256
FY 2015	0	0	6,597
Total, MIE funding	67,000	67,000	67,000
Line item construction funding			
FY 2014	75,700	75,700	22,213
FY 2015	138,700	138,700	156,387
FY 2016	200,300	200,300	194,800
FY 2017	189,100	189,100	178,000
FY 2018	176,000	176,000	186,000
FY 2019	69,600	69,600	68,700
FY 2020	0	0	43,300
Total, Line item construction funding	849,400	849,400	849,400
Total, TEC[a]	916,400	916,400	916,400
Other Project Cost (OPC)			
OPC except D&D			
MIE funding			
FY 2010	1,126	1,126	938
FY 2011	9,474	9,474	8,033
FY 2012	8,000	8,000	8,893
FY 2013[b]	0	0	116
FY 2014	0	0	439
FY 2015	0	0	181
Total, MIE funding	18,600	18,600	18,600

[a] This project has not yet received CD-2 approval; funding and cost estimates are preliminary. Amounts shown include MIE funding of $67,000,000 in the TEC, $18,600,000 in the OPC, and $85,600,000 in the TPC.
[b] FY 2013 funding was requested as a line item, but due to a Continuing Resolution, FY 2013 funds were executed as an MIE.

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Line item construction funding			
FY 2014	10,000	10,000	8,142
FY 2015	9,300	9,300	2,858
FY 2016	0	0	4,000
FY 2017	0	0	4,300
FY 2018	5,900	5,900	5,700
FY 2019	4,800	4,800	4,300
FY 2020	0	0	700
Total, Line item construction funding	30,000	30,000	30,000
Total, OPC	48,600	48,600	48,600
Total Project Cost (TPC)			
MIE funding			
FY 2010	1,126	1,126	938
FY 2011	9,474	9,474	8,033
FY 2012	52,500	30,000	24,755
FY 2013[a]	22,500	45,000	32,401
FY 2014	0	0	12,695
FY2015	0	0	6,778
Total, MIE funding	85,600	85,600	85,600
Line item construction funding			
FY 2014	85,700	85,700	30,355
FY 2015	148,000	148,000	159,245
FY 2016	200,300	200,300	198,800
FY 2017	189,100	189,100	182,300
FY 2018	181,900	181,900	191,700
FY 2019	74,400	74,400	73,000
FY 2020	0	0	44,000
Total, Line item construction funding	879,400	879,400	879,400
Total, TPC[b]	965,000	965,000	965,000

6. Details of Project Cost Estimate

	(dollars in thousands)		
	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	37,770	37,770	N/A

[a] FY 2013 funding was requested as a line item, but due to a Continuing Resolution, FY 2013 funds were executed as an MIE.
[b] This project has not yet received CD-2 approval; funding and cost estimates are preliminary. Amounts shown include MIE funding of $67,000,000 in the TEC, $18,600,000 in the OPC, and $85,600,000 in the TPC.

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Contingency	9,230	9,230	N/A
Total, Design	47,000	47,000	N/A
Construction			
Site Preparation	24,700	4,700	N/A
Equipment	564,800	564,800	N/A
Other Construction	58,500	38,500	N/A
Contingency	221,400	191,400	N/A
Total, Construction	869,400	799,400	N/A
Total, TEC	916,400	846,400	N/A
Contingency, TEC	230,630	200,630	N/A
Other Project Cost (OPC)			
OPC except D&D			
Conceptual Planning	1,980	1,980	N/A
Conceptual Design	23,658	23,658	N/A
Research and Development	1,972	1,972	N/A
Start-Up	11,550	11,550	N/A
Contingency	9,440	9,440	N/A
Total, OPC	48,600	48,600	N/A
Contingency, OPC	9,440	9,440	N/A
Total, TPC[a]	965,000	895,000	N/A
Total, Contingency	240,070	210,070	N/A

(dollars in thousands)

7. Schedule of Appropriations Requests

($K)

Request		Prior Years	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	Outyears	Total
FY 2012 (MIE)	TEC	22,000	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	OPC	18,600	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
	TPC	40,600	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
FY 2013[b] (MIE)	TEC	165,800	94,000	105,300	19,900	0	0	0	0	385,000
	OPC	19,300	0	700	0	0	0	0	0	20,000
	TPC	185,100	94,000	106,000	19,900	0	0	0	0	405,000
FY 2014	TEC	162,000	122,500	100,500	0	0	0	0	0	385,000
	OPC	19,300	0	700	0	0	0	0	0	20,000
	TPC	181,300	122,500	101,200	0	0	0	0	0	405,000

[a] This project has not yet received CD-2 approval; funding and cost estimates are preliminary. Amounts shown include MIE funding of $67,000,000 in the TEC, $18,600,000 in the OPC, and $85,600,000 in the TPC.
[b] FY 2013 funding was requested as a line item, but due to a Continuing Resolution, FY 2013 funds were executed as an MIE.

Request		Prior Years	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	Outyears	Total
FY 2015[a]	TEC	142,700	138,700	204,000	185,100	156,000	19,900	0	0	846,400
	OPC	28,600	9,300	0	0	5,900	4,800	0	0	48,600
	TPC	171,300	148,000	204,000	185,100	161,900	24,700	0	0	895,000
FY 2016[n]	TEC	142,700	138,700	200,300	189,100	176,000	69,600	0	0	916,400
	OPC	28,600	9,300	0	0	5,900	4,800	0	0	48,600
	TPC	171,300	148,000	200,300	189,100	181,900	74,400	0	0	965,000

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	4QFY2020
Expected Useful Life (number of years)	25
Expected Future Start of D&D of this capital asset (fiscal quarter)	4QFY2045

(Related Funding Requirements)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations and Maintenance	$38.6M	N/A	$1,317.0M	N/A

The numbers presented are the incremental lifecycle operations and maintenance costs above the existing LCLS. The estimate will be updated and additional details provided after CD-2.

9. D&D Information

The new area being constructed in this project is not replacing existing facilities.

	Square Feet
New area being constructed by this project at SLAC	10,000
Area of D&D in this project at SLAC	0
Area at SLAC to be transferred, sold, and/or D&D outside the project including area previously “banked”	10,000
Area of D&D in this project at other sites	0
Area at other sites to be transferred, sold, and/or D&D outside the project including area previously “banked”	0
Total area eliminated	10,000

[a] This project has not yet received CD-2 approval; funding and cost estimates are preliminary. Amounts shown include MIE funding of $67,000,000 in the TEC, $18,600,000 in the OPC, and $85,600,000 in the TPC.

Prior to implementing the revised LCLS-II project, the original LCLS-II scope included construction of the Sector 10 Annex. This facility is 2,275 ft^2 and was offset by demolition of a 1,630 ft^2 building with the balance offset using banked space. The information above reflects only the new construction associated with the revised project.

10. Acquisition Approach

DOE has determined that the LCLS-II project will be acquired by the SLAC National Accelerator Laboratory under the existing DOE M&O contract.

A Conceptual Design Report for the LCLS-II project has been completed and will be revised based on the new technical parameters. Key design activities, requirements, and high-risk subsystem components will be identified to reduce cost and schedule risk to the project and expedite the startup. The necessary project management systems are fully up-to-date, operating, and are maintained as a SLAC-wide resource.

SLAC is partnering with other SC laboratories for design and procurement of key technical subsystem components. Technical system designs will require research and development activities. Preliminary cost estimates for these systems are based on actual costs from LCLS and other similar facilities, to the extent practicable. Recent cost data has been exploited fully in planning and budgeting for the project. Design of the technical systems will be completed by SLAC or partner laboratory staff. Technical equipment will either be fabricated in-house or subcontracted to vendors with the necessary capabilities.

All subcontracts will be competitively bid and awarded based on best value to the government. Project performance metrics for SLAC are included in the M&O contractor's annual performance evaluation and measurement plan.

Lessons learned from the LCLS Project and other similar facilities will be exploited fully in planning and executing LCLS-II.

Biological and Environmental Research

Overview

The mission of the Biological and Environmental Research (BER) program is to support fundamental research and scientific user facilities to achieve a predictive understanding of complex biological, climatic, and environmental systems for a secure and sustainable energy future.

The program seeks to understand the continuum of biological, biogeochemical, and physical processes needed to describe both simple and complex genomes, on the smallest scales, to environmental and Earth system change, on the largest scales. The program strives to describe and explain how genomic information is translated to functional capabilities, enabling more confident redesign of microbes and plants for sustainable biofuels production, improved carbon storage, and understanding the biological transformation of materials such as nutrients and contaminants in the environment. BER research also advances understanding of how the Earth's dynamic, physical, and biogeochemical systems (the atmosphere, land, oceans, sea ice, and subsurface) interact and cause future climate and environmental change, to provide information that will inform plans for future energy and resource needs.

BER research uncovers nature's secrets from the diversity of microbes and plants to understand how biological systems work, how they interact with each other, and how they can be manipulated to harness their processes and products. Starting with the genetic potential encoded by organisms' genomes, BER scientists seek to define the principles that guide the translation of the genetic code into functional proteins and the metabolic and regulatory networks underlying the systems biology of plants and microbes as they respond to and modify their environments. BER plays a unique and vital role in supporting research on atmospheric and terrestrial system processes, interactions between ecosystems and greenhouse gases (especially carbon dioxide [CO_2]), climate and earth system modeling, and analysis of impacts and interdependencies of climatic change with energy production and use. BER research addresses the three most important sources of uncertainty in our understanding of the earth's radiant energy balance—clouds, aerosols, and atmospheric greenhouse gases—through coordinated efforts in climate modeling and observation. BER also supports research to improve the understanding of terrestrial ecosystem processes and their representation in Earth system models. Finally, BER research seeks understanding of the critical role that biogeochemical processes play in controlling the cycling and mobility of energy byproducts (e.g., carbon, nutrients, radionuclides and heavy metals) in the earth's subsurface and across key surface-subsurface interfaces in the environment.

BER's scientific impact has been transformative. Efforts to map the human genome, including the U.S.-supported international Human Genome Project, which DOE formally began in 1990, initiated the era of modern biotechnology and genomics-based systems biology. Today, with its Genomic Sciences activity and the DOE Joint Genome Institute (JGI), BER researchers are using the powerful tools of plant and microbial systems biology to pursue fundamental breakthroughs needed to develop cost-effective cellulosic biofuels. The three DOE Bioenergy Research Centers lead the world in fundamental biofuels-relevant research.

Since the 1950s, BER has been a critical contributor to climate science research in the U.S., beginning with atmospheric circulation studies that were the forerunners of modern climate models. Today, BER research contributes to model development and analysis using community-based models, e.g., Community Earth System Model (CESM), the Advanced Climate Model for Energy (ACME), and the Global Change Assessment Model (GCAM). These leading U.S. models are used to address two of the most critical areas of uncertainty in contemporary climate science—the impacts of clouds and of aerosols—with data provided by the Atmospheric Radiation Measurement Climate Research Facility (ARM), a DOE user facility serving hundreds of scientists worldwide. Also, BER has been a pioneer of ecological and environmental studies in terrestrial ecosystems and seeks to describe the continuum of biological, biogeochemical, and physical processes across multiple scales that control the flux of climate and environmentally-relevant compounds between the terrestrial surface and the atmosphere. BER's Environmental Molecular Sciences Laboratory (EMSL) provides the scientific community with powerful suites of instruments and a high performance computer to characterize biological organisms and molecules.

Highlights of the FY 2016 Budget Request

Biological and Environmental Research will support core research and scientific user facilities in key areas of bioenergy, climate, and environmental sciences.

Biological Systems Science

Investments in Biological Systems Science will provide the fundamental understanding to underpin advances in sustainable bioenergy production, and to gain a predictive understanding of carbon cycling in the environment and bioremediation processes. Genomic Sciences research activities continue with core research currently underway at the DOE Bioenergy Research Centers to provide a scientific basis for sustainable and cost effective bioenergy production. These efforts are complemented by continued research on potential plant feedstocks for bioenergy purposes, new efforts to understand the sustainability of bioenergy production, and biosystems design efforts to modify plants and microbes for bioenergy purposes. Efforts to understand the impact of microbial communities on the cycling of carbon, nutrients and contaminants in understudied environments continues as well as the development of new enabling technologies to visualize the spatial and temporal relationships of key metabolic processes within and among cells. These fundamental genomic science activities are supported by ongoing integrative efforts to combine genomic information in hypothesis-testing computational formats and continued developments to sequence and interpret DNA from a wide variety of plants and microbial communities at the Joint Genome Institute (JGI). The JGI remains an essential component for DOE systems biology efforts providing high quality genome sequence data and analysis techniques to the research community. The JGI continues to implement a new strategic plan to incorporate new capabilities to not only sequence DNA but to interpret, manipulate, and synthesize DNA in support of biofuels, biodesign, and environmental research. Funding levels decrease for efforts in Structural Biology Infrastructure and are completed for Radiological Sciences as Biological Systems Science activities continue to prioritize on DOE's bioenergy and environmental missions.

Climate and Environmental Sciences

Climate and Environmental Research activities will focus on scientific analysis of the sensitivity and uncertainty of climate predictions to physical as well as biogeochemically dominated processes, within both Arctic and Tropical environments, as part of the Next Generation Ecosystem Experiments (NGEEs) in Alaska and at tropical sites. Each major field study contains a modeling component. A new investment in Climate Model Development and Validation focuses on model architecture restructuring, exploiting new software engineering and computational upgrades, incorporating scale-aware physics in all model components and enhanced efforts to assess and validate model results. Increased investment will produce an earth system model capability that includes a human component involving vulnerability analysis and integrated assessment, tailored to DOE requirements, e.g., new research to understand the interdependencies of water, energy and climate change, for a variety of scenarios applied to spatial scales as small as 10km. The model system will have improved resolution that will include new codes for running on numerous processors, flexibility toward future computer architectures, and enhanced usability, testing, adaptability, multi-scale treatments, and provenance. The modeling efforts will be validated against new atmospheric and terrestrial observations.

ARM continues long-term measurements at fixed sites in Alaska, Oklahoma, and the Azores, selected for scientific impact on improving climate models. The ARM mobile facilities will rotate deployments to three climate-sensitive regions demanding focused and targeted measurements in the Arctic, Antarctic, and the Pacific Ocean. EMSL will focus on an aggressive research agenda, utilizing the High Resolution and Mass Accuracy Capability (HRMAC), i.e., a powerful magnet integrated with a sophisticated spectrometer that combines with major computational assets.

The Data Management effort will focus on advancing the Climate and Environmental Data Analysis and Visualization activity that will incorporate high resolution Earth system models with interdependent components involving energy and infrastructure sector models, field observations, raw data from environmental field experiments, and analytical tools for system diagnostics, validation, and uncertainty quantification.

Within the FY 2016 Budget Request, the Climate and Environmental Sciences supports the DOE Energy-Water Nexus Crosscut. Specifically, BER Climate and Earth System Modeling Integrated Assessment activities support the crosscut. These investments position DOE to contribute strongly to the Nation's transition to more resilient energy and coupled energy-water systems.

The energy-water nexus crosscut is an integrated set of cross-program collaborations designed to accelerate the Nation's transition to more resilient energy and coupled energy-water systems. The crosscut supports: (1) an advanced, integrated data, modeling, and analysis platform to improve understanding and inform decision-making for a broad range of users and at multiple scales; (2) investments in targeted technology research opportunities within the system of energy-water flows that offer the greatest potential for positive impact; and (3) policy analysis and stakeholder engagement designed to build from and strengthen the two preceding areas while motivating more rapid community involvement and response.

As part of the Exascale Crossscut, BER will be responsible for determining the scope and management of the Climate Modeling programs. Climate modeling science requires resolution of atmospheric and terrestrial processes across multiple scales, to project how systems such as aerosols, clouds, precipitation, ecosystems, and Arctic tundra will shift with climate. Energy and infrastructure planning will require precise projection of temperature exceedances, water availability, sea-level rise, storm likelihood, and crop potentials. The Extreme Challenges workshop series and the Advanced Scientific Computing Advisory Committee Subcommittee report on Exascale climate science articulated the need to understand the dynamic ecological and chemical evolution of the climate system, with quantification of the uncertainties in the impacts on regional and decadal scales.

Exascale systems are needed to support areas of research that are critical to national security objectives as well as applied research advances in areas such as climate models, combustion systems, and nuclear reactor design that are not within the capacities of today's systems. Exascale systems' computational power are needed for increasing capable data-analytic and data-intense applications across the entire Federal complex. Exascale is a component of long-term collaboration between the SC's Advanced Scientific Computing Research (ASCR) program and the National Nuclear Security Administration's (NNSA) Advanced Simulation and Computing Campaign (ASC) program.

FY 2016 Crosscuts ($K)

	Energy-Water	Exascale Computing	Total
Biological and Environmental Research	11,800	18,730	30,530

Biological and Environmental Research
Funding ($K)

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Biological Systems Science					
Genomic Science					
Foundational Genomics Research	74,225	74,225	73,228	76,125	+2,897
Genomics Analysis and Validation	10,052	10,052	10,000	9,248	-752
Metabolic Synthesis and Conversion	19,562	19,562	16,262	16,262	0
Computational Biosciences	16,480	16,480	16,395	16,395	0
Bioenergy Research Centers	75,000	75,000	75,000	75,000	0
Total, Genomic Science	**195,319**	**195,319**	**190,885**	**193,030**	**+2,145**
Mesoscale to Molecules	**7,990**	**7,990**	**9,680**	**9,623**	**-57**
Radiological Sciences					
Radiochemistry and Imaging Instrumentation	11,861	11,861	2,665	1,000	-1,665
Radiobiology	3,217	3,217	2,409	1,000	-1,409
Total, Radiological Sciences	**15,078**	**15,078**	**5,074**	**2,000**	**-3,074**
Biological Systems Facilities and Infrastructure					
Structural Biology Infrastructure	14,990	14,990	14,895	10,000	-4,895
Joint Genome Institute	70,143	70,143	69,500	69,500	0
Total, Biological Systems Facilities and Infrastructure	**85,133**	**85,133**	**84,395**	**79,500**	**-4,895**
SBIR/STTR	8,251		9,858	10,118	+260
Total, Biological Systems Science	**311,771**	**303,520**	**299,892**	**294,271**	**-5,621**
Climate and Environmental Sciences					
Atmospheric System Research	**26,632**	**26,632**	**25,892**	**26,392**	**+500**
Environmental System Science					
Terrestrial Ecosystem Science	45,256	45,256	44,034	40,035	-3,999
Subsurface Biogeochemical Research	24,422	24,422	23,533	23,207	-326
Total, Environmental System Science	**69,678**	**69,678**	**67,567**	**63,242**	**-4,325**

[1] Funding reflects the transfer of SBIR/STTR to the Office of Science.

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Climate and Earth System Modeling					
Climate Model Development and Validation	0	0	0	18,730	+18,730
Regional and Global Climate Modeling	28,472	28,472	26,159	30,088	+3,929
Earth System Modeling	35,541	35,541	35,303	35,569	+266
Integrated Assessment	10,028	10,028	9,733	17,567	+7,834
Total, Climate and Earth System Modeling	**74,041**	**74,041**	**71,195**	**101,954**	**+30,759**
Climate and Environmental Facilities and Infrastructure					
Atmospheric Radiation Measurement Climate Research Facility	68,644	68,644	67,429	65,429	-2,000
Environmental Molecular Sciences Laboratory	46,942	46,942	45,501	43,191	-2,310
Data Management	3,653	3,653	5,000	7,066	+2,066
General Purpose Equipment (GPE)	250	250	0	0	0
General Plant Projects (GPP)	250	250	0	0	0
Total, Climate and Environmental Facilities and Infrastructure	**119,739**	**119,739**	**117,930**	**115,686**	**-2,244**
SBIR/STTR	7,835	0	9,524	10,855	+1,331
Total, Climate and Environmental Sciences	**297,925**	**290,090**	**292,108**	**318,129**	**+26,021**
Total, Biological and Environmental Research	**609,696**	**593,610**	**592,000**	**612,400**	**+20,400**

SBIR/STTR Funding:

- FY 2014 transferred: SBIR $13,666,000 and STTR $2,420,000 of FY 2014 dollars, plus $3,277,000 in unobligated prior year dollars for SBIR.
- FY 2015 projected: SBIR $17,034,000; STTR $2,348,000
- FY 2016 Request: SBIR $18,238,000; STTR $2,735,000

Biological and Environmental Research
Explanation of Major Changes ($K)

	FY 2016 vs. FY 2015
Biological Systems Science: Investments in Genomic Science continue integrative efforts at the Bioenergy Research Centers with complementary research on potential bioenergy feedstock plants, sustainability research for bioenergy, biosystems design, microbial community impacts on carbon and nutrient cycling, and integrative computational approaches for systems biology research. The development of enabling technology to visualize key metabolic processes within and among cells continues with application across the Genomic Science portfolio. JGI continues to provide DNA sequencing, analysis and synthesis support to researchers. Funding for Radiological Sciences is completed and funding for Structural Biology Infrastructure decreases as activities within the portfolio continue to emphasize fundamental genomic science in support of bioenergy and environmental research.	**-5,621**
Climate and Environmental Sciences: Climate and Earth System modeling increases with investments in new research to evaluate geographic regions complementary to existing efforts in the Arctic and the Tropics, that are cause for significant sources of prediction uncertainty. With this new research, science will focus on understanding the interdependencies of water, energy, and climate changes, on spatial resolutions as low as 10 km. Climate Model Development and Validation is initiated to support model architecture restructuring, exploit new software engineering and computational upgrades, and incorporate scale-aware physics in all model components. Environmental System Science decreases and will exploit opportunities for greater efficiencies by aggregating a higher fraction of its research into decadal-scale climate-ecosystem science campaigns e.g., NGEE Arctic, NGEE Tropics, a northern peatland experiment, and AmeriFlux. The Environmental Molecular Sciences Laboratory (EMSL) will address a more focused set of scientific challenges, resulting in sunsetting some capabilities and more efficient utilization of remaining instrumentation and laboratory data collected at EMSL. The Climate and Environmental Data Analysis and Visualization activity increases to provide an integrated capability that allows compatibility and interoperability involving both observed and model generated climate information. Information as part of this activity involves multiple model products in the Earth System Grid Federation (ESGF), and data from environmental field experiments, ARM facility observations, and components of the EMSL data base. ARM decreases its investments in a planned field deployment of the first ARM mobile facility (AMF1) due to delays in field campaigns schedules.	**+26,021**
Total, Biological and Environmental Research	**+20,400**

Basic and Applied R&D Coordination

BER research underpins the needs of DOE's energy and environmental missions. Basic research on microbes and plants provide fundamental understanding that can be used to develop new bioenergy crops and improved biofuel production processes that enable a sustainable bioeconomy. This research is relevant to other DOE offices and agencies, including DOE's Office of Energy Efficiency and Renewable Energy (EERE) and the Advanced Research Projects Agency-Energy (ARPA-E), and the U.S. Department of Agriculture. Coordination with other federal agencies on priority science needs occurs through the Biomass Research and Development Board, a Congressionally mandated interagency group created by the Biomass Research and Development Act of 2000, as amended by the Energy Policy Act of 2005 and the Agricultural Act of 2014, and under the White House Office of Science and Technology Policy (OSTP). Additionally, memoranda of agreements (MOAs) have been signed with the National Science Foundation (NSF) and the National Institute of Allergy and Infectious Diseases (NIAID) to cooperate on computational biology and bioinformatic developments within the DOE Systems Biology Knowledgebase (KBase).

BER research to understand and predict future changes in the earth's climate system provides important tools that link climate predictions to evaluations of new energy policies and help to guide the design criteria for next generation energy infrastructures. An example is water. Water and energy bring together the Office of Science, energy technology offices, and energy policy offices of the Department. Coordination among these offices is important for understanding not only water required for all facets of energy production, from biofuels to thermoelectric cooling, but also the energy required to provide water for various uses. BER research on the transport and transformation of energy-related substances in subsurface environments provides understanding that can enable DOE's Office of Environmental Management (EM) to develop new strategies for the remediation of weapons-related and other contaminants at DOE sites. In general, BER coordinates with DOE's applied technology programs through regular joint program manager meetings, by participating in their internal program reviews and in joint principal investigator meetings, as well as conducting joint technical workshops. Coordination with other federal agencies on priority climate science needs occurs through the interagency U.S. Global Climate Change Research Program under OSTP.

Program Accomplishments

Fundamental Bioenergy Research. DOE's Bioenergy Research Centers (BRCs) continue to advance the fundamental research enabling future efficient use of plant biomass for biofuel production. Detailed studies of how plants build cell walls have yielded new clues to inform the eventual development of woody trees such as poplar as a dedicated bioenergy crop with modified cell wall structures more amendable to sugar release upon biomass deconstruction. New insights into the metabolism of microbes living in extreme environments has resulted in the consolidation of biomass deconstruction and conversion processes in a single microbe, thereby demonstrating proof of concept for direct conversion of plant biomass to ethanol without pre-treatment, which would present a significant potential cost savings for biofuel production. Additionally, incorporation of new metabolic pathways engineered or derived from other organisms in nature, combined with the latest insights into gene regulation have produced a range of advanced biofuels and/or important precursors to advanced biofuels in model platform microorganisms. These results are but a snapshot of a much larger volume of research from the BRCs that continue to provide a firm scientific foundation to cellulosic biofuels development.

Genome-Enabled Systems Biology Research. New Genomic Science research on carbon cycling that combines DNA sequencing of the full microbial community (metagenomics) and analysis of expressed proteins has led to the identification of key active members of a methane-generating microbial community present in thawing arctic bogs. This new group of methanogenic microbes is widely dispersed in similar arctic bogs around the world and could help to simplify efforts to predict microbial methane production in these environments. In related studies, detailed genome-enabled approaches applied to methane-consuming bacteria led to the discovery of microbial methane consumption via a new fermentative pathway in the absence of oxygen. Combined, these discoveries are providing detailed new knowledge on how the activity of multiple members of a microbial community impact and control the cycling of methane in key environments.

New Translations of the Genetic Blueprint. Researchers at the Joint Genome Institute (JGI) used a combination of microbial community DNA sequencing techniques (metagenomics) and single-cell recovery and genome sequencing of microorganisms from a broad range of environments demonstrated that alternative translations of the genetic code exist in nature. Analysis of genomic DNA from some species could not be interpreted using the canonical techniques; however, translating the sequence using the new alternative coding rules revealed interpretable genomes. These results challenge researchers to consider alternative interpretations of genomes recovered from nature, with profound implications for understanding the origins of the genetic code, evolutionary pressures on genome coding and manipulation of metabolic pathways for beneficial purposes.

Improving Climate Models to Better Predict Precipitation. While climate models are adept at predicting future temperature changes on regional and global scales, the quality of precipitation predictions has not kept pace. To address this need, scientists used observations from the DOE Atmospheric Radiation Measurement Climate Research Facility (ARM) to discover that precipitation forecasts are limited largely by overly simplistic formulas for Secondary Organic Aerosols (SOAs) that influence droplet initiation and cloud formation. Using laboratory and field experimental data, the research has improved the understanding of SOA chemistry, including better understanding of how SOAs serve as cloud condensation nuclei. The improved formulas were incorporated into a climate model with significantly improved predictability of clouds and precipitation.

Simulating Agricultural Irrigation in Earth System Models. World agriculture consumes about 87 percent of global fresh water withdrawal, acting as a dominant component of the global water cycle with impacts on local and regional climates. Previous studies of irrigation impacts on climate have focused on a subset of local surface processes, but no study has applied uncertainty quantification methodologies to the combination of atmospheric, terrestrial, and water cycle interdependencies. Scientists upgraded the land component (CLM4) of the Community Earth System Model (CESM), to simulate irrigation water use and climatic feedbacks. Drawing upon two widely-used data sets from the agriculture census, they found that CLM4 could be improved by applying updated calibrations and incorporating information on the spatial distribution and intensity of irrigated areas. More importantly, the team identified a way to realistically assess the impacts of irrigation on climate and strategies to improve water management practices. Their results integrate a new set of CLM4 modules into CESM that describe groundwater pumping and irrigation efficiency, stream flow routing, and water management.

Description

Biological Systems Science integrates discovery- and hypothesis-driven science with technology development on plant and microbial systems relevant to DOE bioenergy mission needs. Systems biology is the multidisciplinary study of complex interactions specifying the function of entire biological systems—from single cells to multicellular organisms—rather than the study of individual components. The Biological Systems Science subprogram focuses on using systems biology approaches to define the functional principles that drive living systems, from microbes and microbial communities to plants and other whole organisms.

Key questions that drive these studies include:

- What information is encoded in the genome sequence?
- How is information exchanged between different subcellular constituents?
- What molecular interactions regulate the response of living systems and how can those interactions be understood dynamically and predictively?

The subprogram builds upon a successful track record in defining and tackling bold, complex scientific problems in genomics—problems that required the development of large tools and infrastructure; strong collaboration with the computational sciences community and the mobilization of multidisciplinary teams focused on plant and microbial bioenergy research. The approaches employed include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of information into computational models that can be iteratively tested and validated to advance a predictive understanding of biological systems from molecules to mesoscale.

The subprogram supports operation of a scientific user facility, the DOE Joint Genome Institute (JGI), and use of structural biology facilities through the development of instrumentation at DOE's national scientific user facilities. Support is also provided for research at the interface of the biological and physical sciences and instrumentation for radiochemistry to develop new methods for real-time, high-resolution imaging of dynamic biological processes.

<u>Genomic Science</u>

The Genomic Science activity supports research aimed at identifying the fundamental principles that drive biological systems relevant to DOE missions in energy, climate, and the environment. These principles guide the translation of the genetic code into functional proteins and the metabolic/regulatory networks underlying the systems biology of plants, microbes, and communities. Advancing fundamental knowledge of these systems will enable new solutions to national challenges in sustainable bioenergy production, understanding how microbial activity impacts the fate and transport of materials such as nutrients and contaminants in the environment, and developing new approaches to examine the role of biological systems in carbon cycling, biosequestration, and global climate.

The major objectives of the Genomic Science activity are to determine the molecular mechanisms, regulatory elements, and integrated networks needed to understand genome-scale functional properties of microbes, plants, and communities; develop "-omics" experimental capabilities and enabling technologies needed to achieve a dynamic, system-level understanding of organism and community functions; and develop the knowledgebase, computational infrastructure, and modeling capabilities to advance predictive understanding, manipulation and design of biological systems.

A major effort within the portfolio seeks to provide a fundamental understanding of the biology of plants and microbes as a basis for developing cost effective processes for biofuel production from cellulosic biomass. The DOE Bioenergy Research Centers (BRCs) are central to this effort and have provided a substantial body of scientific literature and intellectual property towards this goal. Additional efforts within Genomic Sciences include fundamental research on new plant feedstocks for bioenergy, new sustainability research for bioenergy production, biosystems design to develop new plants and microbes with bioenergy-relevant traits and environmental microbiological research to understand the cycling and fate of carbon, nutrients and contaminants in the environment. These systems biology efforts are supported by the ongoing development of bioinformatics and computational biology capabilities within the DOE Systems Biology Knowledgebase (KBase). The integrative KBase projects seek to develop the necessary hypothesis-generating analysis techniques and simulation capabilities on high performance computing platforms to accelerate systems biology research within the Genomic Sciences.

Mesoscale to Molecules

BER approaches to systems biology focus on translating information encoded in an organism's genome to those traits expressed by the organism. These genotype to phenotype translations are key to gaining a predictive understanding of cellular function under a variety of environmental and bioenergy-relevant conditions. The Mesoscale to Molecules activity will continue to encourage the development of new measurement and imaging technologies to visualize the spatial and temporal relationships of key metabolic processes governing phenotypic expression in plants and microbes. This information is crucial towards developing an understanding of the impact of various environmental and/or biosystems design impacts on whole cell or community function.

Radiological Sciences

Radiological Sciences supports radionuclide tracer synthesis and imaging research for real-time visualization of dynamic biological processes in energy and environmentally relevant contexts. The activity has significantly transitioned from its historical focus on nuclear medicine research and applications for human health to focus on real-time, whole organism understanding of metabolic and signaling pathways in plants and nonmedical microbes. Radionuclide imaging continues to be a singular tool for studying living organisms in a manner that is quantitative, three dimensional, temporally dynamic, and non-perturbative of the natural biochemical processes. The instrumentation research focuses on improved metabolic imaging in living systems, including plants and microbial-communities, relevant to biofuels production and environmental processes. The activity also supports fundamental research on the impacts of low dose radiation on metabolic processes and DNA repair mechanisms in model biological systems.

Biological Systems Science Facilities and Infrastructure

Biological Systems Science supports unique scientific facilities and infrastructure related to genomics and structural biology that are widely used by researchers in academia, the national laboratories, and industry. The DOE Joint Genome Institute (JGI) is the only federally funded major genome sequencing center focused on genome discovery and analysis in plants and microbes for energy and environmental applications. High-throughput DNA sequencing underpins modern systems biology research, providing fundamental biological data on organisms and groups of organisms. By understanding shared features of multiple genomes, scientists can identify key genes that may link to biological function. These functions include microbial metabolic pathways and enzymes that are used to generate fuel molecules, affect plant biomass formation, degrade contaminants, or capture CO_2, leading to the optimization of these organisms for biofuels production and other DOE missions.

The JGI is developing aggressive new strategies for interpreting complex genomes through new high-throughput functional assays, DNA synthesis and manipulation techniques and, genome analysis tools in association with the DOE Systems Biology KBase. These new capabilities are part of the JGI's latest strategic plan to provide users with additional capabilities supporting biosystems design efforts for biofuels and environmental process research. The JGI also performs metagenome (genomes from multiple organisms) sequencing and analysis from environmental samples and single cell sequencing techniques for hard-to-culture microorganisms from understudied environments relevant to the DOE missions.

BER also supports development and use of specialized instrumentation for biology at major DOE user facilities, such as synchrotron light sources and neutron facilities, in collaboration with the other SC program offices. These research facilities enable science aimed at understanding the structure and properties of biological molecules at resolutions and scales not accessible with instrumentation available in university, research institute, or industrial laboratories. This information is critical in contributing to our understanding of the relationship between genome, biological structure, and function. BER is also taking steps to ensure that the data will be integrated into the DOE Systems Biology KBase to help accelerate practical applications of this knowledge for energy and the environment.

Biological and Environmental Research
Biological Systems Science

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Biological Systems Science $299,892,000	**$294,271,000**	**-$5,621,000**
Genomic Science ($190,885,000)	**($193,030,000)**	**(+$2,145,000)**
Genomic Science research remains a priority activity. Foundational Genomics Research continues to support development of biosystems design tools and biodesign technologies for plant and microbial systems relevant to bioenergy production, and genomics enabled approaches to examine impacts of bioenergy production and climate change on carbon and nutrient cycling processes in terrestrial ecosystems. At least 5% of the funding for biodesign efforts is used to study the environmental, ethical, legal, and societal impacts. Genomics Analysis and Validation integrates experimental biology and technology development to improve functional characterization of genomic datasets. The emphasis of research in Metabolic Synthesis and Conversion shifts to advancing systems biology understanding and developing tools for the genetic modification of a broader set of plant and microbial species relevant to carbon cycling and bioenergy production. Research efforts at the Bioenergy Research Centers continue to advance biofuels development from foundational biological systems science. Computational Biosciences continues to support the operation of the DOE Systems Biology KBase, providing the research community with online tools for data integration and predictive modeling and increasing development of interoperable platforms for varying data types and scaling of data environments	Genomic Science will continue to remain a top priority. Foundational Genomics will increase to develop biosystems design techniques for plants and microbial systems relevant to bioenergy production and research on key parameters influencing the sustainability of bioenergy crops. Genome Analysis and Validation will continue research on improving the functional characterization of microorganisms and microbial communities relevant to biofuel production. Metabolic Synthesis and Conversion will continue research to broaden the range of model plant and microbial systems available for bioenergy research and, to understand the impact of microbial communities on the fate of carbon, nutrients and contaminants in the environment. At least 5% of the funding for biodesign efforts will be used to study the environmental, ethical, legal, and societal impacts. Computational Biosciences will continue to advance the bioinformatics and computational biology techniques needed within the DOE Systems Biology KBase to accelerate systems biology research. Bioenergy research at the DOE Bioenergy Research Centers will continue to provide a fundamental scientific basis for cellulosic biofuels production.	Increased efforts in Biosystems design efforts will develop additional metabolic engineering techniques for bioenergy production. Other Genomic Science research including bioenergy, computational biology and, plant and microbial research relevant to bioenergy and environmental research continue at near FY 2015 levels. Genome Analysis and Validation is reduced in order to support biosystems design efforts.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
across multiple levels of biological organization.		
Mesoscale to Molecules ($9,680,000)	**($9,623,000)**	**(-$57,000)**
The properties of many complex systems at one observational scale cannot be extrapolated accurately from processes at another scale because the nature of the scaling relationships is unknown. Increased investments complement pilot projects initiated in FY 2014 and continue efforts to understand the spatial organization of metabolic processes in cells and the physical rules that govern metabolism in subcellular organelles in biological systems. Identifying scaling relationships allows accurate representation of functional relationships within the cell, facilitating improved predictions of multicellular interactions and biological organism behavior with respect to energy and the environment. New modeling concepts will be developed and validated with new imaging tools and resources at the national scientific user facilities and within the DOE Systems Biology KBase.	The development of new enabling technologies to visualize key metabolic processes in plants and microbes will continue. These new techniques will provide integrative information on the spatial and temporal relationships of metabolic processes occurring within and among cells. This information is crucial to integrating molecular scale understanding of metabolic processes into the context of the dynamic whole cell environment and to the development of predictive models of cell function.	No significant change.
Radiological Sciences ($5,074,000)	**($2,000,000)**	**(-$3,074,000)**
Core activities in Radiochemistry and Imaging Instrumentation continue to stress development of radiotracer techniques and instrumentation to visualize metabolic processes in plants and microbes non-invasively and in real time. Core efforts in radiobiology continue to evaluate methods to translate molecular-scale effects of low dose radiation to whole model organisms.	Funds are requested for an orderly closeout of Radiological Science activities in FY 2016.	Activities within the Radiological Sciences continue to decrease as research within the Biological Systems Science activity is prioritized on bioenergy and environmental research within the Genomic Science activity. Funding levels are reduced as these activities are proposed to be closed out in FY 2016.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Biological Systems Science Facilities and Infrastructure ($84,395,000)	**($79,500,000)**	**(-$4,895,000)**
The JGI maintains its efforts to provide high quality DNA sequence and also brings on new capabilities to interpret, manipulate, and write DNA in support of biofuels, biodesign, and environmental research as part of the implementation of JGIs' new strategic plan. JGI continues to maintain a close linkage with the DOE Systems Biology KBase allowing the research community to access and analyzes the latest genome sequence information produced by the JGI.	The JGI remains an essential component for genomic research within BER. The facility will continue to implement its latest strategic plan and provide scientific users with plant and microbial genome sequences of the highest quality and advanced capabilities to analyze, interpret and manipulate genes in support of bioenergy, biosystems design and environmental research. The JGI will continue to collaborate closely with the DOE Systems Biology KBase to provide not only community access to sequenced genomes but access to computational systems to experimentally interrogate those genomes.	No significant change in funding. The number of JGI users is expected to increase as new functional genomics and DNA synthesis capabilities become available.
Support continues for the instrumentation and end stations for structural biology at the DOE synchrotron light and neutron sources. Additional efforts are made to link the resulting data from these stations with the DOE Systems Biology KBase.	Access to the Structural Biology Infrastructure at the DOE synchrotron light and neutron sources will continue to provide information on the structural features of biomolecules and continue to make this information available to the larger research community through the Protein Data Base and the DOE Systems Biology KBase.	Structural Biology decreases as efforts in bioenergy and environmental research in Genomic Science are prioritized within the current budget request. End stations at the DOE synchrotron light and neutron sources will continue to support scientific users. The portfolio will be assessed to ensure that the latest capabilities are available to and being used by the scientific community.

Description

The Climate and Environmental Sciences subprogram supports fundamental science and research capabilities that enable major scientific developments in climate-relevant atmospheric and ecosystem process and modeling research, in support of DOE's mission goals for basic science, energy, and national security. This includes research on clouds, aerosols, and the terrestrial carbon cycle; large-scale climate change and Earth system modeling; the interdependence of climate change and ecosystems; and integrated analysis of climate change impacts on energy and related infrastructure. It also supports subsurface biogeochemical research that advances fundamental understanding of coupled physical, chemical, and biological processes controlling both the terrestrial component of the carbon cycle and the environmental fate and transport of energy byproducts, including greenhouse gases. This integrated portfolio of research from molecular-level to field-scales emphasizes the coupling of multidisciplinary experimentation and advanced computer models and is aimed at developing predictive, systems-level understanding of the fundamental science associated with climate change and other energy-related environmental challenges. The Department will continue to advance the science necessary to further develop predictive climate and Earth system models targeting resolution at the regional spatial scale and interannual to centennial time scales and to focus on areas of critical uncertainty including Arctic ecology and permafrost thaw, tropical ecological change, and carbon release, in close coordination with the U.S. Global Change Research Program (USGCRP) and the international science community. In addition, environmental research activities will support fundamental research to explore advances in environmental cleanup and reductions in life cycle costs.

The subprogram supports three primary research activities, two national scientific user facilities, and a major data activity. The two national scientific user facilities are the Atmospheric Radiation Measurements Climate Research Facility (ARM) and the Environmental Molecular Sciences Laboratory (EMSL). ARM provides unique, multi-instrumented capabilities for continuous, long-term observations needed to develop and test understanding of the central role of clouds and aerosols on the earth's climate. EMSL provides integrated experimental and computational resources needed to understand the physical, chemical, and biological processes that underlie DOE's energy and environmental mission. The data activity encompasses observations collected by dedicated field experiments, routine and long term observations accumulated by user facilities, and model generated information derived from climate modeling platforms.

Atmospheric System Research

Atmospheric System Research (ASR) is the primary U.S. activity addressing two major areas of uncertainty in climate change model projections: the role of clouds and the effects of aerosols on precipitation, and the atmospheric radiation balance. ASR coordinates with ARM, using the facility's continuous long-term datasets that provide three-dimensional measurements of radiation, aerosols, clouds, precipitation, dynamics, and thermodynamics over a range of environmental conditions at diverse climate-sensitive locations. The long-term observational datasets are supplemented with laboratory studies and shorter-duration ground-based and airborne field campaigns to target specific atmospheric processes under a diversity of locations and atmospheric conditions. ASR research results are incorporated into Earth system models developed by Climate and Earth System Modeling to both understand the processes that govern atmospheric components and to advance Earth system model capabilities with greater certainty of predictions. ASR seeks to develop integrated, scalable test-beds that incorporate process-level understanding of the life cycles of aerosols, clouds, and precipitation into dynamic models.

Environmental System Science

Environmental System Science supports research to provide a robust, predictive understanding of terrestrial surface and subsurface ecosystems, including the effects of climate change, from the subsurface to the top of the vegetated canopy and from molecular to global scales. This includes understanding the role of ecosystems in climate with an emphasis on carbon cycling and the role of subsurface biogeochemical processes in the fate and transport of carbon, nutrients, radionuclides, and heavy metals.

A significant fraction of the carbon dioxide (CO_2) released to the atmosphere during fossil fuel combustion is taken up by terrestrial ecosystems, but the impacts of climatic change, particularly warming, on the uptake of CO_2 by the terrestrial biosphere remain poorly understood. The significant sensitivity of climate models to terrestrial carbon cycle feedback and the uncertain signs of that feedback make resolving the role of the terrestrial biosphere on the carbon balance a high priority. Using decadal-scale investments such as the Next Generation Ecosystem Experiments (NGEEs) to study the variety of time scales and processes associated with ecological change, the research focuses on understanding, observing, and modeling the processes controlling exchange rates of greenhouse gases, in particular CO_2 and methane (CH_4), between atmosphere and terrestrial biosphere, evaluating terrestrial source-sink mechanisms for CO_2 and CH_4, and improving and validating the representation of terrestrial ecosystems in coupled Earth system models. This research supports the USGCRP interagency priority to understand the impacts of global change on the Arctic Region and resulting effects on global climate.

Subsurface biogeochemical research supports integrated experimental and modeling research, ranging from molecular to field scales, to understand and predict the role that biogeochemical processes play in controlling the cycling and mobility of energy-relevant materials in the subsurface and across key surface-subsurface interfaces in the environment, including environmental contamination from past nuclear weapons production.

Climate and Earth System Modeling

Climate and Earth System Modeling develops physical, chemical, and biological model components, as well as fully coupled Earth system models that combine with sophisticated representations of human activities. This research includes the interactions of human and natural Earth systems needed to simulate climate variability and change from years to decades to centuries at regional and global scales. The research specifically focuses on quantifying and reducing the uncertainties in Earth system models based on more advanced model development, diagnostics, and climate system analysis. Priority model components include the ocean, sea-ice, land-ice, aerosols, atmospheric chemistry, terrestrial carbon cycling, multi-scale dynamical and physical interdependencies, and dynamical cores. This research supports the USGCRP interagency priority in intraseasonal to centennial predictability, predictions and projections, including focus on extreme events.

In FY 2016, BER will initiate an investment in Climate Model Development and Validation. The focus of the investment involves model architecture restructuring, exploiting new software engineering and computational upgrades, and incorporating scale-aware physics in all model components, as part of the DOE-wide Exascale crosscut. DOE modeling activities will continue development of modularized components that can act either alone or as a system able to run on current and next generation supercomputers, thus allowing greater certainty of predictions in a flexible structure. Because model development requires systematic validation at each step, investment in model assessment and validation will continue. Examples include the use of ARM data combined with scale-aware Large Eddy Simulation products. High resolution ARM and model ensemble data bases will be integrated into the advanced data management infrastructure effort, the Climate and Environmental Data Analysis and Visualization activity, for use by the scientific research community. Other validation platforms include the sensitivity and uncertainty of climate predictions to explore climate sensitive geographies or processes as well as the representation of extreme events in these next generation models.

The Regional and Global Climate modeling activity will increase investments in scientific analyses using DOE's investments in climate and Earth system model development combined with new efforts to advance and apply modeling and analysis tools as part of the DOE-wide Energy-Water Nexus Tobjectives, with particular focus on developing regional simulations based on interdependencies of climate change with dynamical representation of components of energy flow Sankey diagrams. The Regional and Global Climate modeling activity will additionally conduct scientific analyses to study the predictability of statistical distributions of future weather extremes; causes and distributions of droughts; biogeochemical controls on abrupt climate change; the role of the highly resolved patterns of carbon budgets on regional and global climate change; energy-water interdependencies; and the roles of cryospheric phenomena (sea ice, glaciers, ice sheets, and permafrost thaw) on Arctic climate, sea level rise, and large scale modes of variability. Also, research will explore model derived analogs that combine historical and projected climate changes, with an objective to validate and improve the uncertainty characterization of future climate projections based on the prediction successes using existing data testbeds. To rapidly and efficiently advance model capabilities, BER supports a unique and powerful intercomparison resource, the Program for Climate Model Diagnosis and Intercomparison (PCMDI), for global climate model development, validation, diagnostics, and outputs, using over 40 world-leading climate models. This set of diagnostic and intercomparison activities combined with scientific analysis, ensures that BER funded researchers can exploit the best available science and practice within each of the world's leading climate research programs.

The Earth System Modeling activity in BER will continue to coordinate with the National Science Foundation (NSF) to provide support for greater sophistication of Earth system models, in particular the Community Earth System Model system (CESM) that is co-funded by DOE and NSF. CESM is designed by the research community with open access and broad use by climate researchers worldwide. In addition, DOE will continue to advance a new version of CESM, i.e., the Advanced Climate Model for Energy (ACME), as a computationally efficient model adaptable to emerging computer architectures and with greater sophistication and fidelity for high resolution simulation. This system of models provides a critical capacity for regional climate projections, including information on how the frequency of occurrence and intensity of storms, droughts, heat waves, and regional sea-level will change as climate evolves. The scientific priorities for improvement of the community models are based on efforts to quantify uncertainties relative to specific scientific questions; and the outputs of the intercomparison and validation resource allow one to determine best features of all global models that can be considered for incorporation into DOE's ACME modeling platform. DOE also has provided computational capability and expertise to the climate research community through a partnership between BER and the Office of Science's Advanced Scientific Computing Research (ASCR) program, which is investing in innovative code and algorithm designs for optimal model computation on its petascale computers. Climate modeling, simulation, and analysis tools are essential for informing investment decision-making processes for infrastructure associated with future large-scale deployment of energy supply and transmission.

The Integrated Assessment activities in BER develop integrated assessment (IA) models and impacts analyses, and will add in FY 2016 a new effort to integrate adaptation and vulnerability (IAV) capabilities into the modeling and predictive capabilities. These new efforts will specifically support the Energy-Water Nexus objectives, with focus on development and demonstration of a novel high resolution community IA-IAV hybrid model system, improving not only the resolution but the detailed process representations for autonomous elements as well as for coupled energy-water-land system interdependencies. New efforts will also include development of a generalized regional connected infrastructure model, with software compatibility to IA, IAV, and climate system models. The Integrated Assessment activity will also address uncertainty characterization of both the individual physical, biogeophysical, and sectoral (including energy infrastructure as well as emerging clean energy technology deployment) drivers, extending from macroscale (greater than 50 km resolution) to the much finer scales of Earth system prediction (order of 10 km).

Climate and Environmental Facilities and Infrastructure

Climate and Environmental Facilities and Infrastructure include two scientific user facilities, and climate data management for the climate science community. The scientific user facilities—the Atmospheric Radiation Measurement Climate Research Facility (ARM) and the Environmental Molecular Sciences Laboratory (EMSL)—provide the broad scientific community with technical capabilities, scientific expertise, and unique information to facilitate science in areas integral to BER's mission.

ARM is a multi-platform multi-site national scientific user facility, providing the world's most comprehensive continuous field measurements of climate data to advance atmospheric process understanding and climate models through precise observations of atmospheric phenomena. ARM currently consists of three fixed long-term measurement facility sites (in Oklahoma, Alaska, and the Azores), three mobile facilities, and an airborne research capability that operates at sites selected by the scientific community. The ARM fixed sites and mobile measurement campaigns are distributed around the world in locations where the scientific community most critically needs enhanced understanding and data to incorporate into climate models, thereby improving model performance and predictive capabilities. Each of the ARM sites includes scanning radars, lidar systems, and in situ meteorological observing capabilities; the sites are additionally used to demonstrate technologies as they are developed by the community. ARM experiments to study the impact of evolving clouds, aerosols, and precipitation on the Earth's radiative balance and rate of climate change address the two most significant scientific uncertainties in climate research. ARM will incorporate very high resolution Large Eddy Simulations (LES) at the permanent Oklahoma site, during specific campaigns requested by the scientific community. Also, BER is also maintaining the exponentially increasing data archive to support enhanced analyses and model development. The data extracted from the archive are used to improve climate projections at higher resolution, greater sophistication, and lower uncertainty.

EMSL provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences. EMSL enables users to undertake molecular-scale experimental and theoretical research on biological systems, biogeochemistry, aerosol chemistry, and interfacial and surface science relevant to climate, energy, and environmental challenges facing DOE and the Nation. This includes science supporting alternative energy sources, improved catalysts and materials for industrial applications, insights into factors influencing climate change and carbon sequestration processes, and subsurface biogeochemical drivers.

Data sets generated by ARM, other DOE and Federal Earth observing activities, and Earth system modeling activities, are enormous. The information in Earth observations data can be used to achieve broad benefits ranging from planning and development of energy infrastructure to natural disaster impact mitigation to commercial supply chain management to natural resource management. Access to and uses of these data are fundamental to supporting decision-making, scientific discovery, and technological innovation. DOE's data management activities will be coordinated with the Big Data Research and Development Initiative,[a] and internally collaborative with the Advanced Scientific Computing Research program.

In FY 2016, the BER Data Management activity includes efforts to harmonize and integrate metadata from the Earth System Grid Federation, ARM and NGEE field experiments, and relevant components of data. Analytical tools will be integrated into the program, including capabilities for diagnostics, validation, and uncertainty quantification.

[a] (http://www.whitehouse.gov/sites/default/files/microsites/ostp/big_data_press_release_final_2.pdf)

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Climate and Environmental Sciences $292,108,000	**$318,129,000**	**+$26,021,000**
Atmospheric System Research (ASR) ($25,892,000)	**($26,392,000)**	**(+$500)**
ASR continues to focus on highest priority areas of uncertainty in climate projections—the behavior and function of clouds and aerosols and their role in controlling the atmospheric radiation balance.	ASR will continue to focus on atmospheric cloud and aerosol issues that limit climate modeling capabilities, with a particular emphasis on Arctic mixed phase clouds and tropical systems with large variations of aerosol characterization. ASR will also exploit Large Eddy Simulation (LES) as a tool to understand scale-aware physics governing aerosol transformations, cloud nuclei formation and growth, and cloud evolution. ASR will utilize a combination of observations and LES modeling to explore strongly heterogeneous environments, as observed in the Arctic and the Tropics, to advance the range of conditions applicable to nonhydrostatic parameterizations (models with less than 10 km resolution).	Initiation of a new effort will demonstrate use of Large Eddy Simulations to improve understanding of mid-latitude cloud physics.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Environmental System Science (ESS) ($67,567,000)	**($63,242,000)**	**(-$4,325,000)**
Research continues to understand and predict the roles of terrestrial ecosystems in the larger earth system. NGEE Arctic will begin the transition to Phase II of the project, building from three years of field sampling and process modeling at the Barrow, Alaska site for Phase I and extending to seven additional years of multiple site sampling, multiple site process modeling, and dynamic model integration. NGEE Tropics continues with investments to carefully connect field and modeling activities. AmeriFlux emphasizes efforts to encourage common practices and protocols across the network. Subsurface biogeochemistry continues to focus on fundamental processes that control the fate and transport of energy byproducts, including greenhouse gasses in the subsurface and across key surface-subsurface interfaces in the environment.	Research will continue with NGEE Arctic Phase II, with multiple sites in northern Alaska involved in observation and modeling. NGEE Tropics will begin early observations to test new modeling architectures, appropriate for tropical terrestrial systems. The subsurface biogeochemistry investments will involve a combination of advanced modeling architectures and field research, with existing data used to test predictive modeling concepts. AmeriFlux will support efforts to improve terrestrial land modeling component, to test new concepts and build testbeds for high resolution land model validation.	Environmental System Sciences decreases but will exploit opportunities for greater efficiencies by aggregating a higher fraction of its research into decadal-scale climate-ecosystem science campaigns e.g., NGEE Arctic, NGEE Tropics, a northern peat land experiment, and AmeriFlux. This peat land site in northern Minnesota will be fully accessible for research in FY 2016, with numerous laboratory and academic research projects coordinated under a strategy to advance system predictability.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Climate and Earth System Modeling ($71,195,000)	**($101,954,000)**	**(+$30,759,000)**
Research to provide advanced software and improved algorithms for DOE Climate Modeling leads to improved Earth system model code that is designed to run optimally on next-generation supercomputers with numerous processors. Research on climate model development and analysis focuses on the science underpinning high-resolution predictability. Emphasis continues on land and atmosphere modeling investments that parallel and connect with investments in the process research aspects of the subprogram.	Research will continue to extend capabilities for the Advanced Climate Model for Energy (ACME) to include nonhydrostatic atmospheric modeling (less than 10 km resolution), more sophisticated ice sheet physics, and a new approach for terrestrial modeling that uses plant functional traits instead of plant "types" for more physical representation of biology. Investments will begin to advance software and physics describing the interface between ice-sheets and other components (ocean, land and atmosphere). New methods for capturing the statistics of climate change will be initiated. Regional climate analysis will address interdependencies involving the water and energy sectors, using details on existing and projected infrastructures. In addition, new multi-ensemble statistical methods for vulnerability analysis applied to the energy-water-land nexus will be developed, with special focus on regional coastal inundation and storm-surge, changes in water availability for a coupled climate-human system, and energy implications of extreme events. Interdependencies of the energy-water nexus will be explored within a full climate system analysis, as well as developing vulnerability analysis techniques to treat the energy-water nexus with existing and projected infrastructure. Climate Model Development and Validation will focus on model architecture restructuring, exploiting new software engineering and computational upgrades, incorporating scale-aware physics in all model components and enhanced efforts to assess and validate model results.	Climate and Earth System Modeling will increase investment to understand the interdependencies of the energy-water-land nexus, using a combination of integrated assessment and impacts, analysis, and vulnerability (IAV) that couple with Earth system models. New multi-ensemble statistical methods will be incorporated into the analysis, and software interfaces will be improved to accommodate IAV coupling with IA and Earth system models. Funding also increase for the new investment in Climate Model Development and Validation that will employ new software and improved scale-aware physics to allow fully integrated climate models to achieve much higher spatial resolution.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Core research in Regional and Global Climate Modeling, Earth System Modeling and Integrated Assessment continues to underpin high-resolution predictability using adaptive grids and uncertainty characterization. These investments provide scientific analyses based on DOE's climate and Earth system model capabilities including the predictability of statistical distributions of extreme events, carbon budgets the impacts of changes in cryospheric phenomena, and large scale modes of variability. Continued development of a system of models provides a critical capacity for regional climate projections, including information on how the frequency of extreme events will change as climate evolves. Support also is provided for the development of integrated assessment model components with a focus on assessing the interdependencies of energy, water, and land sector activities that are coupled to the physical and biogeochemical drivers of climate and earth system change.	Core research in Regional and Global Climate Modeling, Earth System Modeling and Integrated Assessment will continue to underpin high-resolution predictability using adaptive grids and uncertainty characterization, and more sophisticated data management.	Funding is increased for unified metadata and analytical methods from the modeling and observational components of the program, with a goal increase scientific output using multi-disciplinary and multi-media capabilities.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Climate and Environmental Facilities and Infrastructure ($117,930,000)	**($115,686,000)**	**(-$2,244,000)**
ARM continues to support its long-term measurements at fixed sites, and the mobile facilities are deployed to three climate-sensitive regions demanding targeted measurements. The first mobile facility remains in the Amazon Basin; the second is deployed on the NOAA ship Ron Brown for a campaign in the Pacific Ocean; the third continues the experiment in Oliktok, Alaska. These observations are key to reducing the earth system model uncertainties attributed to clouds and aerosols.	ARM will continue to support its long-term measurements at fixed sites, and the mobile facilities will be deployed to three climate-sensitive regions demanding targeted measurements. The first mobile facility will remain in the Amazon Basin for the first quarter, thereafter undergo maintenance; the second will be deployed to Antarctica; the third will continue the experiment in Oliktok, Alaska. These observations, combined with dedicated modeling and simulation, are key to reducing the earth system model uncertainties attributed to clouds and aerosols. The ARM second mobile facility deployment to Antarctica will represent the first major ARM campaign in the southern hemisphere. Incorporation of modeling and simulation as part of ARM data acquisition will be initiated	ARM decreases its investments in a planned field deployment of the first ARM mobile facility, AMF1, due to delays in field campaigns schedules.
EMSL continues to support users and their research in biological systems, biogeochemistry, aerosol chemistry, and interfacial and surface science relevant to climate, energy, and environmental challenges facing DOE and the Nation. Emphasis is placed on utilization of new capabilities in the Radiological Annex and Quiet wing. In FY 2015 the integrated HRMAC system will be tested to meet specifications, and procedures will be developed for user operations. EMSL will develop a plan for targeting and attracting users for the new capability.	EMSL continues to support users and their research in biological systems, biogeochemistry, aerosol chemistry, and interfacial and surface science relevant to climate, energy, and environmental challenges facing DOE and the Nation. Emphasis will be placed on utilization of new capabilities in the Radiological Annex and Quiet wing. In FY 2016 the integrated HRMAC system will be available for new research. The installation and availability of the HRMAC, with its 21Tesla magnet, will provide unique enhancements to EMSL's capabilities available to the research community.	EMSL funding decreases and EMSL will address a more focused set of scientific challenges, resulting in sunsetting some capabilities and more efficient utilization of remaining instrumentation.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
The Climate and Environmental Data Analysis and Visualization activity combines high resolution earth system models with interdependent components involving energy and infrastructure sector models, field observations, raw data from environmental field experiments, and analytical tools for system diagnostics, validation, and uncertainty quantification. Existing data management activities are combined with new capabilities to create this Climate and Environmental Data Analysis and Visualization activity which will integrate and add value to the subprogram's high resolution modeling needs and output, expanding observational data sets and extensive data from field and laboratory experiments and observations.	The Climate and Environmental Data Analysis and Visualization activity will continue to advance high resolution earth system models and data management capabilities, with a greater focus on nonhydrostatic dynamical cores, extreme events, and the assimilation of Large Eddy Simulation ensembles to provide statistics of sub-grid parameterizations for a wider range of conditions involving extreme events. Model-data fusion will be explored with new visualization technologies.	Funding is increased for the Climate and Environmental Data Analysis and Visualization activity so that the existing metadata from the components of BER climate and environmental facilities (ARM, EMSL), NGEEs, and modeling can achieve compatibility. They will be unified under a common architecture with new visualization technologies.
Participation in the Big Earth Data Initiative continues.	Participation in the Big Earth Data Initiative continues.	No change.
In FY 2015, ORISE GPP/GPE is transferred to the Science Laboratories Infrastructure program.	In FY 2015, ORISE GPP/GPE was transferred to the Science Laboratories Infrastructure program.	No change.

Biological and Environmental Research
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program. The following table shows the targets for FY 2014 through 2016.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**BER Climate Model—Develop a coupled climate model with fully interactive carbon and sulfur cycles, as well as dynamic vegetation to enable simulations of aerosol effects, carbon chemistry, and carbon sequestration by the land surface and oceans and the interactions between the carbon cycle and climate**		
Target	Use global models to estimate most sensitive elements of terrestrial carbon to climate change for tropics, mid-latitudes, and polar regions	Develop capabilities to extend temporal resolution to sub-decadal for earth system models.	Develop and apply a fully coupled ice-sheet model to estimate near-term changes to the West Antarctic ice sheet.
Result	Met	TBD	TBD
Endpoint Target	BER supports the Community Earth System Model, a leading U.S. climate model, and addresses two of the most critical areas of uncertainty in contemporary climate science—the impacts of clouds and aerosols. Delivery of improved scientific data and models (with quantified uncertainties) about the potential response of the earth atmosphere system to more accurately predict the earth's future climate is essential to plan for future energy needs, water resources, and land use. DOE will continue to advance the science necessary to further develop predictive climate and earth system models at the regional spatial scale and decadal to centennial time scales, involving close coordination with the U.S. Global Change Research Program and through the international science community.		
Performance Goal (Measure)	**BER Predictive Understanding of Biological Systems—Advance an iterative systems biology approach to the understanding and manipulation of plant and microbial genomes as a basis for biofuels development and predictive knowledge of carbon and nutrient cycling in the environment.**		
Target	Not Applicable	Develop 1 new computationally enabled approach to analyze complex genomic datasets.	Develop an improved metabolic engineering method for modifying microorganisms for biofuel production from cellulosic sugars.
Result	Not Applicable	TBD	TBD
Endpoint Target	BER will advance understanding of the operating principles and functional properties of plants, microbes, and complex biological communities relevant to DOE missions in energy and the environment. Deciphering the genomic blueprint of organisms and determining how this information is translated to integrated biological systems permits predictive modeling of bioprocesses and enables targeted redesign of plants and microbes. BER research will address fundamental knowledge gaps and provide foundational systems biology information necessary to advance development of sustainable bioenergy systems and predict impacts of changing environmental conditions on carbon cycling and other biogeochemical processes.		

Biological and Environmental Research
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Capital Operating Expenses Summary							
Capital equipment projects under $2 million TEC	n/a	n/a	6,751	6,751	4,667	4,500	-167
General plant projects (GPP) under $5 million TEC	n/a	n/a	250	250	0	0	0
Total, Capital Operating Expenses	**n/a**	**n/a**	**7,001**	**7,001**	**4,667**	**4,500**	**-167**

Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	392,391	392,391	375,293	403,307	+28,014
Scientific user facilities operations and research	200,719	200,719	197,325	188,120	-9,205
Major items of equipment	0	0	0	0	0
Other[a]	16,586	500	19,382	20,973	+1,591
Total, Biological and Environmental Research	**609,696**	**593,610**	**592,000**	**612,400**	**+20,400**

Facility Operations ($K)

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE B FACILITIES					
Atmospheric Radiation Measurement Climate Research Facility (ARM)	**$68,644**	**$68,644**	**$67,429**	**$65,429**	**-$2,000**
Number of users	1,000	1,000	900	900	N/A
Joint Genome Institute	**$70,143**	**$70,143**	**$69,500**	**$69,500**	**0**
Number of users	1,000	1,000	1,000	1,100	+100

[a] Includes SBIR, STTR, GPE, and non-Facility related GPP.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Environmental Molecular Sciences Laboratory	**$46,942**	**$46,942**	**$45,501**	**$43,191**	**-$2,310**
Number of users	750	750	750	750	N/A
Structural Biology Infrastructure[a]	**$14,990**	**$14,990**	**$14,895**	**$10,000**	**-$4,895**
Total Facilities	**$200,719**	**$200,719**	**$197,325**	**$188,120**	**$-9,205**
Number of users	2,750	2,750	2,650	2,750	+100

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Estimate	FY 2016 vs. FY 2015
Number of permanent Ph.D.'s	1,290	1,290	1295	1,350	+55
Number of postdoctoral associates	315	315	320	330	+10
Number of graduate students	400	400	440	450	+10
Other[b]	315	315	320	330	+10

[a] Structural Biology Infrastructure activities are at Basic Energy Sciences user facilities and the user statistics are included in the BES user statistics.
[b] Includes technicians, engineers, computer professionals and other support staff.

Fusion Energy Sciences

Overview

The Fusion Energy Sciences (FES) program mission is to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation needed to develop a fusion energy source. This is accomplished through the study of plasma, the fourth state of matter, and how it interacts with its surroundings.

The next frontier for all the major fusion programs around the world is the study of the burning plasma state, in which the fusion process itself provides the dominant heat source for sustaining the plasma temperature (i.e., self-heating). Production of strongly self-heated fusion plasma will allow the discovery and study of a number of new scientific phenomena. These include the effects of highly energetic fusion produced helium particles on plasma stability and confinement; the strongly nonlinear coupling that will occur among fusion alpha particles, the pressure-driven self-generated current, turbulent transport, and boundary-plasma behavior; the properties of materials in the presence of high heat and particle fluxes and neutron irradiation; and the self-organized nature of plasma profiles over long time scales.

To achieve these research goals, FES invests in flexible U.S experimental facilities of various scales, international partnerships leveraging U.S. expertise, large-scale numerical simulations based on experimentally validated theoretical models, the development of advanced fusion-relevant materials, and the invention of new measurement techniques.

The knowledge base being established through FES research supports U.S. goals for future scientific exploration on ITER, a major international fusion facility currently under construction in St. Paul-lez-Durance, France. ITER will be the world's first magnetic confinement long-pulse, high-power burning plasma experiment aimed at demonstrating the scientific and technical feasibility of fusion energy. Execution and oversight of the U.S. contribution to the ITER project are carried out within FES.

To support the program mission and its major focus, the U.S. fusion program is constructed from four mutually supportive elements:

- Burning Plasma Science: Foundations;
- Burning Plasma Science: Long Pulse;
- Burning Plasma Science: High Power; and
- Discovery Plasma Science.

Highlights of the FY 2016 Budget Request

The most notable changes in the FY 2016 budget include:

- *Increase for the operation of the National Spherical Torus Experiment Upgrade (NSTX-U)* —After the first year of experimental operations with the upgraded device in FY 2015, funding for operations of the NSTX-U user facility will support 14 weeks of run time. Fabrication is supported for two important facility enhancements—a divertor cryopump for better control of the plasma density and a set of magnetic control coils to improve stable, high-performance operation.
- *Progress in hardware contributions for U.S. ITER Project*—Funding provided for critical path items will ensure that U.S. in-kind contributions maintain U.S. commitments to FY 2016 project needs. Funding is provided for ITER Project Office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including industrial procurements and fabrication of central solenoid magnet modules and structures, toroidal field magnet conductor fabrication and delivery, diagnostics, and tokamak cooling water system component procurement, fabrication, and delivery.

Fusion Energy Sciences
Funding ($K)

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Burning Plasma Science: Foundations					
Advanced Tokamak	100,036	100,036	105,348	92,486	-12,862
Spherical Tokamak	65,055	65,055	72,919	65,624	-7,295
Theory & Simulation	33,404	33,404	34,670	28,170	-6,500
GPE/GPP/Infrastructure	5,900	5,900	3,125	5,479	+2,354
Total, Burning Plasma Science: Foundations	**204,395**	**204,395**	**216,062**	**191,759**	**-24,303**
Burning Plasma Science: Long Pulse					
Long Pulse: Tokamak	7,348	7,348	7,695	6,045	-1,650
Long Pulse: Stellarators	5,175	5,175	6,419	5,069	-1,350
Materials & Fusion Nuclear Science	22,126	22,126	24,842	19,795	-5,047
Total, Burning Plasma Science: Long Pulse	**34,649**	**34,649**	**38,956**	**30,909**	**-8,047**
Discovery Plasma Science					
Plasma Science Frontiers	42,274	42,274	46,024	32,609	-13,415
Measurement Innovation	3,500	3,500	3,575	3,575	0
SBIR/STTR & Other	20,359	11,537	12,883	11,148	-1,735
Total, Discovery Plasma Science	**66,133**	**57,311**	**62,482**	**47,332**	**-15,150**

[1] Funding reflects the transfer of SBIR/STTR to the Office of Science.

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Construction					
14-SC-60 International Thermonuclear Experimental Reactor (ITER)	199,500	199,500	150,000	150,000	0
Total, Construction	**199,500**	**199,500**	**150,000**	**150,000**	**0**
Total, Fusion Energy Sciences	**504,677**	**495,855**	**467,500**	**420,000**	**-47,500**

SBIR/STTR:
FY 2014 Transferred: SBIR: $7,719,000; STTR: $1,103,000
FY 2015 Enacted: SBIR $7,388,000 and STTR $1,019,000
FY 2016 Projected: SBIR: $7,642,000; STTR: $1,146,000

Fusion Energy Sciences
Explanation of Major Changes ($K)

	FY 2016 vs FY 2015
Burning Plasma Science: Foundations: Funding for advanced tokamak research is decreased as Alcator C-Mod operates for the final year and as DIII-D upgrades, operating time, and research are reduced. Funding for the operations of the NSTX-U user facility is decreased, but fabrication of two key facility enhancements is still supported. Funding for General Plant Projects (GPP) at Princeton Plasma Physics Laboratory (PPPL) is increased to enhance and modernize laboratory infrastructure.	-24,303
Burning Plasma Science: Long Pulse: No major changes	-8,047
Discovery Plasma Science: Operations and research at the Neutralized Drift Compression Experiment–II (NDCX-II) at Lawrence Berkeley National Laboratory cease. No new research awards as part of the SC/NNSA Joint Program for high energy density laboratory plasma science commence.	-15,150
Total Funding Change, Fusion Energy Sciences	**-47,500**

Basic and Applied R&D Coordination

FES carries out a discovery-driven plasma science research program in partnership with the National Science Foundation (NSF), with research extending to a wide range of natural phenomena, including the origin of magnetic fields in the universe and the heating of the solar corona. Also, FES operates a joint program with the National Nuclear Security Administration (NNSA) in High Energy Density Laboratory Plasma (HEDLP) physics. Both programs involve coordination of solicitations, peer reviews, and workshops. The Fusion Energy Sciences Advisory Committee (FESAC) provides technical and programmatic advice to FES and NNSA for the joint HEDLP program.

Program Accomplishments

ITER component production underway; first major deliveries made—The U.S. ITER Project delivered one 100-meter superconducting length of active conductor and the first of nine 800-meter production lengths of active conductor to the European Union's Toroidal Field Coil fabricator in Italy. It also delivered the first lot of high-voltage circuit breakers to the ITER site, which are part of the Steady State Electric Network. Fabrication of the first nuclear-grade Tokamak Cooling Water System drain tank (>61,000 gallon capacity) was completed.

Improved understanding of the effects of edge magnetic field perturbations on tokamak plasmas—A multi-institutional team of scientists achieved new insight into how three-dimensional magnetic perturbations applied at the tokamak edge can improve plasma confinement. Notably, suppression of undesirable instabilities localized at the edge was experimentally demonstrated on the DIII-D tokamak with as few as five of the full set of 12 magnetic feedback coils, thus indicating that suppression (and good plasma performance) can be maintained in ITER even if a partial failure of its planned magnetic feedback coil set were to occur.

Advanced scenario modeling for NSTX-U—The NSTX-U team significantly improved the TRANSP code, widely used in the U.S. and abroad for predictive modeling of tokamak plasma performance. The code is now capable of simulating how radio-frequency wave heating can affect the injection of beams of high-energy neutral particles, which can drive current. This is an important simulation capability for NSTX-U with its newly installed second neutral beam line and also for other tokamaks such as DIII-D. In addition, the code can now predict the level of feedback control on the plasma rotation that is needed for maintaining plasma stability.

Fusion modeling advanced with leadership-class computing—Participants in an FES-supported Scientific Discovery Through Advanced Computing (SciDAC) center carried out code optimizations in partnership with the Advanced Scientific Computing Research (ASCR) program and achieved a 400% processing speedup with excellent scalability on the TITAN supercomputer for simulations of edge plasma behavior, which strongly affects overall fusion confinement for the success of ITER.

Experiment mimics solar eruptions—In laboratory experiments on the Magnetic Reconnection Experiment facility at PPPL, scientists discovered new mechanisms for converting magnetic field energy into particle energy. The results provide improved understanding of what triggers coronal mass ejections, in which energetic plasma particles spewed from the Sun can disrupt terrestrial communications and power grids.

Creation of ultra-high-energy-density plasmas with table-top lasers—Researchers discovered that ultra-short (femtosecond) laser pulses with very high intensity can be trapped within an ordered array of nano-wires and then used to heat matter that is nearly solid to temperatures of tens of millions of degrees, leading to the creation of plasmas with exceedingly high (gigabar) pressures. This novel method thus allows the regime corresponding to the central spot of strongly compressed thermonuclear fusion plasmas to be approached simply with the use of table-top lasers.

Fusion Energy Sciences
Burning Plasma Science: Foundations

Description

The Burning Plasma Science: Foundations subprogram advances the predictive understanding of plasma confinement, dynamics, and interactions with surrounding materials. Among the activities supported by this subprogram are:

- Research at major experimental facilities aimed at resolving fundamental advanced tokamak and spherical torus science issues, including developing the predictive understanding needed for ITER operations and providing solutions to high-priority ITER concerns.
- Research on small-scale magnetic confinement experiments to elucidate physics principles underlying toroidal confinement and to validate theoretical models and simulation codes.
- Theoretical work on the fundamental description of magnetically confined plasmas and the development of advanced simulation codes on current and emerging high-performance computers.
- Research on technologies needed to support the continued improvement of the experimental program and facilities.
- Support for infrastructure improvements at Office of Science laboratories conducting fusion research.

Advanced Tokamak

The DIII-D user facility at General Atomics in San Diego, California, is the largest magnetic fusion research experiment in the U.S. and can magnetically confine plasmas at temperatures relevant to burning plasma conditions. Researchers from the U.S. and abroad perform experiments on DIII-D for studying stability, confinement, and other properties of fusion-grade plasmas under a wide variety of conditions. The DIII-D research goal is to establish the scientific basis to optimize the tokamak approach to magnetic confinement fusion. Much of this research concentrates on developing the advanced tokamak concept, in which active control techniques are used to manipulate and optimize the plasma to obtain conditions scalable to robust operating points and high fusion gain for ITER and future fusion reactors. Near-term targeted efforts address scientific issues important to the ITER design. Longer-term research focuses on advanced scenarios to maximize ITER performance. Another high-priority DIII-D research area is foundational fusion science, pursuing a basic scientific understanding across all fusion plasma topical areas.

The Alcator C-Mod user facility at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, is a compact tokamak device employing intense magnetic fields to confine high-temperature, high-density plasmas in a small volume. Key research areas are disruption mitigation, radio-frequency heating and current drive science, plasma edge physics, and plasma-material interactions. C-Mod research is organized around integrated operating scenarios at plasma conditions relevant to fusion energy production. The compact size and high magnetic field of the Alcator C-Mod tokamak make it useful for dimensionless scaling studies. It can operate at and above the ITER design values for magnetic field and plasma density, and it has all-metal walls that experience heat fluxes approaching those projected for ITER. Also, it produces tokamak plasmas with very high pressure, near that expected in burning plasmas. The Alcator C-Mod facility resumed operation in FY 2014 and will continue operation in FY 2015 to complete student research and critical experimental work before the facility ceases operations by the end of FY 2016.

The Enabling Research and Development (R&D) element develops the technology to enhance the capabilities for existing and next-generation fusion research facilities, enabling these facilities to achieve higher levels of performance and flexibility needed to explore new science regimes.

Small-scale tokamak plasma research projects provide data in regimes of relevance to the FES mainline tokamak magnetic confinement efforts and help confirm theoretical models and simulation codes in support of the FES goal to develop an experimentally-validated predictive capability for magnetically confined fusion plasmas. This activity consists of small-scale focused experiments.

Spherical Tokamak

The NSTX-U user facility at PPPL is designed to explore the physics of plasmas confined in a spherical torus (ST) configuration. A major advantage of this configuration is the ability to confine plasma at a pressure that is high compared to the magnetic field energy density, which could lead to the development of more compact and economical future fusion research facilities based on the ST concept. The ST configuration, with its very strong magnetic curvature, has different confinement and stability properties from those of conventional tokamaks.

The NSTX-U MIE project will be completed in FY 2015. The upgrade of the center stack assembly enables a doubling of the magnetic field and plasma current and an increase in the plasma pulse length from 1 to 5 seconds, making NSTX-U the world's highest-performance ST. The addition of a second neutral beam system doubles the available heating power, which makes it possible to achieve higher plasma pressure and providing improved neutral beam current drive efficiency and current profile control, which are needed for achieving fully non-inductive operation. Together, these upgrades will support a strong research program to develop the improved understanding of the ST configuration required to establish the physics basis for next-step ST facilities and broaden scientific understanding of plasma confinement. The capability for controllable fully-non-inductive current drive will also contribute to an assessment of the ST as a potentially cost-effective path to fusion energy.

During its first year of research operations in FY 2015, the NSTX-U team will achieve magnetic fields and plasma currents about one and a half times higher than those prior to the upgrade project. During FY 2016, the NSTX-U team will achieve the design values for the magnetic field and plasma current, which are twice those achieved in NSTX.

Small-scale spherical torus plasma research projects doing focused experiments provide data in regimes of relevance to the FES spherical torus magnetic confinement program. This effort helps confirm theoretical models and simulation codes in support of the FES goal to develop an experimentally-validated predictive capability for magnetically confined fusion plasmas. It also involves high-risk, but high-payoff, experimental efforts useful to advancing spherical torus science.

Theory & Simulation

The Theory and Simulation element contributes to the FES goal of developing the predictive capability needed for a sustainable fusion energy source. This element includes two main interrelated but distinct activities: the Theory activity and the Scientific Discovery through Advanced Computing (SciDAC) activity.

The Theory activity is focused on advancing the scientific understanding of the fundamental physical processes governing the behavior of magnetically confined plasmas. The efforts supported by this activity range from small single-investigator grants mainly at universities to large coordinated teams at national laboratories, universities, and private industry, while the supported research ranges from fundamental analytic theory to mid- and large-scale computational work using high-performance computing resources. In addition to its scientific discovery mission, the Theory activity provides the scientific grounding for the physics models implemented in the advanced simulation codes developed under the SciDAC activity described below, and supports validation efforts at major experiments.

The FES SciDAC activity, a component of the Office of Science (SC)-wide SciDAC program, is aimed at advancing scientific discovery in fusion plasma science by exploiting leadership-class computing resources and associated advances in computational science. The eight multi-institutional and interdisciplinary centers in the FES SciDAC portfolio address challenges in magnetic confinement science and computational fusion materials science and are well-aligned with the needs and priorities of ITER and burning plasmas. Three of these centers are set up as partnerships between FES and ASCR. These include a new FES-ASCR partnership in the area of multi-scale integrated modeling for fusion energy science, which was added to the portfolio in FY 2014.

GPE/GPP/Infrastructure

Funding in this category provides support for general infrastructure repairs and upgrades for the PPPL site. This funding is based upon quantitative analysis of safety requirements, equipment reliability, and research needs.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Advanced Tokamak $105,348,000	**$92,486,000**	**-$12,862,000**
DIII-D Research ($36,065,000)	*DIII-D Research ($32,038,000)*	*DIII-D Research (-$4,027,000)*
DIII-D Operations ($43,885,000)	*DIII-D Operations ($39,310,000)*	*DIII-D Operations (-$4,575,000)*
Research is conducted in three program areas, with DIII-D staff and collaborator support for diagnostics and data analysis to exploit enhanced DIII-D operations in FY 2015: ▪ Dynamics and control studies to test transport models, evaluate plasma performance in ITER-like conditions, and begin exploring methods of active control to avoid disruptions and operate near stability boundaries under steady-state conditions. ▪ Boundary and pedestal research to assess the benefits of divertor geometry in dissipating heat flux, investigate fueling and Edge Localized Mode control at higher density, and develop compatible core-edge solutions for high-performance plasmas. ▪ Burning plasma physics research to explore and suppress energetic particle instabilities and to understand and control transport barrier formation and confinement transitions.	Twelve weeks of research operations at the DIII-D facility are planned for FY 2016, with experiments focusing on high-priority advanced tokamak issues. Areas of research will include studies of transport and radiative processes in detached divertor conditions, disruption physics and mitigation systems, methods to exploit 3D field control to enable robust high performance operations, and exploration of scenarios at high normalized magnetic pressure to evaluate the relevant transport, stability, and energetic ion physics. Targeted upgrades to the facility will involve completion and commissioning of an additional high-power microwave heating system, installation of new magnet power supplies for the 3D and shaping coils, and continued work on improving the neutral beam heating control system and designing the modifications necessary for a second off-axis neutral beam.	The DIII-D research level of effort and the number of research staff will be reduced, and the level of upgrade activity for the DIII-D facility will decrease. Operating time is reduced by three weeks.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Disruption studies will continue to be emphasized in order to guide the design of the ITER disruption mitigation system. The DIII-D user facility will operate for 15 weeks to support experiments. Infrastructure modifications to support an eighth gyrotron system and upgrades to the power supply systems for the field shaping and magnetic perturbation coils will continue.		
C-Mod Research ($9,460,000) *C-Mod Operations ($12,800,000)* C-Mod research continues to focus on resolving high-priority issues of ITER-relevant boundary and divertor physics, with the goal of completing specific high priority research tasks relevant to ITER for which C-Mod is uniquely suited. C-Mod scientists will initiate enhanced research collaborations on other experimental facilities. The C-Mod facility will operate for 12 weeks to support experiments and complete student research. Maintenance and refurbishment activities to support the safe and efficient operation of C-Mod will continue.	*C-Mod Research ($6,145,000)* *C-Mod Operations ($11,855,000)* Five weeks of research operations at the Alcator C-Mod facility are planned for its final year of operation in FY 2016. Research will be focused on high-priority topics that exploit the unique capabilities of the facility. Experiments will be conducted to study disruption physics and mitigation techniques, develop the database for the critical interactions between the plasma and material components under ITER and reactor-relevant conditions, explore robust high-performance stationary regimes free of Edge-Localized Modes, and advance radiofrequency heating and current drive technology and physics understanding. The facility will be closed after final operations, and the research staff will complete analysis of existing data and begin making a transition to collaborations involving other research facilities.	*C-Mod Research (-$3,315,000)* *C-Mod Operations (-$945,000)* The research level of effort, number of staff, and scope of facility refurbishments will be reduced in the final year of operation of the Alcator C-Mod facility. Operating time is reduced by seven weeks.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Enabling R&D ($2,165,000)	*Enabling R&D ($2,165,000)*	*Enabling R&D ($0)*
Support is provided for research in superconducting magnet technology, and fueling and plasma heating technologies, to enhance the performance for existing and future magnetic confinement fusion devices.	Support will continue to be provided for research in superconducting magnet technology, and fueling and plasma heating technologies, to enhance the performance for existing and future magnetic confinement fusion devices.	No change.
Small-scale Experimental Research ($973,000)	*Small-scale Experimental Research ($973,000)*	*Small-scale Experimental Research: ($0)*
Small-scale tokamak plasma research provides data in regimes of relevance to the mainline tokamak magnetic confinement efforts and helps confirm theoretical models and simulation codes in support of the goal to develop an experimentally-validated predictive capability for magnetically confined fusion plasmas.	Research will continue on providing data in regimes relevant to mainline tokamak confinement and experimentally validating models and codes.	No change.
Spherical Tokamak $72,919,000	**$65,624,000**	**-$7,295,000**
NSTX-U Research ($28,500,000)	*NSTX-U Research ($26,000,000)*	*NSTX-U Research (-$2,500,000)*
NSTX-U Operations ($38,250,000)	*NSTX-U Operations ($36,925,000)*	*NSTX-U Operations (-$1,325,000)*
NSTX-U MIE ($3,470,000)	*NSTX-U MIE ($0)*	*NSTX-U MIE (-$3,470,000)*
The NSTX-U research staff begins research on the enhanced facility. Initial experiments concentrate on developing operating scenarios for high-performance plasmas, assessing transport and stability at higher plasma current and magnetic field, developing advanced divertor configurations, advancing techniques for non-inductive start-up, and assessing neutral-beam injection for current ramp-up and sustainment.	During FY 2016, the NSTX-U team will extend performance to full field and current (1 Tesla, 2 mega Amps) and will address divertor heat flux mitigation and plasma confinement at full parameters. The team will also begin experiments on full non-inductive current drive and sustainment. Finally, the team will begin to develop scenarios for achieving and controlling high-performance discharges.	Funding for the operations of the NSTX-U user facility is decreased; fabrication of two key facility enhancements is supported. The NSTX-U Major Item of Equipment (MIE) project is completed in FY 2015.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
With the completion of the MIE project, the operations team completes integrated systems testing and begins research operations, with a goal of 12 weeks of operation. Funding shifts from the MIE project back to facility operations. The design of facility modifications, including a divertor cryopump, a set of non-axisymmetric control coils, and a 1 megawatt electron cyclotron heating system, is initiated.	A total of 14 weeks of operation is planned in FY 2016. Operation is planned at full design values for the magnetic field and plasma current, which are twice those achieved prior to the upgrade. In mid-FY 2016, a shutdown is planned to install a cryopump in the lower divertor and a row of tungsten tiles on the cryo-baffle.	
Small-scale Experimental Research ($2,699,000) Small-scale tokamak plasma research provides data in regimes of relevance to the mainline spherical torus magnetic confinement efforts and helps confirm theoretical models and simulation codes in support of the goal to develop an experimentally-validated predictive capability for magnetically confined fusion plasmas.	*Small-scale Experimental Research ($2,699,000)* Research will continue on providing data in regimes relevant to mainline spherical torus confinement and experimentally validating models and codes.	*Small-scale Experimental Research ($0)* No change.
Theory & Simulation $34,670,000	**$28,170,000**	**-$6,500,000**
Theory ($25,170,000) The Theory activity continues to support fundamental research at universities, national laboratories, and private industry. Coordination between theory and experiment leading to model validation will be emphasized, especially in areas where the resolution of essential physics issues is urgently needed before first plasma in ITER.	*Theory ($21,170,000)* The Theory activity will continue to advance the scientific understanding of the fundamental physical processes governing the behavior of magnetically confined plasmas. Emphasis on addressing ITER priorities will continue to guide the selection of new and renewal awards via competitive merit reviews.	*Theory (-$4,000,000)* Approximately eight fewer awards to universities and private industry will be made compared to FY 2015. Efforts at the national laboratories will be level with FY 2015.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
SciDAC ($9,500,000) The FES SciDAC centers continue to contribute to the FES goal of developing a predictive capability for fusion plasmas. The two FES-ASCR partnerships selected in FY 2012 will undergo a mid-term progress review while the third partnership selected in FY 2014 enters its second year. The five centers selected in FY 2011 will undergo a merit review for a possible one-year extension of their research activities, to align their project periods with the SC-wide SciDAC program and strengthen their collaborations with computational scientists.	*SciDAC ($7,000,000)* The five SciDAC centers, pending a positive outcome of the merit review held in FY 2015, will be entering the final year of their research activities, while the three FES–ASCR partnerships will continue their efforts in the areas of boundary physics, materials science, and multiscale integrated modeling. FES and ASCR will develop a plan emphasizing integration for the science areas represented by the entire FES SciDAC portfolio, and will initiate preparations for a competitive merit review.	*SciDAC (-$2,500,000)* The scope of the FES SciDAC portfolio will be narrowed.
GPE/GPP/Infrastructure $3,125,000	**$5,479,000**	**+$2,354,000**
Necessary facility and utility infrastructure improvements required to fully support NSTX-U operations are funded, while ensuring mission readiness and enhanced reliability. Several small projects will be executed to modernize and/or replace aging infrastructure elements such as electrical distribution and cooling water utilities and building heating, ventilation, and air conditioning systems. Environmental monitoring needs at PPPL are also supported.	Continued support of NSTX-U operations, as well as enhanced International Collaborations, will be provided through improvements to the Princeton Plasma Physics Laboratory Computer Center (PPPLCC) and establishment of remote control room configurations. Environmental monitoring needs at PPPL will continue to be supported.	Increased funding is provided for facility and utility improvements for supporting the full NSTX-U operations, enhancing International collaboration capabilities, addressing single-point failure liabilities, and replacing end-of-life critical physical plant infrastructure.

Burning Plasma Science: Long Pulse

Description

The Burning Plasma Science: Long Pulse subprogram explores new and unique scientific regimes that can be achieved with long-duration superconducting international machines and addresses the development of the materials required to withstand the extreme conditions in a burning plasma environment. The key objectives of this area are to utilize these new capabilities to accelerate our scientific understanding of how to control and operate a burning plasma, as well as to develop the basis for a future fusion nuclear science facility. This subprogram includes long-pulse international tokamak and stellarator research and fusion nuclear science and materials research.

Long Pulse: Tokamak

U.S. research teams will be supported to work on the long-pulse international tokamaks that are coming on-line either now or in the near future. These teams will build on the experience gained from U.S. fusion facilities to conduct long-pulse research on the international tokamaks. Long plasma pulse research will enable the exploration of new plasma physics regimes, and allow the U.S. fusion program to gain the knowledge needed to operate long plasma discharges in ITER and other fusion energy devices.

Long Pulse: Stellarator

Stellarators offer steady-state confinement regimes eliminating transient events such as harmful disruptions. The 3-D shaping of the plasma in a stellarator provides for a broader range in design flexibility than is achievable in a 2-D system. The U.S. collaboration on Wendelstein 7-X (W7-X) in Germany provides an opportunity to develop and assess 3D divertor configurations for long-pulse, high-performance stellarators. In this collaboration, the U.S. plans to develop control schemes to maintain plasmas with stable operational boundaries, including the challenges of control with superconducting coils and issues of the diagnosis-control cycle in long-pulse conditions. The collaboration will have key roles in developing the operational scenarios and hardware configuration for high-power, steady-state operation, an accomplishment that will advance the performance/pulse length frontier for fusion. The U.S. contributions during the W7-X construction phase have earned the U.S. formal partnership status, with opportunities for full U.S. participation in W7-X research and access to data.

The U.S. domestic stellarator program, with two small-size facilities, is focused on optimization of the stellarator concept through quasi-symmetric shaping of the toroidal magnetic field. A conventional stellarator lacks axial symmetry, resulting in reduced confinement of energetic ions, which are needed to heat the plasma. Quasi-symmetric shaping, invented in the U.S., provides an improved solution for stable, well confined, steady-state stellarator plasma confinement.

Materials & Fusion Nuclear Science

The fusion environment is extremely harsh in terms of temperature, particle flux, and neutron irradiation. The Materials and Fusion Nuclear Science element supports the development, characterization, and modeling of structural, plasma-facing, and blanket materials used in the fusion environment. Materials that can withstand this environment under the long-pulse or steady-state conditions anticipated in future fusion experiments are a prerequisite to the future of fusion research and development activities. Studies that help identify the various scientific challenges to fusion energy deployment and that determine how to address them in a safe and environmentally responsible manner are a key component of the Materials and Fusion Nuclear Science element.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Long Pulse: Tokamak $7,695,000	**$6,045,000**	**-$1,650,000**
Support continues for the two U.S. teams performing long-pulse plasma heating and control research on the Experimental Advanced Superconducting Tokamak (EAST) and Korea Superconducting Tokamak Advanced Research (KSTAR) facilities. Collaborations in support of ITER-relevant science are carried out.	Improved control systems for EAST and KSTAR will be commissioned. ITER operating scenarios will be explored and evaluated on EAST and KSTAR. Radio frequency heating and current drive and neutral beam injection actuator models for EAST and KSTAR will be developed and validated.	Collaborations will be slightly reduced, and no diagnostic fabrications are planned.
Long Pulse: Stellarators $6,419,000	**$5,069,000**	**-$1,350,000**
Superconducting Stellarator Research ($3,850,000)	*Superconducting Stellarator Research ($2,500,000)*	*Superconducting Stellarator Research (-$1,350,000)*
The design of the scraper element for the W7-X steady-state divertor, a tool that will permit early experimental investigation of the edge magnetic configuration in the first full W7-X research campaign, is completed. One or two new university collaborations on international facilities may be initiated.	Planned operations will be carried out on W7-X up to 10 seconds at 10 megawatts and 50 seconds at 1 megawatt of heating power. U.S. scientists will participate in experiments on the development of steady-state operating scenarios. The performance of inertially cooled divertor components will be evaluated.	No additional hardware design activities are planned for W7-X. The university collaboration awards selected in FY 2015 will be fully funded in that year.
Compact Stellarator Research ($2,569,000)	*Compact Stellarator Research ($2,569,000)*	*Compact Stellarator Research ($0)*
Compact stellarator research provides data in regimes of relevance to the mainline stellarator magnetic confinement efforts and helps confirm theoretical models and simulation codes in support of the goal to develop an experimentally validated predictive capability for magnetically confined fusion plasmas.	Research will continue on providing data in regimes relevant to mainline stellarator confinement and experimentally validating models and codes.	No change.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Materials & Fusion Nuclear Science $24,842,000	**$19,795,000**	**-$5,047,000**
Fusion Nuclear Science ($11,245,000)	*Fusion Nuclear Science ($9,835,000)*	*Fusion Nuclear Science (-$1,410,000)*
Key areas of interest are studying plasma-facing materials and plasma-material interaction under reactor-relevant plasma conditions, breeding and processing of fusion fuel, neutronics and safety research. Scoping studies characterize significant research gaps in the materials and fusion nuclear sciences research program.	The focus will remain the utilization of existing experimental capabilities to conduct research in the areas of plasma-facing materials and plasma-material interactions. Research toward understanding tritium retention and permeation, neutronics, and material-corrosion issues for blankets will continue. Scoping studies will continue on characterizing significant research gaps in the materials and fusion nuclear sciences program.	Efforts to produce prototypic conditions for plasma materials testing will decrease.
Materials Research ($13,597,000)	*Materials Research ($9,960,000)*	*Materials Research (-$3,637,000)*
Efforts focus on elucidating the response of materials to the extreme conditions created by a burning plasma. Key areas of interest are structural materials response under reactor-relevant plasma conditions.	The focus will remain the utilization of existing experimental capabilities to conduct research in the area of material response to simulated fusion neutron irradiation. Research toward structural materials that can withstand high levels of damage, increasing the ductility of tungsten, and modeling of helium damage in numerous materials will continue.	Efforts to produce prototypic conditions for structural materials testing will decrease.

Fusion Energy Sciences
Discovery Plasma Science

Description

Plasma science is not only fundamental to achieving the production and control of fusion energy, but also to understanding the nature of visible matter throughout the cosmos. Discoveries in plasma science are leading to an ever increasing array of practical applications ranging from energy efficient lighting to low-heat, chemical-free sterilization processes. The Discovery Plasma Science subprogram supports research that explores the fundamental properties and complex behavior of matter in the plasma state to improve the understanding required to control and manipulate plasmas for a broad range of applications.

The ability to create and manipulate plasmas with densities and temperatures spanning many orders of magnitude has led to the establishment of plasma science as a multi-disciplinary field, necessary for understanding the flow of energy and momentum in the universe as well as enabling the development of breakthrough technologies. The subprogram supports a rich portfolio of research projects and small-scale experimental facilities, exploring the diverse frontiers of plasma science. The portfolio of this subprogram is carried out through inter- and intra-agency partnerships at academic institutions, private companies, and national laboratories across the country. The Discovery Plasma Science subprogram is organized into two principal activities: Plasma Science Frontiers and Measurement Innovation.

Plasma Science Frontiers

The frontiers of plasma science exist at the extremes of the plasma state, ranging from the very small (several atom systems) to the extremely large (plasma structure spanning light years in length), from the very fast (attosecond processes) to the very slow (hours), from the diffuse (interstellar medium) to the extremely dense (diamond compressed to tens of gigabar pressures), and from the ultracold (tens of micro kelvin) to the extremely hot (stellar core). The Plasma Science Frontiers activities support research at the fore-front of each of these ranges, challenging our ability to produce and measure matter at the extremes. In addition to the experimental and diagnostic challenges, simulating such systems requires the development of sophisticated modeling tools and use of advanced computing platforms.

The Plasma Science Frontiers portfolio includes coordinated research activities in the following three areas:

- *General Plasma Science* – Understanding the behavior of non-neutral and single-component plasmas, ultra-cold neutral plasmas, dusty plasmas, and micro-plasmas, as well as the study of dynamical processes in classical plasmas including turbulence and turbulent transport, and plasma waves, structures, and flows.
- *High Energy Density Laboratory Plasmas* – Structural and dynamical studies of ionized matter at extreme densities and temperatures.
- *Exploratory Magnetized Plasma* – Research on complex, magnetized plasma systems that spontaneously evolve toward a state of long-range order through dissipative processes (e.g., compact toroidal plasma).

Through partnerships with the National Science Foundation (NSF), the National Nuclear Security Administration (NNSA), and the Office of Science's Basic Energy Sciences (BES) program, this activity maintains a leadership role in the national stewardship of plasma science by leveraging access to best-in-class experimental facilities as well as by the stewardship and operation of world-class plasma science user facilities at the intermediate scale. Along with facilitating discovery, intermediate-scale platforms are also providing critical data for the verification and validation of advanced fusion modeling codes.

Measurement Innovation

The Measurement Innovation activity supports the development of novel and innovative diagnostic techniques and their application to new, unexplored, or unfamiliar plasma regimes or scenarios. The challenge is to develop diagnostics with the spatial, spectral, and temporal resolution necessary to validate plasma physics models used to predict the behavior of fusion plasmas. Advanced diagnostic capabilities successfully developed through this activity are migrated to domestic and international facilities, as part of the Burning Plasma Science: Foundations and Burning Plasma: Long Pulse subprograms. The implementation of mature diagnostics systems is supported via the research programs at FES user facilities.

SBIR/STTR & Other

Funding for SBIR/STTR is included in this subprogram. Other activities that are supported include research at Historically Black Colleges and Universities (HBCUs), the U.S. Burning Plasma Organization (USBPO), a national organization that coordinates research in burning plasma science, peer reviews for solicitations across the program, and the Fusion Energy Sciences Advisory Committee (FESAC).

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
Plasma Science Frontiers $46,024,000	**$32,609,000**	**-$13,415,000**
General Plasma Science ($15,800,000)	*General Plasma Science ($15,500,000)*	*General Plasma Science (-$300,000)*
Core research elements of this activity continue. With input from the NRC Plasma Science Committee, the program also supports multi-institutional teams targeting interdisciplinary connections, and intermediate-scale facilities expanding experimentally accessible parameters and providing broad access to users. National Undergraduate Fellowship for Fusion and Plasma Research (NUF) continues to support undergraduate research internships as it completes its merger with the Office of Science's Science Undergraduate Laboratory Internships (SULI) activity operated by the Workforce Development for Teachers and Scientists (WDTS).	Core research elements of this activity will continue. The establishment of one or more new intermediate-scale user facilities will be emphasized.	The Office of Science will complete the merger of the NUF with SULI within the WDTS program.
High Energy Density Laboratory Plasmas ($19,815,000)	*High Energy Density Laboratory Plasmas ($6,700,000)*	*High Energy Density Laboratory Plasmas (-$13,115,000)*
Research utilizing the Matter in Extreme Conditions (MEC) Instrument at the Linac Coherent Light Source (LCLS) at the Stanford National Accelerator Laboratory is emphasized, along with completion of phase two of the scheduled short-pulse laser upgrade to deliver 200	Research utilizing the MEC at LCLS will be emphasized, including continued support for the MEC beam-line science team and the HEDLP research group at SLAC, as well as grants for external HED science users of MEC.	Contraction of the HEDLP program will result in no new research awards as part of the SC/NNSA Joint Program in HEDLP science, no new research projects at DOE national laboratories, and the cessation of operations and research at the Neutralized Drift

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
terawatts on target and research awards for external HED science users of MEC. Fundamental HEDLP science is supported through academic awards as part of the SC/NNSA Joint Program in HEDLP and operation of the Neutralized Drift Compression Experiment-II.		Compression Experiment-II.
Exploratory Magnetized Plasma ($10,409,000)	*Exploratory Magnetized Plasma ($10,409,000)*	*Exploratory Magnetized Plasma ($0)*
Research on the Madison Symmetric Torus emphasizes measurement of the scaling of tearing mode fluctuations with current and temperature to support the validation of nonlinear MHD codes. Physics extensions beyond MHD will be studied by measuring the Hall dynamo and comparing it to extended MHD simulations. Other smaller-scale experiments in this portfolio support validation and verification of codes and models.	This portfolio will be evaluated through a competitive peer-review process. Future research direction and emphasis will be informed by the outcome of the review.	No change.
Measurement Innovation $3,575,000	**$3,575,000**	**$0**
Efforts continue toward developing innovative techniques to address current and emerging measurement needs in the FES program. A community-informed planning activity is assessing the need for long pulse, plasma control, disruption, and burning plasma diagnostics.	All core research elements of the Measurement Innovation activity will continue.	No change.

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
SBIR/STTR & Other $12,883,000	**$11,148,000**	**-$1,735,000**
Funding supports all the elements in this category, including the USBPO activities, HBCUs, peer reviews for solicitations, and FESAC. SBIR/STTR funding is statutorily set at 3.3 percent of noncapital funding in FY 2015.	Funding will continue to support USBPO activities, HBCUs, peer reviews for solicitations, and FESAC. SBIR/STTR funding is statutorily set at 3.45 percent of noncapital funding in FY 2016.	Funding will decrease with the reduction in total FES noncapital funding.

Fusion Energy Sciences
Construction

Description

The exploration of high-power burning (self-heated) plasmas is the next critical area of scientific research for fusion. Previously the U.S. and European fusion programs had investigated burning plasmas at low power (10 megawatt level). The ITER facility, currently under construction in St. Paul-lez-Durance, France, will provide access to burning plasmas with fusion power output approaching reactor levels of hundreds of megawatts, for hundreds of seconds. ITER will thus be the first-ever facility capable of assessing the scientific and technical feasibility of fusion energy. As a collaborator in the ITER project, the U.S. contributes in-kind-hardware components, personnel, and direct funding to the ITER Organization (IO) for the ITER construction phase, as established by the terms of the ITER Joint Implementing Agreement. The key objective of these efforts is the completion of all activities associated with the U.S. Contributions to ITER project.

U.S. Contributions to ITER Project

The ITER international fusion project is designed to be the first magnetic confinement fusion facility to achieve a burning plasma. As ITER construction activities continue, careful and efficient management of the U.S. contributions to the international project by the U.S. ITER Project Office (USIPO) at Oak Ridge National Laboratory (ORNL) continue to be a high priority for FES.

ITER is designed to generate the world's first sustained (300-second discharge, self-heated) burning plasma. It aims to generate fusion power 30 times the levels produced to date and to exceed the external power applied to the plasma by at least a factor of ten. ITER will be a powerful tool for discovery, capable of addressing the new challenges of the burning plasma frontier and assessing the scientific and technical feasibility of fusion energy.

The ITER Project is being designed and built by an international consortium consisting of the U.S., China, India, Japan, South Korea, the Russian Federation, and the European Union (the host). The U.S. is committed to the scientific mission of ITER and will work with ITER partners to accomplish this goal, while maintaining a balanced domestic research portfolio. Executing a program with well-aligned domestic and international components will sustain U.S. international leadership in fusion energy sciences. The U.S. magnetic fusion research program in experiment, theory, and computation is configured to make strong contributions to ITER's science and to bring a high level of scientific return from it. ITER joins the broader FES research portfolio in elevating plasma sciences for both practical benefit and increased understanding.

The U.S. Contributions to ITER Project activity represents 9.09 percent of the ITER Project construction costs. The U.S. contributions, consisting of primarily of in-kind hardware components, with additional contributions of personnel and cash to the IO for the ITER construction phase, are established by the terms of the ITER Joint Implementing Agreement. In exchange for this contribution, the U.S. gains access to 100% of the ITER research output. ITER is similar to other modern large science projects being conducted as international collaborations that pool financial, technical, and scientific resources to achieve critical science at a scale beyond the reach of individual countries.

The U.S. contributions are managed by the USIPO at ORNL, in partnership with PPPL and Savannah River National Laboratory. The U.S. ITER Project differs from most other DOE and SC projects in the "hand-off" of U.S. in-kind hardware contributions to a central project team outside direct DOE oversight and in the risks associated with performing work that depends on the execution of project responsibilities by our international partners. The requested level of funding for FY 2016 will ensure that U.S. in-kind contributions fulfill U.S. commitments to FY 2016 project needs.

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Change FY 2016 vs. FY 2015
U.S. Contributions to ITER Project $150,000,000	**$150,000,000**	**$0**
Funding is provided for ITER Project Office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including industrial procurements of central solenoid magnet modules and structures, toroidal field magnet conductor fabrication, diagnostics, and the tokamak cooling water system procurement.	Funding will be provided for ITER Project Office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including ongoing industrial fabrication of central solenoid magnet modules and structures, fabrication and delivery of the final lengths of toroidal field magnet conductors and components of the steady state electric network, development and design of diagnostics and associated port plugs, and continued procurement of the tokamak cooling water system.	No change.

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for and tracks progress toward achieving performance goals for each program. The following table shows the targets for FY 2014 through FY 2016.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**FES Facility Based Experiments—Experiments conducted on major fusion facilities (DIII-D, Alcator C-Mod, NSTX-U) leading toward predictive capability for burning plasmas and configuration optimization**		
Target	Conduct experiments and analysis to investigate and quantify plasma response to non-axisymmetric (3D) magnetic fields in tokamaks. Effects of 3D fields can be both beneficial and detrimental and research will aim to validate theoretical models in order to predict plasma performance with varying levels and types of externally imposed 3D fields. Dependence of response to multiple plasma parameters will be explored in order to gain confidence in predictive capability of the models.	Conduct experiments and analysis to quantify the impact of broadened current and pressure profiles on tokamak plasma confinement and stability. Broadened pressure profiles generally improve global stability but can also affect transport and confinement, while broadened current profiles can have both beneficial and adverse impacts on confinement and stability. This research will examine a variety of heating and current drive techniques in order to validate theoretical models of both the actuator performance and the transport and global stability response to varied heating and current drive deposition.	Conduct research to detect and minimize the consequences of disruptions in present and future tokamaks, including ITER. Coordinated research will deploy a disruption prediction/warning algorithm on existing tokamaks, assess approaches to avoid disruptions, and quantify plasma and radiation asymmetries resulting from disruption mitigation measures, including both pre-existing and resulting MHD activity, as well as the localized nature of the disruption mitigation system. The research will employ new disruption mitigation systems, control algorithms, and hardware to help avoid disruptions, along with measurements to detect disruption precursors and quantify the effects of disruptions.
Result	Met	TBD	TBD

	FY 2014	FY 2015	FY 2016
Endpoint Target	Magnetic fields are the principal means of confining the hot ionized gas of a plasma long enough to make practical fusion energy. The detailed shape of these magnetic containers leads to many variations in how the plasma pressure is sustained within the magnetic bottle and the degree of control that experimenters can exercise over the plasma stability. These factors, in turn, influence the functional and economic credibility of the eventual realization of a fusion power reactor. The key to their success is a detailed physics understanding of the confinement characteristics of the plasmas in these magnetic configurations. The major fusion facilities can produce plasmas that provide a wide range of magnetic fields, plasma currents, and plasma shapes. By using a variety of plasma control tools, appropriate materials, and having the diagnostics needed to measure critical physics parameters, scientists will be able to develop optimum scenarios for achieving high performance plasmas in ITER and, ultimately, in reactors.		
Performance Goal (Measure)	**FES Facility Operations—Average achieved operation time of FES user facilities as a percentage of total scheduled annual operation time**		
Target	≥ 90%	≥ 90%	≥ 90%
Result	Met	TBD	TBD
Endpoint Target	Many of the research projects that are undertaken at the SC scientific user facilities take a great deal of time, money, and effort to prepare and regularly have a very short window of opportunity to run. If the facility is not operating as expected the experiment could be ruined or critically set back. In addition, taxpayers have invested millions or even hundreds of millions of dollars in these facilities. The greater the period of reliable operations, the greater the return on the taxpayers' investment.		

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**FES Theory and Simulation—Performance of simulations with high physics fidelity codes to address and resolve critical challenges in the plasma science of magnetic confinement**		
Target	Understanding alpha particle confinement in ITER, the world's first burning plasma experiment, is a key priority for the fusion program. Linear instability trends and thresholds of energetic particle-driven shear Alfvén eigenmodes in ITER are determined for a range of parameters and profiles using a set of complementary simulation models (gyrokinetic, hybrid, and gyrofluid). Initial nonlinear simulations are carried out to assess the effects of the unstable modes on energetic particle transport.	Perform massively parallel plasma turbulence simulations to determine expected transport in ITER. Starting from best current estimates of ITER profiles, the turbulent transport of heat and particles driven by various micro-instabilities (including electromagnetic dynamics) will be computed. Stabilization of turbulence by nonlinear self-generated flows is expected to improve ITER performance, and will be assessed with comprehensive electromagnetic gyrokinetic simulations.	Predicting the magnitude and scaling of the divertor heat load width in magnetically confined burning plasmas is a high priority for the fusion program and ITER. One of the key unresolved physics issues is what sets the heat flux width at the entrance to the divertor region. Perform massively parallel simulations using 3D edge kinetic and fluid codes to determine the parameter dependence of the heat load width at the divertor entrance and compute the divertor plate heat flux applicable to moderate particle recycling conditions. Comparisons will be made with data from DIII-D, NSTX-U, and C-Mod.
Result	Met	TBD	TBD
Endpoint Target	Advanced simulations based on high physics fidelity models offer the promise of advancing scientific discovery in the plasma science of magnetic fusion by exploiting the SC high performance computing resources and associated advances in computational science. These simulations are able to address the multi-physics and multi-scale challenges of the burning plasma state and contribute to the FES goal of advancing the fundamental science of magnetically confined plasmas to develop the predictive capability needed for a sustainable fusion energy source.		
Performance Goal (Measure)	**FES Construction/MIE Cost & Schedule— Cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects**		
Target	< 10%	< 10%	< 10%
Result	Met	TBD	TBD
Endpoint Target	Adhering to the cost and schedule baselines for a complex, large scale, science project is critical to meeting the scientific requirements for the project and for being good stewards of the taxpayers' investment in the project.		

Fusion Energy Sciences
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
Capital Operating Expenses Summary							
Capital equipment	n/a	n/a	27,487	27,487	7,798	6,799	-999
General plant projects (GPP)	n/a	n/a	3,700	3,700	2,500	5,000	+2,500
Total, Capital Operating Expenses	**n/a**	**n/a**	**31,187**	**31,187**	**10,298**	**11,799**	**+1,501**
Capital Equipment							
Major items of equipment							
National Spherical Torus Experiment Upgrade (TPC $94,300)	83,665	56,495	23,700	23,700	3,470	0	-3,470
U.S. Contributions to ITER (TPC TBD)	TBD	673,385	0	0	0	0	0
Total MIEs	**n/a**	**729,880**	**23,700**	**23,700**	**3,470**	**0**	**-3,470**
Other capital equipment projects under $2 million TEC	n/a	n/a		671	5,269	5,199	-70
Total, Capital equipment	**n/a**	**n/a**		**24,371**	**8,739**	**5,199**	**-3,540**
General Plant Projects							
General Plant Projects under $2 million TEC	n/a	n/a	3,700	3,700	2,500	5,000	+2,500

Fusion Energy Sciences Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	200,967	192,145	215,970	176,431	-39,539
Scientific user facility operations	74,610	74,610	94,935	88,090	-6,845
Major items of equipment	23,700	23,700	3,470	0	-3,470
Other (GPP, GPE, and infrastructure)	5,900	5,900	3,125	5,479	+2,354
Construction	199,500	199,500	150,000	150,000	0
Total, Fusion Energy Sciences	**504,677**	**495,855**	**467,500**	**420,000**	**-47,500**

Scientific User Facility Operations and Research ($K)

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

Definitions:

Achieved Operating Hours – The amount of time (in hours) the facility was available for users.

Planned Operating Hours –

- For Past Fiscal Year (PY), the amount of time (in hours) the facility was planned to be available for users.
- For Current Fiscal Year (CY), the amount of time (in hours) the facility is planned to be available for users.
- For the Budget Fiscal Year (BY), based on the proposed budget request the amount of time (in hours) the facility is anticipated to be available for users.

Optimal Hours – The amount of time (in hours) a facility would be available to satisfy the needs of the user community if unconstrained by funding levels.

Percent of Optimal Hours – An indication of utilization effectiveness in the context of available funding; it is not a direct indication of scientific or facility productivity.

- For BY and CY, Planned Operating Hours divided by Optimal Hours expressed as a percentage.
- For PY, Achieved Operating Hours divided by Optimal Hours.

Unscheduled Downtime Hours - The amount of time (in hours) the facility was unavailable to users due to unscheduled events. NOTE: For type “A” facilities, zero Unscheduled Downtime Hours indicates Achieved Operating Hours equals Planned Operating Hours.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
DIII-D National Fusion Facility	**$74,958**	**$74,958**	**$79,950**	**$71,348**	**-$8,602**
Number of Users	576	576	579	545	-34
Achieved operating hours	756	756	N/A	N/A	N/A
Planned operating hours	720	720	600	480	-120
Optimal hours	1,000	1,000	1,000	1,000	0
Percent optimal hours	75.6%	75.6%	60%	48%	N/A
Unscheduled downtime hours	0	0	TBD	N/A	N/A
Alcator C-Mod	**$21,940**	**$21,940**	**$22,260**	**$18,000**	**-$4,260**
Number of Users	170	170	170	140	-30
Achieved operating hours	364	364	N/A	N/A	N/A
Planned operating hours	384	384	384	160	-224
Optimal hours	800	800	800	800	0
Percent optimal hours	45.5%	45.5%	48%	20%	N/A
Unscheduled downtime hours	20	20	TBD	N/A	N/A
National Spherical Torus Experiment-Upgrade	**$38,656**	**$38,656**	**$66,750**	**$62,925**	**-$3,825**
Number of Users	165	165	250	250	0
Achieved operating hours	0	0	N/A	N/A	N/A
Planned operating hours	0	0	480	560	+80
Optimal hours	0	0	500	1,000	+500
Percent optimal hours	0%	0%	96%	56%	N/A
Unscheduled downtime hours	0	0	TBD	N/A	N/A

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Total Facilities	**$135,554**	**$135,554**	**$168,960**	**$152,273**	**-$16,687**
Number of Users	911	911	999	935	-64
Achieved operating hours	1,120	1,120	N/A	N/A	N/A
Planned operating hours	1,104	1,104	1,464	1,200	-284
Optimal hours	1,800	1,800	2,300	2,800	+500
Percent of optimal hours[a]	62.2%	62.2%	73.1%	48%	N/A
Unscheduled downtime hours	20	20	N/A	N/A	N/A

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Number of permanent Ph.D.'s (FTEs)	710	710	724	603	-121
Number of postdoctoral associates (FTEs)	91	91	93	79	-14
Number of graduate students (FTEs)	264	264	268	195	-73
Other[b]	1,081	1,081	1,102	937	-165

[a] For total facilities only, this is a "funding weighted" calculation FOR ONLY TYPE A facilities: $\frac{\sum_1^n [(\%OH\ for\ facility\ n)\times(funding\ for\ facility\ n\ operations)]}{Total\ funding\ for\ all\ facility\ operations}$

[b] Includes technicians, engineers, computer professionals, and other support staff.

14-SC-60, U.S. Contributions to ITER

1. Significant Changes and Summary

Significant Changes

This Construction Project Data Sheet (CPDS) is an update of the FY 2015 CPDS and does not include a new start for the budget year.

The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-1, Approve Alternative Selection and Cost Range, was approved on January 25, 2008, with a preliminary cost range of $1.45–$2.2 billion and projected completion date in FY 2014. Since CD-1, it has not been possible to baseline the project because of technical challenges, continued delays in the international ITER construction schedule, and lack of stable project funding. Until such time as CD-2 can be approved, the U.S. funding will be managed to address annual project needs and to allow flexibility to adapt to the changing state of the project. Since the project does not have CD-2 approval, the schedule and cost estimates contained in this PDS are identified as "TBD". The current best estimate of the total cost range, prior to CD-2, is $4,000,000,000-$6,500,000,000.

The approving official for all critical decisions is the Director of the Office of Science (SC-1).

A Federal Project Director has been assigned to this project and has approved this CPDS.

Summary

The U.S. Contributions to ITER (U.S. ITER) is a U.S. Department of Energy project to provide the U.S. share of hardware (e.g., subsystems, equipment, and components), as well as cash contributions to support the ITER construction project in Cadarache, France. ITER is a major fusion research facility being constructed in France by an international partnership of seven governments. Since it will not result in a facility owned by the U.S. or located in the U.S., ITER is not classified as a capital asset project. Sections of this CPDS have been tailored accordingly to reflect the nature of this project.

The U.S. ITER project is managed as a DOE Office of Science (SC) project. The project began as a major item of equipment (MIE) in FY 2006, and was changed to a Congressional control point beginning in FY 2014. This did not change SC's overall program and project management approach for the U.S. ITER Project. As with all SC projects, the principles of DOE Order 413.3B are applied in the effective management of the project, including critical decision milestones and their supporting prerequisite activities. Requirements for project documentation, monitoring and reporting, change control, and regular independent project reviews are being applied with the same degree of rigor as other SC projects. An approved FY 2015 Annual Performance Plan (APP) authorizes the work activities to be performed, as well as establishes high-level milestones for project performance against which progress will be measured. Progress and performance against the APP is reported regularly in monthly performance metrics and project status reports.

The U.S. ITER project is making significant progress in the areas of design completion and fabrication of hardware. As of the end of FY 2014, overall the U.S. ITER project is 25% complete; and the design of all twelve technical systems the U.S. is responsible for delivering, is 55% complete. Two of the largest U.S. systems, the Tokamak Cooling Water System (TCWS) and the Central Solenoid (CS) Magnets are in or beyond final design. Active fabrication is underway in four of the U.S. twelve hardware systems (TCWS, Steady State Electric Network (SSEN) Components, Toroidal Field (TF) Conductor and CS Magnets). The U.S. is on schedule to complete the fabrication of five nuclear-grade cooling water drain tanks and deliver them to the ITER site in FY 2015. These components, which are time critical for ITER construction sequencing and which are fabricated in accordance with French Nuclear regulations, will be one of the first major hardware components delivered to the site in France in FY 2015. The U.S. is also in the process of procuring major high-voltage electric power components (e.g., transformers, switch gear, voltage regulators). Multiple deliveries of U.S. electric power components to the ITER site in France began in FY 2014 and will continue through FY 2015. In addition, fabrication of TF conductor is well underway. Purchase of superconducting strand material is complete; cabling activities are well underway, and production of both non-active (sample) and active (superconducting) lengths of conductor are in progress. The U.S. has shipped finished lengths of both non-active (for winding trials) and active conductors to the European Union, one of the ITER Members responsible for TF Magnet fabrication. TF conductor shipments will continue through FY 2015.

Finally, preparations are well underway for the U.S. to begin fabrication of the world's largest superconducting magnets for the ITER CS Magnet system. The U.S. has contracted with General Atomics (GA) for the fabrication of the CS Magnet modules. The GA fabrication facility will be essentially complete by the end of FY 2014 with the installation and commissioning of multiple work stations needed for fabrication of each of the seven modules the U.S. is responsible for delivering. The U.S. is on schedule to achieve two major milestones in FY 2015 with the start and completion of fabrication of a mockup (non-active) coil to provide assurance of manufacturing processes, and most notably the start of winding the first production (active) module with superconducting CS conductor provided by the Japanese Domestic Agency. Initiation of fabrication activities in the GA facility represents the culmination of several years of preparation and a major investment for the U.S.

FY 2016 funding will support ITER Project Office operations; the U.S. cash contribution; and continued progress on in-kind contributions, including ongoing industrial fabrication of central solenoid magnet modules and structures, fabrication and delivery of the final lengths of toroidal field magnet conductors and components of the steady state electric network, development and design of diagnostics and associated port plugs, and continued procurement of the tokamak cooling water system.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2006	7/5/2005		TBD	TBD		TBD	N/A	TBD
FY 2007	7/5/2005		TBD	TBD		TBD	N/A	2017
FY 2008	7/5/2005		1/25/2008	4Q FY 2008		TBD	N/A	2017
FY 2009	7/5/2005	09/30/2009[a]	1/25/2008	4Q FY 2010		TBD	N/A	2018
FY 2010	7/5/2005	07/27/2010[b]	1/25/2008	4Q FY 2011		TBD	N/A	2019
FY 2011	7/5/2005	05/30/2011[c]	1/25/2008	4Q FY 2011	04/12/2011[d]	TBD	N/A	2024
FY 2012	7/5/2005	07/10/2012[e]	1/25/2008	3Q FY 2012	05/02/2012[f]	TBD	N/A	2028
FY 2013	7/5/2005	12/11/2012[g]	1/25/2008	TBD[h]	04/10/2013[i]	TBD	N/A	2033
FY 2014	7/5/2005		1/25/2008	TBD	12/10/2013[j]	TBD	N/A	2034
FY 2015[k]	7/5/2005		1/25/2008	TBD		TBD	N/A	TBD

[a] Electron Cyclotron Heating Transmission lines (06/22/2009); Tokamak Cooling Water System (07/21/2009); CS Modules, Structures, and Assembly Tooling (09/30/2009)
[b] Ion Cyclotron Heating Transmission Lines (10/14/2009); First Wall / Blanket (02/02/2010); Tokamak Exhaust Processing (05/17/2010); Diagnostics: Residual Gas Analyzer (07/14/2010), Upper VIR (07/27/2010)
[c] Vacuum Auxilliary System (VAS) – Main Piping (12/13/2010); Diagnostics LFS (05/30/2011)
[d] Cooling Water Drain Tanks (04/12/2011);
[e] Diagnostics: Upper Port (10/03/2011), ECE (12/06/2011), Equatorial Port E-9 and TIP (01/02/2012), Equatorial Port E-3 (07/10/2012)
[f] Steady State Electrical Network (05/02/2012)
[g] VAS Supply (11/13/2012); Disruption Mitigation (12/11/2012); Pellet Injection (04/29/2013); Diagnostics: MSE (05/29/2013), CIXS (06/01/2013)
[h] The CD-2 date will be determined upon acceptable resolution of issues related to development of a high-confidence ITER Project Schedule and establishment of an approved funding profile.
[i] First Wall and Blanket (04/10/2013)
[j] CS Modules and Structures (11/18/2013); VAS Main Piping B-2, L-1, L-2 (12/10/2013)
[k] This project is pre-CD-2, and the schedule and cost estimate are preliminary.

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2016[a]	7/5/2005		1/25/2008	TBD		TBD	N/A	TBD

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection, Cost Range, and Start of Long-lead Procurements
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of Fabrication
CD-4 – Approve Project Completion

3. Project Cost History

It has not been possible to baseline the project due to both technical challenges and continued delays in the international ITER construction schedule. The factors that delayed CD-2 approval (e.g., schedule delays, design and scope changes, regulatory requirements, risk mitigations, and project management issues in the ITER Organization) have placed pressure on the cost range, resulting in increased estimates. The current best estimate of the total cost range, prior to CD-2, is $4,000,000,000-$6,500,000,000.

4. Project Scope and Justification

Introduction

ITER is an international partnership between seven Member governments (China, the European Union, India, Japan, the Republic of Korea, the Russian Federation, and the United States) aimed at demonstrating the scientific and technological feasibility of fusion energy for peaceful purposes. The *Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project* (ITER Agreement), signed on November 21, 2006, provides the legal framework for the four phases of the program: construction, operation, deactivation, and decommissioning. The ITER Agreement specifies that, as the Host, the European Union will bear five-elevenths (45.45%) of the ITER facility's construction cost, while the other six Members, including the U.S., will each support one-eleventh (9.09%) of the ITER facilities cost. The ITER Agreement also provides for operation, deactivation, and decommissioning of the facility to be funded through a different cost-sharing formula in which the U.S. will contribute a 13% share. Responsibility for ITER integration, management, design, licensing, installation, and operation rests with the ITER Organization (IO), which is an international legal entity located in France.

Scope

ITER Construction Project Scope

The U.S. ITER project includes three major elements:

- Hardware components, built under the responsibility of the U.S., then shipped to the ITER site for IO assembly, installation, and operation.
- Funding to the IO to support common expenses, including ITER research and development (R&D), IO staff and infrastructure, IO-provided hardware, on-site assembly/installation/testing of all ITER components, and IO Central Reserve, which serves as a contingency fund.
- Other costs, including R&D and conceptual design related activities.

The U.S. ITER project hardware scope is limited to design, fabrication, and delivery of mission-critical tokamak subsystems and is described below.

- **Tokamak Cooling Water System**: manages the thermal energy generated during the operation of the tokamak.

[a] This project is pre-CD-2, and the schedule and cost estimate are preliminary.

- **15% of ITER Diagnostics**: provides the measurements necessary to control, evaluate, and optimize plasma performance and to further the understanding of plasma physics.
- **Disruption Mitigation Systems ($20M cost cap)**: limit the impact of plasma disruptions to the tokamak vacuum vessel, blankets, and other components.
- **Electron Cyclotron Heating Transmission Lines**: bring additional power to the plasma and deposits power in specific areas of the plasma to minimize instabilities and optimize performance.
- **Tokamak Exhaust Processing System**: separates hydrogen isotopes from tokamak exhaust.
- **Fueling System (Pellet Injection)**: injects fusion fuels in the form of deuterium-tritium ice pellets into the vacuum chamber.
- **Ion Cyclotron Heating Transmission Lines**: bring additional power to the plasma.
- **Central Solenoid Magnet System**: confines, shapes and controls the plasma inside the vacuum vessel.
- **8% of Toroidal Field (TF) Conductor**: component of the TF magnet that confines, shapes, and controls the plasma.
- **75% of the Steady State Electrical Network**: supplies the electricity needed to operate the entire plant, including offices and the operational facilities.
- **Vacuum Auxiliary System**: creates and maintains low gas densities in the vacuum vessel and connected vacuum components.
- **Roughing Pumps**: evacuate the tokamak, cryostat, and auxiliary vacuum chambers prior to and during operations.

Justification

The purpose of ITER is to investigate the burning plasma regime that exists in the performance region between the current scientific knowledge base and that needed for a practical fusion power. There are two parts of this need that will be achieved by ITER. The first part is to investigate the fusion process in the form of a "burning plasma," in which the heat generated by the fusion process exceeds that supplied from external sources (i.e., self-heating). The second part of this need is to sustain the burning plasma for a long duration (e.g., several hundred to a few thousand seconds), during which time equilibrium conditions can be achieved within the plasma and adjacent structures. ITER is the necessary next step to establish the confidence in proceeding with development of a demonstration fusion power plant.

5. Financial Schedule

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Hardware			
FY 2006	13,754	13,754	6,169
FY 2007	34,588	34,588	24,238
FY 2008	25,500	25,500	24,122
FY 2009	85,401	85,401	26,278
FY 2010	85,266	85,266	46,052
FY 2011	63,875	63,875	84,321
FY 2012	91,716	91,716	99,229
FY 2013	107,660	107,660	110,298
FY 2014[a]	161,605	161,605	153,367

[a] Appropriations prior to FY 2014 reflect major item of equipment funding. Starting in FY 2014, this project is funded as a Congressional control point.

	(dollars in thousands)		
	Appropriations	Obligations	Costs
FY 2015	125,654	125,654	128,704
FY 2016	105,223	105,223	124,402
Subtotal	900,242	900,242	827,180
Outyears	TBD	TBD	TBD
Total, Hardware	TBD	TBD	TBD
Cash Contributions			
FY 2006	2,112	2,112	2,112
FY 2007	7,412	7,412	7,412
FY 2008	2,644	2,644	2,644
FY 2009	23,599	23,599	23,599
FY 2010	29,734	29,734	29,734
FY 2011	3,125	3,125	3,125
FY 2012	13,214	13,214	13,214
FY 2013	13,805	13,805	13,805
FY 2014[a]	32,895	32,895	32,895
FY 2015	18,985	18,985	18,985
FY 2016	44,777	44,777	44,777
Subtotal	192,302	192,302	192,302
Outyears	TBD	TBD	TBD
Total, Cash Contributions	TBD	TBD	TBD
Total, TEC	TBD	TBD	TBD
Other project costs (OPC)			
FY 2006	3,449	3,449	1,110
FY 2007	18,000	18,000	7,607
FY 2008	-2,074	-2,074	7,513
FY 2009	15,000	15,000	5,072
FY 2010	20,000	20,000	7,754
FY 2011	13,000	13,000	10,032
FY 2012	70	70	22,322
FY 2013	2,535	2,535	5,760
FY 2014[a]	5,000	5,000	2,726
FY 2015	5,361	5,361	5,499
FY 2016	0	0	574
Subtotal	80,341	80,341	75,969
Outyears	TBD	TBD	TBD
Total, OPC	TBD	TBD	TBD

[a] Appropriations prior to FY 2014 reflect major item of equipment funding. Starting in FY 2014, this project is funded as a Congressional control point.

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Total Project Costs (TPC)			
FY 2006	19,315	19,315	9,391
FY 2007	60,000	60,000	39,257
FY 2008	26,070	26,070	34,279
FY 2009	124,000	124,000	54,949
FY 2010	135,000	135,000	83,540
FY 2011	80,000	80,000	97,478
FY 2012	105,000	105,000	134,765
FY 2013	124,000	124,000	129,863
FY 2014[a]	199,500	199,500	188,988
FY 2015	150,000	150,000	153,188
FY 2016	150,000	150,000	169,753
Subtotal	1,172,885	1,172,885	1,095,451
Outyears	TBD	TBD	TBD
Total, TPC	TBD	TBD	TBD

6. Details of the 2014 Project Cost Estimate

The current best estimate of the total cost range, prior to CD-2, is $4,000,000,000–$6,500,000,000. This range was determined under the assumption that the annual funding level will not exceed $225,000,000 per year starting in FY 2014 through first plasma; and taking into account risks associated with assembly and operations costs, the international project schedule, nuclear construction, and technical challenges in providing U.S. project hardware scope.

7. Schedule of Appropriation Requests

Request Year		Prior Years	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Outyears	Total
				(dollars in thousands)					
FY 2006	TEC	889,000	120,000	29,000	0	0	0	0	1,038,000
	OPC	74,400	6,200	3,400	0	0	0	0	84,000
	TPC	963,400	126,200	32,400	0	0	0	0	1,122,000
FT 2007	TEC	800,151	130,000	116,900	30,000	0	0	0	1,077,051
	OPC	44,949	0	0	0	0	0	0	44,949
	TPC	845,100	130,000	116,900	30,000	0	0	0	1,122,000
FY 2008	TEC	801,330	130,000	116,900	30,000	0	0	0	1,078,230
	OPC	43,770	0	0	0	0	0	0	43,770
	TPC	845,100	130,000	116,900	30,000	0	0	0	1,122,000
FY 2009[b]	TEC	266,366	0	0	0	TBD	TBD	TBD	TBD
	OPC	38,075	0	0	0	TBD	TBD	TBD	TBD
	TPC	304,441	0	0	0	TBD	TBD	TBD	TBD

[a] Appropriations prior to FY 2014 reflect major item of equipment funding. Starting in FY 2014, this project is funded as a Congressional control point.
[b] The Prior Years column for FY 2009 through FY 2012 reflects the total of appropriations and funding requests only through the year of that row. Thus, for example, in the FY 2010 row, it reflects only funding from FY 2006 to FY 2010.

Request Year		Prior Years	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	Outyears	Total
					(dollars in thousands)				
FY 2010	TEC	294,366	0	0	0	TBD	TBD	TBD	TBD
	OPC	70,019	0	0	0	TBD	TBD	TBD	TBD
	TPC	364,385	0	0	0	TBD	TBD	TBD	TBD
FY 2011	TEC	379,366	0	0	0	TBD	TBD	TBD	TBD
	OPC	65,019	0	0	0	TBD	TBD	TBD	TBD
	TPC	444,385	0	0	0	TBD	TBD	TBD	TBD
FY 2012[a]	TEC	304,566	90,000	0	0	TBD	TBD	TBD	TBD
	OPC	60,019	15,000	0	0	TBD	TBD	TBD	TBD
	TPC	364,385	105,000	0	0	TBD	TBD	TBD	TBD
FY 2013	TEC	371,366	104,930	140,965	0	TBD	TBD	TBD	TBD
	OPC	73,019	70	9,035	0	TBD	TBD	TBD	TBD
	TPC	444,385	105,000	150,000	0	TBD	TBD	TBD	TBD
FY 2014	TEC	371,366	104,930	105,572	225,000	TBD	TBD	TBD	TBD
	OPC	73,019	70	70	0	TBD	TBD	TBD	TBD
	TPC	444,385	105,000	105,642[b]	225,000	TBD	TBD	TBD	TBD
FY 2015[c]	TEC	377,010	104,930	121,465	194,500	144,639	TBD	TBD	TBD
	OPC	67,375	70	2,535	5,000	5,361	TBD	TBD	TBD
	TPC	444,385	105,000	124,000	199,500	150,000	TBD	TBD	TBD
FY 2016[d]	TEC	377,010	104,930	121,465	194,500	144,639	150,000	TBD	TBD
	OPC	67,375	70	2,535	5,000	5,361	0	TBD	TBD
	TPC	444,385	105,000	124,000	199,500	150,000	150,000	TBD	TBD

8. Related Operations and Maintenance Funding Requirements

The U.S. Contributions to ITER operations is assumed to begin with initial commissioning activities and continue for a period of 15 to 25 years. The fiscal year in which commissioning activities begin depends on the international ITER project schedule and is therefore TBD.

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	TBD
Expected Useful Life (number of years)	15–25
Expected Future start of D&D for new construction (fiscal quarter)	TBD

9. D&D Funding Requirements

Since ITER is being constructed in France by a coalition of countries and will not be a DOE asset, the “one-for-one” requirement is not applicable to this project.

[a] The FY 2012 request was submitted before a full-year appropriation for FY 2011 was in place, and so FY 2011 was TBD at that time. Hence, the Prior Years column for FY 2012 reflects appropriations for FY 2006 through FY 2010 plus the FY 2012 request.
[b] The FY 2013 amount shown in the FY 2014 request reflected a short-term continuing resolution level annualized to a full year and based on the FY 2012 funding level for ITER.
[c] Prior to FY 2015, the requests were for a major item of equipment broken out by TEC, OPC, and TPC.
[d] Prior to FY 2015, the requests were for a major item of equipment broken out by TEC, OPC, and TPC.

The U.S. Contributions to ITER Decommissioning are assumed to begin when operations commence and continue for a period of 20 years. The U.S. is responsible for 13 percent of the total decommissioning cost.

The U.S. Contributions to ITER Deactivation are assumed to begin 20 years after commissioning and continue for a period of 5 years. The U.S. is responsible for 13 percent of the total deactivation cost.

10. Acquisition Approach for US Hardware Contributions

The U.S. ITER Project Office (USIPO) at Oak Ridge National Laboratory, with its two partner laboratories (Princeton Plasma Physics Laboratory and Savannah River National Laboratory), will procure and deliver in-kind hardware in accordance with the Procurement Arrangements established with the IO.

The USIPO will subcontract with a variety of research and industry sources for design and fabrication of its ITER components, ensuring that designs are developed that permit fabrication, to the maximum extent possible, under fixed-price subcontracts (or fixed-price arrangement documents with the IO) based on performance specifications, or more rarely, on build-to-print designs. USIPO will use cost-reimbursement type subcontracts only when the work scope precludes accurate and reasonable cost contingencies being gauged and established beforehand.

USIPO will utilize best value, competitive source selection procedures to the maximum extent possible, including foreign firms on the tender/bid list where appropriate. Such procedures shall allow for cost and technical trade-offs during source selection.

For the large-dollar-value subcontracts (and critical path subcontracts as appropriate), USIPO will utilize unique subcontract provisions to incentivize cost control and schedule performance.

In addition, where it is cost effective and it reduces risk, the USIPO will participate in common procurements led by the IO, or request the IO to perform activities that are the responsibility of the U.S.

High Energy Physics

Overview

The High Energy Physics (HEP) program mission is to understand how the universe works at its most fundamental level by discovering the elementary constituents of matter and energy, probing the interactions between them, and exploring the basic nature of space and time.

HEP offers research opportunities for individual investigators and small-scale collaborations, as well as very large international collaborations, chosen for their scientific merit and potential for significant impact. More than 20 HEP-supported physicists have received the Nobel Prize. Moreover, many of the advanced technologies and research tools originally developed for high energy physics have proven widely applicable to other scientific disciplines as well as industry, medicine, and national security.

Our current understanding of the elementary constituents of matter and energy is captured in what is called the Standard Model of particle physics. It describes the elementary particles that comprise ordinary matter and forces that govern them with very high precision. However, recent observations that are not explained by the Standard Model suggest that it is incomplete and new physics may be discovered by future experiments. Astronomical observations indicate that ordinary matter makes up only about 5% of the universe, the remainder being 70% dark energy and 25% dark matter, both "dark" because they are either nonluminous or unknown. The observation of very small but non-zero masses of the elementary particles known as neutrinos provides further hints of new physics beyond the Standard Model.

A world-wide program of particle physics research is underway to discover what lies beyond the Standard Model. Five intertwined science drivers of particle physics provide compelling lines of inquiry that show great promise for discovery:

- Use the Higgs boson as a new tool for discovery
- Pursue the physics associated with neutrino mass
- Identify the new physics of dark matter
- Understand cosmic acceleration: dark energy and inflation
- Explore the unknown: new particles, interactions and physical principles

The HEP program enables scientific discovery through a strategy organized along three frontiers of particle physics:

- Energy Frontier, where researchers accelerate particles to the highest energies ever made by humanity and collide them to produce and study the fundamental constituents of matter. This requires some of the largest machines ever built. The Large Hadron Collider (LHC), 17 miles in circumference, accelerates and collides high-energy protons while sophisticated detectors, some the size of apartment buildings, observe newly produced particles that provide insight into fundamental forces of nature and the conditions of the early universe.
- Intensity Frontier, where researchers use a combination of intense particle beams and highly sensitive detectors to make extremely precise measurements of particle properties, study some of the rarest particle interactions predicted by the Standard Model of particle physics, and search for new physics. Measurements of the mass and other properties of neutrinos may have profound consequences for understanding the evolution and ultimate fate of the universe.
- Cosmic Frontier, where researchers seek to reveal the nature of dark matter and dark energy by using naturally occurring particles to explore new phenomena. The highest-energy particles ever observed have come from cosmic sources, and the ancient light from distant galaxies allows the distribution of dark matter to be mapped and perhaps the nature of dark energy to be unraveled. Ultra-sensitive detectors deep underground may glimpse the dark matter passing through Earth. Observations of the cosmic frontier reveal a universe far stranger than ever thought possible.

These three frontiers are supported by the Theoretical and Computational Physics and the Advanced Technology R&D subprograms. Theoretical and Computational Physics provides the framework to explain experimental observations and gain a deeper understanding of nature. A thriving theory program is essential to support current experiments and identify new directions for the field. Theoretical physicists take the lead in the interpretation of a broad range of experimental results and synthesize new ideas as they search for deep connections and develop testable models. Advanced computing tools are necessary for designing, operating, and interpreting experiments while performing the computational science and simulations that enable discovery research in the three frontiers. Advanced Technology R&D fosters fundamental research into particle acceleration and detection techniques and instrumentation. These in turn provide the enabling technologies and new research methods that can advance scientific knowledge in high energy physics and a broad range of related fields, advancing the DOE's strategic goals for science.

The Accelerator Stewardship subprogram supports R&D efforts that are synergistic with the HEP mission but also impact activities outside the tradition HEP boundaries. The activities of the Stewardship subprogram include: improving access to Office of Science (SC) accelerator R&D infrastructure for industrial and other users; near-term translational R&D to adapt HEP accelerator technology for potential uses in medical, industrial, security, defense, energy and environmental applications; and long-term R&D for science and technology needed to build future generations of accelerators, with a focus on transformational opportunities.

Highlights of the FY 2016 Budget Request

In September 2013, the DOE and the National Science Foundation (NSF) charged the High Energy Physics Advisory Panel (HEPAP) to convene a Particle Physics Project Prioritization Panel (P5) in order to develop a ten-year strategic plan for U.S. high energy physics in the context of a 20-year global vision. The panel was charged to respond to three realistic budget scenarios provided by the funding agencies. In May 2014, HEPAP unanimously approved the P5 report and its recommendations. The report provides a practical, long-term strategy that enables discovery and maintains the U.S. position as a global leader in particle physics. The DOE accepted the recommendations in the P5 report and is committed to implementing a successful program based on this new vision.

The FY 2016 budget request implements the recommendations contained in the P5 report. Support is requested for full operation of existing major HEP facilities and experiments; the planned construction funding profile for the Muon to Electron Conversion Experiment (Mu2e) and fabrication for recent major items of equipment (MIEs) for the Super Cryogenic Dark Matter Search at the new Sudbury Neutrino Observatory laboratory (SuperCDMS-SNOLab), the Large Underground Xenon (LUX) –ZonEd Proportional scintillation in LIquid Noble gases (ZEPLIN) experiment (LZ), and the Dark Energy Spectroscopic Instrument (DESI) projects. Capital equipment funding is requested to continue support of the planned funding profiles for the camera for the Large Synoptic Survey Telescope (LSSTcam) project, the Muon g-2 Experiment, and the U.S. contributions to the Large Hadron Collider (LHC) A Toroidal LHC Apparatus (ATLAS) Detector Upgrade, and the LHC Compact Muon Solenoid (CMS) Detector Upgrade. The internationalization and re-scoping of the Long Baseline Neutrino Experiment to optimize science impact is a major recommendation from P5. HEP will pursue the development of a more capable long baseline experiment by recruiting international partners. To recognize this change, P5 suggested a name change to Long Baseline Neutrino Facility (LBNF), and the name has been adopted here.

<u>Energy Frontier Experimental Physics</u>

The LHC will resume operations in 2015 at collision energies of at least 13 TeV, a substantial increase from 8 TeV in the last run. This will increase the reach of the LHC into the search for new physics, particularly in high-impact topics such as supersymmetry, dark matter candidates, and evidence for extra space-time dimensions. Investments are made for U.S. contributions to future planned LHC detector upgrades that will exploit the full physics potential of the higher luminosities.

<u>Intensity Frontier Experimental Physics</u>

FY 2016 will feature full operations for the NOvA detector in the world's most intense neutrino beam from Fermilab. The physics goals of this experiment include improved measurements of neutrino mixing and first results on the neutrino mass hierarchy and the search for Charge Parity (CP) violation in the neutrino sector. The MicroBooNE detector will be in full operation in the Fermilab Booster Neutrino Beam, with a goal of resolving certain anomalies seen in several previous accelerator based neutrino experiments.

The Mu2e construction project and the Muon g-2 major item of equipment will be in the fabrication phase; physics studies and simulations will continue to optimize the physics output of these experiments. These experiments will probe energy scales beyond the LHC through the study of rare processes and precision measurements. U.S. contributions to the Belle II detector upgrade will be complete in FY 2015. The Belle II detector is located at a particle accelerator facility in Tsukuba, Japan and will study rare decays and CP violation in the heavy quark systems.

Cosmic Frontier Experimental Physics

A coordinated program of dark energy science will continue in FY 2016: the Dark Energy Survey enters its fourth year of operations; next generation imaging and spectroscopic experiments enter fabrication, specifically the Large Synoptic Survey Telescope's digital camera, the LSSTcam; and the Dark Energy Spectroscopic Instrument (DESI) project will be baselined. Three second generation experiments were selected in 2014 to directly detect dark matter, including the small-scale Axion Dark Matter Search Generation 2 (ADMX-G2), which completes its development phase in FY 2016. The LZ and SuperCDMS-SNOLab projects were selected and are expected to be baselined in FY 2016. Community planning for a large-scale Cosmic Microwave Background (CMB) experiment, which will be used to study the nature of Inflation in the early universe, will continue in FY 2016, along with a suite of operating experiments and R&D efforts addressing priority science areas identified in the P5 report.

Theoretical and Computational Physics

The current high priority thrusts of the Theoretical Physics subprogram are to understand the LHC data and develop new search strategies that can be used at the LHC in the future; to develop new models of dark matter; and to suggest new experimental probes that can reveal physics beyond the Standard Model. The computational physics effort supports research on computation, simulation, data tools, and software that cut across all HEP programs. It provides partnership opportunities with other Office of Science programs as well as other agencies.

Advanced Technology R&D

In the past five years, HEP built two accelerator R&D test facilities (BELLA, Berkeley Lab Laser Accelerator, at LBNL; and FACET, Facility for Advanced Accelerator Experimental Tests, at SLAC) to support research using plasmas to accelerate charged particles much more effectively than conventional electromagnetic cavities. Both are supported for continued operations and research in this budget request. These techniques hold the promise of reducing the size of particle accelerators by approximately 90%, making them considerably less expensive to build. The energy to drive the plasma can come either from lasers or electron beams. Both techniques have successfully accelerated beams while maintaining good beam quality. These discoveries are being followed with research programs in FY 2016 to determine if practical particle accelerators can be built with these techniques, and which possible scientific applications of these new devices are most promising.

The LHC Accelerator Research Program develops powerful focusing magnets made from niobium-tin superconductors that have higher magnetic fields than those currently used in the LHC. Successful development of these new magnets will allow the U.S. to make a unique and critical contribution to the upgrade of the LHC to produce more particle collisions per second, which in turn will provide more data for the researchers. Funding for this effort is increased in FY 2016 to meet the schedule for delivery of prototype magnets. Following HEPAP recommendations and external technical reviews, the Muon Accelerator Program is being ramped down; some key elements with broad applications will be redirected into General Accelerator R&D.

Accelerator Stewardship

The first call for Accelerator Stewardship proposals in 2014 emphasized applications identified by a technical working group in 2012, which were further developed in cross-disciplinary community workshops in 2013. These applications include accelerator technology to enable ion-beam therapy of cancer; and R&D for high-power ultrafast lasers, a supporting technology that has grown steadily in importance to accelerators and science in general. This call also solicited proposals for accelerator R&D with the potential to significantly increase accelerator performance and decrease cost. Applications funded in the initial call for proposals will be ongoing in FY 2016. The pilot program to open DOE national laboratory accelerator test facilities to industry users, scheduled to begin in 2015, is also planned to continue.

The main accelerator test facility that supports this subprogram, the Brookhaven Accelerator Test Facility (ATF), is undergoing relocation and expansion in FY 2016 to accommodate more users.

The FY 2016 funding request provides support for a new research thrust in energy and environmental applications of accelerators and expands the open test facilities effort. The energy and environment topic was also identified by the 2012 technical working group report, and in response to a subsequent broadly-based Request for Information in 2014. Cross-disciplinary community workshops planned for 2015 will identify targeted R&D areas appropriate for a new Stewardship funding opportunity announcement.

<u>Construction</u>

Two construction projects are underway to support Intensity Frontier Physics. The Muon to Electron Conversion Experiment (Mu2e), which will search for violation of charged lepton flavor conservation, completes its design phase and proceeds with construction in FY 2015. The LBNF will continue its design phase in FY 2016. Following recommendations of the P5 report, LBNF design efforts will be optimized to support a reconfigured international Long Baseline Neutrino Facility. International in-kind contributions are actively being sought, and will be incorporated into a revised project as the overall baseline cost and technical scope are developed over the next few years.

High Energy Physics
Funding ($K)

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Energy Frontier Experimental Physics					
Research	94,987	94,987	78,782	78,837	+55
Facility Operations and Experimental Support	57,399	57,399	53,802	56,718	+2,916
Projects	0	0	15,000	19,000	+4,000
Total, Energy Frontier Experimental Physics	**152,386**	**152,386**	**147,584**	**154,555**	**+6,971**
Intensity Frontier Experimental Physics					
Research	56,401	56,401	55,181	55,924	+743
Facility Operations and Experimental Support	157,186	157,186	165,073	157,572	-7,501
Projects	37,400	37,400	43,970	33,700	-10,270
Total, Intensity Frontier Experimental Physics	**250,987**	**250,987**	**264,224**	**247,196**	**-17,028**
Cosmic Frontier Experimental Physics					
Research	52,712	52,712	49,310	50,079	+769
Facility Operations and Experimental Support	13,510	13,510	11,832	10,545	-1,287
Projects	30,705	30,705	45,728	58,701	+12,973
Total, Cosmic Frontier Experimental Physics	**96,927**	**96,927**	**106,870**	**119,325**	**+12,455**
Theoretical and Computational Physics					
Research					
Theory	52,613	52,613	50,224	50,182	-42
Computational HEP	8,462	8,462	8,050	8,135	+85
Total, Research	61,075	61,075	58,274	58,317	+43
Projects	3,200	3,200	1,000	2,000	+1,000
Total, Theoretical and Computational Physics	**64,275**	**64,275**	**59,274**	**60,317**	**+1,043**

[1] Funding reflects the transfer of SBIR/STTR to the Office of Science.

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Advanced Technology R&D					
Research					
HEP General Accelerator R&D	55,617	55,617	45,452	39,924	-5,528
HEP Directed Accelerator R&D	25,463	25,463	22,570	21,500	-1,070
Detector R&D	24,402	24,402	21,914	21,922	+8
Total, Research	105,482	105,482	89,936	83,346	-6,590
Facility Operations and Experimental Support	44,788	44,788	30,318	32,023	+1,705
Total, Advanced Technology R&D	**150,270**	**150,270**	**120,254**	**115,369**	**-4,885**
Accelerator Stewardship					
Research	3,275	3,275	5,900	8,200	+2,300
Facility Operations and Experimental Support	5,800	5,800	4,100	5,800	+1,700
Total, Accelerator Stewardship	**9,075**	**9,075**	**10,000**	**14,000**	**+4,000**
SBIR/STTR	21,601	0	20,794	21,138	+344
Subtotal, High Energy Physics	**745,521**	**723,920**	**729,000**	**731,900**	**+2,900**
Construction					
11-SC-40, Long Baseline Neutrino Facility	16,000	16,000	12,000	16,000	+4,000
11-SC-41, Muon to Electron Conversion Experiment	35,000	35,000	25,000	40,100	+15,100
Total, Construction	**51,000**	**51,000**	**37,000**	**56,100**	**+19,100**
Total, High Energy Physics	**796,521**	**774,920**	**766,000**	**788,000**	**+22,000**

SBIR/STTR:

- FY 2014 Transferred: SBIR: $18,901,000; STTR: $2,700,000
- FY 2015 Projected: SBIR: $18,273,000; STTR: $2,521,000
- FY 2016 Request: SBIR: $18,381,000; STTR: $2,757,000

High Energy Physics
Explanation of Major Changes ($K)

	FY 2016 vs. FY 2015
Energy Frontier Experimental Physics: Increased funding continues LHC detector upgrade fabrication activities, scheduled for completion by 2018. Research efforts are maintained at approximately FY 2015 levels to support continuing analysis and interpretation of LHC data as well as exploratory physics studies. Initial investments are made to support R&D activities for longer-term operations of the LHC detectors at higher luminosities, in accordance with the long-term strategic plan for particle physics recommended by HEPAP.	+6,971
Intensity Frontier Experimental Physics: Reductions are primarily from moving Facility Operations, particularly the continued operation of facilities for testing of, and R&D on, superconducting radiofrequency acceleration (RF) cavities to Advanced Technology Facility Operations, which is more appropriate for an R&D-driven activity. Project R&D efforts funded as LBNF Other Project Cost (OPC) also ramp-down as that project moves into the engineering design phase. Optimal operations of the upgraded NuMI beamline for NOvA continue, as do refurbishment of the oldest portions of the Fermilab accelerator complex, including a modernization of the front-end linac; and support for R&D and fabrication of current and future experiments, including a new short baseline neutrino program at Fermilab, as recommended in the HEPAP strategic plan. Research efforts are slightly increased in order to maintain support for data analysis of current experiments as well as physics studies for next-generation experiments.	-17,028
Cosmic Frontier Experimental Physics: Funding increases are dominated by the ramp-up of the LSSTcam MIE according to its planned profile and proceeding with MIE fabrication phases for recent, next-generation dark energy (DESI) and dark matter (LZ and SuperCDMS-SNOLab) experiments, in accordance with the long-term strategic plan for particle physics recommended by HEPAP. Some operations support of current experiments is redirected to support R&D and fabrication efforts for these new experiments. Research efforts are slightly increased in order to maintain support for data analysis of current experiments as well as physics studies for next-generation experiments.	+12,455
Theoretical and Computational Physics: The Lattice QCD project increases by $1,000,000 according to its profile. Research efforts are slightly increased in order to maintain support for analysis and interpretation of data as well as exploratory physics studies.	+1,043
Advanced Technology R&D: Research activities are reduced to shift towards higher priority R&D activities aligned with the HEPAP strategic plan. In particular, funding for the Muon Accelerator Program is reduced further with the last year of funding in FY 2017.	-4,885
Accelerator Stewardship: Research activities are increased to provide support for new stewardship research topics and expand the open test facilities effort. Increases in Facility Operations will allow completion of the BNL Accelerator Test Facility (ATF) relocation, which will accommodate more users.	+4,000
SBIR/STTR: Funding provided in accordance with the legislatively directed percentage of HEP operating budgets.	+344
Construction: Funding is provided according to the planned profile for construction of the Muon to Electron Conversion Experiment. Funding for engineering and design of the LBNF is requested, in accordance with the P5 recommendation.	+19,100
Total, High Energy Physics	**+22,000**

Basic and Applied R&D Coordination

HEP funded research has frequently resulted in unanticipated technology applications. Although it has been recognized that many of these technology developments have transformative impacts in the areas of national security, medicine, energy and environment, industry, and discovery science (including accelerator science), there has been no systematic way of enhancing technology transfer to these other fields.

HEP developed the Accelerator Stewardship subprogram based on input from accelerator R&D and experts in this field drawn from universities, national laboratories, and industry to help identify specific research areas and infrastructure gaps where HEP investments could have significant impacts beyond the SC research mission. This program is closely coordinated with the SC's Basic Energy Sciences and Nuclear Physics programs and partner agencies to ensure all federal stakeholders have input in crafting funding opportunity announcements, reviewing applications, and evaluating the efficacy and impact of funded activities.

More broadly, HEP coordinates its program with other offices and agencies with related programs and missions. The U.S. LHC program is supported by the HEP and the National Science Foundation's (NSF) Physics Division, and overseen by a Joint Oversight Group (JOG). Dark matter research is also jointly sponsored by these agencies, which are coordinating their planning on next generation experiments. Both HEP and NSF Physics use the High Energy Physics Advisory Panel (HEPAP) as part of their advisory structure. HEP also coordinates with NSF Astronomy on the Dark Energy Survey and the Large Synoptic Survey Telescope, each of which is overseen by a JOG. Both agencies as well as NASA receive advice from the Astronomy and Astrophysics Advisory Committee on areas of joint interest. HEP also coordinates with other offices with the Office of Science to identify common scientific interests and to prevent duplication.

Program Accomplishments

Significant discoveries, substantial sensitivity improvements, and world-record achievements moved the frontiers of particle physics forward in FY 2014.

LHC experiments confirm the Standard Model Higgs boson has been found (Energy Frontier). François Englert and Peter Higgs were awarded the 2013 Nobel Prize in Physics for their contributions to our understanding of the origin of mass, confirmed by the discovery of the Higgs boson in 2012 by the ATLAS and CMS experiments at CERN's Large Hadron Collider. Additional data published during 2013- 2014 made the signal for the Higgs boson indisputable and provided additional measurements of its fundamental properties consistent with the predictions of the Standard Model. U.S. HEP research groups have made leading contributions to both the discovery and the confirmation of the Higgs.

First results from the Large Underground Xenon (LUX) dark matter direct detection experiment set the world's most stringent limits (Cosmic Frontier). With 350 kg of xenon mass, LUX is currently the world's largest operating dual-phase liquid xenon detector. The new limits are based on the initial 110 days of data recorded with the experiment installed 4,850 feet underground at the Sanford Underground Research Facility (SURF). LUX continues to take data in parallel with the development of LUX-ZEPLIN (LZ), a second-generation dark matter direct detection experiment that will use seven tons of active liquid xenon to significantly improve sensitivity.

The *Baryon Oscillation Spectroscopic Survey (BOSS) measured the scale of the universe to an accuracy of one percent (Cosmic Frontier).* Dark energy is believed to be the force driving the accelerating expansion of the universe, but to verify this theory one needs precise measurements of distance scales in the universe at different epochs. The BOSS measurement and future data at this level of precision are the keys to determining the nature of dark energy. The Dark Energy Survey (DES) experiment completed its first full year of a five year survey using imaging observations, which will provide complementary precision measurements to BOSS in understanding the nature of dark energy.

The Berkeley Lab Laser Accelerator (BELLA) set a new world record for laser-driven plasma wakefield acceleration (Advanced Technology R&D). Research in plasma wakefield acceleration aims to create compact and cost-effective acceleration technology for future particle accelerators. BELLA accelerated electrons to 4.25 GeV using a 9 cm plasma channel created by a 390 TW laser pulse. Today's technology would require a 200 meter long accelerator to achieve the same energy.

High Energy Physics
Energy Frontier Experimental Physics

Description

The Energy Frontier Experimental Physics subprogram supports research at the LHC with the goal of determining to what extent the Standard Model correctly describes the natural world. Exploring new physics at the highest energies and new dynamics of already discovered elementary particles are now the foundation for much of the LHC research program.

Research activities at the Energy Frontier in FY 2016 will be focused on the LHC, which will resume operations in FY 2015 after a planned shutdown that began in FY 2013 to bring the collider to the full design energy of at least 13 TeV. Data collected during this period will be used to address at least three of the five primary science drivers identified by the recent P5 strategic plan:

- *Use the Higgs boson as a new tool for discovery*

  In the Standard Model of particle physics, the Higgs boson is responsible for generating the mass for all fundamental particles. In July 2012, CERN announced the discovery of a new particle consistent, within the limited statistical accuracy, with being the Standard Model Higgs boson. Since the discovery, experiments at the LHC have continued to actively measure the particle's properties and results thus far have strongly indicated consistency of the Higgs boson with the Standard Model picture. However, more data are required to precisely measure its properties. Through such studies, scientists will be able to establish the particle's exact character and discover if there are additional effects that are the result of new physics beyond the Standard Model.

- *Explore the unknown, new particles, interactions, and physical principles.*

  Researchers at the LHC hope to find evidence of what lies beyond the Standard Model or significantly constrain postulated modifications to it, such as supersymmetry, mechanisms for black hole production, extra dimensions, and other exotic phenomena. During their second run in FY 2016, the LHC detectors will be equipped to be much more sensitive to potential deviations from the Standard Model that may be exposed by the increase in collision energy from 8 TeV to at least 13 TeV.

- *Identify the new physics of dark matter.*

  If dark matter particles are light enough, they can be produced in LHC collisions and their general properties measured by inference (since they interact only weakly with normal matter). This "indirect" detection of dark matter is complementary to, and a powerful cross-check on, the ultra-sensitive "direct" detection experiments on the Cosmic Frontier where one tries to observe the very faint signal of ambient cosmic dark matter particles colliding with nuclei. Limits on dark matter production set by the LHC experiments already significantly constrain many theoretical models.

The LHC hosts two large multi-purpose particle detectors, CMS and ATLAS, which are partially supported by DOE and the NSF and used by large collaborations of international scientists. U.S. researchers make up approximately 20% of the ATLAS collaboration and approximately 30% of the CMS collaboration and play critical leadership roles in all aspects of each experiment.

The Energy Frontier Experimental Physics subprogram also supports the LHC detector operations program, which covers the maintenance of U.S. supplied detector systems for the ATLAS and CMS detectors at the LHC and the U.S. based computer infrastructure for the analysis of LHC data by U.S. physicists.

<u>Research</u>

University-based Energy Frontier research is carried out by groups at over 65 institutions performing experiments at the LHC. Grant-supported scientists typically constitute about 50–75% of the personnel needed to create, run, and analyze an experiment, usually working in collaboration with other university and laboratory groups. Grant-based research efforts are selected based on external competitive peer review, and funding allocations take into account the quality and scientific priority of the research proposed. Energy Frontier research also supports physicists from five national laboratories. These are typically large groups that also have significant responsibilities for detector operations, maintenance, and upgrades, particularly at the laboratories that host large computing and analysis-support centers as well as maintain unique instrumentation facilities. HEP conducted an external peer review of laboratory research groups in this activity in 2012, and findings from this review are being used to inform the funding decisions in subsequent years. HEP will review this activity again in late FY 2015 and evaluate progress.

Facility Operations and Experimental Support

U.S. LHC Detector Operations funding supports the maintenance of U.S. supplied detector systems for the CMS and ATLAS detectors at the LHC and for the U.S.-based computer infrastructure used by U.S. physicists to analyze LHC data, including Tier 1 computing centers at Fermi National Accelerator Laboratory (Fermilab) and the Brookhaven National Laboratory (BNL). There are 11 LHC Tier 1 computing centers around the world. The Tier 1 centers provide round-the-clock support for the LHC Computing Grid and are responsible for storing a proportional share of raw and reconstructed data, as well as performing large-scale data reprocessing and storing the corresponding output. This program also supports investments in R&D activities aimed at improvements to the LHC detectors so they can operate in the long-term at higher luminosities.

Projects

This activity will support the fabrication of major items of equipment (MIE) for the Energy Frontier subprogram, namely upgrades to the ATLAS and CMS detectors.

CERN plans to upgrade the LHC machine to produce two to three times the instantaneous luminosity currently delivered. This work is planned to be completed in 2018. The objective of the two detector upgrade projects is to enable each experiment to fully exploit the physics opportunities offered by the LHC for exploration of new physics and to make precision measurements of properties of known phenomena.

The ATLAS Detector Upgrade Project was a new MIE start in FY 2015. The project was baselined (CD-2) and approved for a fabrication start (CD-3) in FY 2015. Upgrades are needed to the Muon Subsystem, the Liquid Argon Calorimeter Detector and Trigger and Data Acquisition System to take advantage of the increased luminosity.

The CMS Detector Upgrade Project was a new MIE start in FY 2015. The project was baselined (CD-2) and approved for a fabrication start (CD-3) in FY 2015. Upgrades are needed to the Pixelated Inner Tracking Detector, the Hadron Calorimeter Detector, and Trigger System to take advantage of the increased luminosity.

Energy Frontier Experimental Physics

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Energy Frontier Experimental Physics $147,584,000	**$154,555,000**	**+$6,971,000**
Research ($78,782,000)	**Research ($78,837,000)**	**Research (+$55,000)**
U.S. university and laboratory scientists focus on continuing research activities in conducting high-profile studies, including precision measurements of the recently discovered Higgs boson and search for new physics.	U.S. university and laboratory scientists will begin analyzing the newly acquired data from LHC's second run that begins in early-2015. Research activities will focus on addressing key areas within the five science drivers outlined in the long-range strategic plan for particle physics, which include using the Higgs boson as a new tool for discovery and exploring new particles and their interactions.	Funding for the Energy Frontier research is maintained at a constant level to support U.S. scientists continuing research activities in high-profile analyses topics during LHC's second run.
Facility Operations and Experimental Support ($53,802,000)	**Facility Operations and Experimental Support ($56,718,000)**	**Facility Operations and Experimental Support (+$2,916,000)**
The LHC resumes full operations in mid FY 2015, and activities supported shift to routine maintenance and calibration of the detectors. The computing centers will process the newly acquired data in addition to supporting data analysis and simulation.	Operation of the LHC ATLAS and CMS detectors will be supported during LHC's second run. Major activities include continuing the routine maintenance and calibration of the detectors as well as the processing of newly acquired data. Initial investments will be made to support critical R&D activities for longer-term operations of the LHC detectors at higher luminosities.	FY 2016 will be the first year of full operations after an extended shutdown ends in mid FY 2015 and funding is increased to meet the increased operational expenses.
Projects ($15,000,000)	**Projects ($19,000,000)**	**Projects (+$4,000,000)**
In order to take advantage of the increased LHC luminosity, two new MIEs are initiated. The LHC ATLAS Detector Upgrade provides upgrades to the Muon Subsystem, the Liquid Argon Calorimeter Detector, and Trigger and Data Acquisition System.	The LHC ATLAS and CMS Detector Upgrade projects were baselined in FY 2015 and fabrication activities will continue into FY 2016.	Increased funds are provided to support the ramp up of fabrication activities for the two LHC Detector Upgrades according to funding profiles approved at CD-2.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
The CMS Detector Upgrade provides upgrades to the Pixelated Inner Tracking Detector, the Hadron Calorimeter Detector, and Trigger System.		

Description

The Intensity Frontier Experimental Physics subprogram investigates some of the rarest processes in nature including unusual interactions of fundamental particles or subtle effects requiring large data sets to observe and measure. This subprogram in particular shares some deep intellectual connections with Nuclear Physics. Generally this HEP subprogram focuses on using high-power particle beams or other intense particle sources to make precision measurements of fundamental particle properties. These measurements in turn probe for new phenomena that cannot be directly observed at the Energy Frontier, either because they occur at much higher energies and their effects can only be seen indirectly; or because they are due to interactions that are too weak to be detected in a high-background environment such as the LHC.

Activities at the Intensity Frontier will be focused primarily on operating new and existing facilities while continuing investments that maintain a world-leading program into the future. These facilities and investments are concentrated primarily in the areas of neutrino and muon physics at Fermilab. The NOvA neutrino detector was completed in FY 2014 and will have a full run in FY 2015 with the upgraded NuMI beam, the world's most powerful neutrino beam. Operation of the Daya Bay Reactor Neutrino Experiment in China will continue in FY 2016. Fabrication funding also continues for the Muon g-2 Experiment. Data collected during this period will be used to address at least three of the five key science drivers identified by the recent P5 report:

- *Pursue the physics associated with neutrino mass.*

  Of all known particles, neutrinos are perhaps the most enigmatic and certainly the most elusive. The three known varieties of neutrinos were all discovered by HEP researchers working at U.S. facilities. HEP supports research into fundamental neutrino properties that may reveal important clues about the unification of forces and the very early history of the universe.

- *Identify the new physics of dark matter.*

  The lack of experimental evidence from current generation dark matter detectors has led some to propose theoretical models with new "dark" particles and forces that have ultra-weak couplings to normal matter. These particles and forces are effectively invisible to conventional experiments, but could be connected to the cosmic dark matter. Using intense accelerator beams at U.S. national laboratories outfitted with highly capable high rate detectors allows for probes of these models via subtle quantum mechanical mixing effects. These experiments complement the searches for dark matter performed in Cosmic Frontier and Energy Frontier experiments.

- *Explore the unknown, new particles, interactions, and physical principles.*

  Prominent in this category are experiments addressing the poorly understood large scale absence of antimatter in the universe and the puzzling three generation family structure of the fundamental constituents of matter[a].

Research

The HEP experimental research activity at the Intensity Frontier consists of groups at over 50 academic institutions and physicists from eight national laboratories, performing experiments at a variety of locations. The laboratory groups typically have a portfolio of significant responsibilities ranging from detector operations and maintenance to computing and data analysis. Research efforts are selected based on a competitive peer-review process in order to maintain activities with the highest scientific merit and potential impact. HEP conducted an external peer review of all laboratory research groups in this subprogram in 2013, and findings from this review will be used to inform the funding decisions in subsequent years. The next laboratory research review is planned for 2016.

Facility Operations and Experimental Support

There are several distinct facility operations and experimental support efforts in the Intensity Frontier subprogram. The largest is the Fermilab Accelerator Complex User Facility. The operation of the accelerator, detectors, and computing are

[a] www.particleadventure.org/three_gen.html

included in this activity. Improvements to the facility are supported via General Plant Project (GPP) and Accelerator Improvement Project (AIP) funding. The major experimental efforts will be the NOvA and MicroBooNE experiments using the NuMI and Booster neutrino beams. Operation support for the LUX and Majorana demonstrator experiments at the Homestake Mine is also provided under this activity.

Projects

This activity supports the fabrication of major items of equipment for the Intensity Frontier subprogram. It also covers preconceptual R&D for proposed new Intensity Frontier efforts and the other project costs (OPC) of line item construction for the Intensity Frontier.

The Muon g-2 project is an MIE to provide equipment needed to adapt an existing muon storage ring from Brookhaven National Laboratory (BNL) to utilize the higher intensity proton beam at Fermilab. The storage ring was successfully moved from BNL to Fermilab in FY 2013. Critical tests of the storage ring's superconducting magnets will be completed in FY 2015. New detectors, a muon production target, and muon beam transport will be fabricated.

Other Project Costs for LBNF are funded to support efforts to develop international partnerships in response to recommendations of P5. A more complete discussion of LBNF can found in the Construction section. Future Project R&D funding is provided for R&D on an upgrade to the front-end of the Fermilab Accelerator complex. The front-end is the oldest part of the complex and needs to be replaced to improve reliability and to provide higher intensity muon and neutrino beams. The current R&D plan is concentrated on superconducting RF technology because of its ability to handle the higher beam power needed for the future Intensity Frontier subprogram.

Intensity Frontier Experimental Physics

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Intensity Frontier Experimental Physics $264,224,000	**$247,196,000**	**-$17,028,000**
Research ($55,181,000)	**Research ($55,924,000)**	**Research (+$743,000)**
Commissioning of the Belle II detector, datataking and physics analysis with the ongoing experiments of NOvA, MicroBooNE, T2K, MINOS+ and MINERvA; research and development for the future experiments of Muon g-2, Mu2e are all supported. Support for research to enhance the development of LBNF in cooperation with international partners is provided.	Commissioning of the Belle II detector will be completed followed by initial data taking. Physics analysis leading to first results from the NOvA and MicroBooNE experiments will occur. The MINOS+ program will finish and pursue final data analyses. LBNF physics studies and optimization will continue under the umbrella of a new, fully internationalized Long Baseline Neutrino Facility. Research activities for the Daya Bay Reactor Neutrino experiment will continue to ramp down. Research and development efforts for the Fermilab Muon g-2 and Mu2e experiments will continue. New research and development activities for a Fermilab Short Baseline Neutrino program will be underway, following the P5 recommendations. Other proposed small-scale efforts may be supported depending on the outcomes of peer review.	Funding for the Intensity Frontier research is maintained to support current and future experimental capabilities. Some research staff previously supported under Research will be redirected to lead the internationalization of LBNF or develop other elements of the Fermilab neutrino program. Support for Daya Bay and BaBar research is ramped down as analyses are completed.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Facility Operations and Experimental Support ($165,073,000)	**Facility Operations and Experimental Support ($157,572,000)**	**Facility Operations and Experimental Support (-$7,501,000)**
The Fermilab Accelerator complex *($141,738,000)* continues to operate to support neutrino physics. In addition there are specific infrastructure and machine enhancements to support the muon and neutrino physics programs. There are two GPP projects in the Muon Campus (MC) complex in FY 2015 (Beamline Enclosure and MC Infrastructure) whose funding is planned at $5,100,000. Another GPP project to support the neutrino program, Short Baseline Neutrino Far Hall is included at $6,287,000. In addition, there are four AIP projects in the Muon Campus in FY 2015 (Cryogenics, Recycler RF, Beam Transport and Delivery Ring) whose aggregate funding is planned at $12,100,000. Operational support ($15,000,000) is provided to the LUX and Majorana demonstrator experiments at the Homestake Mine.	The Fermilab Accelerator complex *($135,100,000)* will continue to operate to support neutrino physics. FY 2016 is an important funding year for two AIPs that provide enhancements for the future operations program: the delivery ring AIP, which will modify the antiproton accumulator to store protons for the muon program, and the Recycler RF AIP, which will upgrade the RF power in the recycler to handle high intensity proton beams for both the muon program and the short baseline neutrino program at Fermilab. Funding for the Short Baseline Neutrino Far Hall GPP Project ($2,302,000) will be completed. Operational Support at Homestake Mine ($15,000,000) will be continued as LUX completes its data-taking and the Majorana demonstrator continues.	The reduction in funding is primarily due to the rampdown of funding for the GPP and AIP projects according to their profiles.
Projects ($43,970,000)	**Projects ($33,700,000)**	**Projects (-$10,270,000)**
FY 2015 is the final year of funding for the Belle II detector upgrade. Funding for the Muon g-2 MIE project provides the critical test of the superconducting magnet and accelerator modifications necessary for the project to begin.	Funding for the Muon g-2 MIE project ($10,200,000) will continue accelerator modifications and fabrication of the beamline and detectors.	Other projects (Muon g-2 and Belle II) follow their planned profiles.
Other Project Costs for LBNF are included.	Funding is provided for Other Project Costs for the LBNF ($4,000,000) to support the development of an international collaboration.	Funding for LBNF OPC is reduced (-$6,000,000) as PED funding in the Construction program is increased to support the LBNF design work.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Preconceptual R&D for a possible upgrade of the front-end of the Fermilab Accelerator Complex is included.	Future project R&D funding ($19,500,000) will support the development of a new superconducting proton linac to replace the more than 40-year-old existing linac. The goal of this development is to significantly increase the beam power of the entire complex and improve its reliability. P5 recommended this improvement to make the Fermilab neutrino and muon programs sustainable through the next decade.	Funding for the development of Fermilab linac replacement with a superconducting RF linac is continued.

High Energy Physics
Cosmic Frontier Experimental Physics

Description

The Cosmic Frontier Experimental Physics subprogram supports the study of high energy physics through measurements of naturally occurring cosmic particles and observations of the universe. The activities in this subprogram use diverse tools and technologies, from ground-based telescopes and space-based experiments to large detectors deep underground, to probe fundamental physics questions and offer new insight about the nature of dark matter, dark energy, inflation in the early universe and other phenomena. In FY 2016, as the operations and analysis of current experiments continues, a varied suite of complementary, staged experiments are planned that will lead to measurements with greater precision. The program includes investments in projects for the future in accordance with the long-term strategic plan in particle physics.

Experiments in this subprogram can be classified into four main categories: direct-detection searches for dark matter; studies of the nature of dark energy; measurements of the Cosmic Microwave Background (CMB) to study the inflationary epoch in the early universe; and measurements of high-energy cosmic and gamma rays to search for indirect signals of dark matter, the presence of primordial antimatter and other fundamental phenomena. Data collected will be used to address at least three of the five key science drivers identified by the recent P5 report:

- *Understand cosmic acceleration: dark energy and inflation*

  Observations of supernovae suggest that, for approximately the last six billion years, the universe has been expanding at an accelerating rate due to a mysterious "dark energy" that appears to overcome gravitational attraction. The Nobel Prize in Physics in 2011 was awarded for the discovery of the acceleration of the expansion of the universe. In addition, theoretical cosmological models have postulated a period of rapid expansion in the universe shortly after the Big Bang, a phenomenon known as "inflation", and some recent experimental results have suggested this epoch can now be observed in CMB data.

- *Identify the new physics of dark matter.*

  A wide variety of astronomical data suggest that there could be large quantities of matter in the universe that the Standard Model does not explain. This dark matter, so-called because it does not emit electromagnetic radiation that we cannotcan notcannot yet detect, played a dominant role in the formation of structures in the Universe. Direct-detection experiments search for cosmic dark matter particles' rare interactions with atomic nuclei, while indirect-detection observatories search for dark matter signatures in the interactions of high-energy cosmic particles. These experiments complement the searches for dark matter performed in Intensity Frontier and Energy Frontier experiments.

- *Explore the unknown: new particles, interactions, and physical principles.*

  High-energy cosmic and gamma rays can probe energy scales well beyond what can be produced with man-made particle accelerators, albeit not in a controlled experimental environment. Searches for new phenomena in high-energy cosmic surveys may yield surprising discoveries about the fundamental nature of the universe.

<u>Research</u>

The Cosmic Frontier experimental research program consists of groups at about 40 academic and research institutions and 8 national laboratories performing experiments at a wide variety of locations. These groups, as part of scientific collaborations, typically have a broad portfolio of significant responsibilities and leadership roles including R&D, experimental design, fabrication, commissioning, operations, and maintenance, as well as scientific simulations, computing, and data analysis on the experiments in the subprogram. Research efforts are selected based on a competitive peer-review process in order to maintain activities with the highest scientific merit and potential impact. HEP conducted an external peer review of all laboratory research groups in this subprogram in 2013, and findings from this review are being used to inform the funding decisions in subsequent years. A follow-on review is being planned for 2016.

Research efforts are supported for operating or recently completed experiments including the suite of first generation dark matter direct detection experiments, and dark energy experiments using imaging and spectroscopic surveys, including the Dark Energy Survey (DES) and Baryon Oscillation Spectroscopic Survey (BOSS). Research activities are also supported for the space-based Alpha Magnetic Spectrometer II (AMS-II) and the Fermi Gamma-ray Space Telescope (FGST); and the High Altitude Water Cherenkov (HAWC) detector array.

Research activities continue to support design, fabrication and science planning for anticipated next generation experiments for direct-detection of dark energy and dark matter (DM-G2), and CMB experiments, including the Large Synoptic Survey Telescope (LSST), the Dark Energy Spectroscopic Instrument (DESI), Axion Dark Matter Search Generation 2 (ADMX-G2), the Large Underground Xenon (LUX) – ZEPLIN experiment (LZ), the Super Cryogenic Dark Matter Search at the Sudbury Neutrino Observatory Laboratory (SuperCDMS-SNOLab), and the South Pole Telescope generation 3 (SPT-3G). Support for R&D and science planning of possible future experiments in the program, such as community planning for a large-scale CMB experiment, is also included.

Facility Operations and Experimental Support

This activity supports the DOE share of personnel, data processing, and other expenses necessary for the successful maintenance, operations, and data production of Cosmic Frontier experiments. These experiments are typically not sited at DOE facilities. Many experiments have large multi-national collaborations and DOE's fraction of the support cost is based on the magnitude of U.S. roles and responsibilities. In addition, there are DOE-only experiments and partnerships with NSF and NASA. HEP conducted a scientific peer review of Cosmic Frontier operations in 2012 and a follow-on review was held in early FY 2015. Findings from this review are being used to monitor the experiments and inform decisions concerning the continuation of specific activities in subsequent years.

Projects

This activity supports design and fabrication of Cosmic Frontier projects, including major items of equipment (MIEs) as well as development of small experiments and R&D for future experiments. The FY 2016 Request supports the continued fabrication of the three billion pixel precision camera for the Large Synoptic Survey Telescope (LSSTcam), which is the DOE contribution to the NSF-led LSST Project. It also supports fabrication for the DM-G2 projects selected in FY 2014, LZ and SuperCDMS-SNOLab; and the design and baselining of the DESI project which will provide complementary Stage IV techniques to LSST for studying dark energy. Support for fabrication of the small-scale ADMX-G2 dark matter experiment is also included.

Cosmic Frontier Experimental Physics

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Cosmic Frontier Experimental Physics $106,870,000	**$119,325,000**	**+$12,455,000**
Research ($49,310,000)	**Research ($50,079,000)**	**Research (+$769,000)**
Research activities continue on the operating experiments including DES, AMS-II, and FGST. Data analysis continues on BOSS, which completed its survey in FY 2014. Research activities continue to support design, fabrication and science planning for planned next generation dark energy, dark matter (DM-G2) direct detection, and CMB experiments.	The FY 2016 request supports research efforts on the currently operating or recently-completed suite of cosmic-ray and high-energy gamma-ray telescope experiments, the suite of DM-G1 experiments, and dark energy experiments including DES and BOSS, which completed operations in FY 2014. Research activities will continue to support design, fabrication and science planning for the next generation of dark energy, dark matter and CMB experiments, as well as R&D and science planning of possible future experiments.	Research efforts are increased as P5-recommended initiatives in dark matter and dark energy are pursued with high priority.
Facility Operations and Experimental Support ($11,832,000)	**Facility Operations and Experimental Support ($10,545,000)**	**Facility Operations and Experimental Support (-$1,287,000)**
Dark matter searches currently underway complete operations in FY 2015, with data processing and analysis expected to continue for another year. Operations are supported for AMS-II, DES, and the FGST.	Operations support will continue for experiments that are in the data-taking phase, including the AMS-II cosmic-ray experiment, the FGST and HAWC gamma-ray experiments, and for imaging and spectroscopic dark energy experiments including the Dark Energy Survey. Final data processing efforts continue while analyses are completed on experiments that have finished their science mission, including DM-G1 experiments, the VERITAS gamma-ray experiment and the Pierre Auger cosmic ray experiment.	Funding for operations decreases as the operations and data processing efforts for experiments completed in recent years begin to ramp down.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Projects ($45,728,000)	**Projects ($58,701,000)**	**Projects (+$12,973,000)**
There are four MIE projects supported with $43,403,000. LSSTcam fabrication activities continue ($35,000,000). Three new MIE projects, LZ, SuperCDMS-SNOLab, and DESI, are started in FY 2015 with $8,403,000 (TEC and OPC funding). Small projects below MIE thresholds and future project R&D are funded at $2,325,000.	Funding is provided for LSSTcam according to its approved baseline funding profile ($40,800,000). The three smaller MIEs to study dark energy or dark matter started in FY 2015 are expected to be baselined in FY 2016: DESI ($5,300,000), LZ ($9,000,000), and SuperCDMS-SNOLab ($2,000,000). Small projects below MIE thresholds are funded at $1,601,000.	Funding increases support the MIE projects.

Description

The Theoretical and Computational Physics subprogram provides the mathematical, phenomenological, and computational framework to understand and extend our knowledge of the dynamics of particles and forces, and the nature of space and time. This research is essential for proper interpretation and understanding of the experimental research activities described in other HEP subprograms.

Major research thrusts focus on the central science drivers for HEP as recently identified by the P5 report, intertwining the physics of the Higgs boson, neutrino mass, and the dark universe along with exploring the unknown. Theory and computation cross cut the science drivers and the energy, intensity, and cosmic experimental frontiers.

This subprogram supports theoretical research ranging from detailed calculations of the predictions of the Standard Model to the formulation and exploration of possible theories of new phenomena such as dark matter and dark energy and the identification of experimental signatures that would validate these new ideas. This subprogram also supports computational approaches to advance understanding of fundamental physical laws describing the elementary constituents of matter and energy, including computational science and simulations for scientific discovery and computing and software tools to enable and advance experimental and theoretical research at the three High Energy Physics frontiers.

Theory

The HEP theory research activity supports groups at over 70 academic and research institutions supported by research grants and 7 national laboratory research groups. Both university and laboratory research groups play important roles in addressing the leading research areas discussed above, with laboratory groups typically more focused on data-driven theoretical investigations and model-building, and university groups typically focused on more formal or mathematical theory. Research efforts are selected based on competitive peer review to maintain the activities with the highest scientific impact and potential. All laboratory research groups are reviewed every three years and the review in this subprogram was held in 2014, and findings from this review are being used to inform the funding decisions in subsequent years.

Computational HEP

Computation is necessary at all stages of a HEP experiment—from planning and constructing accelerators and detectors, to theoretical modeling, to supporting computationally intensive experimental research and large-scale data analysis. In addition, scientific simulation and advanced computing help extend the boundaries of scientific discovery to regions not directly accessible by experiments, observations, or traditional theory. Computational HEP supports partnership projects such as SciDAC with the Advanced Scientific Computing Research program that focus on HEP topics that benefit most strongly from advanced computational techniques. Examples of previous SciDAC projects include accelerator modeling, cosmological simulations, and directed efforts to develop and maintain and HEP specific computational tools.

Projects

The Projects activity currently funds acquisition and operation of dedicated hardware for the Lattice Quantum Chromodynamics (LQCD) computing effort. These techniques can address both nuclear and high energy physics topics, and to avoid any duplication of effort, this program is managed in partnership with the Office of Nuclear Physics (NP). The LQCD Project provides dedicated computer hardware for the simulation of the strong interaction of gluons and quarks in bound states. Within the HEP program, its goals are most directly applicable to the Intensity and Energy Frontiers, and the results generated by its users are critical for the interpretation of data from the HEP experimental program in these Frontiers.

Based on strong peer reviews and programmatic endorsement from HEPAP in 2014, the LQCD project will be extended in FY 2015 for a five-year period. Coordination with NP on LQCD ensures that the research results are productively used by both communities and ensure efforts are not duplicated.

Theoretical and Computational Physics

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Theoretical and Computational Physics $59,274,000	**$60,317,000**	**+$1,043,000**
Theory ($50,224,000)	**Theory ($50,182,000)**	**Theory (-$42,000)**
This activity funds research for university and laboratory groups as well as the Particle Data Group. Research proposals in the general topic areas described above are selected based on peer review by technical experts.	This activity will fund research for university and laboratory groups as well as the Particle Data Group. Research proposals in the general topic areas described above will be selected based on peer review by technical experts.	Funding is slightly reduced for HEP research activities.
Computational HEP ($8,050,000)	**Computational HEP ($8,135,000)**	**Computational HEP (+$85,000)**
HEP is currently planning a new SciDAC solicitation for FY 2015 in partnership with ASCR.	SciDAC projects selected in FY 2015 will be continued in FY 2016. Other ongoing projects and directed funding will continue at approximately the same funding level.	Funding is held nearly constant.
Projects ($1,000,000)	**Projects ($2,000,000)**	**Projects (+$1,000,000)**
Funds are supplied to continue operation of the existing LQCD hardware, while planning for the acquisition of new hardware is carried out.	FY 2016 funding plan includes acquisition of new hardware as well as continued operations of the LQCD.	Funding is provided according to the planned profile.

Description

The Advanced Technology R&D subprogram fosters cutting-edge research in the physics of particle beams, accelerator research and development (R&D), and particle detection—all of which are necessary for continued progress in high energy physics. New developments are stimulated and supported through peer reviewed research. This subprogram supports and advances research at all three experimental Frontiers.

Advanced Technology R&D includes particle accelerator, detector, and beam physics areas. Long-term multi-purpose accelerator research, applicable to fields beyond HEP, is carried out under the Accelerator Stewardship subprogram.

HEP General Accelerator R&D

HEP General Accelerator R&D focuses on understanding the science underlying the technologies used in particle accelerators and storage rings, as well as the fundamental physics of charged particle beams. Long-term research goals include developing technologies to enable breakthroughs in particle accelerator size, cost, beam intensity, and control.

This activity supports research at 8 DOE national laboratories and about 30 academic or other research institutions. Funding is awarded based on external competitive peer reviews. The program also trains new accelerator physicists with approximately 50 graduate students supported per year through research grants. Graduate level training for students and laboratory staff in areas of accelerator physics and technology is supported in this program.

HEP Directed Accelerator R&D

HEP Directed Accelerator R&D supports innovative technologies for possible future HEP accelerator projects, with proof-of-principle demonstrations, prototype component development, and advancing technical readiness. This includes R&D and prototyping to bring new concepts to a stage of engineering readiness where they can be incorporated into existing facilities or be applied to the design of new facilities. Research efforts within this activity are generally limited in time and have concrete milestones. The current components of the HEP Directed Accelerator R&D activity are the LHC Accelerator Research Program (LARP) and the Muon Accelerator Program (MAP).

LARP is carrying out R&D needed for possible U.S. deliverables to the High Luminosity LHC (HL-LHC) that CERN is planning to begin building late in this decade. LARP is investigating how to build niobium-tin superconducting magnets to decrease the size of the beam, “crab” cavities that causes the beam to meet head on rather than at an angle, and feedback systems to keep the intense beams in a compact configuration. The MAP program was created to carry out R&D on the feasibility of creating and accelerating muon beams for either the production of neutrinos or a very high energy lepton collider. Following the HEPAP strategic plan recommendations, these applications are now seen as less scientifically compelling. The Muon Accelerator Program is being ramped down, and some key elements with broad applications will be redirected into General Accelerator R&D.

Detector R&D

Detector R&D addresses the need for continuing development of the next generation instrumentation and detectors at the Energy, Intensity, and Cosmic Frontiers. New instrumentation and detectors must be developed with increased capabilities while keeping the cost and schedule from conception to operation at a minimum. To meet these challenges, HEP actively supports investments in innovative, generic instrumentation and detector research with the potential for wide applicability and/or high payoff. This activity supports research at 5 DOE national laboratories and about 20 academic or other research institutions.

Facility Operations and Experimental Support

Facility Operations and Experimental Support provides operations funding for proposal-driven user facilities like the Facility for Advanced Accelerator Experimental Tests (FACET) at SLAC, as well as laboratory experimental and test facilities, including the Berkeley Lab Laser Accelerator (BELLA) facility at LBNL. HEP supports the maintenance and operation of fabrication and test facilities for superconducting magnets and superconducting RF. These facilities are centralized at Fermilab due to the cost to build and operate them. The current priorities for these facilities are the programs to develop higher field magnets for the LHC (LARP), the LCLS-II cryomodule production and testing, and the R&D on a future upgrade of the Fermilab accelerator frontend. BELLA, FACET, and the superconducting magnet facility and SRF infrastructure at Fermilab are all in operation.

Advanced Technology R&D

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Advanced Technology R&D $120,254,000	**$115,369,000**	**-$4,885,000**
HEP General Accelerator R&D ($45,452,000)	**HEP General Accelerator R&D ($39,924,000)**	**HEP General Accelerator R&D (-$5,528,000)**
The general portfolio of topics described above continue to be supported, but there is a shift in emphasis as some of the accelerator personnel with expertise in superconducting magnets, beam simulations, and beam physics are being redirected to support HEP Directed Accelerator R&D.	The general portfolio of topics described above will continue to be supported, but the emphasis on each will be adjusted based on the detailed recommendation from the HEPAP Accelerator R&D Subpanel (planned to report in March 2015) to optimize alignment with the HEPAP strategic plan.	Research activities are reduced and shifted towards higher priority R&D activities as recommended in the HEPAP strategic plan.
HEP Directed Accelerator R&D ($22,570,000)	**HEP Directed Accelerator R&D ($21,500,000)**	**HEP Directed Accelerator R&D (-$1,070,000)**
LARP develops a prototype superconducting quadrupole magnet with the large apertures needed to increase luminosity at the LHC. MAP commissions the Muon Ionization Cooling Experiment (MICE) that will demonstrate critical technologies for the collection of muons.	LARP will increase effort to develop a prototype superconducting quadrupole magnets with the large apertures needed to increase luminosity at the LHC. MAP effort will be ramping down as recommended by P5 according to a detailed ramp-down plan which will be developed in FY 2015.	Reductions are due to the ramp down of MAP effort, partially offset by an increase in LARP superconducting magnet effort to meet schedule for delivery of magnet prototypes.
Detector R&D ($21,914,000)	**Detector R&D ($21,922,000)**	**Detector R&D (+$8,000)**
Research activities continue at U.S. universities and national laboratories. HEP programmatic decisions informed by community input and the P5 report have been a factor in setting priorities in detector development at a time of budget constraints, with increased emphasis on R&D support for near-term projects.	Research activities will continue at U.S. universities and national laboratories, with resources continuing to shift towards near-term requirements of the high-priority efforts and towards strengthening the university activities, as recommended in the P5 report.	Support for detector research activities is held constant.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Facility Operations and Experimental Support ($30,318,000)	**Facility Operations and Experimental Support ($32,023,000)**	**Facility Operations and Experimental Support (+$1,705,000)**
Support for activities at FACET, BELLA and SRF Infrastructure continues.	Support for operation of BELLA and SRF Infrastructure will continue. Superconducting magnet fabrication and test facilities support will be provided in this area. FACET will be supported at a reduced level.	The primary changes are that superconducting magnet test facilities are included under this activity which increase funding (+$5,668,000) and FACET running is reduced providing some savings (-$3,963,000).

Description

This subprogram stewards accelerator science & technology through three principal activities: improving access to SC accelerator R&D infrastructure for industrial and other users; near-term translational R&D to adapt accelerator technology for medical, industrial, security, defense, energy and environmental applications; and long-term R&D for the science and technology needed to build future generations of accelerators. HEP manages this program in close consultation with other Office of Science programs, including Nuclear Physics and Basic Energy Sciences, and in consultation with other federal stakeholders of accelerator technology, most notably DOD, NSF, and NIH.

Accelerator Stewardship pursues targeted R&D to develop new uses of accelerator technology with broad applicability. Initial workshops and a request for information in 2014 identified three target application areas with broad impact: accelerator technologies for ion beam therapy of cancer, laser technologies for accelerators, and energy and environmental applications of accelerators. As the program evolves, new cross-cutting areas of research will be identified based on input from the federal stakeholders, R&D performers, and U.S. industry.

HEP and other SC programs will continue to conduct programmatic near- and mid-term R&D on accelerator and beam physics issues related to the scientific facilities they operate. This subprogram will not replace or duplicate those R&D efforts, which are driven by specific science goals and program priorities.

Research

This research supports activities that have been identified for applications in areas broader than just HEP. Research is conducted at national laboratories, universities, and in industry. The stewardship supports both near-term translational R&D and long-term accelerator R&D.

Near-term R&D funding is structured to produce practical prototypes of new applications in five to seven years. The needs for applications chosen for this category have been specifically identified by federal stakeholders and developed further by workshops. Near-term R&D funding opportunities are specifically structured to strengthen academic-industrial collaboration.

Long-term R&D funding is targeted at scientific innovations enabling breakthroughs in particle accelerator size, cost, beam intensity, and control. This activity in FY 2014 supported 10 university grants in broadly applicable areas of advanced accelerator science, beam physics, and related technologies.

Facility Operations and Experimental Support

The Accelerator R&D Stewardship subprogram supports facility operations through two mechanisms: a dedicated Accelerator Stewardship facility (the Brookhaven Accelerator Test Facility (ATF)) and the Accelerator Test Facility Pilot Program, which provides seed funding to engage a broader user community, including industry users, at Office of Science national laboratories.

The Brookhaven ATF is a low-power electron and laser test facility dedicated to accelerator studies. Experiments at ATF study the interactions of high power electromagnetic radiation and high brightness electron beams, including free-electron lasers and laser acceleration of electrons and the development of electron beams with extremely high brightness, photo-injectors, electron beam and radiation diagnostics and computer controls. Beam time at the ATF is awarded based on a merit-based peer review process.

The Accelerator Test Facility Pilot Program will launch in FY 2015, and provide operations support for non-traditional users to access accelerator test infrastructure at seven of DOE's national laboratories (ANL, BNL, Fermilab, LBNL, ORNL, SLAC, and TJNAF). Unlike the SC user facilities, this class of SC assets is frequently unseen and underexploited by the broader community. A public portal[a] has been created, and public events will be held to make the broad community aware of these facilities, encourage proposals to be submitted for limited-scale engagements to use these facilities, and seed-fund the

[a] www.acceleratorsamerica.org

operation of the test facilities for a few test cases. Based on experience from the pilot program, a long-term mechanism for making SC's unique accelerator test facilities more available will be formulated.

Accelerator Stewardship

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Accelerator Stewardship $10,000,000	**$14,000,000**	**+$4,000,000**
Research ($5,900,000)	**Research ($8,200,000)**	**Research (+$2,300,000)**
Continue to support research activities at laboratories and universities. Initiate research support for selected technology areas including laser development for accelerators, ion-beam therapy and green RF sources, which have been identified through Office of Science led workshops. The best research proposals in these areas are selected based on peer review by technical experts.	Will continue to support research activities at laboratories, universities, and in industry. As funds allow, will initiate research support for selected technology areas such as energy & environmental applications of accelerators, as identified by SC workshops.	Additional research funding is requested to initiate support for accelerator R&D for energy and environmental applications.
Facility Operations and Experimental Support ($4,100,000)	**Facility Operations and Experimental Support ($5,800,000)**	**Facility Operations and Experimental Support (+$1,700,000)**
Supports facility operation of the ATF for a broad program of long-term accelerator research. Provides continued support for relocation of the ATF to a larger building. Initiate the Accelerator Test Facility Pilot Program, to enable wider use of SC accelerator test infrastructure.	Will support continued ATF operations, continuation of the Accelerator Test Facility Pilot Program, and the completion of the relocation of the ATF to a larger building.	Additional facility operations funding is requested to complete the ATF relocation to a larger building.

High Energy Physics
SBIR/STTR

Description

SBIR/STTR funding is provided in accordance with the Small Business Innovation Development Act and subsequent related legislation.

Activities and Explanation Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
SBIR/STTR $20,794,000	**$21,138,000**	**+$344,000**
In FY 2015, SBIR/STTR funding is set at 3.3% of non-capital funding.	In FY 2016, SBIR/STTR funding is set at 3.45% of non-capital funding.	The SBIR/STTR amount is adjusted to mandated percentages for non-capital funding.

High Energy Physics
Construction

Description

This subprogram supports all line item construction for the entire HEP program. All Total Equipment Costs are funded in this subprogram, including both engineering and design and construction.

The Muon to Electron Conversion Experiment (Mu2e) will be built at Fermilab and is an important component of the Intensity Frontier subprogram. It will utilize a proton beam to produce muons and determine if those muons can undergo a quantum flavor conversion into electrons. There is no known mechanism for such interactions of charged leptons in the Standard Model, but similar processes have been observed in neutrinos. Evidence of muon to electron flavor change would further probe physics beyond the Standard Model at very high energy scales.

The Mu2e CD-1 was approved on July 11, 2012. Funds appropriated in FY 2013 and 2014 were used to complete the preliminary engineering design and establish the performance baseline. Construction funds in FY 2014 are being used to initiate long-lead procurement of technical materials in order to reduce cost and schedule risk. The project baseline will be approved (CD-2) in FY 2015 and civil construction will be initiated in FY 2015.

The Long Baseline Neutrino Facility (LBNF) will analyze transformations of muon neutrinos in a beam from Fermilab to a large detector in South Dakota, 800 miles away. The experiment will analyze the rare, flavor-changing transformations of neutrinos in flight, from one lepton flavor to another, that are expected to help explain the fundamental physics of neutrinos and the matter-antimatter asymmetry of the universe.

The new national strategic plan for U.S. Particle Physics, developed by P5 and approved by HEPAP in May 2014, recommended “a change in approach for the LBNE Project through reformulation under the auspices of a new international collaboration, as an internationally coordinated and funded program, with Fermilab as host and international participation in defining the program’s scope and capabilities.”[a]

The HEP Program is responding to the recommendation by modifying the preliminary design in order to facilitate international participation, with the goal of achieving enhanced scientific capability through non-DOE contributions to the construction project and the experiment. HEP has begun discussions with foreign funding agencies on successful management models for large science projects. The LHC model where all contributions are provided as in-kind to a host laboratory that has responsibility to coordinate and integrate the contributions has been shown to succeed and will be emulated. All DOE project activities will be managed under DOE Order 413.3B and Office of Science oversight.

DOE is now assessing and evaluating the opportunities to incorporate contributions from international collaborators. The FY 2016 request includes design funding to support modifying the preliminary design in order to facilitate international participation with the goal of achieving enhanced scientific capability through non-DOE contributions. Operating funds for LBNF Other Project Cost (OPC) are requested under the Intensity Frontier subprogram to enable international collaborative activities.

[a] P5 Report, “*Building for Discovery: Strategic Plan for U.S. Particle Physics in the Global Context*,” May 2014. Available at http://science.energy.gov/~/media/hep/hepap/pdf/May%202014/FINAL_P5_Report_Interactive_060214.pdf

Construction

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Construction $37,000,000	**$56,100,000**	**+$19,100,000**
11-SC-40, Long Baseline Neutrino Facility ($12,000,000)	**11-SC-40, Long Baseline Neutrino Facility ($16,000,000)**	**11-SC-40, Long Baseline Neutrino Facility (+$4,000,000)**
Design funds will be used to modify the preliminary design in order to facilitate international participation with the goal of achieving enhanced scientific capability through non-DOE contributions.	Funds are requested to continue the development of an internationally supported project.	Funding is increased in accordance with the P5 recommendation.
11-SC-41, Muon to Electron Conversion Experiment ($25,000,000)	**11-SC-41, Muon to Electron Conversion Experiment ($40,100,000)**	**11-SC-41, Muon to Electron Conversion Experiment (+$15,100,000)**
Funds are for final design work, construction of the detector hall, and fabrication of the accelerator beamline and detector components.	Construction funds are requested to continue civil construction and initiate fabrication of technical components (solenoid magnets and particle detectors).	Funding is increased according to the planned funding profile.

High Energy Physics
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program. The following table shows the targets for FY 2014 through FY 2016.

	2014	2015	2016
Performance Goal (Measure)	**HEP Facility Operations—Average achieved operation time of HEP user facilities as a percentage of total scheduled annual operation time**		
Target	≥ 80%	≥ 80%	≥ 80%
Result	85%	TBD	TBD
Endpoint Target	Many of the research projects that are undertaken at the Office of Science's scientific user facilities take a great deal of time, money, and effort to prepare and regularly have a very short window of opportunity to run. If the facility is not operating as expected the experiment could be ruined or critically setback. In addition, taxpayers have invested millions or even hundreds of millions of dollars in these facilities. The greater the period of reliable operations, the greater the return on the taxpayers' investment.		
Performance Goal (Measure)	**HEP Construction/MIE Cost & Schedule— Cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects**		
Target	< 10%	< 10%	< 10%
Result	4%	TBD	TBD
Endpoint Target	Adhering to the cost and schedule baselines for a complex, large scale, science project is critical to meeting the scientific requirements for the project and for being good stewards of the taxpayers' investment in the project.		
Performance Goal (Measure)	**HEP Neutrino Model—Carry out series of experiments to test the standard 3-neutrino model of mixing**		
Target	Begin operation of full NOvA detector using neutrino beam from Fermilab for purpose of measuring mixing angle between muon neutrinos and electron neutrinos ($\sin^2(2\theta_{13})$) using the appearance of electron neutrinos.	Physics analyses results from the first year of datataking with the full detector will be presented by the NOvA and MicroBooNE experimental collaborations at the FY 2015 summer conferences.	Physics analyses results from datataking will be presented by the NOvA and MicroBooNE experimental collaborations at the FY 2016 summer conferences.
Result	Operation of the detector has been successfully started.	TBD	TBD

	2014	2015	2016
Endpoint Target	Similar to quarks, the mixing between neutrinos is postulated to be described by a unitary matrix. Measuring the independent parameters of this matrix in different ways and with adequate precision will demonstrate whether this model of neutrinos is correct. Such a model is needed to correctly extract evidence for CP violation in the neutrino sector.		

High Energy Physics
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Capital Operating Expenses Summary							
Capital equipment	n/a	n/a	41,152	41,152	74,452	101,797	+27,345
General plant projects (GPP)	n/a	n/a	13,558	13,558	12,463	7,100	-5,363
Accelerator improvement projects (AIP)	n/a	n/a	11,700	11,700	12,750	10,300	-2,450
Total, Capital Operating Expenses	**n/a**	**n/a**	**66,410**	**66,410**	**99,665**	**119,197**	**+19,532**
Capital Equipment							
Major items of equipment							
Energy Frontier Experimental Physics							
LHC ATLAS Detector Upgrades[a]	25,500	0	0	0	7,500	9,500	+2,000
LHC CMS Detector Upgrades[b]	24,967	0	0	0	7,500	9,500	+2,000
Intensity Frontier Experimental Physics							
Belle II[c]	8,870	0	7,900	7,900	970	0	-970
Muon g-2 Experiment[d]	26,400	0	2,000	2,000	8,000	10,200	+2,200
Cosmic Frontier Experimental Physics							
Large Synoptic Survey Telescope Camera (LSSTcam)[e]	150,300	0	19,700	19,700	35,000	40,800	+5,800
Dark Energy Spectroscopic Instrument (DESI)[f]	44,783	0	0	0	250	4,800	+4,550
LUX-ZEPLIN[g] (LZ)	36,250	0	0	0	250	9,000	+8,750
SuperCDMS-SNOLab[h]	11,950	0	0	0	250	2,000	+1,750
Total MIEs	n/a	n/a	29,600	29,600	59,720	85,800	+26,080

[a] Critical Decision CD-2/3 for the LHC ATLAS Detector Upgrade Project was approved on November 12, 2014. The TPC is $33,250,000.
[b] Critical Decision CD-2/3 for the LHC CMS Detector Upgrade Project was approved on November 12, 2014. The TPC is $33,217,000.
[c] Critical Decision CD-2/3 was approved on April 23, 2014. The TPC is $15,000,000.
[d] Critical Decision CD-1 for the Muon g–2 Project was approved on December 19, 2013. The TPC range is $43,000,000 to $50,100,000.
[e] Critical Decision CD-2 for the Large Synoptic Survey Telescope Camera was approved on January 7, 2015. The TPC is $168,000,000.
[f] This project is not yet baselined. This project received CD-0 on September 12, 2012 with a cost range of $25,000,000 to $42,000,000.
[g] This MIE was one of two MIEs selected to meet the Dark Matter Second Generation Mission Need. The project is not yet baselined.
[h] This MIE was one of two MIEs selected to meet the Dark Matter Second Generation Mission Need. The project is not yet baselined.

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Other capital equipment projects under $2 million TEC	n/a	n/a	11,552	11,552	14,732	15,997	+1,265
Total, Capital equipment	**n/a**	**n/a**	**41,152**	**41,152**	**74,452**	**101,797**	**+27,345**
General Plant Projects (GPP)							
MC-1 Building	9,500	8,000	1,000	1,000	500	0	-500
Muon Campus Beamline Enclosure	8,700	400	3,700	3,700	4,600	0	-4,600
Short Baseline Neutrino Far Hall	9,800	0	1,211	1,211	6,287	2,302	-3,985
Other projects under $5 million TEC	n/a	n/a	7,647	7,647	1,076	4,798	+3,722
Total, Plant Project (GPP)	**n/a**	**n/a**	**13,558**	**13,558**	**12,463**	**7,100**	**-5,363**
Accelerator Improvement Projects (AIP)							
Muon Campus Cryogenics	9,700	1,100	5,100	5,100	1,300	800	-500
Recycler RF Upgrades	8,600	400	1,000	1,000	3,800	3,400	-400
Beam Transport	6,700	300	2,400	2,400	3,700	300	-3,400
Delivery Ring	9,500	200	1,700	1,700	3,300	4,300	+1,000
Other projects under $5 million TEC	n/a	n/a	1,500	1,500	650	1,500	+850
Total, Accelerator Improvement Projects	**n/a**	**n/a**	**11,700**	**11,700**	**12,750**	**10,300**	**-2,450**

Major Items of Equipment Descriptions

Energy Frontier Experimental Physics MIEs:

By 2019, CERN plans to increase the LHC luminosity by 100–200% compared to its 2015–2017 running period. The increase will result in higher particle rates and densities as well as a large increase in the number of overlapping collisions, leading to more rapid radiation damage to individual detector subsystems, larger volumes of data, and challenging event conditions. In order to cope with these effects and continue to fully exploit the physics opportunities offered at the LHC, the detectors will need upgrades. DOE supported part of the original construction of two of the four LHC detectors (CMS and ATLAS), and proposes to support the upgrade of those detectors to maintain their capabilities at the higher luminosity LHC. The HEPAP strategic plan identifies the LHC upgrades their highest priority near term projects.

The *ATLAS Detector Upgrade Project* started as a new MIE in FY 2015 and ramp up of fabrication activities for U.S. built detectors systems are planned in FY 2016. The planned U.S. scope includes upgrades to the muon subsystem, the liquid argon calorimeter detector, and the trigger and data acquisition system to take advantage of the increased luminosity. The LHC ATLAS Detector Upgrade Project received CD-2, Approve Performance Baseline, and CD-3, Approve Start of Construction, on November 12, 2014, with a total project cost of $33,250,000 and completion date of FY 2018.

The *CMS Detector Upgrade Project* started as a new MIE in FY 2015 and ramp up of fabrication activities for U.S. built detector systems are planned in FY 2016. The planned U.S. scope includes upgrades to the pixelated Inner tracking detector, the hadron calorimeter detector, and trigger system to take advantage of the increased luminosity. The LHC CMS Detector Upgrade Project received CD-2, Approve Performance Baseline, and CD-3, Approve Start of Construction on November 12, 2014, with a total project cost of $33,217,000 and completion date of FY 2018.

Intensity Frontier Experimental Physics MIEs:

The *Belle II* project will fabricate detector subsystems for the upgraded Belle detector located at the Japanese B-Factory, which is currently being upgraded to deliver much higher luminosity. U.S. groups are making key contributions to the particle identification systems. CD-2/3 was approved in April 2014 with a TPC of $15,000,000 and a project completion date in FY 2016.

The *Muon g-2* project will fabricate an experiment that seeks to improve the measurement of the muon anomalous magnet moment, which is sensitive to new physical interactions such as supersymmetry. The project will repurpose a storage ring from a previous experiment at Brookhaven National Laboratory with upgraded detectors to be located at Fermilab in order to utilize the high intensity proton beam available there to produce the needed muons. CD-1 was approved on December 19, 2013, with a TPC range of $43,000,000 to $50,100,000. Transfer of the BNL storage ring to Fermilab occurred in FY 2013. The Muon g-2 Project plans for CD-2 in FY 2015. New instrumentation for the storage ring will be provided, in part, by in-kind contributions from non-DOE sources including NSF. The Muon g−2 experiment offers a strategic opportunity to search for new physics that may be inaccessible to the LHC. P5 recommended completing muon g-2 as an immediate target of opportunity for searching new physics and identifying future directions for the field.

Cosmic Frontier Experimental Physics MIEs:

The *Large Synoptic Survey Telescope Camera (LSSTcam*) was a new MIE start in FY 2014. It is a digital camera for a next-generation, wide-field, ground-based optical and near-infrared LSST observatory, located in Chile, and is designed to provide deep images of half the sky every few nights. The project is carried out in collaboration with NSF, which leads the project, along with private and foreign contributions. DOE will provide the camera for the facility. CD-3A for long-lead procurement of camera sensors was approved in June 2014. CD-2 for the LSSTcam project was approved on January 7, 2015, with a TPC of $168,000,000 and completion date of FY 2022. P5 reiterated the importance of LSST to the Cosmic Frontier program in its 2014 report.

The *Dark Energy Spectroscopic Instrument (DESI)* project is a new MIE in FY 2015. The project will fabricate an instrument that will measure the effect of dark energy on the expansion of the universe using the baryon acoustic oscillation and other techniques that rely on spectroscopic measurements. DESI will provide measurements complementary to the LSST survey. The instrument will be mounted on the Mayall 4-meter telescope at Kitt Peak National Observatory in Arizona. The DESI survey will obtain optical spectra for tens of millions of galaxies and quasars to construct a 3-dimensional map spanning the nearby universe and to a distance of 10 billion light years. CD-0 was approved September 12, 2012 with an estimated Total Project Cost of $25,000,000–$42,000,000. CD-1 is planned for FY 2015 and CD-2 for FY 2016. P5 recommended building DESI as part of a program of dark energy studies that also includes LSST since the two projects study dark energy using different methods.

The LUX- ZEPLIN (LZ) project is a new MIE in FY 2015. This MIE was one of two MIEs selected to meet the Dark Matter Second Generation Mission Need and the concept for the experiment was developed by a merger of the LUX and ZEPLIN collaborations from the U.S. and the United Kingdom respectively. The project will fabricate a detector using seven tons of liquid xenon inside a Time Projection Chamber (TPC) to search for xenon nuclei that recoil in response to collisions with an impinging flux of dark matter particles known as Weakly Interacting Massive Particles (WIMPs). The detector will be located 4850-foot deep the Sanford Underground Research Facility (SURF) in Lead, South Dakota. CD-1 is planned for FY 2015 and CD-2 for FY 2016. P5 identified the search for dark matter as a science driver and recommended a program of dark matter searches that would maximize the probability of successfully discovering.

The *Super Cryogenic Dark Matter Search at Sudbury Neutrino Observatory Laboratory (SuperCDMS-SNOLab)* project is a new MIE in FY 2015. This MIE was one of two MIEs selected to meet the Dark Matter Second Generation Mission Need. The project will fabricate an instrument that utilizes ultra-clean, cryogenically-cooled silicon (Si) and germanium (Ge) detectors to search for Si or Ge nuclei recoiling in response to collisions with WIMPs. The detector will be located 2 km deep in the SNOLab in Sudbury, Ontario, Canada. SuperCDMS will be optimized to detect low mass WIMPS. This will cover a range of WIMP mass that LZ is not sensitive to. This is in response to the P5 recommendation to develop a comprehensive dark matter search program CD-1 is planned for FY 2015 and CD-2 for FY 2016.

High Energy Physics Construction Project Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
11-SC-40, Long Baseline Neutrino Facility							
TEC	783,393	7,781	16,000	16,000	12,000	16,000	+4,000
OPC	89,539	65,539	10,000	10,000	10,000	4,000	-6,000
TPC	872,932	73,320	26,000	26,000	22,000	20,000	-2,000
11-SC-41, Muon to Electron Conversion Experiment							
TEC	250,000	32,000	35,000	35,000	25,000	40,100	+15,100
OPC	23,677	23,677	0	0	0	0	0
TPC	273,677	55,677	35,000	35,000	25,000	40,100	+15,100
Total, Construction							
TEC	n/a	n/a	51,000	51,000	37,000	56,100	+19,100
OPC	n/a	n/a	10,000	10,000	10,000	4,000	-6,000
TPC	n/a	n/a	61,000	61,000	47,000	60,100	+13,100

Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	382,533	360,932	358,177	355,841	-2,336
Facilities Operations[a]					
Scientific User Facilities Operations	144,121	144,121	150,798	140,197	-10,601
Other Facilities	134,562	134,562	114,327	122,461	+8,134
Total, Facilities Operations	**278,683**	**278,683**	**265,125**	**262,658**	**-2,467**

[a] In previous budget submissions, B-Factory and LHC were included in Scientific User Facility Operations; these activities are now captured under Other Facilities.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Projects					
Major Items of Equipment	54,300	54,300	72,373	86,300	+13,927
Other Projects	20,005	20,005	23,325	23,101	-224
Construction[a]	61,000	61,000	47,000	60,100	+13,100
Total, Projects	**135,305**	**135,305**	**142,698**	**169,501**	**+26,803**
Total, High Energy Physics	**796,521**	**774,920**	**766,000**	**788,000**	**+22,000**

Scientific User Facility Operations ($K)

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

Definitions:

Achieved Operating Hours – The amount of time (in hours) the facility was available for users.

Planned Operating Hours –

- For Past Fiscal Year (PY), the amount of time (in hours) the facility was planned to be available for users.
- For Current Fiscal Year (CY), the amount of time (in hours) the facility is planned to be available for users.
- For the Budget Fiscal Year (BY), based on the proposed budget request the amount of time (in hours) the facility is anticipated to be available for users.

Optimal Hours – The amount of time (in hours) a facility would be available to satisfy the needs of the user community if unconstrained by funding levels.

Percent of Optimal Hours – An indication of utilization effectiveness in the context of available funding; it is not a direct indication of scientific or facility productivity.

- For BY and CY, Planned Operating Hours divided by Optimal Hours expressed as a percentage.
- For PY, Achieved Operating Hours divided by Optimal Hours.

Unscheduled Downtime Hours - The amount of time (in hours) the facility was unavailable to users due to unscheduled events. NOTE: For type "A" facilities, zero Unscheduled Downtime Hours indicates Achieved Operating Hours equals Planned Operating Hours.

[a] Includes Other Project Costs funding for LBNF.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
Fermilab Accelerator Complex	**$135,173**	**$135,173**	**$141,738**	**$135,100**	**-$6,638**
Number of Users	2,097	2,097	2,200	2,310	+110
Achieved operating hours	6,455	6,455	N/A	N/A	N/A
Planned operating hours	5,760	5,760	4,200	4,800	+600
Optimal hours	5,760	5,760	4,200	4,800	+600
Percent optimal hours	112.1%	112.1%	100.0%	100.0%	N/A
Unscheduled downtime hours	N/A	N/A	N/A	N/A	N/A
FACET	**$8,948**	**$8,948**	**$9,060**	**$5,097**	**-$3,963**
Number of Users	150	150	155	52	-103
Achieved operating hours	4,215	4,215	N/A	N/A	N/A
Planned operating hours	3,502	3,502	5,176	1,482	-3,694
Optimal hours	3,502	3,502	5,176	4,448	-728
Percent optimal hours	120.4%	120.4%	100.0%	33.3%	N/A
Unscheduled downtime hours	N/A	N/A	N/A	N/A	N/A
Total Facilities[a]	**$144,121**	**$144,121**	**$150,798**	**$140,197**	**-$10,601**
Number of Users	2,247	2,247	2,355	2,362	+7
Achieved operating hours	10,670	10,670	N/A	N/A	N/A
Planned operating hours	9,262	9,262	9,376	6,282	-3,094
Optimal hours	9,262	9,262	9,376	9,248	-128
Percent of optimal hours[b]	112.6%	112.6%	100.0%	97.6%	N/A
Unscheduled downtime hours	N/A	N/A	N/A	N/A	N/A

[a] In previous budget submissions, B-Factory and LHC were included in Scientific User Facility Operations; these activities are now captured under Other Facilities.

[b] For total facilities only, this is a "funding weighted" calculation FOR ONLY TYPE A facilities: $\frac{\sum_1^n[(\%OH\ for\ facility\ n)\times(funding\ for\ facility\ n\ operations)]}{Total\ funding\ for\ all\ facility\ operations}$

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Estimate	FY 2016 Estimate	FY 2016 vs. FY 2015
Number of permanent Ph.D.'s (FTEs)	950	950	905	905	0
Number of postdoctoral associates (FTEs)	405	405	370	370	0
Number of graduate students (FTEs)	480	480	485	485	0
Other[a]	1,990	1,990	1,880	1,920	+40

[a] Includes technicians, engineers, computer professionals and other support staff.

11-SC-40, Long Baseline Neutrino Facility (LBNF), Fermi National Accelerator Laboratory, Batavia, Illinois
Project is for Design and Construction

1. Significant Changes and Summary

Significant Changes

This Construction Project Data Sheet (CPDS) is an update of the FY 2012 CPDS and does not include a new start for the budget year. No CPDS was submitted for FY 2013, FY 2014, or FY 2015 because no TEC funds were requested; however, design funds were provided in each year's appropriation. The title is changed to Long Baseline Neutrino Facility following recommendation of the Particle Physics Project Prioritization Panel and endorsed by OMB. The scope of the full LBNF project has not changed. The original CPDS submitted for the FY 2011 request covered only the design stage; in order to accurately reflect the full cost and schedule of the project, the scope of the CPDS has been adjusted to capture both design and construction.

Summary

The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-1, which was approved December 10, 2012 with a preliminary cost range of $805,000,000 to $1,110,000,000 and CD-4 of FY 2025. The CD-4 date has been revised to FY 2027 reflecting new outyear funding projections since the CD-1 approval. The current Total Project Cost point estimate is $872,932,000.

A Federal Project Director has been assigned to this project and has approved this CPDS.

The Long Baseline Neutrino Facility (LBNF) will analyze transformations of muon neutrinos in a beam from Fermilab to a large detector in South Dakota, 800 miles away. The experiment will analyze the rare, flavor-changing transformations of neutrinos in flight, from one lepton flavor to another, that are expected to help elucidate the fundamental physics of neutrinos and perhaps explain the puzzling matter-antimatter asymmetry observed in the universe.

LBNF was originally envisioned as a joint DOE-NSF project with NSF providing the Deep Underground Science and Engineering Laboratory (DUSEL) as a site for the LBNF far detector. However, the National Science Board terminated NSF's DUSEL project in December 2010. Due to the broad interest in this physics around the world and the significant cost, the new HEP strategic plan developed by the Particle Physics Project Prioritization Panel and endorsed by the High Energy Physics Advisory Panel recommended that DOE seek international partners to participate while the technical, cost, and schedule baseline is being developed over the next several years. The planned funding for the design phase has been spread over several years so that non-DOE partners can engage in and contribute to the design, construction and operation of the experiment.

The TEC funds requested for FY 2016 will be used for civil and geotechnical engineering design for the detector cavern in South Dakota, for technical design of the neutrino-production beam line and related facilities at Fermilab, for site preparation, and to support modification of the technical design of the experimental facility, infrastructure, and detectors.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2011	1/8/2010		1Q FY 2011	TBD	4Q FY 2013	TBD	TBD	TBD
FY 2012	1/8/2010		2Q FY 2012	TBD	2Q FY 2015	TBD	TBD	TBD
FY 2016	1/8/2010	12/10/2012	12/10/2012	4Q FY 2017[a]	4Q FY 2019	4Q FY 2019[a]	N/A	4Q FY 2027[a]

CD-0 – Approve Mission Need
Conceptual Design Complete – Actual date the conceptual design was completed
CD-1 – Approve Design Scope and Project Cost and Schedule Ranges
CD-2 – Approve Project Performance Baseline
Final Design Complete – Estimated date the project design will complete
CD-3 – Approve Start of Construction
D&D Complete – Completion of D&D work (see section 9)
CD-4 – Approve Start of Operations or Project Closeout
PB – Indicates Performance Baseline

3. Project Cost History

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2011	102,000	TBD	TBD	22,180	TBD	TBD	TBD
FY 2012	133,000	TBD	TBD	42,621	TBD	TBD	TBD
FY 2016[b]	127,781	655,612	783,393	89,539	N/A	89,539	872,932

4. Project Scope and Justification

Scope

The Long Baseline Neutrino Facility (LBNF) will be composed of a neutrino beamline, a large neutrino detector located underground at least 800 miles "downstream" from the neutrino source, and a smaller neutrino detector for monitoring the neutrino beam near its source. A neutrino beam aimed through the earth will begin in a tunnel holding the proton beamline, followed by a target for converting the protons into particles that decay into neutrinos, and a long empty tunnel where the particles decay into neutrinos. The neutrinos will pass through the earth to the far detector. The Neutrinos at the Main Injector (NuMI) beam at Fermilab is an existing example of this type of configuration for a neutrino beam facility. The LBNF new beam line would provide a neutrino beam of lower energy and greater intensity than the NuMI beam, and would point to a far detector at a greater distance than is used with NuMI experiments in order to provide the distance needed for the study of neutrino oscillations.

[a] CD dates beyond CD-1 reflect outyear funding projections revised since CD-1 approval.
[b] The project is Pre-CD-2 and has not been baselined. All estimates are preliminary. The TPC point estimate is $872,932,000. The preliminary TPC range is $805,000,000 to $1,110,000,000.

Justification

The recent progress in neutrino physics has laid the basis for new discovery opportunities. Determining relative masses and mass ordering of the three known neutrinos will give guidance and constraints to theories beyond the Standard Model of particle physics. The study and observation of the different behavior of neutrinos and antineutrinos will offer insight into the dominance of matter over antimatter in our universe and therefore, the very structure of our universe. The only other source of the matter-antimatter asymmetry, in the quark sector, is too small to account for the observed matter dominance.

Among the technical issues addressed in the alternatives analysis were the preferred detector technology and the neutrino beamline design. After a thorough study, both technologies were found to be capable of meeting the performance requirements if located underground, only liquid argon could work on the surface, and is less expensive. A low energy neutrino beam to the Homestake mine and the current NuMI beam were compared. The new beam with its lower energy and longer distance to the detector was shown to be superior.

The project is being conducted in accordance with the project management requirements in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets.

5. Financial Schedule[a]

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Cost (TEC)				
Design Only				
FY 2012	4,000	4,000	0	0[b]
FY 2013	3,781	3,781	0	801
FY 2014	16,000	16,000	0	7,109
FY 2015	12,000	12,000	0	18,000
FY 2016	0	0	0	9,871
Total, Design Only	35,781	35,781	0	35,781
Design (Design and Construction)				
FY 2016	N/A	N/A	0	16,000
FY 2017-FY 2019	TBD	TBD	0	TBD
Total, Design (Design and Construction)	TBD	TBD	0	TBD

[a] Design and international collaboration plans are currently being developed; outyear appropriation levels will be determined at a later date.

[b]$1,078,000 was erroneously costed to this project in FY 2012, the accounting records were adjusted in early FY 2013.

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total, Design[a]	TBD	TBD	0	TBD
Construction				
FY 2020- FY 2027	TBD	TBD	0	TBD
Total, Construction[a]	TBD	TBD	0	TBD
TEC[b]				
FY 2012	4,000	4,000	0	0
FY 2013	3,781	3,781	0	801
FY 2014	16,000	16,000	0	7,109
FY 2015	12,000	12,000	0	18,000
FY 2016	16,000	16,000	0	25,871
FY 2017-FY 2027	TBD	TBD	0	TBD
Total, TEC[a]	TBD	TBD	0	TBD

[a] The project is Pre-CD-2 and has not been baselined. All estimates are preliminary. The TPC point estimate is $872,932,000. The preliminary TPC range is $805,000,000 to $1,110,000,000.
[b] Design and international collaboration plans are currently being developed; outyear appropriation levels will be determined at a later date.

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Other Project Cost (OPC)				
OPC except D&D				
FY 2009 Recovery Act	12,486[a]	12,486	0	0
FY 2010	14,178	14,178	4,696	6,336
FY 2011	7,768	7,750	7,233	11,321
FY 2012	17,000	17,018[b]	557[c]	17,940
FY 2013	14,107	14,107	0	13,022
FY 2014	10,000	10,000	0	11,505
FY 2015	10,000	10,000	0	11,000
FY 2016	4,000	4,000	0	5,929
Total, OPC	89,539	89,539	12,486	77,053
Total Project Cost (TPC)[d]				
FY 2009 Recovery Act	12,486	12,486	0	0
FY 2010	14,178	14,178	4,696	6,336
FY 2011	7,768	7,750	7,233	11,321
FY 2012	21,000	21,018	557	17,940
FY 2013	17,888	17,888	0	13,823
FY 2014	26,000	26,000	0	18,614
FY 2015	22,000	22,000	0	29,000
FY 2016	20,000	20,000	0	31,800
FY 2017-FY 2027	TBD	TBD	0	TBD
Total, TPC[e]	TBD	TBD	12,486	TBD

[a] $13,000,000 of Recovery Act funding was originally planned for the conceptual design; the difference of $512,000 relates to pre-conceptual design activities needed prior to approval of mission need (CD-0).
[b] $18,000 of FY 2011 funding was attributed towards the Other Project Costs activities in FY 2012.
[c] During FY 2012, $1,000 of Recovery Act funding was recategorized from pre-conceptual design and so became part of the OPC. $3,000 was deobligated and expired because Recovery Act funds are no longer available for obligation.
[d] Design and international collaboration plans are currently being developed; outyear appropriation levels will be determined at a later date.
[e] The project is Pre-CD-2 and has not been baselined. All estimates are preliminary. The TPC point estimate is $872,932,000. The preliminary TPC range is $805,000,000 to $1,110,000,000.

6. Details of Project Cost Estimate[a]

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
	(dollars in thousands)		
Total Estimated Cost (TEC)			
Design			
Design	100,000	101,000	N/A
Contingency	27,781	32,000	N/A
Total, Design	127,781	133,000	N/A
Construction[b]			
Site Work	20,000	N/A	N/A
Civil Construction	400,000	N/A	N/A
Technical Equipment[c]	75,000	N/A	N/A
Contingency	160,612	N/A	N/A
Total, Construction	655,612	N/A	N/A
Total, TEC	783,393	133,000	N/A
Contingency, TEC	188,393	32,000	N/A

[a] The project is Pre-CD-2 and has not been baselined. All estimates are preliminary. The TPC point estimate is $872,932,000. The preliminary TPC range is $805,000,000 to $1,110,000,000.
[b] This project is not yet baselined and all construction costs are derived from the middle of the cost range approved with CD-1. The cost reflects the current SC outyear budget plan, post CD-1.
[c] Technical equipment in the DOE scope, estimated here, will be supplemented by in-kind contributions of additional technical equipment, for the accelerator beam and particle detectors, from non-DOE partners as described in Section 1.

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Other Project Cost (OPC)			
OPC except D&D			
R&D	16,000	6,000	N/A
Conceptual Planning	30,000	13,000	N/A
Conceptual Design	34,000	15,000	N/A
Contingency	9,539	8,621	N/A
Total, OPC	89,539	42,621	N/A
Contingency, OPC	9,539	8,621	N/A
Total, TPC	872,932	175,621	N/A
Total, Contingency	197,932	40,621	N/A

7. Schedule of Appropriation Requests[a]

Request Year		Prior Years	FY 2013	FY 2014	FY 2015	FY 2016	Out-years	Total
FY 2011	TEC	47,000	55,000	0	0	0	0	102,000
	OPC	22,180	0	0	0	0	0	22,180
	TPC	69,180	55,000	0	0	0	0	124,180
FY 2012	TEC	17,000	36,000	38,000	42,000	0	0	133,000
	OPC	42,621	0	0	0	0	0	42,621
	TPC	59,621	36,000	38,000	42,000	0	0	175,621
FY 2016[b]	TEC	4,000	3,781	16,000	12,000	16,000	TBD	783,393
	OPC	51,432	14,107	10,000	10,000	4,000	TBD	89,539
	TPC	55,432	17,888	26,000	22,000	20,000	TBD	872,932

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	FY 2026
Expected Useful Life	20 years

[a] Design and international collaboration plans are currently being developed; outyear appropriation levels will be determined at a later date.
[b] The project is Pre-CD-2 and has not been baselined. All estimates are preliminary. The TPC point estimate is $872,932,000. The preliminary TPC range is $805,000,000 to $1,110,000,000.

Expected Future Start of D&D of this capital asset FY 2046

Operations and maintenance of this experiment will become part of the existing Fermilab accelerator facility. Annual related funding estimates include the incremental cost of 20 years of full operation, utilities, maintenance and repairs with the accelerator beam on. The estimates also include operations and maintenance for the remote site of the large detector.

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations	9,000	N/A	180,000	N/A
Utilities	8,000	N/A	160,000	N/A
Maintenance & Repair	1,000	N/A	20,000	N/A
Recapitalization	0	N/A	0	N/A
Total	18,000	N/A	360,000	N/A

9. Required D&D Information

	Square Feet
Area of new construction	142,000 SF
Area of existing facility being replaced and D&D'd by this project	0
Area of other D&D outside the project	0
Area of any additional D&D space to meet the "one-for-one" requirement taken from the banked area.	142,000 SF

The one-for-one replacement has been met through banked space. A waiver from the one-for-one requirement to eliminate excess space at Fermilab to offset the LBNF project was approved by DOE Headquarters on November 12, 2009. The waiver identified and transferred to Fermilab 575,104 square feet of excess space to accommodate the new LBNF facilities and other as yet unbuilt facilities from space that was banked at other DOE facilities.

10. Acquisition Approach

The LBNF apparatus is a unique, geographically distributed, complex system of scientific equipment consisting of a beam source at Fermilab and particle detectors both nearby at Fermilab and at a remote site 800 miles away in South Dakota. The acquisition approach is documented in the Acquisition Strategy approved as part of CD-1. DOE is acquiring design, construction, fabrication and operation of LBNF through the M&O contractor responsible for Fermilab, Fermi Research Alliance (FRA). FRA and Fermilab, through the LBNF Project based at Fermilab, is responsible to DOE to manage and complete construction of the LBNF facility and detector configuration at both the near and remote site locations. The basis for this choice and strategy is that:

- Fermilab is the site of the only existing neutrino beam facility in the U.S and, in addition to these facilities, provides a source of existing staff and expertise to be utilized for beamline and detector construction.
- Fermilab can best ensure the design; construction and installation of key LBNF components are coordinated effectively and efficiently with other research activities at Fermilab.
- Fermilab has a DOE-approved procurement system with established processes and acquisition expertise needed to obtain the necessary components and services to build the scientific hardware, equipment and conventional facilities for the accelerator beamline, and detectors for LBNF.

- Fermilab has extensive experience in managing complex construction, fabrication and installation projects involving multiple National Laboratory, University and other partner institutions, building facilities both on-site and at remote off-site locations.
- Fermilab, through the LBNF Project, has established a close working relationship with the Sanford Underground Research Facility (SURF) and the South Dakota Science and Technology Authority (SDSTA), organizations that manage and operate the remote site for the far detector in Lead, SD; Fermilab will work through SDSTA to award and manage contracts needed to complete the LBNF work at the remote site.

In leading the LBNF Project, Fermilab will collaborate and work with many institutions, including several DOE National Laboratories (BNL, LBNL and LANL), dozens of universities, foreign research institutions, SURF, and the SDSTA. Fermilab will be responsible for overall project management, near site conventional facilities and the beamline. Fermilab is also responsible for the Far Detector (FD) design and construction, with BNL assuming responsibility for acquisition and procurement of select FD subsystems. Fermilab will work through SDSTA/SURF to complete the conventional facilities construction at the remote site needed to house and outfit the FD.

International participation in the design, construction and operation of LBNF will be of essential importance because High Energy Physics is international by nature, necessary talent and expertise are globally distributed, and DOE does not have the procurement or technical resources to self-perform all of the construction and fabrication work needed. Contributions from other nations will be predominantly through the delivery of components built in their own countries by their own researchers. DOE will negotiate agreements in cooperation with the Department of State on a bilateral basis with all contributing nations to specify their expected contributions and the working relationships during the construction and operation of the experiment.

DOE funding for the LBNF Project will be provided directly to Fermilab and collaborating DOE National Laboratories via approved financial plans, and under management control of the LBNF Project Office. The Project Office also manages and controls DOE funding to the other LBNF institutions contributing to detector design and construction. In addition to the work performed by DOE National Laboratories, a combination of university subcontracts and direct fixed-price purchases with vendors is anticipated to design, fabricate and install the LBNF technical components. All actions will be in accordance with the DOE approved procurement policies and procedures.

Much of the neutrino beamline component design, fabrication, assembly and installation will be done by Fermilab staff or by subcontract temporary staff working directly with Fermilab personnel. The acquisition approach includes both new procurements based on existing designs and re-purposed equipment from the Fermilab accelerator complex. Some highly specialized components will be designed and fabricated by or in consultation with long-standing Fermilab collaborators having proven experience with such components.

Delivery of LBNF conventional facilities at Fermilab will be responsibility of the laboratory. Procurement is through existing Fermilab master subcontracts with national architect/engineering companies for design services and contracts will be incrementally phase-funded since they will span multiple years.

Delivery of LBNF conventional facilities at SURF will be responsibility of Fermilab working with SDSTA, the owner of the site and land (which has been donated to SDSTA by the Homestake Mining Company for the sole purpose of facilitating scientific and technological research and development). Fermilab plans to enter into sole-source contracts with the SDSTA to include one for professional design and construction management (CM) preconstruction services, and one for construction of LBNF facilities. During the design phase, the CM will be responsible for independent estimates, design constructability review and reconciliation, developing construction sequencing schedule and acquisition plans, and integration support to project staff to integrate cost, schedule and risk for the major design contracts. The CM contract will be structured with an option to provide staff to augment the SDSTA staff through construction.

The contract for construction of LBNF far-site facilities will involve SDSTA executing multiple construction sub-tier contracts on behalf of LBNF and will also allow SDSTA to self-perform some construction work including items such as electrical distribution to the site. Construction sub-tier contract values would be added to the SDSTA subcontract as those sub-tier contracts are bid and awarded. LBNF and SDSTA would participate in the selection of construction contractors. These selections will include participation from procurement and engineering management in the LBNF Project and Fermilab since LBNF, through Fermilab, will fund these activities and will be ultimately responsible to DOE for their completion.

Prior to the start of far-site conventional facilities construction, it is planned for DOE to enter into a land lease with SDSTA covering the area on which the DOE funded facilities to house and support the LBNF detector will be built. Under the land lease SDSTA will maintain control of the far site facilities until the facilities are turned over to DOE for beneficial occupancy. It is planned that Fermilab will have responsibility for managing and operating the LBNF far detector and facilities for a useful lifetime of 20 year duration, and may contract with SDSTA for day-to-day management and maintenance services. At the end of useful life, federal regulations permit transfer of ownership to SDSTA which is willing to accept ownership as a condition for the lease. An appropriate decommissioning plan will be developed prior to lease signing.

11-SC-41, Muon to Electron Conversion Experiment (Mu2e), Fermi National Accelerator Laboratory, Batavia, Illinois
Project is for Design and Construction

1. Significant Changes and Summary

Significant Changes

This Construction Project Data Sheet (CPDS) is an update of the FY 2015 CPDS and does not include a new start for the budget year. The Independent Project Review held in October 2014 made several recommendations to improve the quality of the baseline and these will be implemented before approving the baseline. Critical Decisions CD-2 and CD-3B are planned for establishing the scope, cost and schedule baseline and for initiating civil construction in 2Q FY 2015. CD-2 date was adjusted by two quarters. CD-3C was established concurrent with completion of final design. CD-4 was extended to 1Q FY 2023 with the application of schedule contingency to mitigate risk.

Development of the preliminary design during FY 2014 refined the baseline scope definition and construction cost estimates by incorporating lessons learned from the NOvA Project at Fermilab relevant to the technical labor effort, risk mitigation and appropriate cost contingency. Consequently the projected Total Project Cost grew from $233,577,000 to $273,677,000, which is well within the Total Project Cost range of $200,000,000–$310,000,000. The funding profile was changed to support this new cost estimate.

The new national strategic plan for U.S. Particle Physics, released by the High Energy Physics Advisory Panel in May 2014, recommends completion of the Mu2e experiment at Fermilab in the near term because it could reveal the presence of new particles with masses up to a million times heavier than that of a proton, well beyond the reach of the Large Hadron Collider (LHC) at CERN.

Summary

The most recent DOE Order 413.3B approved Critical Decision (CD) is CD-3A – Approve Long-Lead Procurement that was approved on 7/10/2014. The preliminary cost range of $200,000,000–$310,000,000 was approved at CD-1 on 7/11/2012. The current CD-4 milestone is 1Q FY 2023.

A Federal Project Director with a certification level 4 has been assigned to this project and has approved this CPDS.

The preliminary design was completed and is being reviewed in preparation for establishing the performance baseline in 2Q FY 2015. Later in FY 2015, civil construction and long-lead procurement for the Transport Solenoid system will start, and the project will initiate the final design and prototyping for technical components. In FY 2016, civil construction activities will continue and fabrication of the solenoid magnets and particle detector systems will be initiated.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2011	11/24/2009		4Q FY 2010	TBD	4Q FY 2012	TBD	TBD	TBD
FY 2012	11/24/2009		4Q FY 2011	TBD	4Q FY 2013	TBD	TBD	TBD
FY 2013	11/24/2009		4Q FY 2012	4Q FY 2013	4Q FY 2014	4Q FY 2014	N/A	4Q FY 2018
FY 2014	11/24/2009		7/11/2012	2Q FY 2014	2Q FY 2015	4Q FY 2015	N/A	2Q FY 2021
FY 2013 Repro-gramming	11/24/2009		7/11/2012	2Q FY 2014	2Q FY 2015	4Q FY 2015	N/A	2Q FY 2021

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2015	11/24/2009		7/11/2012	4Q FY 2014	2Q FY 2015	4Q FY 2014	N/A	2Q FY 2021
FY 2016	11/24/2009	7/11/2012	7/11/2012	2Q FY 2015[a]	3Q FY 2016[a]	3Q FY 2016[a]	N/A	1Q FY 2023[a]

CD-0 – Approve Mission Need
Conceptual Design Complete – Actual date the conceptual design was completed
CD-1 – Approve Design Scope and Project Cost and Schedule Ranges
CD-2 – Approve Project Performance Baseline
Final Design Complete – Estimated/Actual date the project design will be/was complete/d
CD-3 – Approve Start of Construction
D&D Complete – Completion of D&D work (see section 9)
CD-4 – Approve Start of Operations or Project Closeout
PB – Indicates the Performance Baseline

	Performance Baseline Validation	CD-3A	CD-3B	CD-3C
FY 2014		3Q FY 2013		
FY 2013 Reprogram-ming		3Q FY 2013		
FY 2015		3Q FY 2014		
FY 2016	2Q FY 2015	7/10/2014	2Q FY 2015	3Q FY 2016

CD-3A – Approve Long-Lead Procurement of superconducting wire for the magnet systems.
CD-3B – Approve Long-Lead Procurement for superconducting solenoid magnet modules and for construction of the detector hall.
CD-3C – Approve All Construction and Fabrication (CD-3)

3. Project Cost History

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2011	35,000	TBD	TBD	10,000	TBD	TBD	TBD
FY 2012	36,500	TBD	TBD	18,777	TBD	TBD	TBD
FY 2013	44,000	N/A	N/A	24,177	0	24,177	68,177
FY 2014	61,000	162,000	223,000	26,177	0	26,177	249,177
FY 2013 Reprogram-ming	49,000	162,000	211,000	23,677	0	23,677	234,677
FY 2015	47,000	162,900	209,900	23,677	0	23,677	233,577

[a] Schedule estimates are preliminary since this project has not received CD-2 approval.

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2016	57,000	193,000	250,000	23,677	N/A	23,677	273,677[a]

4. Project Scope and Justification

Scope

Project will modify existing and construct new proton beam lines for muon production and muon transport into the experimental detector, construct an experimental hall, fabricate three superconducting solenoid magnet systems (the Production Solenoid, Transport Solenoid and Detector Solenoid), and fabricate detector systems including a tracker, electromagnetic calorimeter, cosmic ray veto, trigger and data acquisition subsystems.

Justification

The conversion of a muon to an electron in the field of a nucleus provides a unique window for discovery of charged lepton flavor symmetry violation and allows access to new physics at very high mass scales. In 2008, the Particle Physics Project Prioritization Panel (P5), a subpanel of HEPAP, recommended this type of experiment for the Intensity Frontier of particle physics. The most recent P5 report repeated this recommendation in their 2014 report. This project provides accelerator beam and experimental apparatus to identify unambiguously neutrinoless muon-to-electron conversion events.

The project is being conducted in accordance with the project management requirements in DOE 413.3B, Program and Project Management for the Acquisition of Capital Assets.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2013	N/A	N/A	14,653
FY 2014	N/A	N/A	15,404
FY 2015	N/A	N/A	18,000
FY 2016	N/A	N/A	8,943
Total, Design	N/A	N/A	57,000
Construction			
FY 2014	N/A	N/A	0
FY 2015	N/A	N/A	20,000
FY 2016	N/A	N/A	30,000
FY 2017	N/A	N/A	40,000
FY 2018	N/A	N/A	40,000
FY 2019	N/A	N/A	32,000
FY 2020	N/A	N/A	25,000

[a] This project has not received CD-2 approval. No construction, other than long-lead procurement, will be performed until the project performance baseline has been validated and CD-3 has been approved.

	(dollars in thousands)		
	Appropriations	Obligations	Costs
FY 2021	N/A	N/A	6,000
Total, Construction	N/A	N/A	193,000
TEC			
FY 2012	24,000	24,000	0
FY 2013	8,000[a]	8,000	14,653
FY 2014	35,000[b]	35,000	15,404
FY 2015	25,000[c]	25,000	38,000
FY 2016	40,100	40,100	38,943
FY 2017	43,500	43,500	40,000
FY 2018	44,400	44,400	40,000
FY 2019	30,000	30,000	32,000
FY 2020	0	0	25,000
FY 2021	0	0	6,000
Total, TEC	250,000	250,000	250,000
Other Project Costs (OPC)			
OPC except D&D			
FY 2010	4,777	4,777	3,769
FY 2011	8,400	8,400	8,940
FY 2012	8,000	8,000	6,740
FY 2013	2,500	2,500	1,020
FY 2014	0	0	2,136
FY 2015	0	0	1,072
Total, OPC	23,677	23,677	23,677
Total Project Cost (TPC)			
FY 2010	4,777	4,777	3,769
FY 2011	8,400	8,400	8,940
FY 2012	32,000	32,000	6,740
FY 2013	10,500	10,500	15,673
FY 2014	35,000	35,000	17,540
FY 2015	25,000	25,000	39,072
FY 2016	40,100	40,100	38,943
FY 2017	43,500	43,500	40,000
FY 2018	44,400	44,400	40,000

[a] Congress approved a reprogramming that reduced the FY 2013 funding to $8,000,000 from the $22,685,000 that was originally appropriated.
[b] $5,162,907 is for long-lead procurements of superconducting wire for the magnet systems.
[c] $25,000,000 is for long-lead procurements for the superconducting solenoid magnet modules and for construction of the detector hall.

(dollars in thousands)

	Appropriations	Obligations	Costs
FY 2019	30,000	30,000	32,000
FY 2020	0	0	25,000
FY 2021	0	0	6,000
Total, TPC	273,677[a]	273,677[a]	273,677[a]

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	55,000	40,000	N/A
Contingency	2,000	7,000	N/A
Total, Design	57,000	47,000	N/A
Construction			
Site Work	2,000	2,000	N/A
Construction	19,000	17,000	N/A
Equipment	119,000	99,000	N/A
Contingency	53,000	44,900	N/A
Total, Construction	193,000	162,900	N/A
Total, TEC	250,000	209,900	N/A
Contingency, TEC	55,000	51,900	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D	6,600	6,600	N/A
Conceptual Planning	4,350	4,350	N/A
Conceptual Design	12,727	12,727	N/A
Contingency	0	0	N/A
Total, OPC	23,677	23,677	N/A
Contingency, OPC	0	0	N/A
Total, TPC	273,677	233,577	N/A
Total, Contingency	55,000	51,900	N/A

[a] This project has not yet received CD-2 approval.

7. Schedule of Appropriation Requests

(dollars in thousands)

Request Year		Prior Years	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	Total
FY 2011	TEC	5,000	30,000	0	0	0	0	0	0	0	35,000
	OPC	10,000	0	0	0	0	0	0	0	0	10,000
	TPC	15,000	30,000	0	0	0	0	0	0	0	45,000
FY 2012	TEC	0	24,000	12,500	0	0	0	0	0	0	36,500
	OPC	12,777	6,000	0	0	0	0	0	0	0	18,777
	TPC	12,777	30,000	12,500	0	0	0	0	0	0	55,277
FY 2013	TEC	0	24,000	20,000	0	0	0	0	0	0	44,000
	OPC	13,177	6,000	5,000	0	0	0	0	0	0	24,177
	TPC	13,177	30,000	25,000	0	0	0	0	0	0	68,177
FY 2014	TEC	0	24,000	24,147	35,000	32,000	44,000	45,000	23,000	0	223,000
	OPC	13,177	8,000	8,049	0	0	0	0	0	0	26,177
	TPC	13,177	32,000	32,196[a]	35,000	32,000	44,000	45,000	23,000	0	249,177
FY 2013 Repro-gram-ming	TEC	0	24,000	8,000	35,000	32,000	44,000	45,000	23,000	0	211,000
	OPC	13,177	8,000	2,500	0	0	0	0	0	0	23,677
	TPC	13,177	32,000	10,500	35,000	32,000	44,000	45,000	23,000	0	234,677
FY 2015	TEC	0	24,000	8,000	35,000	25,000	42,000	43,000	32,900	0	209,900
	OPC	13,177	8,000	2,500	0	0	0	0	0	0	23,677
	TPC	13,177	32,000	10,500	35,000	25,000	42,000	43,000	32,900	0	233,577
FY 2016	TEC	0	24,000	8,000	35,000	25,000	40,100	43,500	44,400	30,000	250,000
	OPC	13,177	8,000	2,500	0	0	0	0	0	0	23,677
	TPC	13,177	32,000	10,500	35,000	25,000	40,100	43,500	44,400	30,000	273,677

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	FY 2023
Expected Useful Life	10 years
Expected Future Start of D&D of this capital asset	FY 2033

Operations and maintenance of this experiment will become part of the existing Fermilab accelerator facility. Annual related funding estimates are for the incremental cost of five years of full operation, utilities, maintenance and repairs with the accelerator beam on. Five subsequent years are planned for further analysis of the data while the detector and beam line are maintained in a minimal maintenance state (with annual cost of approximately 3% of full operations) to preserve availability for future usage with much smaller annual cost.

[a] The FY 2013 amount shown reflected the P.L. 112-175 continuing resolution level annualized to a full year. The TEC, OPC, and TPC total and outyear appropriation assumptions were not been adjusted to reflect the final FY 2013 level; the FY 2013 Request level of $25,000,000 ($20,000,000 TEC and $5,000,000 OPC) were assumed instead.

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations	3,100	3,100	16,000	16,000
Utilities	2,400	2,400	12,400	12,400
Maintenance & Repair	100	100	600	600
Recapitalization	0	0	0	0
Total	5,600	5,600	29,000	29,000

9. Required D&D Information

	Square Feet
Area of new construction	Approximately 25,000
Area of existing facility being replaced and D&D'd by this project	0
Area of other D&D outside the project..	0
Area of any additional D&D space to meet the "one-for-one" requirement taken from the banked area.	Approximately 25,000

The one-for-one replacement has been met through banked space. A waiver from the one-for-one requirement to eliminate excess space at Fermilab to offset the Mu2e project was approved by DOE Headquarters on November 12, 2009. The waiver identified and transferred to Fermilab 575,104 square feet of excess space to accommodate the new Mu2e facilities and other as yet unbuilt facilities from space that was banked at other DOE facilities.

10. Acquisition Approach

The acquisition approach is fully documented in the Acquisition Strategy approved as part of CD-1. This is a high-level summary of material from that document.

DOE has awarded the prime contract for the Mu2e project to the Fermi Research Alliance (FRA), the Fermilab Management and Operating (M&O) contractor, rather than have the DOE compete a contract for fabrication to a third party. FRA has a strong relationship with the high energy physics community and its leadership, including many Fermilab scientists and engineers. This arrangement will facilitate close cooperation and coordination between the Mu2e scientific collaboration and an experienced team of project leaders managed by FRA. FRA will have primary responsibility for oversight of all subcontracts required to execute the project. These subcontracts are expected to include the purchase of components from third party vendors as well as subcontracts with university groups to fabricate detector subsystems.

The largest procurements will be the magnet systems and the civil construction. The superconducting solenoid magnets are divided into three systems that could be procured independently but which must ultimately perform as a single integrated magnetic system. Two of the systems are similar to systems that have been successfully built in private industry, so the engineering design and fabrication for two of the solenoids may be subcontracted to third party vendors, if a planned study of industrial vendor capabilities confirms that the technical risks are acceptable. The third solenoid is relatively unique, and no good industrial analog exists. This solenoid will be designed and fabricated at Fermilab, though most of the parts will be procured from third party vendors.

There will be two major subcontracts for the civil construction for Mu2e. An architecture and engineering (A&E) contract will be placed on a firm-fixed-price basis for Preliminary (Title I) Design, and Final (Title II) Design with an option for construction (Title III) support. The general construction subcontract will be placed on a firm-fixed-price basis. It is expected that the design specifications will be sufficiently detailed to allow prospective constructors to formulate firm-fixed-price offers without excessive contingency and allowances.

All subcontracts will be competitively bid and awarded based on best value to the government. Chicago Office provides contract oversight for FRA's plans and performance. Project performance metrics for FRA are included in the M&O contractor's annual performance evaluation and measurement plan.

Nuclear Physics

Overview

One of the enduring mysteries of the universe is the nature of matter—what are its basic constituents and how do they interact to form the properties we observe? The largest contribution by far to the mass of the matter we are familiar with comes from protons and heavier nuclei. The mission of the Nuclear Physics (NP) program is to discover, explore, and understand all forms of nuclear matter. Although the fundamental particles that compose nuclear matter—quarks and gluons—are themselves relatively well understood, exactly how they interact and combine to form the different types of matter observed in the universe today and during its evolution remains largely unknown. Nuclear physicists seek to understand not just the familiar forms of matter we see around us, but also exotic forms such as those which existed in the first moments after the Big Bang and that exist today inside neutron stars, and to understand why matter takes on the specific forms now observed in nature.

Nuclear physics addresses three broad, yet tightly interrelated, scientific thrusts: Quantum Chromodynamics (QCD), Nuclei and Nuclear Astrophysics, and Fundamental Symmetries that can be probed by studying neutrons and nuclei. QCD seeks to develop a complete understanding of how the fundamental particles that compose nuclear matter, the quarks and gluons, assemble themselves into composite nuclear particles such as protons and neutrons, how nuclear forces arise between these composite particles that lead to nuclei, and what forms of bulk, strongly interacting matter can exist in nature, such as the quark-gluon plasma. Nuclei and Nuclear Astrophysics seeks to understand how protons and neutrons combine to form atomic nuclei, including some now being observed for the first time, and how these nuclei have arisen during the 13.8 billion years since the birth of the cosmos. Fundamental Symmetries seeks to develop a better understanding of fundamental interactions by studying the properties of neutrons and by targeted, single focus experiments using nuclei to study whether the neutrino is its own anti-particle. Neutrinos are very light, nearly undetectable fundamental particles produced during interactions involving the weak force, through which they were first indirectly observed in nuclear beta decay experiments.

The quest to understand the properties of different forms of nuclear matter requires both theoretical and experimental efforts. Theoretical approaches are based on a description of the interactions of quarks and gluons described by the theory of QCD. This theory is studied by scientists using today's most advanced computers. Other theoretical research that models the forces between nucleons seeks to understand and predict the structure of nuclear matter. In experimental research, scientists accumulate experimental data about the behavior of quarks and gluons as well as their composite protons, neutrons, and nuclei in a variety of settings. Most experiments today in nuclear physics use large particle accelerators that collide bits of matter together at nearly the speed of light, producing short-lived forms of matter for investigation. Comparing experimental observations and theoretical predictions tests the limits of our understanding of nuclear matter and suggests new directions for both experimental and theoretical research.

At the heart of the NP program are groups of highly trained scientists who conceive, plan, execute, and interpret transformative experiments. NP supports university and national laboratory scientists and a variety of international collaborations. It provides more than 90 percent of the nuclear science research funding in the U.S. with an average of 85 Ph.D. degrees granted annually to students for research supported by the program. NP research is guided by DOE's mission and priorities, and helps develop the core expertise needed to achieve the goals of the NP program. National laboratory scientists work and collaborate with academic scientists and other national laboratory experimental and theoretical researchers to collect and analyze data and to construct, support, and maintain the detectors and facilities used in experiments. The national laboratories also provide state-of-the-art resources for targeted detector and accelerator R&D for future upgrades and new facilities. This research develops knowledge, technologies, and scientists to design and build next-generation NP accelerator facilities. It is also of relevance to such machines being developed by other domestic and international programs.

The world-class user facilities and their associated instrumentation necessary to advance the U.S. nuclear science program supported by NP are large and complex, and account for a significant portion of NP's budget. Three scientific user facilities are currently supported, each with unique capabilities: the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL); the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF); and the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL). These facilities provide particle beams for an international user community of more than 2,800 research scientists. Approximately 37 percent of these researchers are from institutions outside of the U.S. and provide very significant benefits to leverage the U.S. program through contributed capital, human capital, experimental equipment, and intellectual contributions. Researchers supported by other SC programs (High Energy Physics, Basic Energy Sciences), DOE Offices (National Nuclear Security Administration [NNSA] and Nuclear Energy), Federal agencies (National Science Foundation [NSF], National Aeronautics and Space Administration [NASA], and Department of Defense), and industries also use NP scientific user facilities and their core competencies to carry out their research programs. As part of the ongoing 12 GeV CEBAF Upgrade project, a major energy upgrade to the CEBAF accelerator at TJNAF was completed in July 2014, five months ahead of schedule; the experimental equipment portion of the construction project will be completed in 2017. Construction of a world-class nuclear physics scientific user facility with unique capabilities in nuclear structure and astrophysics, the Facility for Rare Isotope Beams (FRIB), is underway at Michigan State University (MSU).

Involving students in the development and construction of NP facilities and advanced instrumentation, along with the development of accelerator technology and computational techniques, helps to develop the highly trained workforce needed in the field of nuclear science. In addition to significant advances in discovery science, these facilities and techniques provide collateral benefits such as the creation of new technologies with broad-based applications in industry and society. While the High Energy Physics program supports long-term and generic accelerator R&D that is applicable to a variety of basic and applied missions, NP supports short- or mid-term accelerator R&D that is specific to the programmatic needs of its current or planned facilities. In the process, technological advances and core competencies in accelerator science developed by NP are also often relevant to other applications and SC programs. For example, superconducting radio frequency (SRF) particle acceleration developed for NP programmatic missions has provided technological advances for a broad range of applications including materials research, cancer therapy, food safety, bio-threat mitigation, waste treatment, and commercial fabrication. The Office of Science programs coordinate closely on the different types of accelerator R&D activities to exploit synergies.

Highlights of the FY 2016 Budget Request

The FY 2016 request for Nuclear Physics provides increases for research, operations of facilities and construction. Support for university and laboratory research in NP increases across the program to address important challenges identified by the research community, and to restore and enhance support for high priority research areas that have been impacted by constrained resources over the past five years. This research funding request will foster significant advances in nuclear structure, nuclear astrophysics, the study of matter at extreme conditions, hadronic physics, fundamental properties of the neutron, and neutrinoless double beta decay. Operations of the RHIC facility are maintained at the FY 2015 level with increases provided for the critical staff, equipment, and materials that are required for effective and reliable support of operations; research is focused on characterizing the perfect quark-gluon liquid discovered in collisions of relativistic heavy nuclei through research on particle flow and jet energy loss. Operations of the ATLAS facility are optimized, exploiting the new capabilities of the Californium Rare Ion Breeder Upgrade (CARIBU) and completing the campaign with the GRETINA gamma ray spectrometer. Beam development and commissioning activities continue to ramp up at CEBAF as the 12 GeV CEBAF Upgrade project approaches completion and scientific instrumentation is implemented in the experimental halls. Support for the Isotope Development and Production for Research and Applications subprogram maintains mission readiness for the production of radioisotopes that are in short supply for research and a wide array of applications. Research investments in this subprogram increase to develop new cutting-edge approaches for important isotopes that are not currently available to the public in sufficient quantities, such as the establishment of full-scale production capability of the promising alpha-emitter, actinium-225, to enable clinical trials for cancer therapy. Finally, construction continues according to the baselined profile for the FRIB project, which will provide intense beams of rare isotopes for a wide variety of studies in nuclear structure, nuclear astrophysics, and fundamental symmetries.

Nuclear Physics
Funding ($K)

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Medium Energy Nuclear Physics					
Research	35,506	35,506	35,646	38,402	+2,756
Operations	94,494	94,494	97,050	100,170	+3,120
SBIR/STTR and Other	16,963	2,627	18,196	19,490	+1,294
Total, Medium Energy Nuclear Physics	**146,963**	**132,627**	**150,892**	**158,062**	**+7,170**
Heavy Ion Nuclear Physics					
Research	34,283	34,283	33,894	36,431	+2,537
Operations	165,072	165,072	166,072	174,935	+8,863
Total, Heavy Ion Nuclear Physics	**199,355**	**199,355**	**199,966**	**211,366**	**+11,400**
Low Energy Nuclear Physics					
Research	50,017	50,017	48,377	52,125	+3,748
Operations	26,599	26,599	26,819	27,663	+844
Total, Low Energy Nuclear Physics	**76,616**	**76,616**	**75,196**	**79,788**	**+4,592**
Nuclear Theory					
Theory Research	39,269	39,269	35,715	38,583	+2,868
Nuclear Data	7,031	7,031	7,381	7,637	+256
Total, Nuclear Theory	**46,300**	**46,300**	**43,096**	**46,220**	**+3,124**
Isotope Development and Production for Research and Applications					
Research	4,562	4,562	4,815	6,133	+1,318
Operations	14,842	14,842	15,035	15,531	+266
Total, Isotopes	**19,404**	**19,404**	**19,850**	**21,664**	**+1,814**
Subtotal, Nuclear Physics	**488,638**	**474,302**	**489,000**	**517,100**	**+28,100**

[1] Funding reflects the transfer of SBIR/STTR to the Office of Science.

	FY 2014 Enacted	FY 2014 Current[1]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Construction					
06-SC-01, 12 GeV CEBAF Upgrade, TJNAF	25,500	25,500	16,500	7,500	-9,000
14-SC-50, Facility for Rare Isotope Beams	55,000	55,000	90,000	100,000	+10,000
Total, Construction	**80,500**	**80,500**	**106,500**	**107,500**	**+1,000**
Total, Nuclear Physics	**569,138**	**554,802**	**595,500**	**624,600**	**+29,100**

SBIR/STTR:

- FY 2014 transferred: SBIR: $12,544,000 ; STTR: $1,792,000
- FY 2015 projected: SBIR: $13,024,000; STTR: $1,796,000
- FY 2016 Request: SBIR: $14,271,000; STTR: $2,141,000

Nuclear Physics
Explanation of Major Changes ($K)

	FY 2016 vs. FY 2015
Medium Energy Nuclear Physics: Increased funding is provided for commissioning the upgraded CEBAF facility, including incremental power costs of the newly upgraded machine; beam commissioning will establish routine operations and deliver physics quality beam in preparation for the full start of the physics program in FY 2017. The focus is on enhancing the performance and operational reliability of the accelerator and experimental equipment in order to prepare for a high impact 12 GeV experimental program to advance the understanding of strongly interacting matter and its description in QCD, and to search for evidence of new physics beyond the Standard Model. Increased funding is also requested for researchers preparing for the 12 GeV scientific program, including support of the new scientific team devoted to the recently completed new experimental Hall D, and for additional high priority research efforts at national laboratories and universities. Finally, NP program support for the SBIR/STTR programs, which is included within this subprogram, increases.	**+7,170**
Heavy Ion Nuclear Physics: Operations of RHIC are maintained at FY 2015 levels, but with increased funding to adequately support and maintain the operations and experimental staff and to provide the equipment, materials, and supplies required to ensure reliable and efficient machine operations. During prior years, short-term investments in machine maintenance and improvements were postponed in order to maintain 22 weeks of data taking within available resources, a strategy which is only feasible for a short duration before reliability and productivity are impacted. The requested funding restores the highest priority investments needed to ensure robust operations of the RHIC accelerator which continues to enable world-leading research in heavy ion nuclear physics. The FY 2016 request supports a 22 week run which is essential to understand results on heavy quark propagation in the quark-gluon plasma discovered at RHIC and interpret data collected over the past several years. Funding also increases modestly to meet commitments in LHC computing, and to continue research activities on current and future experimental capabilities of the heavy ion LHC ALICE detector. Increased funding is requested to restore the highest priority research efforts at national laboratories and universities.	**+11,400**
Low Energy Nuclear Physics: Operations of the ATLAS facility, the only operating DOE-supported scientific user facility in nuclear structure and astrophysics, continue to be supported at optimal levels. The demands for use of this facility have increased quickly as the scientific community from the Holifield Radioactive Ion Beam Facility (HRIBF), currently being dispositioned, looks towards the ATLAS facility for available beam time and experimental capabilities. Increased funding is requested to restore the highest priority research efforts at national laboratories and universities, including neutrinoless double-beta decay research and neutron science at the Sanford Underground Research Facility (SURF) and the Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source (SNS), respectively. Increased funding is also requested to support continued development and implementation of instrumentation in nuclear structure and astrophysics at ATLAS and FRIB.	**+4,592**
Nuclear Theory: The requested increase restores theory research efforts at laboratories and universities, and supports a second round of 5-year topical theory collaborations that will be recompeted near the end of FY 2015 and funded in FY 2016. The first round of collaborations has been very successful in addressing high-priority topics in nuclear theory that merit a concentrated theoretical effort. Funding also increases to enhance support for the U.S. Nuclear Data Program.	**+3,124**

	FY 2016 vs. FY 2015
Isotope Development and Production for Research and Applications: Funding increases to enhance isotope research efforts at national laboratories and universities and to maintain mission readiness of the isotope production and processing facilities at a constant level of effort at Brookhaven, Oak Ridge, and Los Alamos National Laboratories. R&D efforts will focus on developing full-scale production capabilities of alpha-emitters for medical clinical trials. Increased funding also enables the modest support of base research at university sites that have recently joined the DOE Isotope Program, providing cost-effective production capabilities for research isotopes.	**+1,814**
Construction: FY 2016 construction funding increases for the Facility for Rare Isotope Beams (+$10,000,000) and decreases for the 12 GeV CEBAF Upgrade project (-$9,000,000) according to the approved baseline profiles for both projects.	**+1,000**
Total, Nuclear Physics	**+29,100**

Basic and Applied R&D Coordination

The NP mission supports the pursuit of unique opportunities for R&D integration and coordination with other DOE Program Offices, Federal Agencies and non-Federal entities. For example, researchers from the High Energy Physics (HEP), NP, and Advanced Scientific Computing Research (ASCR) programs coordinate and leverage forefront computing resources and technical expertise through the Lattice Quantum Chromodynamics (LQCD) and SciDAC projects to determine the properties of as-yet unobserved exotic particles predicted by the theory of Quantum Chromodynamics, advance progress towards a model of nuclear structure with predictive capability, and dramatically improve modeling of neutrino interactions during core collapse supernovae. The U.S. Nuclear Data Program provides evaluated cross-section and decay data relevant to reactor design (e.g., of interest to the Nuclear Energy [NE] and Fusion Energy Sciences [FES] programs), materials under extreme conditions (of interest to the Basic Energy Sciences [BES] and FES programs), and nuclear forensics (National Nuclear Security Administration [NNSA], Department of Homeland Security [DHS], and Federal Bureau of Investigations [FBI]). NP research develops technological advances relevant to the development of advanced fuel cycles for next generation nuclear reactors (NE); advanced cost-effective accelerator technology and particle detection techniques for medical diagnostics and treatment (National Institutes of Health [NIH], HEP); and research in developing neutron, gamma, and particle beam sources with applications in cargo screening and nuclear forensics (NNSA, DHS, and FBI).

R&D coordination and integration are hallmarks of the NP Isotope Development and Production for Research and Applications (Isotope) subprogram, which produces commercial and research isotopes in short supply and critical for basic research and applications. It also supports research for the development of new or improved production and separation techniques of stable and radioactive isotopes. NP has taken significant steps in aligning the Federal, industrial, and research stakeholders of the Isotope Program and improving communication between the various communities. To ascertain current and future demands of the research and applied communities, NP organizes working groups, workshops, symposia, and discussions with Federal agencies and community and industrial stakeholders on a continuous basis; and works collaboratively with other DOE Offices (NNSA and NE) to help ensure adequate supplies of isotopes needed for the nuclear power industry as well as for deep space exploration (NASA). The Isotope Program conducts annual Federal workshops to identify isotope demand and supply across a broad range of Federal agencies (including NIH, NASA, FBI, DOD, DHS, DOT, NSF, and DOE) to ensure that isotopes are available for the federal complex to accomplish its missions.

Program Accomplishments

RHIC's luminosity sets new records in FY 2014. Improvements designed to increase luminosity have been underway at RHIC for several years; the higher the luminosity, the higher the probability that rare nuclear events will occur frequently enough to enable new discoveries about the state of matter that existed under the extreme conditions that occurred soon after the Big Bang. In 2014, a technology breakthrough to prevent beam losses from the interaction of densely bunched beam particles, as well as the fully commissioned Electron Beam Ion Source, led to an integrated luminosity for gold on gold (Au-Au) collisions exceeding the sum of all previous Au-Au runs—the average heavy ion luminosity is now 25 times the design value. This record-setting heavy ion luminosity allowed sufficient progress that a third, previously unscheduled beam species (He3), could be run to test the interpretation of new data from RHIC and the LHC that appear to show that particle flow similar to that found in the discovery of the Quark Gluon Plasma may also occur in violent proton-lead, proton-proton and light nucleus-nucleus collisions.

Quantum Chromodynamics (QCD) at finite temperature with physical quark masses. Computational studies of strong interaction physics using lattice QCD have long been limited by the difficulty of carrying out numerical simulations with the correct up and down quark masses, which are very small (about 1 percent) compared with the mass of the proton. The HotQCD Collaboration has now achieved this goal. Using leadership class computational resources, and supported in part by DOE's Scientific Discovery through Advanced Computing (SciDAC) program, this collaboration has reported new theoretical results for the properties of strongly interacting nuclear matter using realistic values for the light quark masses. In these new studies, rapid variations in a thermodynamic quantity were observed near a temperature of approximately 155 MeV. This is considered to be evidence for the long sought QCD critical point in nuclear matter, which is an analog of the critical point in the phase diagram for water where the liquid and gas phases co-exist. These results will help guide experimental efforts to find the QCD critical point, which is an essential "landmark" for gaining detailed knowledge of the equation of state and phase behavior of dense nuclear matter.

Breakthrough gamma ray detection technology enables a key astrophysical observation. X-ray bursts are frequently-observed thermonuclear flashes that originate from the surface of accreting neutron stars with time periods of hours to days. They are powered by a sequence of nuclear reactions involving the rapid capture of protons on short-lived nuclei. Provided that the underlying nuclear physics can be understood, the comparison of burst observations with models offers a unique pathway to constrain the properties of neutron stars, such as their radii. A reaction key to understanding the underlying physics of bursts is the capture of a proton by a short-lived isotope of copper (^{57}Cu), leading to the creation of an isotope of zinc (^{58}Zn). Using the pioneering GRETINA detector constructed at LBNL from segmented Germanium detectors capable of providing both position and energy information, groundbreaking gamma-ray tracking techniques were employed to precisely determine the energies of critical excited states in ^{58}Zn reducing the uncertainty in the rate of this proton capture reaction by several orders of magnitude, and removing it as an unknown from x-ray burst models. The novel capabilities of GRETINA, which were essential for the success of this key measurement, will enable a broad range of measurements to study the synthesis of elements that take place in powerful stellar reactions.

Development of Production of At-211. Biomolecules labeled with the α-particle-emitting radionuclide astatine-211 (At-211) are of interest as potential therapeutic radiopharmaceuticals for the treatment of diffuse cancers. Reliable and regular supply of the short-lived radionuclide (7.2 hour half-life) is required to support development and application of the radiopharmaceuticals. A recent research and development project supported by the NP-managed DOE Isotope Program resulted in protocols to produce and purify At-211 using a cyclotron and radiochemistry facilities at the University of Washington (UW). As part of the project, all of the procedures required for handling and shipping the isotope to researchers were developed and tested. The DOE Isotope Program and the University of Washington are finalizing agreements under which this important isotope could be routinely made at UW and distributed to researchers under the auspices of the Isotope Program.

New science leadership capabilities enabled by construction of world-class facilities: Civil construction of FRIB began at MSU in March, four weeks earlier than initially planned in the project's baseline schedule. When completed, FRIB will provide unprecedented capability for experiments designed to understand the origin and evolution of the visible matter in the universe as well as the fundamental interactions which determine the structure of nuclei. At TJNAF, the ongoing construction of the12 GeV CEBAF Upgrade received Critical Decision (CD)-4A, *Approve Accelerator Project Completion*, in July, five months ahead of its performance baseline. This approval allows commissioning of the accelerator to bring it up to its full operating capabilities, enabling the capability for early physics running before the full physics agenda is initiated in 2017. Data taking paused at CEBAF in FY 2012 for installation of the 12 GeV upgrade, although new scientific results continue to be published from previous data collection, including a recent paper in *Nature* on electron-quark weak coupling which significantly improves understanding of the energy scale beyond which searches for new physics should be carried out[a].

The ATLAS Facility achieves record-breaking performance of newly commissioned accelerating cavities. In March a new cryomodule containing superconducting radio frequency acceleration cavities was successfully commissioned as part of the ATLAS facility. It now operates with the highest accelerating gradient of any superconducting (SC) linac world-wide for particles traveling in the velocity range of about 10 percent of the speed of light. The broader impact of this achievement will be enabling new science at ATLAS in the next decade and dramatically reducing the physical footprint and overall cost for future accelerators for basic science and applications.

[a] *Nature* 506, 67–70 (06 February 2014)

Nuclear Physics
Medium Energy Nuclear Physics

Description

The Medium Energy Nuclear Physics subprogram focuses primarily on experimental tests of the theory of the strong interaction, known as Quantum Chromodynamics (QCD). According to QCD, all observed nuclear particles, collectively known as hadrons, arise from the strong interaction of quarks, antiquarks, and gluons. The protons and neutrons inside nuclei are the best known examples of hadrons. QCD, although difficult to solve computationally, predicts what hadrons exist in nature, and how they interact and decay. Specific questions addressed within this subprogram include:

- What is the internal landscape of the protons and neutrons (collectively known as nucleons)?
- What does QCD predict for the properties of strongly interacting matter?
- What governs the transition of quarks and gluons into pions (hadronic subatomic particle) and nucleons?
- What is the role of gluons and gluon self-interactions in nucleons and nuclei?

Various experimental approaches are used to determine the distribution of up, down, and strange quarks, their antiquarks, and gluons within protons and neutrons, as well as clarifying the role of gluons in confining the quarks and antiquarks within hadrons. Scattering experiments are used to clarify the effects of the quark and gluon spins within nucleons, and the effect of the nuclear environment on the quarks and gluons. The subprogram also supports experimental searches for higher-mass "excited state" and exotic hadrons predicted by QCD, as well as studies of their various production mechanisms and decay properties.

Medium Energy Nuclear Physics supports research and operations of the subprogram's primary research facility, CEBAF at TJNAF, as well as the RHIC spin physics research that is carried out using RHIC at BNL. CEBAF provides high quality beams of polarized electrons that allow scientists to extract information on the quark and gluon structure of protons and neutrons from measurements of how the electrons scatter when they collide with nuclei. CEBAF also uses polarized electrons to make precision measurements to search for processes that violate a fundamental symmetry of nature, called parity, in order to search for physics beyond what is currently described by the Standard Model. These capabilities are unique in the world. The increase in beam energy provided by the 12 GeV CEBAF Upgrade opens up exciting new scientific opportunities, and will secure continued U.S. world leadership in this area of physics. Research at RHIC, which provides colliding beams of spin-polarized protons, a capability unique to RHIC, seeks to understand the origin of the spin of the proton, another important challenge in QCD. Research support for both facilities includes laboratory and university personnel needed to implement and execute experiments and to conduct the data analysis necessary to extract scientific results. Complementary special focus experiments that require different capabilities are also supported at the High Intensity Gamma Source (HIGS) at Triangle Universities Nuclear Laboratory, Europe, and elsewhere. Efforts are supported at the Research and Engineering Center of the Massachusetts Institute of Technology (MIT), which has specialized infrastructure used to develop and fabricate advanced instrumentation and accelerator equipment.

The SBIR/STTR and Other category within this subprogram provides funding in accordance with the Small Business Innovation Development Act and subsequent related legislation. It also includes funding to meet other NP obligations, such as the annual Lawrence Awards and Fermi Awards for honorees selected by DOE for outstanding contributions to science.

<u>Research</u>

Research groups at TJNAF, BNL, ANL, LANL, and LBNL, and approximately 160 scientists and 125 graduate students at 33 universities carry out research programs and conduct experiments at CEBAF, RHIC, and elsewhere, and participate in the development and fabrication of advanced instrumentation, including state-of-the-art detectors that also have applications in areas such as medical imaging instrumentation and homeland security. TJNAF staff research efforts include developing experiments, acquiring data, and performing data analysis at the three existing CEBAF experimental Halls A, B, and C. A fourth scientific research group at TJNAF is implementing instrumentation in the new experimental Hall D of the 12 GeV CEBAF Upgrade project. Scientists conduct research to identify and develop the opportunities and goals for next generation facilities. An active visiting scientist program at TJNAF and bridge positions with regional universities are also supported as a cost-effective approach to augmenting scientific expertise at the laboratory and boosting research experience opportunities.

ANL scientists preparing for the new experimental program at TJNAF are developing and implementing instrumentation and data analysis techniques. They also lead an experiment at Fermilab to determine the antiquark contribution to the structure of the proton. ANL scientists continue precise measurements of the electric dipole moments of laser-trapped atoms that will set limits on QCD parameters and contribute to the search for possible explanations of the excess of matter over antimatter in the universe. Research groups at BNL and LBNL play leading roles in determining the spin structure of the proton through the development and fabrication of advanced instrumentation for RHIC, as well as contributing to data acquisition and analysis efforts. Researchers at MIT and at TJNAF are developing high current, polarized electron sources for next generation NP facilities.

Accelerator R&D research proposals from universities and laboratories specific to improving operations of current NP facilities or developing new NP facilities are evaluated by peer review through a single competition for funding under the Medium Energy and Heavy Ion subprograms.

Operations

CEBAF's polarized electron beam capabilities are used to study the contributions of quarks and gluons to the properties of hadrons by a user community with a strong international component. Accelerator Operations support is provided for the accelerator physicists at TJNAF that operate CEBAF as well as for maintenance, power costs, capital infrastructure investments, and accelerator improvements. Modest investments in high priority accelerator improvement projects are aimed at increasing the productivity, cost-effectiveness, and reliability of the facility. Support is provided for the most important efforts in developing advances in superconducting radiofrequency (SRF) technology relevant to improving operations of the existing machine. The core competency in SRF technology plays a crucial role in many DOE projects and facilities outside of nuclear physics (such as the Basic Energy Sciences project LCLS II) and has broad applications in medicine and homeland security. For example, SRF research and development at TJNAF has led to improved land-mine detection techniques and carbon nanotube and nano-structure manufacturing techniques for constructing super-lightweight composites such as aircraft fuselages. TJNAF also has a core competency in cryogenics and has developed award-winning techniques that have led to more cost-effective operations at TJNAF and several other Office of Science facilities; their cryogenics expertise is now being applied to the FRIB project and LCLS II. Accelerator capital equipment investments are targeted toward instrumentation needed to support the laboratory's core competencies in SRF and cryogenics. TJNAF accelerator physicists help train the next generation of accelerator physicists, enabled in part by a close partnership with other institutions with accelerator physics expertise. Experimental Support is provided for the scientific and technical staff as well as for materials and supplies for integration, assembly, modification, and disassembly of the large and complex CEBAF experiments. Modest capital equipment investments for experimental support at TJNAF provide scientific instrumentation for the major experiments, including data acquisition computing and supporting infrastructure.

Medium Energy Nuclear Physics

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Medium Energy Nuclear Physics $150,892,000	**$158,062,000**	**+$7,170,000**
Research $35,646,000	**Research $38,402,000**	**Research +$2,756,000**
Efforts continue on preparations for the 12 GeV experimental program at TJNAF such as the implementation of instrumentation and development of the Hall D experimental group, as well as continued analysis of 6 GeV experimental data and RHIC polarized proton beam data. Support for short and mid-term accelerator R&D continues. ANL scientists will complete the measurement of antiquark structure of the nucleon and nucleus with the E906 Drell-Yan experiment.	Researchers focused on the 12 GeV experimental program at TJNAF will continue to implement and develop experimental instrumentation and prepare for the new Hall D physics capabilities and the highly anticipated 12 GeV experimental program which starts in FY 2017. Analysis efforts of RHIC polarized proton beam data to learn more about the origin of the proton's spin, and support for short and mid-term accelerator R&D will also continue.	Increased support is requested to restore high priority research focused on the 12 GeV era scientific program and analysis of RHIC polarized proton beam data.
Operations $97,050,000	**Operations $100,170,000**	**Operations +$3,120,000**
FY 2015 funding supports the transition of an additional 45 FTEs from the 12 GeV CEBAF Upgrade construction project back to base operations support. Beam development is focused on the highest priority activities associated with completion of the 12 GeV CEBAF Upgrade project. Funding is provided for Other Project Costs (within project TPC) as planned as part of the 12 GeV CEBAF Upgrade project profile. The major milestone planned for FY 2015, establishing first beams to Hall D for commissioning activities, has already been successfully demonstrated.	FY 2016 funding will support continued machine development, and its associated incremental power costs, to support the full, future 12 GeV research program, including engineering operations to Hall D and commissioning of newly installed hall equipment for physics running starting in FY 2017. Funding is also provided for Other Project Costs (within project TPC), as planned, as part of the 12 GeV CEBAF Upgrade project profile. The major milestone in FY 2016 will be establishing first beams to Halls B and C for commissioning activities.	Increased funding for commissioning the upgraded CEBAF facility is provided for Operations and Experimental Support to support staff, incremental power costs, and experimental equipment for Halls B, C, and D as the 12 GeV CEBAF experimental program is initiated.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
SBIR/STTR and Other $18,196,000	**SBIR/STTR and Other $19,490,000**	**SBIR/STTR and Other +$1,294,000**
Support is provided for NP's contribution to the SBIR/STTR programs, as well as other DOE and Office of Science obligations.	Funding is provided in accordance with the Small Business Innovation Development Act and subsequent related legislation, as well as for other DOE and Office of Science obligations.	The increase reflects the mandated set-aside for SBIR/STTR.

Description

The Heavy Ion Nuclear Physics subprogram focuses on studies of nuclear matter at extremely high densities and temperatures, directed primarily at answering the overarching questions within the Quantum Chromodynamics (QCD) scientific thrust, including:

- What are the phases of strongly interacting matter, and what roles do they play in the cosmos?
- What governs the transition of quarks and gluons into pions and nucleons?
- What determines the key features of QCD and their relation to the nature of gravity and space-time?

At the Relativistic Heavy Ion Collider (RHIC) facility, scientists continue to pioneer the study of condensed quark-gluon matter at the extreme temperatures characteristic of the infant universe. The goal is to explore and understand unique manifestations of QCD in this many-body environment and their influence on the universe's evolution. Complementary research capability is also provided at the Large Hadron Collider (LHC) at CERN. In the aftermath of collisions at RHIC and at the LHC, researchers have seen signs of the same quark-gluon plasma that is believed to have existed shortly after the Big Bang. With careful measurements, scientists are accumulating data that offer insights into the processes early in the creation of the universe, and how protons, neutrons, and other bits of normal matter developed from that plasma. Important avenues of investigation are directed at learning more about the physical characteristics of the quark-gluon plasma including exploring the energy loss mechanism for quarks and gluons traversing the plasma, determining the speed of sound in the plasma and locating the critical point for the transition between the plasma and normal matter.

The RHIC facility places heavy ion research at the frontier of nuclear physics. RHIC serves two large-scale international experiments called PHENIX and STAR. Operation of RHIC in FY 2016 will take advantage of the recently completed accelerator improvement projects, including electron lenses and a new superconducting cavity installed in FY 2014. The new and ongoing detector upgrades coupled with the enhanced collision rate will contribute further scientific results and understanding. The RHIC facility is uniquely flexible, providing a full range of colliding nuclei at variable energies spanning the transition to the quark-gluon plasma discovered at RHIC. Short and mid-term accelerator R&D is conducted at RHIC in a number of areas including the cooling of high-energy hadron beams based on a new concept called Coherent Electron Cooling; high intensity polarized electron sources; and high-energy, high-current energy recovery linear (ERL) accelerators. The RHIC facility is used by about 1,200 DOE, NSF, and foreign agency-supported researchers annually.

Collaboration in the heavy ion program at the LHC at CERN provides U.S. researchers the opportunity to investigate states of matter under substantially different initial conditions than those provided by RHIC, providing complementary information regarding the matter that existed during the infant universe. Data collected by the ALICE, CMS, and ATLAS detectors confirm that the same quark-gluon plasma is seen at the higher energy. U.S. researchers are making important scientific contributions to the emerging results from all three LHC experiments. In ALICE and CMS U.S. researchers are playing a modest role in developing instrumentation associated with the upgrade of the LHC.

Research

Heavy ion research groups at BNL, LBNL, LANL, ORNL, and LLNL, and about 120 scientists and 80 graduate students at 28 universities are supported to analyze data from RHIC and participate in a modest program at the LHC.

The university and national laboratory research groups provide the scientific personnel and graduate students needed for running the RHIC and LHC heavy ion experiments; analyzing data; publishing results; conducting R&D of next-generation detectors; planning for future experiments; and designing, fabricating, and operating the RHIC and LHC heavy ion detectors. BNL and LBNL provide computing infrastructure for petabyte-scale data analysis and state-of-the-art facilities for detector and instrument development. At LBNL, a large scale computational system, the Parallel Distributed Systems Facility (PDSF), is a major shared resource used for the analysis of RHIC and LHC data in alliance with the National Energy Research Scientific Computing Center (NERSC), which is supported by SC's Advanced Scientific Computing Research (ASCR) program. Additional limited computing resources at ORNL are provided for LHC data analysis.

Accelerator R&D research proposals for short and mid-term accelerator R&D from universities and laboratories specific to improving operations of current NP facilities or developing new NP facilities are evaluated by peer review through a single competition for funding under the Heavy Ion and Medium Energy subprograms.

Operations

Support is provided for the operations, power costs, capital infrastructure investments, and accelerator improvement projects of the RHIC accelerator complex at BNL. This includes the Electron Beam Ion Source (EBIS), Booster, and the Alternating Gradient Synchrotron (AGS) accelerators that together serve as the injector for RHIC. RHIC operations allow for parallel and cost-effective operations of the Brookhaven Linac Isotope Producer Facility (BLIP), supported by NP for the production of research and commercial isotopes critically needed by the Nation, and of the NASA Space Radiation Laboratory Program for the study of space radiation effects applicable to human space flight. Through operations of the RHIC complex, important core competencies are nurtured in accelerator physics techniques to improve RHIC performance and support the NP mission. These core competencies provide collateral benefits to applications in industry, medicine, homeland security, and other scientific projects outside of NP. RHIC accelerator physicists are leading the effort to address technical feasibility issues of relevance to a possible next-generation collider for the NP program, including beam cooling techniques and energy recovery linacs. These physicists also play an important role in the training of next generation accelerator physicists, with support of graduate students and post-doctoral associates.

Heavy Ion Nuclear Physics

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Heavy Ion Nuclear Physics $199,966,000	**$211,366,000**	**+$11,400,000**
Research $33,894,000	**Research $36,431,000**	**Research +$2,537,000**
Researchers continue to participate in the collection and analysis of data from RHIC with newly completed scientific instrumentation to study collisions with a range of light and heavy nuclei to better understand the initial conditions in heavy ion collisions, and in the conduct of limited R&D for innovative detector designs and planning for future experiments. NP provides scientific leadership to the international ALICE, CMS, and ATLAS experiments at the LHC, as well as the required funding to the LHC for U.S. commitments for management and operating costs. Mid- and short-term accelerator R&D relevant to NP programmatic needs is also supported. The STAR Heavy Flavor Detector major item of equipment, planned for completion in FY 2015, was completed ahead of schedule and under budget in September 2014.	Researchers will continue to participate in the collection and analysis of new data from RHIC enabled by the recently completed STAR Heavy Flavor Tracker (HFT) MIE. The FY 2014 run was the commissioning run for the HFT, and is expected to bring important first results, but not final precision measurements. The FY 2015 run will generate the baseline data from proton+proton and proton+Au collisions, and the FY 2016 run will generate the definitive Au+Au data which will address unexplained phenomena with charm and bottom quarks to inform our understanding of the perfect liquid discovered at RHIC in 2005. NP also provides scientific leadership to the heavy ion efforts at the international ALICE, CMS, and ATLAS LHC experiments, as well as the required funding to the LHC for U.S. commitments for management and operating costs. Mid- and short-term accelerator R&D relevant to NP programmatic needs is also supported.	Funding increases to restore research efforts at RHIC focused on heavy quark propagation in the quark-gluon plasma. Funding also increases to meet commitments in LHC computing, and to continue research activities on current and future experimental capabilities of the heavy ion LHC ALICE detector.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Operations $166,072,000	**Operations $174,935,000**	**Operations +$8,863,000**
RHIC operations provide for 2,770 beam hours (approximately 22 weeks or 68 percent utilization) in support of the planned RHIC research program that takes advantage of dramatic improvements in collider performance and versatility made possible by recent RHIC upgrades. Funds for experimental equipment, accelerator R&D, and materials and supplies are reduced in FY 2015 in order to optimize running levels.	RHIC operations will continue to provide for 2,770 beam hours (approximately 22 weeks or 68 percent utilization) in support of the planned RHIC research program that is taking advantage of dramatic improvements in collider performance and versatility made possible by recent RHIC upgrades. The FY 2016 run (Run-16) is essential to understand results on heavy quark propagation in the quark-gluon plasma discovered at RHIC. The high statistics data planned for Run-16 will address these phenomena and are required for researchers to interpret the data acquired from the last two years.	Funds for experimental equipment, accelerator R&D, and materials and supplies are restored in FY 2016 in order to reduce risk and optimize operations, and maintenance and critical staff are fully supported.

Nuclear Physics
Low Energy Nuclear Physics

Description

The Low Energy Nuclear Physics subprogram focuses on answering the overarching questions associated with two scientific thrusts, Nuclei and Nuclear Astrophysics, and Fundamental Symmetries that can be probed by studying neutrons and nuclei.

Questions associated with Nuclei and Nuclear Astrophysics include:

- What is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes?
- What is the origin of simple patterns in complex nuclei?
- What is the nature of neutron stars and dense nuclear matter?
- What is the origin of the elements in the cosmos?
- What are the nuclear reactions that drive stars and stellar explosions?

This subprogram addresses these questions through support of research to develop a comprehensive description of nuclei using beams of stable and rare isotopes to yield new insights and reveal new nuclear phenomena. The subprogram also measures the cross sections of the nuclear reactions that power stars and lead to spectacular stellar explosions, which are responsible for the synthesis of the elements.

Questions addressed in the area of Fundamental Symmetries that can be probed by studying neutrons and nuclei include:

- What experimental approach for a next generation, ton-scale neutrino-less double beta day detector is capable of achieving the sensitivity necessary to determine if the neutrino is its own anti-particle?
- Is there evidence from the electric-dipole moments of atomic nuclei and the neutron that demonstrate our current understanding of the fundamental laws governing nuclear physics is incomplete?
- Does evidence for parity violation in electron scattering and possible lepton number violation in the decay of nuclei indicate forces present at the dawn of the universe that disappeared from view as the universe evolved?

This subprogram addresses these questions through precision measurements primarily with neutrons and with neutrinos from nuclear decays. Beams of cold and ultracold neutrons are used to study fundamental properties of neutrons. Precision studies to observe or set a limit on violation of time-reversal invariance—the principle that the physical laws should not change if the direction of time is reversed—in nucleonic, nuclear, and atomic systems investigate fundamental questions in nuclear physics, astrophysics, and cosmology.

The ATLAS national scientific user facility has been pivotal in making progress in Nuclear Structure and Nuclear Astrophysics, serving a combined international community of approximately 400 scientists. ATLAS provides high-quality beams of all the stable elements up to uranium as well as selected beams of short-lived nuclei for experimental studies of nuclear properties under extreme conditions and reactions of interest to nuclear astrophysics. Although ATLAS is the world's premiere facility for stable beams, it also provides limited capabilities in radioactive or rare isotope beams.

HRIBF ceased operations in 2012. Disposition activities of this facility continue in FY 2016. Analysis of data from HRIBF on exotic nuclei that do not normally exist in nature and reactions of interest to nuclear astrophysics continues. The HRIBF user community has been turning to other facilities for available beam time, including the ATLAS facility. This increased demand is influencing the evolution of the scientific agenda at ATLAS and the need for increased beam time and experimental capabilities.

NP supports the LBNL 88-Inch Cyclotron jointly with the National Reconnaissance Office (NRO) and the U.S. Air Force (USAF). Accelerator operations are supported at two university Centers of Excellence with specific goals and unique physics programs: the Cyclotron Institute at Texas A&M University (TAMU) and accelerator facilities at the Triangle Universities Nuclear Laboratory (TUNL) at Duke University. A third university center, the Center for Experimental Nuclear Physics and Astrophysics (CENPA) at the University of Washington, provides unique expertise and capabilities for instrumentation development.

Progress in nuclear structure and nuclear astrophysics depends increasingly upon the availability of rare isotope beams. One of the highest priorities for the NP program is support for the construction of a facility with world-leading capabilities for short-lived radioactive beams, the Facility for Rare Isotope Beams (FRIB). FRIB is a next-generation machine being constructed at MSU that will advance understanding of rare nuclear isotopes and the evolution of the cosmos by providing beams of rare isotopes with neutron and proton numbers far from those of stable nuclei in order to test the limits of nuclear existence.

Research

Low Energy research groups are supported at ANL, BNL, LBNL, LANL, LLNL, ORNL, and PNNL, as well as 44 universities. The subprogram funds about 170 Ph.D. scientists and nearly 100 graduate students at the national laboratories and universities. About two-thirds of the supported scientists conduct nuclear structure and astrophysics research primarily using specialized instrumentation at the ATLAS national user facility as well as the smaller accelerator facilities at university-based Centers of Excellence. The remaining groups conduct research in fundamental symmetries, including experiments at the Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source, double beta-decay experiments such as the Cryogenic Underground Observatory for Rare Events (CUORE) experiment at Gran Sasso Laboratory in Italy and the Majorana Demonstrator R&D effort at the Sanford Underground Research Facility in Lead, South Dakota, a measurement of the neutrino mass with the Karlsruhe Tritium Neutrino (KATRIN) experiment at the Karlsruhe Institute of Technology in Karlsruhe, Germany, and limited R&D to measure the neutron electric dipole moment.

Operations

ATLAS provides stable and selected radioactive beams and utilizes specialized instrumentation for scientists to conduct research on nuclear structure and nuclear astrophysics, and is the premiere stable beam facility in the world. The Californium Rare Ion Breeder Upgrade (CARIBU) at ATLAS provides targeted unique capabilities to produce radioactive ion beams until FRIB becomes operational in the next decade. The ATLAS facility nurtures a core competency in accelerator science with superconducting radio frequency cavities for heavy ions that are relevant to the next generation of high-performance proton and heavy-ion linacs. This competency is important to the Office of Science mission and international stable and radioactive ion beam facilities.

Low Energy Nuclear Physics

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Low Energy Nuclear Physics $75,196,000	**$79,788,000**	**+$4,592,000**
Research $48,377,000	**Research $52,125,000**	**Research +$3,748,000**
University and laboratory nuclear structure and nuclear astrophysics efforts focus on research at ATLAS, university-based Centers of Excellence, and limited support for highest priority development efforts for instrumentation at FRIB. Commissioning of the Majorana Demonstrator continues and data taking is initiated. The international CUORE major item of equipment is completed. Support continues for the GRETINA detector maintenance and operations and KATRIN operations. The neutron program at the FNPB continues R&D on the feasibility of setting a world leading limit on nEDM.	University and laboratory nuclear structure and nuclear astrophysics efforts will continue to focus on research at ATLAS, university-based Centers of Excellence, as well as the highest priority instrumentation development efforts to realize unique scientific opportunities afforded by stopped, slow, and fast beams at FRIB. Data taking will continue at the Majorana Demonstrator to demonstrate technical feasibility of a next generation detector in double beta decay. Support will continue for maintenance and operations of the GRETINA detector, operations of the KATRIN experiment, and R&D at the FNPB on the feasibility of setting a world leading limit on the electric dipole moment of the neutron (nEDM).	Increased funding is requested to restore the highest priority research efforts at national laboratories and universities, to develop and implement instrumentation in nuclear structure and astrophysics at ATLAS and FRIB, and for neutrinoless double beta decay research and neutron science at the Sanford Underground Research Facility (SURF) and the Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source (SNS).
Operations $26,819,000	**Operations $27,663,000**	**Operations +$844,000**
ATLAS will provide an estimated 5,900 hours (about 37 weeks) of beam time, 95 percent of optimal operations. The Electron Beam Ion Source AIP will be commissioned at ATLAS. Funding continues for equipment disposition activities at HRIBF.	Continued operation of ATLAS in a 7 day per week mode is a high priority as demand for ATLAS beam time continues to far exceed availability. FY 2016 funding will support 5,900 hours (about 37 weeks) of beam time, 95 percent of optimal operations, and a program of modest upgrades continues for the only operating DOE-supported scientific user facility in nuclear structure and astrophysics. Support will continue for equipment disposition activities at HRIBF.	Funding increases primarily for support of key personnel required to provide robust ATLAS operations, implement new capabilities of the accelerator and support the increasing demand from the user community for a wider variety of beams.

Description

The Nuclear Theory subprogram provides the theoretical support needed to interpret the wide range of data obtained from the experimental nuclear science subprograms and to advance new ideas and hypotheses that identify potential areas for future experimental investigations. Nuclear Theory addresses all three of NP's scientific thrusts. One major theme of theoretical research is the development of an understanding of the mechanisms and effects of quark confinement and deconfinement. A quantitative description of these phenomena through QCD is one of this subprogram's greatest intellectual challenges. New theoretical and computational tools are also being developed to describe nuclear many-body phenomena; these approaches will likely also see important applications in condensed matter physics and in other areas of the physical sciences. Another major research area is nuclear astrophysics, which includes efforts to understand the origins of the elements and the consequences that neutrino masses have for nuclear astrophysics.

This subprogram supports the Institute for Nuclear Theory (INT) at the University of Washington. A second round of five-year topical collaborations within the university and national laboratory communities to address high-priority topics in nuclear theory that merit a concentrated theoretical effort will be competed at the end of FY 2015 when the first round of collaborations comes to an end. The Nuclear Theory subprogram also supports the U.S. Nuclear Data Program (USNDP), which collects, evaluates, and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies and their development.

Much of the research supported by the Nuclear Theory subprogram requires extensive access to leading-edge supercomputers. One area that has a particularly pressing demand for large, dedicated computational resources is LQCD. LQCD calculations are critical for understanding and interpreting many of the experimental results from RHIC, LHC, and CEBAF. A five-year computer hardware project "LQCD-ext II" will start in FY 2015 and is being carried out jointly with HEP to ensure effective coordination. It follows the previous joint efforts that address the computational requirements of LQCD research by continuing to provide specialized computing resources for LQCD research. Both HEP and NP require this type of computing capability in order to conduct simulations that address their distinct science programs. The partnering of the two Offices ensures effective coordination to maximize the leverage available for this activity from the infrastructure and intellectual capital of both programs and to prevent duplication of effort on resource-intensive calculations inherently central to quantum chromodynamics and particle physics research.

SciDAC, a collaborative program with ASCR that partners scientists and computer experts in research teams to address major scientific challenges that require supercomputer facilities performing at current technological limits, is also supported within this subprogram. The NP SciDAC program operates on a five year cycle, and supports computationally intensive research projects jointly with other SC and DOE offices in areas of mutual interest. SciDAC-3 awards were made in FY 2012 and will continue through FY 2016.

Theory Research

The Nuclear Theory subprogram supports the research programs of approximately 160 university scientists and 120 graduate students at 50 universities, as well as nuclear theory groups at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF). This research has the goals of improving our fundamental understanding of nuclear physics, interpreting the results of experiments carried out under the auspices of the experimental nuclear physics program, and identifying and exploring important new areas of research. It is aligned with the experimental program through the program performance milestones established by the Nuclear Sciences Advisory Committee (NSAC). Three topical collaborations [JET (QCD in the heavy-ion environment); NuN (neutrinos and nucleosynthesis in hot and dense matter); and TORUS (low-energy nuclear reactions for unstable isotopes)] received their last year of funding in FY 2014. Based on the success and community support of this program, a new round of 5-year topical collaborations to bring together theorists to address specific high-priority theoretical challenges is planned to be competed late in FY 2015 with initial funding to be provided in FY 2016.

Nuclear Data

The USNDP provides current, accurate, and authoritative data for workers in pure and applied areas of nuclear science and engineering. It addresses this goal primarily through maintaining and providing public access to extensive nuclear physics databases, which summarize and cross-correlate the results of over 100 years of research on nuclear science. These databases are an important national and international resource, and currently respond to approximately three million retrievals of nuclear data annually. The USNDP also addresses important gaps in nuclear data through targeted experiments and the development and use of theoretical models. The program involves the combined efforts of approximately 50 nuclear scientists at 10 national laboratories and universities, and is managed by the National Nuclear Data Center (NNDC) at BNL.

Nuclear Theory

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Nuclear Theory $43,096,000	**$46,220,000**	**+$3,124,000**
Theory Research $35,715,000	**Theory Research $38,583,000**	**Theory Research +$2,868,000**
Funding supports the highest priority theoretical research at universities and national laboratories for the interpretation of experimental results obtained at NP facilities, including multi-dimensional fluctuating fluid-dynamical calculations to describe relativistic nuclear collisions. Efforts focus on nucleon and nuclear structure, spectroscopy, and reactions in preparation for the research program at the upgraded CEBAF 12 GeV facility, the research program at the planned FRIB facility, and on topics related to fundamental symmetries. Funding supports ongoing research efforts, the SciDAC-3 grants, and the LQCD ext-II computing project.	Funding will continue to support the highest priority theoretical research at universities and national laboratories for the interpretation of experimental results obtained at NP facilities. Theorists will concentrate on applying QCD to nucleon structure and hadron spectroscopy, to the force between nucleons, and to the structure of light nuclei. Advanced dynamic calculations to describe relativistic nuclear collisions, nuclear structure and reactions, and topics related to fundamental symmetries will focus on activities in preparation for the research program at the upgraded CEBAF 12 GeV facility, the research program at the planned FRIB facility, and ongoing and planned fundamental symmetries experiments. Funding will also continue to support ongoing SciDAC-3 grants and the LQCD ext-II computing project. Support will be provided for the second round of theory topical collaborations.	Funding increases to restore the highest priority nuclear theory research at universities and national laboratories and to support the first year of funding for the second round of high priority targeted theory topical collaborations, and computational research under SciDAC.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Nuclear Data $7,381,000	**Nuclear Data $7,637,000**	**Nuclear Data +$256,000**
Efforts continue to focus on updating online databases containing experimental and evaluated nuclear structure data, nuclear reaction cross sections, and nuclear science literature and on maintaining computing infrastructure needed to support important efforts across the National Nuclear Data program. Specifically, a new XML-based nuclear data structure model will be developed and incorporated into databases.	Nuclear data evaluation is the prime nuclear data product, combining experiment with theory and linking basic science with applications. The emphasis in FY 2016 will be on the compilation and evaluation of nuclear reaction and nuclear structure data which will include advanced nuclear reaction modeling and uncertainty quantification; maintaining and developing nuclear data formats and data verification codes; and archiving nuclear physics data and disseminating it using up to date technology.	Funding increases to avoid the loss of key personnel and to enable NNDC to continue to provide the highest quality nuclear data in support of basic science and users' needs in order to ensure safety, reliability, efficacy, and sustainability of nuclear technologies. This includes the safe and economical utilization of nuclear power, and R&D of innovative reactors and advanced fuel cycles.

Nuclear Physics
Isotope Development and Production for Research and Applications

Description

The Isotope Development and Production for Research and Applications subprogram (Isotope Program) supports the production, distribution, and development of production techniques for radioactive and stable isotopes in short supply and critical to the Nation. Isotopes are commodities of strategic importance for the Nation that are essential for energy exploration and innovation, medical applications, national security, and basic research. The goal of the program is to make key isotopes more readily available to meet U.S. needs. To achieve this goal, the program incorporates all capabilities, including facilities and technical staff, required for supply chain management of critically important isotopes. The subprogram also supports R&D efforts associated with developing new and more cost-effective and efficient production and processing techniques, and on the production of isotopes needed for research purposes. The R&D activities also provide collateral benefits for training, contributing to workforce development and helping to ensure a future U.S.-based expertise in the fields of nuclear chemistry and radiochemistry. These disciplines are foundational not only to radioisotope production but to many other critical aspects of basic and applied nuclear science as well.

The Isotope Program operates a revolving fund to maintain its financial viability by utilizing a combination of appropriations and revenues from the sale of isotopes and services. These resources are used to maintain the staff, facilities, and capabilities at user-ready levels and to support peer-reviewed research and development activities related to the production of isotopes. Isotopes sold to commercial customers are priced to recover the full cost of production, or the market price (whichever is higher). Research isotopes are sold at a reduced price to ensure high priority research requiring them does not become cost prohibitive. Investments in new capabilities are made to meet the growing demands of the Nation and foster future research in applications that will support national security and the health and welfare of the public.

Isotopes are critical national resources used to improve the accuracy and effectiveness of medical diagnoses and therapy, enhance national security, improve the efficiency of industrial processes, and provide precise measurement and investigative tools for materials, biomedical, environmental, archeological, and other research. Some examples are:

- strontium-82 for cardiac imaging;
- californium-252 for well logging, homeland defense, and energy security;
- germanium-68 for the development of gallium-68 radiopharmaceuticals for cancer imaging;
- berkelium-249, californium-251, and curium-244 use as targets for discovery of new superheavy elements;
- selenium-75 use in industrial radiography;
- actinium-225, bismuth-213, lead-212, thorium-227, and radium-223 use in cancer and infectious disease therapy research;
- nickel-63 use in molecular sensing devices and helium-3 (He-3) use in neutron detectors, both for applications in homeland defense;
- strontium-90 and cobalt-60 for cancer therapy;
- arsenic-73 use as a tracer for environmental research; and
- silicon-32 use in oceanographic studies related to climate modeling.

Stable and radioactive isotopes are vital to the mission of many Federal agencies including the National Institutes of Health (NIH), the National Institute of Standards and Technology, the Environmental Protection Agency, the Department of Agriculture, the Department of Homeland Security (DHS), NNSA, and DOE Office of Science programs. NP continues to work in close collaboration with these organizations to develop strategic plans for isotope production and to establish effective communication to better forecast isotope needs and leverage resources. For example, a five-year production strategy has been generated with the NIH that identifies the isotopes and projected quantities needed by the medical community in the context of the Isotope Program production capabilities. In addition, NP conducts an annual workshop, attended by representatives of all Federal agencies that require stable and radioactive isotopes to support research and applications within their realms of responsibility, to provide a comprehensive assessment of national needs for isotope products and services. Another example is participation in the White House Office of Science and Technology Policy (OSTP) working group on molybdenum-99 (Mo-99). While the Isotope Program is not responsible for the production of Mo-99, it recognizes the importance of this isotope for the Nation as a diagnostic in cardiac imaging and is working closely with NNSA, the lead entity responsible for domestic Mo-99 production, and is offering technical and management support. NP participates in the international High-Level Group on the Security of Supply of Medical Isotopes lead by the Organisation for Economic Co-operation and Development (OECD). Consistent with the National Defense Authorization Act for Fiscal Year 2013, NP also initiated and oversaw proceedings of the Nuclear Science Advisory Committee in response to a charge to assess progress by the NNSA GTRI program toward ensuring a domestic supply of Mo-99. NP participates in the Certified Reference Material Working Group which assures material availability for nuclear forensics applications that support national security missions. NP plays a lead role in a federal working group on the He-3 supply issue involving NNSA, DHS, the Department of Defense, NIH, and many other agencies. The objective of the working group is to ensure that the limited supply of He-3 will be distributed to the highest priority applications and basic research. The Isotope Program packages and distributes the isotope, and plays a lead role in working with all of the Federal agencies in forecasting demand for the gas and its allocation.

The National Isotope Development Center (NIDC) is a virtual center that interfaces with the user community and manages the coordination of isotope production across the facilities and business operations involved in the production, sale, and distribution of isotopes. The NIDC includes the Isotope Business Office, which is located at ORNL.

Research

Research is supported to develop new or improved production or separation techniques for high priority isotopes in short supply. Examples of isotope research required to meet national needs include positron-emitting radionuclides to support the rapidly growing area of medical imaging using positron emission tomography (PET), isotopes supporting medical research used to diagnose and treat diseases spread through acts of bioterrorism, research isotopes for various biomedical applications, enriched stable isotopes, and alternative isotope supplies for national security applications and advanced power sources. Priorities in research isotope production are informed by guidance from NSAC. One of the high priorities is to conduct R&D aimed at re-establishing a U.S. capability for stable isotope production. Another high priority is a long-term research effort to produce Ac-225, an isotope that shows great promise in the treatment of diffuse cancers and infections if it can be produced in sufficient quantity and quality. Also, in anticipation of the opportunity FRIB will provide as a unique source of many important isotopes for research and applications, scientists are exploring technologies to potentially harvest some of the isotopes that will be produced during physics research experiments. Isotope Program research also provides training opportunities for workforce development in the areas of nuclear chemistry and radiochemistry. These disciplines are essential to the long-term health of the fields of radioisotope production and applications.

Operations

The Isotope Program is steward of the Isotope Production Facility (IPF) at Los Alamos National Laboratory (LANL) and the Brookhaven Linac Isotope Producer (BLIP) facility at BNL and provides support for hot cell facilities for processing and handling irradiated materials and purified products at ORNL, BNL, and LANL. Facilities at other sites are used as needed, such as the Idaho National Laboratory reactor for the production of cobalt-60, the Pacific Northwest National Laboratory for processing and packaging strontium-90, the Y-12 National Security Complex for processing and packaging lithium-6 and lithium-7, and the Savannah River Site for the extraction and distribution of helium-3.

Isotope Development and Production for Research and Applications

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Isotope Development and Production for Research and Applications $19,850,000	**$21,664,000**	**+$1,814,000**
Research $4,815,000	**Research $6,133,000**	**Research +$1,318,000**
Support maintains research and development competitive awards and laboratory research groups at LANL, BNL, and ORNL. Development of production techniques for alpha-emitters continues to be a high priority, as is R&D aimed at re-establishing a domestic capability for research quantities of stable isotopes. Development for a 100 mA ion source and ion optics for production scale electromagnetic stable isotope separation is completed, which is critical for the re-establishment of enriched stable isotope production in the United States.	Support is continued for research and development competitive awards to universities and laboratories, as well as for support to laboratory research groups at LANL, BNL, and ORNL. Development of production techniques for alpha-emitting radionuclides for medical therapy will continue to be a priority, and is being implemented through a concerted collaborative R&D effort by experts at the national laboratories, particularly at BNL, LANL, and ORNL. Research at universities and national laboratories is also leading to new isotope production technologies and effectively engaging and training students and post-docs in nuclear chemistry and radiochemistry.	Funding increases to enhance core research capabilities at the national laboratories and universities, and the program of competitive R&D, in order to address the high priorities identified by NSAC, particularly with regard to the research effort to produce Ac-225.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Operations $15,035,000	**Operations $15,531,000**	**Operations +$496,000**
Support is provided for infrastructure and maintenance of facilities, core competencies in isotope production and development, and for the NIDC. National laboratory operations are focused on essential activities required to maintain aging facilities in operational conditions. Funding is provided to support university-based operations in support of isotope production. The isotopes produced will represent a balance of commercial isotopes and high priority research isotopes, with prioritization informed by NSAC and the Federal workshop in November 2014. A major milestone will be the development of a rubidium metal target at the IPF for increased production of strontium-82 for medical heart imaging.	Support will provide for infrastructure and maintenance of facilities, core competencies in isotope production and development, and for the NIDC. The maintenance of aging facilities continues to be a funding priority to maintain isotope production capabilities. Funding for program investments and production of particular isotopes will be informed by the Nuclear Science Advisory Committee’s updated long-range plan for the Isotope Program (to be completed in FY 2015) and the Federal workshop to be held in the fall of 2015.	Funding increases to maintain a constant level of effort for the Isotope Production Facility, the Brookhaven Linac Isotope Producer, and processing capabilities at ORNL, BNL, and LANL, and the NIDC.

Description

Funding in this subprogram provides for design and construction needed to meet overall objectives of the Nuclear Physics program. Currently NP is supporting two projects.

The 12 GeV CEBAF Upgrade at TJNAF, which was identified in the 2007 NSAC Long-Range Plan as the highest priority for the U.S. Nuclear Physics program, will enable scientists to address one of the mysteries of modern physics—the mechanism of quark confinement. FY 2016 is the last year of construction funding for the project; it is planned for completion in September 2017.

The Facility for Rare Isotope Beams will provide intense beams of rare isotopes for world-leading research opportunities in nuclear structure, nuclear astrophysics, and fundamental symmetry studies that will advance knowledge of the origin of the elements and the evolution of the cosmos. It offers a facility for exploring the limits of nuclear existence and identifying new phenomena, with the possibility that a broadly applicable theory of the structure of nuclei will emerge. FRIB will provide an essential scientific tool for over 1,300 scientists each year from across academic, industrial and government institutions. The project is funded through a cooperative agreement with Michigan State University and was established as a control point in the FY 2014 appropriation. Prior to that time, funding was provided within the Low Energy subprogram.

Construction

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Construction $106,500,000	**$107,500,000**	**+$1,000,000**
06-SC-01, 12 GeV CEBAF Upgrade, TJNAF $16,500,000	**06-SC-01, 12 GeV CEBAF Upgrade, TJNAF $7,500,000**	**06-SC-01, 12 GeV CEBAF Upgrade, TJNAF -$9,000,000**
Experimental equipment in Halls B, C, and D continue to be procured, fabricated, installed, and commissioned. Project work associated with civil and accelerator construction, scheduled to be complete in the first quarter of FY 2015, was completed 5 months ahead of schedule; CD-4A (Approve Accelerator Project Completion and Start of Operations for the 12 GeV Project) was approved on July 30, 2014. The project continues to work towards completion CD-4B (Approve Experimental Equipment Project Completion and Start of Operations) by the end of FY 2017.	With the scheduled commissioning of the Hall D experimental equipment in FY 2015, the FY 2016 federal funds will support procurements, fabrication, installation, and commissioning of the experimental equipment primarily in Halls B and C; and address continuing project risks in order to optimize the successful completion of this project within the current TEC baseline. FY 2016 is the final year of TEC funding for the project as it works towards completion (CD-4B) by the end of FY 2017.	The decrease reflects the approved baseline profile for the project.
14-SC-50, Facility for Rare Isotope Beams (FRIB) $90,000,000	**14-SC-50, Facility for Rare Isotope Beams (FRIB) $100,000,000**	**14-SC-50, Facility for Rare Isotope Beams (FRIB) +$10,000,000**
Civil and technical construction, major procurements, and fabrication of components as required under the baselined FRIB scope continue.	Work on conventional facilities will continue with construction of items such as the linear accelerator (linac) tunnel and the target, linac support, and cryoplant areas. The technical systems will also be fully underway and will include efforts such as major procurements, fabrication, and assembly for technical components such as the linac, cryomodules, and experimental systems.	Federal funding ramps up for continued FRIB construction according to the Performance Baseline and funding profile established in August 2013.

Nuclear Physics
Performance Measure

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program. The following table shows the targets for FY 2014 through FY 2016.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**NP Facility Operations—Average achieved operation time of NP user facilities as a percentage of total scheduled annual operation time.**		
Target	≥ 80%	≥ 80%	≥ 80%
Result	Met	TBD	TBD
Endpoint Target	Many of the research projects that are undertaken at the Office of Science's scientific user facilities take a great deal of time, money, and effort to prepare and regularly have a very short window of opportunity to run. If the facility is not operating as expected the experiment could be ruined or critically setback. In addition, taxpayers have invested millions or even hundreds of millions of dollars in these facilities. The greater the period of reliable operations, the greater the return on the taxpayers' investment.		
Performance Goal (Measure)	**NP Construction/MIE Cost & Schedule—Cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.**		
Target	< 10%	< 10%	< 10%
Result	Met	TBD	TBD
Endpoint Target	Adhering to the cost and schedule baselines for a complex, large scale, science project is critical to meeting the scientific requirements for the project and for being good stewards of the taxpayers' investment in the project.		
Performance Goal (Measure)	**Conduct fundamental research to discover, explore, and understand all forms of nuclear matter.**		
Target	Perform mass measurements and nuclear reaction studies to infer weak interaction rates in nuclei in order to constrain models of supernovae and stellar evolution	Measure bulk properties, particle spectra, correlations and fluctuations in gold + gold collisions at Relativistic Heavy Ion Collider (RHIC) to search for evidence of a critical point in the Quantum Chromodynamics (QCD) matter phase diagram.	Perform measurements for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma at the Relativistic Heavy Ion Collider (RHIC).
Result	Met	TBD	TBD
Endpoint Target	Increase the understanding of the existence and properties of nuclear matter under extreme conditions, including that which existed at the beginning of the universe.		

Nuclear Physics
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
Capital Operating Expenses Summary							
Capital equipment	n/a	n/a	14,790	14,790	14,750	20,305	+5,555
General plant projects (GPP)	n/a	n/a	2,500	2,500	2,000	2,000	0
Accelerator improvement projects (AIP)	n/a	n/a	4,770	4,770	4,249	4,377	+128
Total, Capital Operating Expenses	**n/a**	**n/a**	**22,060**	**22,060**	**20,999**	**26,682**	**+5,683**
Capital Equipment							
Other capital equipment under $2 million TEC	n/a	n/a	14,790	14,790	14,750	20,305	+5,555
General Plant Projects							
General plant projects under $5 million TEC	n/a	n/a	2,500	2,500	2,000	2,000	0
Accelerator Improvement Projects (AIP)							
RHIC Low Energy Electron Cooling	9,900	1,300	2,300	2,300	2,300	2,369	+69
Other projects under $5 million TEC	n/a	n/a	2,470	2,470	1,949	2,008	+59
Total, Accelerator Improvement Projects	**n/a**	**n/a**	**4,770**	**4,770**	**4,249**	**4,377**	**+128**

Construction Projects Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
06-SC-01, 12 GeV CEBAF Upgrade, TJNAF							
TEC	310,500	261,000	25,500	25,500	16,500	7,500	-9,000
OPC	27,500	13,000	4,500	4,500	4,500	4,500	0
TPC	338,000	274,000	30,000	30,000	21,000	12,000	-9,000
14-SC-50, Facility for Rare Isotope Beams							
DOE TPC	635,500[a]	73,000[b]	55,000	55,000	90,000	100,000	+10,000
Total, Construction (TPC)	**n/a**	**n/a**	**85,000**	**85,000**	**111,000**	**112,000**	**+1,000**

Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	170,668	170,668	165,828	179,311	+13,483
Scientific User Facilities Operations	276,887	276,887	280,663	293,304	+12,641
Other Facility Operations	24,120	24,120	24,313	24,995	+682
Projects					
Major Items of Equipment	0	0	0	0	0
Facility for Rare Isotope Beams	55,000	55,000	90,000	100,000	+10,000
12 GeV Upgrade TEC	25,500	25,500	16,500	7,500	-9,000
Total Projects	80,500	80,500	106,500	107,500	+1,000
Other[c]	16,963	2,627	18,196	19,490	+1,294
Total Nuclear Physics	**569,138**	**554,802**	**595,500**	**624,600**	**+29,100**

[a] This is the DOE TPC; MSU's cost share is $94,500,000 bringing the total project cost to $730,000,000. FRIB is funded with operating dollars through a Cooperative Agreement financial assistance award with a work breakdown structure (WBS) that is slightly different from typical federal capital assets. The WBS totals $730,000,000 including MSU's cost share. Because the WBS scope is not pre-assigned to DOE or MSU funds, DOE's baseline of $635,500,000 cannot be broken down between TEC and OPC.

[b] The PY funding was provided within the Low Energy subprogram. The FY 2014 appropriation established FRIB as a control point.

[c] Includes SBIR/STTR funding in FY 2014 Enacted and FY 2015–FY 2016.

Scientific User Facility Operations ($K)

The treatment of user facilities is distinguished between two types: TYPE A facilities that offer users resources dependent on a single, large-scale machine; TYPE B facilities that offer users a suite of resources that is not dependent on a single, large-scale machine.

Definitions:

Achieved Operating Hours – The amount of time (in hours) the facility was available for users.

Planned Operating Hours –

- For Past Fiscal Year (PY), the amount of time (in hours) the facility was planned to be available for users.
- For Current Fiscal Year (CY), the amount of time (in hours) the facility is planned to be available for users.
- For the Budget Fiscal Year (BY), based on the proposed budget request the amount of time (in hours) the facility is anticipated to be available for users.

Optimal Hours – The amount of time (in hours) a facility would be available to satisfy the needs of the user community if unconstrained by funding levels.

Percent of Optimal Hours – An indication of utilization effectiveness in the context of available funding; it is not a direct indication of scientific or facility productivity

- For BY and CY, Planned Operating Hours divided by Optimal Hours (OH) expressed as a percentage
- For PY, Achieved Operating Hours divided by Optimal Hours.

Unscheduled Downtime Hours - The amount of time (in hours) the facility was unavailable to users due to unscheduled events. NOTE: For type "A" facilities, zero Unscheduled Downtime Hours indicates Achieved Operating Hours equals Planned Operating Hours.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
CEBAF (TJNAF)[a]	**$106,698**	**$106,698**	**$108,694**	**$111,196**	**$2,502**
Number of Users	1,245	1,245	1,235	1,210	N/A
Achieved operating hours	N/A	N/A	N/A	N/A	N/A
Planned operating hours	0	0	0	0	0
Optimal hours	0	0	0	0	0
Percent optimal hours	N/A	N/A	N/A	N/A	N/A
Unscheduled downtime hours	N/A	N/A	N/A	N/A	N/A

[a] During FY 2014-2016, there are no research hours to which the CEBAF facility will be held accountable while the 12 GeV upgrade is commissioned and reliability is expected to be low. In FY 2014, 14 weeks of beam development and tuning are supported as the facility comes back on from a prolonged shutdown. In FY 2015, approximately 19 weeks and in FY 2016, approximately 16 weeks of machine development are supported. The user community is expected to remain active during the shutdown with instrumentation and equipment implementation for the upgraded facility so they continue to be shown in these years.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
RHIC (BNL)	**$172,079**	**$172,079**	**$172,579**	**$181,999**	**$9,420**
Number of Users	1,200	1,200	1,200	1,200	N/A
Achieved operating hours	3,060[a]	3,060	N/A	N/A	N/A
Planned operating hours	2,770	2,770	2,770	2,770	0
Optimal hours	4,100	4,100	4,100	4,100	0
Percent optimal hours	74.6%	74.6%	67.6%	67.6%	N/A
Unscheduled downtime hours	0	0	N/A	N/A	N/A
ATLAS (ANL)[b]	**$22,462**	**$22,462**	**$21,682**	**$22,390**	**$708**
Number of Users	400	400	400	410	N/A
Achieved operating hours	3,820[c]	3,820	N/A	N/A	N/A
Planned operating hours	3,500	3,500	5,900	5,900	0
Optimal hours	4,200	4,200	6,200	6,200	0
Percent optimal hours	91.0%	91.0%	95.2%	95.2%	N/A
Unscheduled downtime hours	0	0	N/A	N/A	N/A
Total Scientific User Facility Operations	**$301,239**	**$301,239**	**$302,955**	**$315,585**	**$12,630**
Number of Users	2,845	2,845	2,835	2,820	N/A
Achieved operating hours	6,880	6,880	N/A	N/A	N/A
Planned operating hours	6,270	6,270	8,670	8,670	0
Optimal hours	8,300	8,300	10,300	10,300	0
Percent of optimal hours[d]	76.5%	76.5%	70.6%	70.6%	N/A
Unscheduled downtime hours	0	0	N/A	N/A	N/A

[a] RHIC was able to deliver more hours than planned due to outstanding FY 2014 performance that exceeded the assumed machine reliability.
[b] The optimal hours at ATLAS in FY 2014–2016 vary due to downtime for installation of upgrades.
[c] During FY 2014, ATLAS exceeded the planned operating hours because operations restarted earlier than planned following installation of upgrades.
[d] For total facilities only, this is a “funding weighted” calculation FOR ONLY TYPE A facilities: $\frac{\sum_1^n[(\%OH\ for\ facility\ n)\times(funding\ for\ facility\ n\ operations)]}{Total\ funding\ for\ all\ Type\ A\ facility\ operations}$

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Estimate	FY 2016 Estimate	FY 2016 vs. FY 2015
Number of permanent Ph.D.'s (FTEs)	695	695	685	695	+10
Number of postdoctoral associates (FTEs)	330	330	315	330	+15
Number of graduate students (FTEs)	495	495	480	495	+15
Other[a]	950	950	950	950	0

[a] Includes technicians, engineers, computer professionals and other support staff.

14-SC-50, Facility for Rare Isotope Beams (FRIB)
Michigan State University (MSU), East Lansing, MI
Project is for a Cooperative Agreement

1. Significant Changes and Summary

Significant Changes

This project data sheet (PDS) does not include a new start for the budget year; it is an update of the FY 2015 PDS.

Summary

The most recent approved Critical Decision (CD) for the Facility for Rare Isotope Beams (FRIB) project is CD-3B (Approve Start of Construction of the Accelerator and Experimental Systems) which was approved on August 26, 2014, with a DOE Total Project Cost (TPC) of $635,500,000 and CD-4 by 3Q FY 2022. In addition, Michigan State University (MSU) is providing a cost share of $94,500,000, bringing the total project cost to $730,000,000. Following enactment of the FY 2014 appropriation, the Acquisition Executive authorized the start of civil construction in January 2014 and an official groundbreaking ceremony was held on March 17, 2014. There are no changes in the scope, cost, and schedule since the establishment of the project's baseline.

FRIB is funded through a cooperative agreement financial assistance award with MSU per 10 CFR 600, and the project is required by this agreement to follow the principles of the DOE Order 413.3B. Funding tables contained in sections 3, 5, and 6 of this PDS differ slightly in how the baseline is presented from a traditional PDS for a federal capital asset construction project in that they include the MSU cost share. The table in section 7, Schedule of Appropriation Requests, displays only DOE funding.

A Federal Project Director has been assigned to this project and approves this CPDS.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3A	CD-3B	D&D Complete	CD-4
FY 2011	2/9/2004		4Q FY 2010	TBD	TBD	TBD	TBD	N/A	FY 2017–2019
FY 2012	2/9/2004		9/1/2010	4Q FY 2012	TBD	TBD	TBD	N/A	FY 2018–2020
FY 2013	2/9/2004		9/1/2010	TBD	TBD	TBD	TBD	N/A	TBD
FY 2014	2/9/2004		9/1/2010	3Q FY 2013	TBD	3Q FY 2013	TBD	N/A	TBD
FY 2015	2/9/2004		9/1/2010	8/1/2013	4Q FY 2014	8/1/2013	4Q FY 2014	N/A	3Q FY 2022
FY 2016	2/9/2004	9/1/2010	9/1/2010	8/1/2013	8/26/2014[a]	8/1/2013	8/26/2014	N/A	3Q FY 2022

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3A – Approve Start of Civil Construction
CD-3B – Approve Start of Technical Construction

[a] This date represents when the design will be substantially complete to allow the start of technical construction (CD-3B). A limited amount of design effort will continue through 4Q FY 2017.

CD-4 – Approve Start of Operations or Project Closeout
D&D Complete – Completion Demolition & Decontamination

3. Project Cost History[a]

(dollars in thousands)

	Design/ Construction	R&D/Conceptual Design/NEPA	Pre-Operations	Total TPC	Less MSU Cost Share	DOE TPC
FY 2015	655,700	24,600	49,700	730,000	-94,500	635,500
FY 2016	655,700	24,600	49,700	730,000	-94,500	635,500

4. Project Scope and Justification

Scope

FRIB scope includes the design, construction, fabrication, assembly, testing, and commissioning of the civil and technical scope that will enable high intensity primary beams of stable isotopes to be accelerated up to a minimum energy of 200 MeV per nucleon by a superconducting linear accelerator (linac) capable of delivering 400 kW of beam power at full energy. The scope also includes the capability for secondary beams of rare isotopes to be produced "in-flight" and separated from unwanted fragments by magnetic analysis. In support of these capabilities, the civil construction portion includes a structure of approximately 220,000 square feet that will house the linac tunnel, target high bay area, linac support area, and cryoplant area. The technical scope includes a 2K/4.5K cryogenics plant, linac front end, cryomodules, and experimental systems.

CD-4 Key Performance Parameters

System	Parameter	Performance Criteria
Accelerator System	Accelerate heavy-ion beam	Measure FRIB driver linac Argon-36 beam with energy larger than 200 MeV per nucleon and a beam current larger than 20 pico nano amps (pnA).
Experimental Systems	Produce a fast rare isotope beam of Selenium-84	Detect and identify Selenium-84 isotopes in FRIB fragment separator focal plane
	Stop a fast rare isotope beam in gas and reaccelerate a rare isotope beam	Measure reaccelerated rare isotope beam energy larger than 3 MeV per nucleon
Conventional Facilities	Linac tunnel	Beneficial occupancy of subterranean tunnel structure of approximately 500 feet path length (minimum) to house FRIB driver linear accelerator
	Cryogenic helium liquefier plant—building and equipment	Beneficial occupancy of the cryogenic helium liquefier plant building and installation of the helium liquefier plant complete
	Target area	Beneficial occupancy of target area and one beam line installed and ready for commissioning

[a] Because this project is funded with operating dollars through a financial assistance award, its baseline is categorized through a work breakdown structure (WBS), which is slightly different from typical federal capital assets. Note that the project's WBS totals $730,000,000 including MSU's cost share. The WBS scope is not pre-assigned to DOE or MSU funds.

As contractually required under the financial assistance award agreement, FRIB is being conducted in accordance with the project management principles in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets, and all appropriate project management requirements have been met.

Justification

The science which underlies the FRIB mission is a core competency of nuclear physics: understanding how protons and neutrons combine to form various nuclear species; understanding how long chains of different nuclear species survive; and understanding how one nuclear species decays into another and what is emitted when that happens. Forefront knowledge and capability in this competency is essential, both for U.S. leadership in this scientific discipline and to provide the knowledge and workforce needed for numerous activities and applications relevant to national security and economic competitiveness.

FRIB will provide intense beams of rare isotopes for a wide variety of studies in nuclear structure, nuclear astrophysics, and other topics in nuclear physics. This facility will enable the study of the origin of the elements and the evolution of the cosmos, and offers an opportunity for exploring the limits of nuclear existence and identifying new phenomena, with the possibility that a more broadly applicable theory of nuclei will emerge. The facility will offer new glimpses into the origin of the elements, leading to a better understanding of key issues by creating exotic nuclei that, until now, have existed only in nature's most spectacular explosion, the supernova.

FRIB is optimized to produce large quantities of a wide variety of rare isotopes by breaking stable nuclei into rare isotopes. High intensity primary beams of stable isotopes are produced in Electron Cyclotron Resonator (ECR) ion sources and accelerated up to a minimum energy of 200 MeV per nucleon by a superconducting linear accelerator capable of delivering 400 kW of beam power at full energy. Secondary beams of rare isotopes are produced "in-flight" and separated from unwanted fragments by magnetic analysis. These rare isotope beams are delivered to experimental areas or stopped in a suite of ion-stopping stations where they can be extracted and used for experiments at low energy, or reaccelerated for astrophysical experiments or for nuclear structure experiments. The project includes the necessary infrastructure and support facilities for operations and the 1,000-person user community.

5. Financial Schedule[a]

(dollars in thousands)

	Appropriations	Obligations	Costs
DOE Total Project Cost (TPC)			
FY 2009	7,000	7,000	1,874
FY 2010	12,000	12,000	13,838
FY 2011	10,000	10,000	13,288
FY 2012	22,000	22,000	19,506
FY 2013	22,000	22,000	22,260
FY 2014[b]	55,000	55,000	48,369
FY 2015	90,000	90,000	88,000
FY 2016	100,000	100,000	100,000
FY 2017	100,000	100,000	105,000
FY 2018	97,200	97,200	100,200

[a] The funding profile represents DOE's portion of the baselined TPC to be provided through federal appropriations.
[b] The first project data sheet submitted for FRIB was in the FY 2015 Congressional Budget Request. It was established as a control point in the FY 2014 appropriation. Funding for the project in FY 2013 and prior years was provided within the Low Energy subprogram.

	(dollars in thousands)		
	Appropriations	Obligations	Costs
FY 2019	75,000	75,000	76,000
FY 2020	40,000	40,000	41,000
FY 2021	5,300	5,300	4,300
FY 2022	0	0	1,865
Total, DOE TPC	635,500	635,500	635,500

6. Details of Project Cost Estimate[a]

	(dollars in thousands)		
	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Design & Construction			
Management and Support	41,340	35,400	35,400
Conventional Facilities	165,720	165,300	165,300
Accelerator Systems	244,837	241,400	241,400
Experimental Systems	54,916	55,000	55,000
Contingency (DOE Held)	148,937	158,650	158,650
Total, Design & Construction	655,750	655,750	655,750
Other Costs			
Conceptual Design/Tech R&D/NEPA	24,640	24,600	24,600
Pre-ops/Commissioning/Spares	34,995	35,500	35,500
Contingency (DOE Held)	14,615	14,150	14,150
Total, Other Costs	74,250	74,250	74,250
Total, TPC	730,000	730,000	730,000
Less MSU Cost Share	-94,500	-94,500	-94,500
Total, DOE TPC	635,500	635,500	635,500
Total, Contingency (DOE Held)	163,552	172,800	172,800

[a] This section shows a breakdown of the total project cost of $730,000,000, which includes MSU's cost share. The scope of work is not pre-assigned to DOE or MSU funds.

7. Schedule of Appropriation Requests[a]

(dollars in thousands)

		Prior Years	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	Outyears	Total
FY 2011	TPC	29,000	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
FY 2012	TPC	59,000	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
FY 2013	TPC	51,000	22,000	TBD	TBD	TBD	TBD	TBD	TBD	TBD
FY 2014	TPC	51,000	22,000	55,000	TBD	TBD	TBD	TBD	TBD	TBD
FY 2015 PB[b]	TPC	51,000	22,000	55,000	90,000	100,000	100,000	97,200	120,300	635,500
FY 2016	TPC	51,000	22,000	55,000	90,000	100,000	100,000	97,200	120,300	635,500

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	3Q FY 2022
Expected Useful Life (number of years)	20
Expected Future Start of D&D of this capital asset	NA[c]

(Related Funding requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations[d]	90,000	N/A	1,800,000[e]	N/A

9. D&D Information

The FRIB project is being constructed at MSU under a cooperative agreement financial assistance award. The one-for-one requirement, which requires the demolition of a square foot of space for every square foot added, is not applicable, since this is not a federal capital acquisition.

10. Acquisition Approach

FRIB project activities will be accomplished following all procurement requirements, which include using fixed-priced competitive contracts with selection based on best value. MSU has contracted for the services of an architect-engineer firm for the design of the conventional facilities. The Driver Linac and Experimental System components will be self-performed by the MSU design staff with assistance from outside vendors and from DOE national laboratories that possess specific areas of unique expertise unavailable from commercial sources. Integration of the conventional facilities with the Driver Linac and Experimental Systems will be accomplished by the MSU FRIB Project Team.

[a] The funding profile represents DOE’s portion of the baselined TPC to be provided through federal appropriations.
[b] The Performance Baseline was approved August 1, 2013. The first project data sheet submitted for FRIB was in the FY 2015 Congressional Budget Request. It was established as a control point in the FY 2014 appropriation. Funding for the project prior to that time was provided within the Low Energy subprogram.
[c] Per the financial assistance award agreement, MSU is responsible for D&D.
[d] Utilities, maintenance, and repair costs are included within the Operations amounts.
[e] The total operations and maintenance (O&M) is estimated at an average annual cost of approximately $90,000,000 (including escalation) over 20 years.

06-SC-01, 12 GeV CEBAF Upgrade
Thomas Jefferson National Accelerator Facility, Newport News, Virginia
Project is for Design and Construction

1. Significant Changes and Summary

Significant Changes

This Construction Project Data Sheet (CPDS) does not include a new start for the budget year; it is an update of the FY 2015 PDS.

Summary

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-4A, Approve Accelerator Project Completion and Start of Operations, which was signed on July 30, 2014 following completion and confirmation of the project achieving the CD-4A Key Performance Parameters.

The FY 2016 TEC funding will allow the completion of the planned procurements, assemblies, and installations of the experimental equipment (i.e., detectors) primarily in Halls B and C, prior to their commissioning. In addition, a recent DOE/SC Office of Project Assessment review recognized that this final year of TEC funds will be required to address the continuing high project risks in order to successfully complete this project within the current TEC baseline.

In 2014, the Federal Project Director (FPD) certification level required for the 12 GeV was lowered to Level 2. Therefore, the FPD is certified at the appropriate level for this project.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4A	CD-4B
FY 2007	3/31/2004		1Q FY 2007	4Q FY 2007	4Q FY 2009	4Q FY 2008	N/A	N/A	1Q FY 2014
FY 2008	3/31/2004		2/14/2006[a]	4Q FY 2007	4Q FY 2009	4Q FY 2008	N/A	N/A	1Q FY 2015
FY 2009	3/31/2004		2/14/2006	11/9/2007	4Q FY 2009	4Q FY 2008	N/A	N/A	3Q FY 2015
FY 2010	3/31/2004		2/14/2006	11/9/2007	4Q FY 2009	9/15/2008	N/A	1Q FY 2015	3Q FY 2015
FY 2011	3/31/2004		2/14/2006	11/9/2007	1Q FY 2010	9/15/2008	N/A	1Q FY 2015	3Q FY 2015
FY 2012	3/31/2004		2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	1Q FY 2015	3Q FY 2015
FY 2013	3/31/2004		2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	1Q FY 2015	3Q FY 2015

[a] CD-1 was approved on 2/14/2006. Engineering and design activities started in 4Q FY 2006 after Congress approved the Department of Energy's request to reprogram $500,000 within the FY 2006 funding for Nuclear Physics, per direction contained in H.Rpt. 109–275.

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4A	CD-4B
FY 2014	3/31/2004		2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	1Q FY 2015	3Q FY 2015
FY 2015	3/31/2004		2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	1Q FY 2015	4Q FY 2017
FY 2016	3/31/2004	2/14/2006	2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	7/30/2014	4Q FY 2017

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of Construction
CD-4A – Approve Accelerator Project Completion and Start of Operations
CD-4B – Approve Experimental Equipment Project Completion and Start of Operations
D&D– Demolition & Decontamination

3. Project Cost History

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2007	21,000	TBD	TBD	11,000	TBD	TBD	TBD
FY 2008	21,000	TBD	TBD	10,500	TBD	TBD	TBD
FY 2009 PB	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2010	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2011	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2012	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2013	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2014	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2015[a]	21,000	289,500	310,500	27,500	N/A	27,500	338,000
FY 2016	21,000	289,500	310,500	27,500	N/A	27,500	338,000

4. Project Scope and Justification

Scope

The 12 GeV CEBAF Upgrade directly supports the Nuclear Physics mission and addresses the objective to measure properties of the proton, neutron, and simple nuclei for comparison with theoretical calculations to provide an improved quantitative understanding of their quark substructure.

[a] The amounts reflect the revised baseline approved in September 2013. A Work-for-Others agreement was approved by DOE that provides $9,000,000 appropriated by the Commonwealth of Virginia to leverage the federal investment for an upgrade of the Jefferson Lab's research facilities. This funding is outside the DOE baseline cost and schedule.

The scope of the project includes upgrading the electron energy capability of the main accelerator from 6 GeV to 12 GeV, building a new experimental hall (Hall D: 11,110 sf) and associated counting house (3,601 sf) and beam-line, and enhancing the capabilities of the existing experimental halls to support the most compelling nuclear physics research.

CD-4A Key Performance Parameters

Subsystem	Technical Definition of Completion
Accelerator	12 GeV capable 5.5 pass machine installed
	11 GeV capable beam line to existing Halls A, B, and C installed
	12 GeV capable beam line to new Hall D tagger area installed
	Accelerator commissioned by transporting a ≥ 2 nA electron beam at 2.2 GeV (1pass)
Conventional Facilities	New Experimental Hall D and the Counting House: ≥ 10,500 square feet.

CD-4B Key Performance Parameters

Subsystem	Technical Definition of Completion
Hall B	Detector operational: events recorded with a ≥ 2 nA electron beam at > 6 GeV beam energy (3 pass)
Hall C	Detector operational: events recorded with a ≥ 2 nA electron beam at > 6 GeV beam energy (3 pass)
Hall D	Detector operational: events recorded with a ≥ 2 nA electron beam at > 10 GeV beam energy (5.5 pass)

Key Performance Parameters to achieve CD-4 are phased between the accelerator and conventional facilities (CD-4A) and the experimental equipment in Halls B, C, and D (CD-4B). The deliverables defining completion are identified in the Project Execution Plan and have not changed since CD-2. Mitigation plans exist for identified risks to help ensure successful project completion after approval of a baseline change proposal due to the directed change and technical challenges.

The project is being conducted in accordance with the project management requirements in DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, and all appropriate project management requirements have been met.

Justification

The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility is the world-leading facility for the experimental study of the structure of matter governed by the “strong force.” The energy upgrade of CEBAF, first identified by the nuclear science community as a compelling scientific opportunity in the 2007 Long Range Plan for Nuclear Science, was reaffirmed as a high priority in the 2013 Report by the Nuclear Sciences Advisory Committee (NSAC) on Major Nuclear Physics Facilities for the next decade, which stated that the 12 GeV upgrade of CEBAF was “absolutely central” in terms of its ability to contribute to world-leading science in the next decade. In the 2007 Long Range Plan, NSAC concluded that completion of the 12 GeV CEBAF Upgrade project was the highest priority for the Nation’s nuclear science program.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Cost (TEC)				
Design				

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
FY 2006	500	500	0	88
FY 2007	7,000	7,000	0	6,162
FY 2008	13,377[a]	13,377	0	9,108
FY 2009	123[a]	123	0	5,370
FY 2010	0	0	0	265
FY 2011	0	0	0	7
Total, Design	21,000	21,000	0	21,000
Construction				
FY 2009	28,500	28,500	0	5,249
FY 2009 Recovery Act	65,000	65,000	2,738	0
FY 2010	20,000	20,000	29,621	18,642
FY 2011[b]	35,928	35,928	25,890	40,801
FY 2012	50,000	50,000	5,203	45,537
FY 2013	40,572	40,572	1,545	51,211
FY 2014	25,500	25,500	3	29,755
FY 2015	16,500	16,500	0	21,000
FY 2016	7,500	7,500	0	11,500
FY 2017	0	0	0	805
Total, Construction	289,500	289,500	65,000	224,500
TEC				
FY 2006	500	500	0	88
FY 2007	7,000	7,000	0	6,162
FY 2008	13,377	13,377	0	9,108
FY 2009	28,623	28,623	0	10,619
FY 2009 Recovery Act	65,000	65,000	2,738	0
FY 2010	20,000	20,000	29,621	18,907
FY 2011	35,928	35,928	25,890	40,808
FY 2012	50,000	50,000	5,203	45,537
FY 2013	40,572	40,572	1,545	51,211
FY 2014	25,500	25,500	3	29,755
FY 2015	16,500	16,500	0	21,000
FY 2016	7,500	7,500	0	11,500
FY 2017	0	0	0	805
Total, TEC	310,500	310,500	65,000	245,500

[a] The baseline FY 2008 PED funding was reduced by $123,000 as a result of a FY 2008 rescission. This reduction was restored in FY 2009 to maintain the TEC and project scope.
[b] The baseline FY 2011 funding was reduced by $72,000 as a result of a FY 2011 rescission.

	(dollars in thousands)			
	Appropriations	Obligations	Recovery Act Costs	Costs
Other Project Cost (OPC)				
OPC except D&D				
FY 2004	700	700	0	77
FY 2005	2,300	2,300	0	2,142
FY 2006	4,000	4,000	0	3,508
FY 2007	2,500	2,500	0	2,751
FY 2008	1,000	1,000	0	1,802
FY 2009	0	0	0	155
FY 2010	0	0	0	62
FY 2013	2,500	2,500	0	2,178
FY 2014	4,500	4,500	0	3,795
FY 2015	4,500	4,500	0	4,500
FY 2016	4,500	4,500	0	5,000
FY 2017	1,000	1,000	0	1,530
Total, OPC	27,500	27,500	0	27,500
Total Project Cost				
FY 2004	700	700	0	77
FY 2005	2,300	2,300	0	2,142
FY 2006	4,500	4,500	0	3,596
FY 2007	9,500	9,500	0	8,913
FY 2008	14,377	14,377	0	10,910
FY 2009	28,623	28,623	0	10,774
FY 2009 Recovery Act	65,000	65,000	2,738	0
FY 2010	20,000	20,000	29,621	18,969
FY 2011	35,928	35,928	25,890	40,808
FY 2012	50,000	50,000	5,203	45,537
FY 2013	43,072	43,072	1,545	53,389
FY 2014	30,000	30,000	3	33,550
FY 2015	21,000	21,000	0	25,500
FY 2016	12,000	12,000	0	16,500
FY 2017	1,000	1,000	0	2,335
Total, TPC[a]	338,000	338,000	65,000	273,000

[a] The TPC reflects the revised baseline approved in September 2013.

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Estimate
Total Estimated Cost (TEC)			
Design			
Design	21,000	21,000	19,200
Contingency	0	0	1,800
Total, Design	21,000	21,000	21,000
Construction Phase			
Construction	30,295	30,347	27,450
Accelerator/Experimental Equipment/ Management	250,793	243,937	174,150
Contingency	8,412	15,216	64,900
Total, Construction	289,500	289,500	266,500
Total, TEC	310,500	310,500	287,500
Contingency, TEC	8,412	15,216	66,700
Other Project Cost (OPC)			
OPC except D&D			
Conceptual Design	3,445	3,445	3,500
R&D	7,052	7,052	6,400
Start-up	11,966	12,618	7,450
Contingency	5,037	4,385	5,150
Total, OPC	27,500	27,500	22,500
Contingency, OPC	5,037	4,385	5,150
Total, TPC	338,000	338,000[a]	310,000
Total, Contingency	13,449	19,601	71,850

7. Schedule of Appropriation Requests

(dollars in thousands)

		Prior Years	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	Total
FY 2007 (Design only)	TEC	21,000	0	0	0	0	0	0	0	0	21,000
	OPC	11,000	0	0	0	0	0	0	0	0	11,000
	TPC	32,000	0	0	0	0	0	0	0	0	32,000
FY 2008 (Design only)	TEC	21,000	0	0	0	0	0	0	0	0	21,000
	OPC	10,500	0	0	0	0	0	0	0	0	10,500
	TPC	31,500	0	0	0	0	0	0	0	0	31,500

[a] The TPC reflects the revised baseline approved in September 2013.

(dollars in thousands)

		Prior Years	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	Total
FY 2009[a] PB	TEC	49,500	59,000	62,000	66,000	40,500	10,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	60,000	59,000	62,000	66,000	43,000	18,000	2,000	0	0	310,000
FY 2010[b]	TEC	114,500	22,000	34,000	66,000	40,500	10,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	125,000	22,000	34,000	66,000	43,000	18,000	2,000	0	0	310,000
FY 2011	TEC	114,500	20,000	36,000	66,000	40,500	10,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	125,000	20,000	36,000	66,000	43,000	18,000	2,000	0	0	310,000
FY 2012	TEC	114,500	20,000	36,000	66,000	40,500	10,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	125,000	20,000	36,000	66,000	43,000	18,000	2,000	0	0	310,000
FY 2013	TEC	114,500	20,000	35,928[c]	50,000	40,572	26,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	125,000	20,000	35,928	50,000	43,072	34,000	2,000	0	0	310,000
FY 2014	TEC	114,500	20,000	35,928	50,000	50,306	25,500	1,000	0	0	287,500
	OPC	10,500	0	0	0	0	4,500	5,000	0	0	22,500
	TPC[d]	125,000	20,000	35,928	50,000	50,306[e]	30,000	6,000	0	0	310,000
FY 2015	TEC	114,500	20,000	35,928	50,000	40,572	25,500	16,500	7,500	0	310,500
	OPC	10,500	0	0	0	2,500	4,500	4,500	4,500	1,000	27,500
	TPC[f]	125,000	20,000	35,928	50,000	43,072	30,000	21,000	12,000	1,000	338,000
FY 2016	TEC	114,500	20,000	35,928	50,000	40,572	25,500	16,500	7,500	0	310,500
	OPC	10,500	0	0	0	2,500	4,500	4,500	4,500	1,000	27,500
	TPC	125,000	20,000	35,928	50,000	43,072	30,000	21,000	12,000	1,000	338,000

[a] The FY 2009 Congressional Budget was the first project data sheet to reflect the CD-2 Performance Baseline which was approved in November 2007.

[b] The project received $65,000,000 from the American Recovery and Reinvestment Act of 2009 which advanced a portion of the baselined FY 2010 and FY 2011 planned funding. The FY 2010 and FY 2011 amounts reflect a total of $65,000,000 in reductions to the originally planned baselined funding profile to account for the advanced Recovery Act funding.

[c] The baseline FY 2011 funding was reduced by $72,000 as a result of the FY 2011 rescission.

[d] The TPC did not reflect the estimated impact resulting from the reduced FY 2012 funding, which has since been assessed and a rebaseline was approved in September 2013.

[e] The FY 2013 amount shown reflected the P.L. 112-175 continuing resolution level annualized to a full year. The TEC, TPC, and outyear appropriation assumptions had not been adjusted to reflect the final FY 2013 funding level; the FY 2013 Request level of $40,572,000 for TEC, $2,500,000 for OPC, and $43,072,000 for TPC was assumed.

[f] The TPC reflects the revised baseline approved in September 2013.

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	4Q FY 2017
Expected Useful Life (number of years)	15
Expected Future start of D&D for new construction (fiscal quarter)	N/A

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life cycle costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations	150,000	150,000	2,250,000[a]	2,250,000
Maintenance	Included above	Included above	Included above	Included above
Total, Operations & Maintenance	150,000	150,000	2,250,000	2,250,000

9. D&D Information

The new area being constructed in this project is not replacing existing facilities. The "one-for-one" requirement is met by offsetting 31,500 square feet of the 80,000 square feet of banked space that was granted to Jefferson Laboratory in a Secretarial waiver.

	Square Feet
Area of new construction	31,500
Area of existing facility(ies) being replaced and D&D'd by this project..............	0
Area of other D&D outside the project	0
Area of additional D&D space to meet the "one-for-one" requirement taken from the banked area.	31,500

10. Acquisition Approach

The Acquisition Strategy was approved February 14, 2006, with CD-1 approval. All acquisitions are managed by Jefferson Science Associates with appropriate Department of Energy oversight. Cost, schedule, and technical performance are monitored using an earned-value process that is described in the Jefferson Lab Project Control System Manual and consistent with DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets. The procurement practice uses firm fixed-price purchase orders and subcontracts for supplies, equipment, and services and makes awards through competitive solicitations. Project and design management, inspection, coordination, tie-ins, testing and checkout witnessing, and acceptance are performed by Jefferson Laboratory and Architectural-Engineering subcontractors as appropriate.

[a] The total operations and maintenance (O&M) is estimated at an average annual cost of approximately $150,000,000 (including escalation) over 15 years. Almost 90% of the O&M cost would still have been required had the existing accelerator not been upgraded and instead continued operations at 6 GeV.

Workforce Development for Teachers and Scientists

Overview

The Workforce Development for Teachers and Scientists (WDTS) program mission is to help ensure that DOE has a sustained pipeline of science, technology, engineering, and mathematics (STEM) workers. This is accomplished through support of undergraduate internships, graduate thesis research, and visiting faculty programs at the DOE laboratories; the Albert Einstein Distinguished Educator Fellowship for K–12 STEM teachers, administered by WDTS for DOE and for a number of other federal agencies; and annual, nationwide, middle- and high-school science competitions culminating in the National Science Bowl® in Washington, D.C. These investments help develop the next generation of scientists and engineers to support the DOE mission, administer programs, and conduct research.

WDTS activities rely significantly on DOE's 17 laboratories, which employ more than 30,000 workers with STEM backgrounds. The DOE laboratory system provides access to leading scientists; world-class scientific user facilities and instrumentation; and large-scale, multidisciplinary research programs unavailable in universities or industry. WDTS leverages these assets to develop and train post-secondary students and educators in support of the DOE mission.

Highlights of the FY 2016 Budget Request

The FY 2016 Request maintains support levels of workforce programs conducted at DOE Laboratories. These experience-based STEM learning opportunity programs enable highly qualified applicants to conduct research at the DOE laboratories, in support of the workforce mission.

Description

Activities at the DOE Laboratories

WDTS supports activities such as the Science Undergraduate Laboratory Internships program, the Community College Internships program, the Office of Science (SC) Graduate Student Research Program, and the Visiting Faculty Program. A goal of these programs is to encourage students to enter STEM careers especially relevant to the DOE mission. By providing research experiences at DOE laboratories under the direction of scientific and technical laboratory staff who serve as research advisors and mentors, these activities provide opportunities for participants to engage in research requiring specialized instrumentation; large-scale, multidisciplinary efforts; and/or scientific user facilities. WDTS activities are aligned with the strategic objectives of the National Science and Technology Council Committee on STEM Education (CoSTEM) Federal STEM Education 5-Year Strategic Plan.[a]

The **Science Undergraduate Laboratory Internships (SULI)** program places students from 2 and 4 year undergraduate institutions as paid interns in science and engineering research activities at DOE laboratories, working with laboratory staff scientists and engineers on projects related to ongoing research programs. Appointments are for 10 weeks during the summer term and 16 weeks during the fall and spring terms. In 2015, General Atomics in San Diego, California, home to DIII-D, the largest magnetic fusion facility in the U.S. and operated as an Office of Science national user facility, will be an additional summer term host institution.

The **Community College Internships (CCI)** program places community college students as paid interns in technological activities at DOE laboratories, working under the supervision of a laboratory technician or researcher. Appointments are for 10 weeks during the summer term and 16 weeks during the planned fall and spring terms.

The **Office of Science Graduate Student Research (SCGSR)** program goal is to prepare graduate students for STEM careers critically important to the SC mission by providing graduate thesis research opportunities at DOE laboratories. The SCGSR program provides supplemental awards for graduate students to pursue part of their graduate thesis research at a DOE laboratory in areas that address scientific challenges central to the SC mission. U.S. graduate students pursuing Ph.D. degrees in physics, chemistry, materials sciences, non-medical biology, mathematics, computer or computational sciences, or specific areas of environmental sciences aligned with the SC mission are eligible for research awards to conduct part of

[a] http://www.whitehouse.gov/sites/default/files/microsites/ostp/stem_stratplan_2013.pdf

their graduate thesis research at a DOE laboratory in collaboration with a DOE laboratory scientist. Research award terms range from three months to one year.

The **Visiting Faculty Program (VFP)** goal is to increase the research competitiveness of faculty members and students at institutions of higher education historically underrepresented in the research community in order to expand the workforce that addresses DOE mission areas. Through direct collaboration with research staff at DOE host laboratories, VFP appointments provide an opportunity for faculty and their students to develop skills applicable to programs at their home institutions; this helps increase the STEM workforce in DOE science mission areas at institutions historically under-represented within the DOE enterprise. Appointments are in the summer term for 10 weeks.

Albert Einstein Distinguished Educator Fellowship

The Albert Einstein Distinguished Educator Fellowship Act of 1994 charges the Department of Energy (DOE) with administering a fellowship program for elementary and secondary school mathematics and science teachers that focuses on bringing teachers' real-world expertise to government to help inform federal STEM education goals and programs. Selected teachers spend eleven months in a Federal agency or a Congressional office. WDTS manages the Albert Einstein Distinguished Educator Fellowship (AEF) Program for the Federal government. Fellows are supported by DOE and other Federal agencies. Typically, SC supports six Fellows each year; four are placed in Congressional offices and two are placed in SC. Participating agencies have included the National Science Foundation (NSF), the National Aeronautics and Space Administration (NASA), and the National Oceanic and Atmospheric Administration (NOAA), as well as other DOE offices. The Fellows provide educational expertise, years of teaching experience, and personal insights to these offices to advance science, mathematics, and technology education programs.

National Science Bowl®

The DOE SC National Science Bowl® (NSB) is a nationwide academic competition testing students' knowledge in all areas of mathematics and science, including energy. High school and middle school students are quizzed in a fast-paced, question-and-answer format. Since 1991, more than 240,000 students have participated in regional and national competitions.

The National Science Bowl® regional winning teams receive all-expenses paid trips to Washington D.C. to compete at the National Finals in late April. Competing teams are composed of four students, one alternate, and a teacher who serves as an advisor and coach. SC manages the National Science Bowl®, provides central management of 116 regional events, and sponsors the NSB Finals competition.

In FY 2014, 5,200 middle school students from 736 schools and 9,300 high school students from 1,351 schools participated in the regional competitions, with 48 middle school and 68 high school teams (560 students) participating in the National Finals in Washington, D.C. More than 5,000 volunteers also participated in the local and national competitions. In FY 2014, for the first time, students from all 50 states, U.S. Virgin Islands, Puerto Rico, and Washington, D.C. participated in a regional event of the National Science Bowl®. Beginning in FY 2015, the National Science Bowl®championship finals are planned to be held at the Lisner Auditorium (located on the campus of The George Washington University) with a live web-streaming broadcast of this event.

The DOE National Science Bowl® is aligned with the CoSTEM Federal STEM Education 5-Year Strategic Plan priority investment area for STEM engagement.

Technology Development and On-Line Application

This activity modernizes on-line systems used to manage applications and review, data collection, and evaluation for WDTS programs. A project to develop, build, and launch new online application and program support systems is progressing to improve program management, execution, and evaluation by WDTS program staff and by DOE laboratory staff. An important component of the systems is the ability to support regular evidence-based evaluation of program performance and impact. A phased approach is being used to develop and build the systems. In FY 2014, systems for the Albert Einstein Distinguished Educator Fellowship, the Office of Science Graduate Student Research Program, and National Science Bowl® were developed and launched, with recurring administrative tool development and system updates scheduled to begin in FY 2015.

Evaluation Studies

The Evaluation Studies activity supports work to assess whether WDTS programs meet established goals through the use of collection and analysis of data and other materials, including pre- and post-participation questionnaires, participant deliverables, notable outcomes (publications, presentations, patents, etc.), and longitudinal participant tracking.

Prior Committee of Visitors reviews found little evaluation of activities across WDTS but noted that the data collection and evaluation plans under development provided innovative options for gathering workforce information and for tracking participants. In FY 2014, evaluation plans for each WDTS activity were completed. Enhanced data analysis efforts initiated in FY 2014 will continue throughout FY 2015, and beyond.

SC completed a study to identify disciplines in which significantly greater emphasis in workforce training at the graduate student or postdoc levels is necessary to address gaps in current and future Office of Science mission needs. In this study, each Office of Science Federal Advisory Committee, each Associate Director, and each Laboratory Director were asked for their expert assessment on the following: (i) STEM disciplines not well represented in academic curricula; (ii) STEM disciplines in high demand, nationally and/or internationally, resulting in difficulties in recruitment and retention at U.S. universities and at DOE laboratories; (iii) STEM disciplines for which the DOE laboratories may play a role in providing needed workforce development; and (iv) recommendations for programs at the graduate student or postdoc levels that can address discipline-specific workforce development needs. The outcomes of this study will guide prioritization of eligible SCGSR programmatic research areas and inform WDTS strategic planning. More broadly, the outcomes of this study have identified for SC both program-specific workforce development needs and crosscutting workforce development needs in areas such as computing and computational sciences.

Evaluation Studies is aligned with the GPRA Modernization Act of 2010, the President's management priorities,[a] and the 2008 Congressionally-mandated Academic Competitiveness Council initiative, which emphasized the need for federal programs (including STEM education programs) to demonstrate their effectiveness through rigorous evidence-based evaluation. WDTS works cooperatively with SC programs, other DOE programs, and other federal agencies through CoSTEM to share best practices for STEM program evaluation to ensure the implementation of evaluation processes appropriate to the nature and scale of the program effort.

Outreach

WDTS engages in outreach activities, some in cooperation with other DOE program offices and select federal agencies, to widely publicize opportunities for student internships, SC Graduate Student Research program, the Visiting Faculty Program, and the Albert Einstein Distinguished Educator Program. The WDTS website[b] is the most widely used tool for prospective program participants to obtain information about WDTS and is the gateway to accessing the online applications for the WDTS programs. To help diversify the applicant pool, outreach is conducted via presentations to targeted key stakeholder groups, and via the web using webinar virtual meetings that highlight the programs, their opportunities, and the WDTS internship experience. A portfolio of recorded webinars is available on the WDTS website.

Laboratory Equipment Donation Program

The Laboratory Equipment Donation Program provides excess laboratory equipment to faculty at non-profit research institutions and post-secondary educational institutions. Through the Energy Asset Disposal System, DOE sites identify excess equipment and colleges and universities can then search for equipment of interest and apply via the website. The equipment is free, but the receiving institution pays for shipping costs.

[a] http://www.whitehouse.gov/administration/eop/ostp/nstc/committees/costem
[b] http://science.energy.gov/wdts/

Workforce Development for Teachers and Scientists
Funding ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Activities at the DOE Laboratories					
Science Undergraduate Laboratory Internships	7,800	7,800	8,300	9,000	+700
Community College Internships	700	700	1,000	1,200	+200
Graduate Student Research Program (formerly Office of Science Graduate Fellowship)	10,700	10,700	2,500	2,500	0
Visiting Faculty Program	1,300	1,300	1,700	1,800	+100
Total, Activities at the DOE Laboratories	**20,500**	**20,500**	**13,500**	**14,500**	**+1,000**
Albert Einstein Distinguished Educator Fellowship	**1,200**	**1,200**	**1,200**	**1,200**	0
National Science Bowl®	**2,800**	**2,800**	**2,900**	**2,900**	0
Technology Development and On-Line Application	**550**	**550**	**750**	**750**	0
Evaluation Studies	**600**	**600**	**600**	**600**	0
Outreach	**800**	**800**	**500**	**500**	0
Laboratory Equipment Donation Program	**50**	**50**	**50**	**50**	0
Total, Workforce Development for Teachers and Scientists	**26,500**	**26,500**	**19,500**	**20,500**	**+1,000**

Program Accomplishments

Science Undergraduate Laboratory Internships (SULI) - In FY 2014, the total number of participating DOE host laboratories increased (from 15 to 16), as did the number of DOE host laboratories (from 11 to 12) participating in the semester terms. This increased participation, largely due to the quality and impact of the program, serves to broaden participant STEM sub-field experience-based training opportunities and enhance their overlap with DOE mission-critical research areas.

Community College Internships (CCI) – In FY 2014, the portfolio of experiential-based learning opportunity sub-fields increased to include combustion science and technologies.

Office of Science Graduate Research (SCGSR) – The SCGSR Program supported 65 supplemental awards to graduate students to conduct their thesis research at 15 DOE national laboratories. Over half of the awards support project terms ranging from 10-12 months.

Visiting Faculty Program (VFP) - A VFP faculty participant from Howard University is now a collaborator on the PHENIX experiment (for Pioneering High Energy Nuclear Interaction eXperiment) at the Relativistic Heavy Ion Collider (RHIC) user facility (Brookhaven National Laboratory). Howard University is the only HBCU (Historically Black Colleges and Universities) member on the PHENIX collaboration.

The ***National Science Bowl®*** - In FY 2014, for the first time, students from all 50 states, U.S. Virgin Islands, Puerto Rico, and Washington, D.C. participated in a regional event of the National Science Bowl®.

Technology Development and On-Line Application - In FY 2014, new application and review systems for the Albert Einstein Distinguished Educator Fellowship, the Office of Science Graduate Student Research Program, and National Science Bowl® were developed and launched.

Workforce Development for Teachers and Scientists

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Activities at the DOE Laboratories $13,500,000	**$14,500,000**	**$+1,000,000**
Science Undergraduate Laboratory Internships ($8,300,000) SULI supports approximately 760 students, including an additional 35 fall and spring semester students. In 2015, General Atomics in San Diego, California, home to DIII-D, the largest magnetic fusion facility in the U.S. and operated as an SC user facility, will be an additional summer term host institution, to help fulfill workforce needs formerly addressed by the National Undergraduate Fellowship Program (NUF). Additional SULI placements will be made at the Princeton Plasma Physics Laboratory as the NUF program, funded within the Fusion Energy Sciences program, completes its merger with SULI.	*Science Undergraduate Laboratory Internships ($9,000,000)* SULI will support approximately 820 students, including support for an additional 45 fall and spring semester students.	*Science Undergraduate Laboratory Internships ($+700,000)* Funding supports additional students internships at the DOE laboratories
Community College Internships ($1,000,000) CCI supports approximately 90 students.	*Community College Internships ($1,200,000)* CCI will support approximately 100 students.	*Community College Internships ($+200,000)* Funding supports additional student internships at the DOE laboratories.
Graduate Student Research Program ($2,500,000) The SCGSR program supports approximately 100 graduate students for periods of 3 months to 1 year to conduct a part of their thesis research at DOE laboratories.	*Graduate Student Research Program ($2,500,000)* The SCGSR program will support approximately 100 graduate students for periods of 3 months to 1 year to conduct a part of their thesis research at DOE laboratories. Targeted priority research areas will be informed by SC's recent workforce training needs study.	*Graduate Student Research Program ($0)* No change.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Visiting Faculty Program ($1,700,000)	*Visiting Faculty Program ($1,800,000)*	*Visiting Faculty Program ($+100,000)*
VFP supports approximately 65 faculty and 30 students.	VFP will support approximately 70 faculty and 35 students.	Funding supports additional faculty and student opportunities at the DOE laboratories.
Albert Einstein Distinguished Educator Fellowship $1,200,000	**$1,200,000**	**$0**
The FY 2015 request supports 6 Fellows.	The FY 2016 request will support 6 Fellows.	No change.
National Science Bowl® $2,900,000	**$2,900,000**	**$0**
WDTS sponsors the finals competition and provides central management of 116 regional events, involving 14,500 students from all fifty states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. National Finals: April 23-27, 2015.	WDTS will sponsor the finals competition and provides central management of 116 regional events, involving 14,500 students from all fifty states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands.	No change.
Technology Development and On-line Application Systems $750,000	**$750,000**	**$0**
Funding in FY 2015 completes the design, build, and implementation of online management systems for the SCGSR, including the participant deliverables and evaluation components, and the National Science Bowl®. Funding also provides increased capacity for collecting data in support of evaluation studies.	Funding will continue development and operation of the on-line systems.	No change.
Evaluation Studies $600,000	**$600,000**	**$0**
FY 2015 funding supports enhanced evaluation efforts initiated in FY 2014, and the implementation of an evaluation plan for the SCGSR, including data archiving, curation, and analyses.	FY 2016 funding will continue support for evaluation activities, including data archiving, curation, and analyses.	No change.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Outreach $500,000	**$500,000**	**$0**
Funding supports development and deployment of a public web portal to track the inventory of STEM workforce internship and outreach activities and opportunities across the DOE laboratory complex.	Funding will support a public web portal to track the inventory of STEM workforce internship and outreach activities and opportunities across the DOE laboratory complex.	No change.
Enhanced outreach activities to the scientific community aimed at assessing the Office of Science mission-driven disciplinary workforce needs in the next 5 to 10 years are initiated.	Funding will support outreach activities to the scientific community targeting Office of Science mission-driven disciplinary workforce needs in the next 5 to 10 years.	
Laboratory Equipment Donation Program $50,000	**$50,000**	**$0**
Funding continues to support the administration of the ongoing program.	Funding will continue the ongoing program.	No change.

Science Laboratories Infrastructure

Overview

The Science Laboratories Infrastructure (SLI) program mission is to support scientific and technological innovation at the Office of Science (SC) laboratories by funding and sustaining mission-ready infrastructure and fostering safe and environmentally responsible operations. The program provides the infrastructure necessary to support world leadership by the SC national laboratories in the area of basic scientific research, now and in the future. The SLI program's primary focus is on long-term modernization of SC laboratory facilities and infrastructure to ensure the mission readiness of SC laboratories by ensuring that laboratories have state-of-the-art facilities and infrastructure that are flexible, reliable, and sustainable in support of scientific discovery. The SLI program also funds Payments in Lieu of Taxes (PILT) to local communities around the Argonne, Brookhaven, and Oak Ridge National Laboratories.

In November 2013, the DOE Secretary chartered[a] the National Laboratory Operations Board (LOB) to assess facilities and infrastructure across the national laboratory complex, among other things. These enterprise-wide assessments resulted in a rigorous and consistent analysis of the condition, utilization, and functionality of the facilities and infrastructure that are the most critical to mission accomplishment. Building on these assessments, SC worked with each of its laboratories to develop comprehensive Campus Strategies, integrated into the SC Annual Laboratory Planning process. Each Campus Strategy identifies activities and infrastructure investments (e.g., line-item construction, General Plant Projects [GPPs]) required to achieve the core capabilities and scientific vision for that laboratory. SC leadership used these Campus Strategies to establish the corporate facilities and infrastructure priorities going forward.

Overall, SC invests over $400 million dollars annually in needed maintenance, repair, and upgrades of general purpose infrastructure. These investments are from a variety of funding sources, including federal appropriations for line-item construction projects and GPPs, as well as overhead-funded investments in institutional GPP work and routine maintenance and repair. The SLI program provides two important pieces of this overall strategy – line-item construction projects and a suite of infrastructure support investments that focus on laboratory core infrastructure and operations. This budget request for SLI reflects the rigor of and output from the broader SC-wide planning activities described above.

Highlights of the FY 2016 Budget Request

Ongoing projects that will provide new laboratory buildings, renovated facilities, and upgraded utilities are proceeding towards on-time completion within budget. While significant improvements to SC infrastructure have been made, it is important to maintain a strong level of investment and continue making improvements across the SC national laboratory complex. This request does so by providing continued funding for the Materials Design Laboratory project at Argonne National Laboratory (ANL), the Photon Science Laboratory Building project at SLAC National Accelerator Laboratory (SLAC), and the Integrative Genomics Building project at Lawrence Berkeley National Laboratory (LBNL).

In addition, this request includes increased funding for the Infrastructure Support subprogram. This increase addresses a basic need in core general purpose infrastructure. The top priorities identified as part of the Campus Strategy discussions include electrical upgrades at SLAC and ANL and facility improvements at Fermi National Accelerator Laboratory (FNAL). The Request also initiates support for nuclear operations at the Oak Ridge National Laboratory (ORNL) that was previously funded by Congressional Direction under The Office of Nuclear Energy.

[a] http://fimsinfo.doe.gov/Downloads/Infrastructure_Assessment_Group.pdf

Science Laboratories Infrastructure
Funding ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Infrastructure Support	**8,236**	**8,236**	**13,590**	**44,690**	**+31,100**
Construction					
Infrastructure and Operational Improvements at PPPL (15-SC-75)	0	0	25,000	0	-25,000
Materials Design Laboratory at ANL (15-SC-76)	0	0	7,000	23,910	+16,910
Photon Science Laboratory Building at SLAC (15-SC-77)	0	0	10,000	25,000	+15,000
Integrative Genomics Building at LBNL (15-SC-78)	0	0	12,090	20,000	+7,910
Utilities Upgrade at FNAL (13-SC-70)	34,900	34,900	0	0	0
Utility Infrastructure Modernization at TJNAF (13-SC-71)	29,200	29,200	0	0	0
Science and User Support Building at SLAC (12-SC-70)	25,482	25,482	11,920	0	-11,920
Total, Construction	**89,582**	**89,582**	**66,010**	**68,910**	**+2,900**
Total, Science Laboratories Infrastructure	**97,818**	**97,818**	**79,600**	**113,600**	**+34,000**

Science Laboratories Infrastructure
Explanation of Major Changes ($K)

	FY 2016 vs. FY 2015
Infrastructure Support: This increase in funding addresses a basic need in core infrastructure. The top priorities identified as part of the Campus Strategy discussions include electrical upgrades at SLAC and ANL and facility improvements at FNAL. Nuclear operations at the Oak Ridge National Laboratory (ORNL) has previously been funded by Congressional Direction under The Office of Nuclear Energy.	+31,100
Construction: Continuation of funding for three FY 2015 new start projects. One FY 2015 new project start requested full funding in FY 2015 and does not require continuation of funding in FY 2016.	+2,900
Total, Science Laboratories Infrastructure	**+34,000**

Program Accomplishments

The SLI program has successfully completed over $600 million of infrastructure projects since FY 2006, when SC initiated a modernization effort to provide impactful infrastructure investments across the laboratory complex.

The *Renovate Science Laboratories, Phase II project at Brookhaven National Laboratory (BNL).* Renovation of the primary physics (Building 510) and chemistry (Building 555) laboratory buildings was completed within budget and on schedule. The project achieved CD-4, Approve Project Completion, on June 4, 2014. Beneficial Occupancy of the renovated portions of Building 555 was achieved on November 20, 2013 and Beneficial Occupancy of the renovated portions of Building 510 was achieved on February 28, 2014. The project scope included the design, selective demolition, construction, and start-up testing of building systems for the renovated areas of each building. The completed project significantly upgraded and rehabilitated existing, obsolete, and inadequate physics and chemistry research labs into modern, efficient research environments commensurate with world-class scientific research. The project is on track to earn two Leadership in Energy and Environmental Design (LEED) Silver certifications, one for Building 510 (physics) and one for Building 555 (chemistry).

The *Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II project at Lawrence Berkeley National Laboratory (LBNL).* Renovation and new construction of this project was completed within budget and ahead of schedule. The renovation of Building 74 was completed on September 25, 2012, with approval of CD-4A/B, Approve Start of Construction for Phase B. Seismic strengthening of Building 85 rectified seismic deficiencies and provided modern general purpose laboratory space used for research in energy and the environment, and was completed in July 2013. The issuance of the Beneficial Occupancy of the General Purpose Laboratory (GPL) building was the document that allowed for the CD-4C awarded on August 5, 2014. This project was completed nearly a year ahead of schedule and under budget while it managed to achieve its threshold key performance parameters. Notably, a LEED Gold certification for the GPL will be awarded, and a LEED Platinum certification for the Building 74 renovation has already been awarded.

The *Research Support Building and Infrastructure Modernization project at SLAC National Accelerator Laboratory (SLAC).* Construction was completed on the Research Support Building (B052) on May 31, 2013. The project replaced more than twelve 35-year old trailers and achieved LEED Gold certification. CD-3B, Approve Start of Construction, which includes the modernization of Building 41, was approved on June 28, 2013.

The *Energy Sciences Building project at Argonne National Laboratory (ANL).* Construction of this laboratory was completed within budget and ahead of schedule. Beneficial Occupancy of the new 173,000-square foot main building was achieved on May 21, 2013 and of a laboratory module extension on May 20, 2014. The project achieved CD-4, Approve Project Completion, on August 6, 2014. The building was designed to encourage collaboration among some of the country's leading scientists in chemistry, materials sciences, and condensed matter physics research and will accommodate over 240 research and support staff. This new building established a new consolidated campus for the energy sciences at ANL. The project is on track to earn LEED Gold certification for the new building.

The *Science and User Support Building project at SLAC National Accelerator Laboratory (SLAC).* Preliminary construction work, including the demolition of an existing cafeteria, commenced in September 2013. The project is progressing ahead of schedule and within budget. Construction of foundations was completed in June 2014 and erection of the steel frame structure began in July 2014.

The *Utilities Infrastructure Modernization project at Thomas Jefferson National Accelerator Laboratory (TJNAF).* Construction of the first phase began after achieving CD-3A, Approve Start of Construction for Phase A, and concurrently with CD-2, Approve Performance Baseline, on May 21, 2014. Construction of the second phase began upon achieving CD-3B, Approve Start of Construction for Phase B, on June 30, 2014. The project is progressing ahead of schedule and under budget.

Science Laboratories Infrastructure
Infrastructure Support

Description

This subprogram funds a suite of infrastructure support investments that focus on laboratory core infrastructure and operations. Investments in core infrastructure (e.g., utility systems, site-wide services, and general-purpose facilities) are an ongoing need that ensures facilities and infrastructure are upgraded when they approach end-of-life, systems are improved to increase reliability and performance, and excess space is removed so that it no longer requires operation and maintenance funding. Without this type of investment, SC laboratories would not be able to keep up with the pace of needed renewals. Activities include General Plant Project upgrades at various laboratories, stewardship-type needs (e.g., roads and grounds maintenance) across the Oak Ridge Reservation, and operations support for the nuclear facilities at Oak Ridge National Laboratory.

This subprogram also funds Payments in Lieu of Taxes (PILT) to local communities around the Argonne, Brookhaven, and Oak Ridge National Laboratories.

Note that this budget request combines the Facilities and Infrastructure activity with the Oak Ridge Landlord activity, which had been broken out separately in prior requests.

Funding ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Infrastructure Support					
Facilities and Infrastructure	900	900	6,100	30,977	+24,877
Nuclear Operations	0	0	0	12,000	+12,000
Oak Ridge Landlord	5,951	5,951	5,777	0	-5,777
Payments in Lieu of Taxes	1,385	1,385	1,713	1,713	0
Total, Infrastructure Support	**8,236**	**8,236**	**13,590**	**44,690**	**+31,100**

<u>Facilities and Infrastructure</u>

In the FY 2016 Request, the Infrastructure and Support subprogram initiates funding of infrastructure support investments that focus on laboratory core infrastructure and operations. Each SC laboratory conducted a rigorous condition assessment of its core infrastructure over the past year, and those assessments validated the need for investments in these basic systems that form the backbone of our campuses. The SLI program, in close collaboration with leadership in the research programs, reviewed these investment needs and the highest priority activities will be funded by this request. Plans for FY 2016 funding include projects such as replacing nine 12kV -480 V substations (K-subs) serving the SLAC linac (where their performance has proved unreliable) and upgrading approximately 1.5 miles of high voltage electrical cable and associated substation equipment at ANL to a fully redundant 138kV system. The latter system will provide support in the event of an electrical failure to key mission critical facilities at ANL. At FNAL, renovations to Wilson Hall will provide for increased collaboration space on 2 of the 15 floors in the lab's largest building and will correct deficiencies on the building exterior.

The subprogram also supports the following activities:

- General facilities and infrastructure support at the New Brunswick Laboratory (NBL) located on the site of the Argonne National Laboratory (ANL), the Office of Scientific and Technical Information (OSTI) and Oak Ridge Institute for Science Education (ORISE).
- Landlord responsibilities including infrastructure for the 24,000–acre Oak Ridge Reservation and DOE facilities in the city of Oak Ridge, Tennessee. Activities include maintenance of roads, grounds, and other infrastructure; support and improvement of environmental protection, safety, and health; and Payments in Lieu of Taxes (PILT) to Oak Ridge communities.

Nuclear Operations

To support critical DOE nuclear operations, this funding is provided to help manage ORNL's nuclear facilities (i.e., Buildings 7920, 7930, 3525, and 3025E) to current expectations, fully compliant with federal regulations and DOE Directives. This funding provides for end-of-life replacement of critical nuclear complex equipment and infrastructure to assure the facilities continue to meet safe standards and supports corrective and routine preventive maintenance on several thousand nuclear safety and facility support components and equipment located within ORNL's non-reactor nuclear facilities.

Payments in Lieu of Taxes

Funding within this activity supports SC stewardship responsibilities for the Payment in Lieu of Taxes (PILT). The Department is authorized to provide discretionary payments to state and local government authorities for real property that is not subject to taxation because it is owned by the United States and operated by the Department. Under this authorization, PILT is provided to communities around the Argonne and Brookhaven National Laboratories to compensate for lost tax revenues for land removed from local tax rolls. PILT payments are negotiated between the Department and local governments based on land values and tax rates.

Science Laboratories Infrastructure
Infrastructure Support

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Infrastructure Support $13,590,000	**$44,690,000**	**+$31,100,000**
Facilities and Infrastructure ($6,100,000)	**($30, 977,000)**	**(+$24,877,000)**
Provides funding for general facility and infrastructure support at NBL, OSTI, and ORISE.	This subprogram will fund a suite of infrastructure support investments that focus on laboratory core infrastructure and operations. It will also support Landlord responsibilities for the Oak Ridge Reservation, and PILT payments to the city of Oak Ridge.	This increase addresses top core infrastructure priorities identified as part of the Campus Strategy discussions, and includes projects such as electrical upgrades at SLAC and ANL and renovations at FNAL. It also supports Landlord responsibilities for the Oak Ridge Reservation, and PILT payments to Oak Ridge.
Nuclear Operations ($0)	**($12,000,000)**	**(+$12,000,000)**
Not included in FY 2015.	This funding is provided to manage ORNL's nuclear facilities to current expectations, fully compliant with federal regulations and DOE Directives. These activities have previously been supported by Congressional Direction under the Office of Nuclear Energy.	This increase will support management of ORNL's nuclear facilities to current expectations, fully compliant with federal regulation and DOE Directives.
Oak Ridge Landlord ($5,777,000)	**($0)**	**(-$5,777,000)**
Provides funding for activities to ensure continuity of operations and minimize interruptions due to infrastructure or other system failures. It also supports Landlord responsibilities for the Oak Ridge Reservation, and PILT payments to the city of Oak Ridge.	In FY 2016, this activity is funded within the Facilities and Infrastructure line.	Decrease reflects relocation of this funding activity to the Facilities and Infrastructure line.
Payments in Lieu of Taxes ($1,713,000)	**($1,713,000)**	**($0)**
Provides funding for PILT payments to communities around the Argonne and Brookhaven National Laboratories.	The FY 2016 request provides funding for PILT payments to communities around the Argonne and Brookhaven National Laboratories.	Funding remains flat.

Science Laboratories Infrastructure
Construction

Description

The SLI Construction program funds line-item projects to maintain and enhance the general purpose infrastructure at SC laboratories. SLI's infrastructure modernization construction projects are focused on the accomplishment of long-term science goals and strategies at each SC laboratory.

The FY 2016 budget request includes funding for three of four ongoing projects that were new starts in FY 2015.

On-Going Projects

Infrastructure and Operational Improvements at PPPL (15-SC-75)

The Infrastructure and Operational Improvements project will provide critical improvements to infrastructure and operations that support plasma and fusion-energy sciences research. Existing facilities and infrastructure at PPPL are marginally adequate to support cost-effective research operations. For example, many researchers and engineers are housed in buildings that were originally built in the 1960s and include obsolete and inadequate enclosure, mechanical, electrical, and plumbing systems. This project will rectify the most significant site, building, utility, and other infrastructure deficiencies as part of a comprehensive campus strategic facilities investment plan being developed for PPPL. Completion of this project will result in improved operational efficiency and modernized infrastructure that is essential necessary to support fusion energy sciences research.

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, which was approved on September 17, 2013. The estimated preliminary Total Project Cost (TPC) range for this project is $21,700,000 to $26,000,000. This cost range and schedule will be further evaluated and may change prior to CD-2 and until the project baseline is established.

This project was a new start in FY 2015 with full funding requested and appropriated. No additional funding is requested in this FY 2016 budget request.

FY 2015 Milestones	FY 2016 Milestones	FY 2017–2020 Key Milestones
CD-1 – Approve Alternative Selection and Cost Range	CD-2 – Approve Performance Baseline CD-3 – Approve Start of Construction	CD-4 – Approve Project Closeout

Materials Design Laboratory at ANL (15-SC-76)

The Materials Design Laboratory project will support research in materials science in energy and a range of other fields. It will entail construction of a 90,000–150,000 gross square foot high-performance laboratory office building and adjacent building renovations. The existing research buildings at Argonne dedicated to this SC research mission are all more than 40 years old, some as old as 55 years. These structures require frequent repair, resulting in interruptions to research activities, and they are unable to meet modern standards for instruments requiring vibration, electromagnetic and/or thermal stability. Additional supporting functions such as utilities or site modifications may be included in the project, if necessary.

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, which was approved on August 27, 2010. The estimated preliminary TPC range for this project is $85,500,000 to $96,000,000. This cost range and project schedule will be further evaluated prior to CD-2.

FY 2016 funding will support construction of this project.

FY 2015 Milestones	FY 2016 Milestones	FY 2017–2020 Key Milestones
CD-1 – Approve Alternative Selection and Cost Range	CD-2 – Approve Performance Baseline	CD-3 – Approve Start of Construction CD-4 – Approve Start of Operations or Project Closeout

Photon Science Laboratory Building at SLAC (15-SC-77)

The Photon Science Laboratory Building project will provide centralized modern laboratory and office space to enable the development and expansion of SLAC's photon science programs. The Photon Science Laboratory Building will support the Linac Coherent Light Source; the Stanford Synchrotron Radiation Lightsource; the Photon Ultrafast Laser Science and Engineering Institute; and the Stanford Institute for Materials and Energy Sciences. Additional supporting functions such as utilities or site modifications may be included in the project, if necessary.

When this project was proposed for initial funding in the FY 2015 budget request, the scope was to construct a facility that would provide a portion of the space that would eventually be needed on-site to support the increase in photon science users on campus. Since that time, Stanford University has initiated design of a larger facility shell that will be built with University funds. *Utilities and services (e.g., elevators, stairways, building-wide mechanical/electrical/plumbing equipment) for the entire building and framing and furnishing up to 75,000 GSF will be provided.* This presents the Department with an opportunity to build out space in that facility for SLAC use, rather than build new. Because of space efficiencies *(shared elevators, hallways, mechanical closets, etc.)* gained in constructing one building versus two, the Office of Science will acquire approximately 30% more square footage of useable space for the same funding than could be acquired under the original project proposal. Therefore, this project has been re-scoped to fund the build-out of specialized photon science laboratories and related infrastructure in the Stanford University building. This strategic approach allows DOE/SLAC to maximize the science capability by leveraging the Stanford University investment.

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, which was approved on May 11, 2011. The estimated preliminary TPC range for this project is $49,500,000 to $57,000,000. This cost range and the project schedule will be further evaluated prior to CD-2.

FY 2016 funding will support continued construction of this project.

FY 2015 Milestones	FY 2016 Milestones	FY 2017–2020 Key Milestones
CD-1 – Approve Alternative Selection and Cost Range	CD-2– Approve Performance Baseline CD-3 – Approve Start of Construction Activities	CD-4 – Approve Start of Operations or Project Closeout

Integrative Genomics Building at LBNL (15-SC-78)

The Integrative Genomics Building project will relocate a significant fraction of the research and operations currently located in commercially leased space onto the main LBNL campus. Portions of the biosciences program at LBNL are located off-site, away from the main laboratory, and dispersed across multiple locations up to 20 miles apart. Collocation of these programs will increase the synergy and efficiency of biosciences and other research at LBNL and will provide a state-of-the-art facility for biosciences research in a collaborative environment close to other key LBNL facilities and programs. Additional supporting functions such as utilities or site modifications may be included in the project, if necessary.

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, which was approved on September 17, 2013. The estimated preliminary TPC range for this project is $86,400,000 to $91,500,000. This cost range and the project schedule will be further evaluated prior to CD-2.

FY 2016 funding will support construction of this project.

FY 2015 Milestones	FY 2016 Milestones	FY 2017–2020 Key Milestones
CD-1 – Approve Alternative Selection and Cost Range	CD-2 – Approve Performance Baseline CD-3 – Approve Start of Construction	CD-4 – Approve Project Completion

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Construction $66,010,000	**$68,910,000**	**+$2,900,000**
Infrastructure and Operational Improvements at PPPL (15-SC-75) ($25,000,000)	**($0)**	**(-$25,000,000)**
FY 2015 funding supports full design and construction of the project.	Full funding was requested in FY 2015.	Full funding was requested in FY 2015.
Materials Design Laboratory at ANL (15-SC-76) ($7,000,000)	**($23,910,000)**	**(+$16,910,000)**
FY 2015 funding supports full design of the project.	Funding is requested in FY 2016 to initiate construction of the project.	Initiation of construction of the project.
Photon Sciences Laboratory Building at SLAC (15-SC-77) ($10,000,000)	**($25,000,000)**	**(+$15,000,000)**
FY 2015 funding supports full design and the start of construction of the project.	Funding is requested in FY 2016 to support ongoing construction of the project.	Continuation of construction of the project.
Integrative Genomics Building at LBNL (15-SC-78) ($12,090,000)	**($20,000,000)**	**(+$7,910,000)**
FY 2015 funding supports full design of the project.	Funding is requested in FY 2016 to initiate construction of the project.	Initiation of construction of the project.
Science and User Support Building at SLAC (12-SC-70) ($11,920,000)	**($0)**	**(-$11,920,000)**
Funding in FY 2015 will support the continuation of construction activities. FY 2015 is the final year of funding for this project.	Final year of funding was requested in FY 2015.	Funding was requested in FY 2015 to complete construction of the project.

Science Laboratories Infrastructure
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
General Plant Projects (GPP)							
Linac K-sub Remediation at SLAC (TEC $9.8M)	9,800	0	0	0	0	9,800	+9,800
Wilson Hall Renovations at FNAL (TEC $9.0M)	9,000	0	0	0	0	9,000	+9,000
Other GPP (TEC <$5M)	n/a	n/a	300	300	800	4,300	+3,500
Total, General Plant Projects (GPP)			**300**	**300**	**800**	**23,100**	**+22,300**

Construction Projects Summary ($K)

	Total Project Cost(TPC)	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Infrastructure and Operational Improvements at PPPL (15-SC-75)							
TEC	25,000[a]	0	0	0	25,000	0	-25,000
OPC[b]	1,000	0	1,000	1,000	0	0	0
TPC	26,000[a]	0	1,000	1,000	25,000	0	-25,000
Materials Design Laboratory at ANL (15-SC-76)							
TEC	95,000[a]	0	0	0	7,000	23,910	+16,910
OPC[b]	1,000	382	300	300	0	0	0
TPC	96,000[a]	382	0	0	7,000	23,910	+16,910
Photon Sciences Laboratory Building at SLAC (15-SC-77)							
TEC	55,000[a]	0	0	0	10,000	25,000	+15,000
OPC[b]	2,000	0	671	671	100	492	+392
TPC	57,000[a]	0	671	671	10,100	25,492	+15,392

[a] This project has not received CD-2 approval; therefore, preliminary cost estimates are shown for TEC and TPC.
[b] Other Project Costs shown are funded through laboratory overhead.

	Total Project Cost(TPC)	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Integrative Genomics Building at LBNL (15-SC-78)							
TEC	90,000[a]	0	0	0	12,090	20,000	+7,910
OPC[b]	1,500	0	1,500	1,500	0	0	0
TPC	91,500[a]	0	1,500	1,500	12,090	20,000	+7,910
Utilities Upgrade at FNAL (13-SC-70)							
TEC	34,900[a]	0	0	34,900	0	0	0
OPC[b]	1,100	1,100	0	0	0	0	0
TPC	36,000[a]	1,100	0	34,900	0	0	0
Utility Infrastructure Modernization at TJNAF (13-SC-71)							
TEC	29,200[a]	0	29,200	29,200	0	0	0
OPC[b]	700	700	0	0	0	0	0
TPC	29,900[a]	700	29,200	29,200	0	0	0
Science and User Support Building at SLAC (12-SC-70)							
TEC	64,000[a]	14,512	25,482	25,482	11,920	0	-11,920
OPC[b]	1,000	562	238	238	200	0	-200
TPC	65,000[a]	15,074	25,720	25,720	12,120	0	-12,120
Research Support Building and Infrastructure Modernization at SLAC (10-SC-70)							
TEC	96,000	83,976	0	0	0	0	0
OPC[b]	1,400	921	230	230	0	0	0
TPC	97,400	84,897	230	230	0	0	0
Total, Construction							
TEC	n/a	n/a	89,582	89,582	66,010	68,910	+2,900
OPC[b]	n/a	n/a	2,968	2,968	300	492	+192
TPC	n/a	n/a	92,550	92,550	66,310	69,402	+3,092

[a]This project has not received CD-2 approval; therefore, preliminary cost estimates are shown for TEC and TPC.
[b] Other Project Costs shown are funded through laboratory overhead.

15-SC-76 Materials Design Laboratory
Argonne National Laboratory (ANL), Argonne, IL
Project is for Design and Construction

1. Significant Changes and Summary

Significant Changes

This Construction Project Data Sheet (CPDS) is an update of the FY 2015 CPDS and does not include a new start for the budget year.

Summary

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-0, Approve Mission Need, which was approved on August 27, 2010. The preliminary Total Estimated Cost (TEC) range for this project is $84,500,000 to $95,000,000. The estimated preliminary Total Project Cost (TPC) range for this project is $85,500,000 to $96,000,000.

A Federal Project Director with the appropriate certification level has been assigned to this project and has approved this CPDS.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2015	08/27/2010	N/A	4Q FY 2014	4Q FY 2015[a]	4Q FY 2016	3Q FY 2016[a]	N/A	2Q FY 2020[a]
FY 2016	08/27/2010	1Q FY 2015	2Q FY 2015	2Q FY 2016[a]	3Q FY 2017	1Q FY 2017[a]	N/A	3Q FY 2020[a]

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of Construction
CD-4 – Approve Start of Operations or Project Closeout

	Performance Baseline Validation
FY 2015	N/A
FY 2016	1Q FY 2017[a]

[a] This project is pre-CD-2 and schedule estimates are preliminary.

3. Project Cost History

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC[a] Except D&D	OPC, D&D	OPC, Total	TPC
FY 2015	7,000	88,000[b]	95,000[b]	1,000	N/A	1,000	96,000[b]
FY 2016	7,000	88,000[b]	95,000[b]	1,000	N/A	1,000	96,000[b]

4. Project Scope and Justification

Scope

The Materials Design Laboratory project is proposed to construct a 90,000 to 150,000 square foot high performance laboratory building with efficient, high-accuracy heating, ventilation, and air conditioning systems.. Additional supporting functions such as utilities or site modifications may be included in the project, if they are deemed necessary. Alternatives will be evaluated prior to CD-1 during acquisition strategy development. Preliminary project Key Performance Parameters are as follows:

Description	Threshold Value (Minimum)	Objective Value (Maximum)
Multistory Laboratory Building	90,000 gross square feet	150,000 gross square feet

Justification

Office of Science (SC) research at ANL supports the development of revolutionary materials and novel molecular processes to transform global energy production and storage. The Materials Design Laboratory will provide the modern collaborative scientific environment critical for this initiative to thrive and will focus on four themes central to implementing the Materials for Energy strategy:

- Frontiers of materials and molecular synthesis, and fabrication of devices;
- Interfacial engineering for energy applications;
- Materials under extreme conditions; and
- In situ characterization and modeling.

Ongoing research at ANL requires flexible and sustainable laboratory and office space needed to support scientific theory/simulation, materials discovery, characterization, and application of new energy-related materials and processes. Efficient, high-accuracy heating, ventilation, and air conditioning systems will be installed to support cutting edge research and the operation of sensitive instrumentation. Comparable space is not currently available at ANL.

FY 2015 funds will be used for preliminary and final design, project management, and support activities. FY 2016 funds will be used for final design, construction, project management, and support activities.

The project has an exemption from the project management requirements in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets; however, the project is being conducted in accordance with the project management requirements in DOE O 413.3B, and all appropriate project management requirements have been met.

[a] Other Project Costs (OPC) are funded through laboratory overhead.
[b] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC range for this project is $84,500,000 to $95,000,000. The preliminary TPC range for this project is $85,500,000 to $96,000,000.

5. Financial Schedule

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2015	7,000	7,000	6,000
FY 2016	0	0	1,000
Total, Design	7,000	7,000	7,000
Construction			
FY 2016	23,910	23,910	18,000
FY 2017	25,090	25,090	20,000
FY 2018	39,000	39,000	25,000
FY 2019	0	0	25,000
Total, Construction	88,000	88,000	88,000
TEC			
FY 2015	7,000	7,000	6,000
FY 2016	23,910	23,910	19,000
FY 2017	25,090	25,090	20,000
FY 2018	39,000	39,000	25,000
FY 2019	0	0	25,000
Total, TEC[a]	95,000	95,000	95,000
Other Project Cost (OPC)[b]			
OPC except D&D			
FY 2010	412	412	412
FY 2011	-30[c]	-30[c]	-30[c]
FY 2014	300	300	300
FY 2018	318	318	318
Total, OPC except D&D	1,000	1,000	1,000

[a] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC range for this project is $84,500,000 to $95,000,000. The preliminary TPC range for this project is $85,500,000 to $96,000,000.
[b] Other Project Costs (OPC) are funded through laboratory overhead.
[c] OPC Funding was adjusted in FY 2011 to reflect FY 2010 actuals ($382,000 for OPC funding in FY 2010).

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Total Project Cost (TPC)			
FY 2010	412	412	412
FY 2011	-30[a]	-30[a]	-30[a]
FY 2014	300[b]	300	300
FY 2015	7,000	7,000	6,000
FY 2016	23,910	23,910	19,000
FY 2017	25,090	25,090	20,000
FY 2018	39,318	39,318	25,318
FY 2019	0	0	25,000
Total, TPC[c]	96,000	96,000	96,000

6. Details of Project Cost Estimate

	(dollars in thousands)		
	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	6,000	5,900	N/A
Contingency	1,000	1,100	N/A
Total, Design	7,000	7,000	N/A
Construction			
Construction	73,000	72,000	N/A
Contingency	15,000	16,000	N/A
Total, Construction	88,000	88,000	N/A

[a] OPC Funding was adjusted in FY 2011 to reflect FY 2010 actuals ($382,000 for OPC funding in FY 2010).
[b] Conceptual Design Cost estimate will be updated to depict actual costs when incurred.
[c] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC range for this project is $84,500,000 to $95,000,000. The preliminary TPC range for this project is $85,500,000 to $96,000,000.

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total, TEC[a]	95,000	95,000	N/A
Contingency, TEC	16,000	17,100	N/A
Other Project Cost (OPC)[b]			
OPC except D&D			
Conceptual Planning	382	382	N/A
Conceptual Design	500	400	N/A
Contingency	118	218	N/A
Total, OPC	1,000	1,000	N/A
Contingency, OPC	118	218	N/A
Total, TPC[a]	96,000	96,000	N/A
Total, Contingency	16,118	17,318	N/A

7. Schedule of Appropriation Requests

($K)

Request Year		Prior Years	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	Total
FY 2015	TEC	0	0	7,000	24,003	36,466	27,531	95,000[a]
	OPC[b]	382	500	0	0	0	118	1,000
	TPC	382	500	7,000	24,003	36,466	27,649	96,000[a]
FY 2016	TEC	0	0	7,000	23,910	25,090	39,000	95,000[a]
	OPC[b]	382	300	0	0	0	318	1,000
	TPC	382	300	7,000	23,910	25,090	39,318	96,000[a]

[a] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC range for this project is $84,500,000 to $95,000,000. The preliminary TPC range for this project is $85,500,000 to $96,000,000.
[b] Other Project Costs (OPC) are funded through laboratory overhead.

8. Related Operations and Maintenance Funding Requirements

Not Applicable

9. D&D Information

The new area being constructed in this project is not replacing existing facilities.

	Square Feet
New area being constructed by this project at *Argonne National Laboratory*	90,000 to 150,000
Area of D&D in this project at *Argonne National Laboratory*	None
Area at *Argonne National Laboratory* to be transferred, sold, and/or D&D outside the project including area previously "banked"	None
Area of D&D in this project at other sites	None
Area at other sites to be transferred, sold, and/or D&D outside the project including area previously "banked"	90,000 to 150,000
Total area eliminated	None

Argonne will comply via the FY 2012 waiver from EM ETTP to Argonne. Argonne's net banked square footage as reported in the FY 2013 Report on DOE's disposition of excess real property for future one-for-one offsets stands at 577,955 SF.

10. Acquisition Approach

The M&O Contractor, UChicago Argonne, LLC, will have prime responsibility for oversight of both the design and construction subcontracts. The M&O Contractor has extensive experience in the management and oversight of contracts of equal or greater complexity than the proposed Material Design Laboratory. The M&O Contractor's project management, construction management, and ES&H management systems have all proven to be effective in the execution and control of projects of similar scale and magnitude.

Various acquisition alternatives will be considered for this project. After considering all alternatives in relation to the schedule, size, and risk, the use of a tailored Design-Bid-Build approach with design by an Architectural/Engineering firm, construction management (CM) services through the industrial partnership, and construction by a General Contractor (GC), all led by the M&O Contractor integrated project team, may provide the best construction delivery method and the lowest risk. In addition, the M&O Contractor's standard procurement practice is to use firm fixed-priced contracts and the M&O Contractor has extensive experience in project management, construction management, and environmental, safety, and health (ES&H) management systems in the acquisition of scientific facilities.

15-SC-77 Photon Science Laboratory Building
SLAC National Accelerator Laboratory, Menlo Park, California
Project is for Design and Construction

1. Significant Changes and Summary

Significant Changes

When this project was proposed for initial funding in the FY 2015 budget request, the scope was to construct a DOE-owned facility that would provide a portion of the space that would eventually be needed on-site to support the increase in photon science users on campus. Since that time, Stanford University has initiated design and construction of a larger facility shell that will be built with University funds. This presents the Department with an opportunity to build out space in that facility for SLAC use, rather than build a new, DOE-owned facility. Because of space efficiencies (shared elevators, hallways, mechanical closets, etc.) gained in constructing one building versus two, the Office of Science (SC) will gain approximately 30% more square footage of useable space for the same investment ($55M Total Project Cost) as could be acquired under the original project proposal. Therefore, this project is re-scoped to fund the build-out of specialized photon science laboratories and related infrastructure in a portion of the Stanford University. This strategic approach allows DOE/SLAC to maximize the science capability by leveraging the Stanford University investment.

Briefings to Congressional Staff were conducted prior to the FY 2015 Appropriations. The purpose of the briefings was to ensure that all parties were aware and accepting of the re-scoped project and the benefits derived by fitting out a building donated to and owned by Stanford University.

Summary

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-0, *Approve Mission Need*, which was approved April 18, 2011. The preliminary Total Estimated Cost (TEC) range for the DOE funded portion of this project is $47,500,000 to $55,000,000. The estimated preliminary Total Project Cost (TPC) range for the DOE funded portion of this project is $49,500,000 to $57,000,000.

A Federal Project Director with the appropriate certification level has been assigned to this project and has approved this CPDS.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4
FY 2015	4/18/2011	N/A	1Q FY 2015	4Q 2015[a]	1Q FY 2017	3Q FY 2016[a]	N/A	1Q FY 2019[a]
FY 2016	4/18/2011	3Q FY 2015	3Q FY 2015	1Q 2016[a]	3Q FY 2016	3Q FY 2016[a]	N/A[b]	2Q FY 2018[a]

CD-0 – Approve Mission Need
CD-1– Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of Balance of Construction Activities
CD-4 – Approve Start of Operations or Project Closeout

[a] This project is pre-CD-2 and schedule estimates are preliminary.
[b] The project is not building additional space; therefore, D&D is not applicable.

	Performance Baseline Validation
FY 2015	N/A
FY 2016	4Q FY 2016[a]

3. Project Cost History

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC[b] Except D&D	OPC, D&D	OPC, Total	TPC
FY 2015	4,000	51,000[c]	55,000	2,000	0	2,000[c]	57,000[c]
FY 2016	6,000	49,000[c]	55,000	2,000	0	2,000[c]	57,000[c]

4. Project Scope and Justification

Scope

To accommodate the growth in research program that has occurred since 2011 and has accelerated in the last few years, modern laboratory/office space is needed above and beyond the existing campus space for a range of simulation, theory and modeling, synthetic and characterization capabilities. The lab/office space will also support research collaborations with outside scientists engaged with SLAC's Linac Coherent Light Source (LCLS) and Stanford Synchrotron Radiation Lightsource (SSRL) user facilities. Upon construction of the shell by the Stanford University, the PSLB project will prepare a large portion of the shell's interior for SLAC use. Utilities and services (e.g., elevators, stairways, building-wide mechanical/electrical/plumbing equipment) for the entire building and framing and furnishing up to 75,000 GSF will be provided. The fit out will be designed and constructed in order to operate a complete and usable facility. The government will maximize the use of appropriated funds by 30% as compared to the concept envisioned at CD-0. These alternatives and the life cycle cost analysis will be studied at CD-1.

Alternatives will be evaluated prior to CD-1 during acquisition strategy development. Preliminary project Key Performance Parameters are as follows:

Description	Threshold Value (Minimum)	Objective Value (Maximum)
Laboratory building interior fit out	60,000 gross square feet	75,000 gross square feet

Justification

Fit out by the Office of Science of the Photon Science Laboratory Building is needed to provide centralized modern laboratory and office space with the necessary performance capabilities and accommodate growth in the existing photon science program. The Photon Science Laboratory Building would leverage the capabilities of two of the country's world-class light sources, LCLS and SSRL, as well as the Photon Ultrafast Laser Science and Engineering (PULSE) and Stanford Institute for Materials and Energy Sciences (SIMES) photon institutes. Without modern facilities suitable for collocated and coordinated

[a] This project is pre-CD-2 and schedule estimates are preliminary.
[b] Other Project Costs (OPC) are funded through laboratory overhead.
[c] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC cost range for this project is $47,500,000 to $55,000,000. The preliminary TPC cost range for this project is $49,500,000 to $57,000,000.

functionality, the laboratory's ability to successfully address and deliver on the long term strategic mission of the laboratory will be limited.

SLAC is an Office of Science (SC) laboratory that supports a large national and international community of scientific users performing cutting-edge research in support of the Department of Energy mission. SLAC was built in 1962 to perform research in accelerator-based particle physics. Expansion and upgrade of the SSRL and the LCLS located at SLAC are producing rapid increases to photon science facility use, thereby increasing the need for space to accommodate the new and expanded research program.

FY 2015 funds will be used for preliminary and final design, and project management and support activities. FY 2016 funds will be used for construction and project management and support activities.

The project has an exemption from the project management requirements in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets; however, the project is being conducted in accordance with the project management requirements in DOE O 413.3B, and all appropriate project management requirements have been met.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2015	6,000	6,000	3,500
FY 2016	0	0	2,000
FY 2017	0	0	500
Total, Design	6,000	6,000	6,000
Construction			
FY 2015	4,000	4,000	0
FY 2016	25,000	25,000	12,500
FY 2017	20,000	20,000	34,500
FY 2018	0	0	2,000
FY 2019	0	0	0
Total, Construction	49,000	49,000	49,000

(dollars in thousands)	Appropriations	Obligations	Costs
TEC			
FY 2015	10,000	10,000	3,500
FY 2016	25,000	25,000	14,500
FY 2017	20,000	20,000	35,000
FY 2018	0	0	2,000
Total, TEC[a]	55,000	55,000	55,000
Other Project Cost (OPC)[b]			
OPC except D&D			
FY 2014	671	671	671
FY 2015	100	100	100
FY 2016	492	492	492
FY 2017	737	737	737
Total, OPC except D&D	2,000	2,000	2,000
Total Project Cost (TPC)			
FY 2014	671	671	671
FY 2015	10,100	10,100	3,600
FY 2016	25,492	25,492	14,992
FY 2017	20,737	20,737	35,737
FY 2018	0	0	2,000
Total, TPC[a]	57,000	57,000	57,000

[a] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC cost range for this project is $47,500,000 to $55,000,000. The preliminary TPC cost range for this project is $49,500,000 to $57,000,000.

[b] Other Project Costs are funded through laboratory overhead.

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	5,000	3,300	N/A
Contingency	1,000	700	N/A
Total, Design	6,000	4,000	N/A
Construction			
Construction	40,500	42,500	N/A
Contingency	8,500	8,500	N/A
Total, Construction	49,000	51,000	N/A
Total, TEC[a]	55,000	55,000	N/A
Contingency, TEC	9,500	9,200	N/A
Other Project Cost (OPC)[b]			
OPC except D&D			
Conceptual Design	1,200	1,200	N/A
Start-Up	450	450	N/A
Contingency	350	350	N/A
Total, OPC	2,000	2,000	N/A
Contingency, OPC	350	350	N/A
Total, TPC[a]	57,000	57,000	N/A
Total, Contingency	9,850	9,550	N/A

[a] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC cost range for this project is $47,500,000 to $55,000,000. The preliminary TPC cost range for this project is $49,500,000 to $57,000,000.
[b] Other Project Costs (OPC) are funded through laboratory overhead.

7. Schedule of Appropriation Requests

($K)

Request Year		FY 2014	FY 2015	FY 2016	FY 2017	Total
FY 2015	TEC	0	12,890	25,770	16,340	55,000[a]
	OPC[b]	1,341	0	200	459	2,000
	TPC	1,341	12,890	25,970	16,799	57,000[a]
FY 2016	TEC	0	10,000	25,000	20,000	55,000[a]
	OPC[b]	671	100	492	737	2,000
	TPC	671	10,100	25,492	20,737	57,000[a]

8. Related Operations and Maintenance Funding Requirements

Start of Construction or Beneficial Occupancy (fiscal quarter and year)	3Q FY 2018
Expected Useful Life (number of years)	50
Expected Future Start of D&D of this capital asset (fiscal quarter and year)	3Q FY 2068

(Related Funding requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations	240	240	12,000	12,000
Maintenance	460	460	23,000	23,000
Total, Operations & Maintenance[c]	700	700	35,000	35,000

9. D&D Information

	Square Feet
New area being constructed by this project at *SLAC National Accelerator Laboratory* ..	N/A
Area of D&D in this project at *SLAC National Accelerator Laboratory*	N/A
Area at *SLAC National Accelerator Laboratory* to be transferred, sold, and/or D&D outside the project including area previously "banked"	N/A

[a] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC cost range for this project is $47,500,000 to $55,000,000. The preliminary TPC cost range for this project is $49,500,000 to $57,000,000.
[b] Other Project Costs (OPC) are funded through laboratory overhead.
[c] This project does not have CD-1 approval; the O&M funding requirements have been based on parametric comparison of similar Argonne new building construction. Actual O&M funding requirements will be developed at CD-1.

	Square Feet
Area of D&D in this project at other sites..	N/A
Area at other sites to be transferred, sold, and/or D&D outside the project including area previously "banked"	N/A
Total area eliminated	N/A

SLAC National Accelerator Laboratory net banked square footage for future one-for-one offset as reported in FIMS stands at 263,000 SF. Since there will not be construction of any additional space in this project, the one-for-one offset is not applicable.

10. Acquisition Approach

Acquisition for this project will be performed by the SLAC Management and Operating (M&O) contractor, Stanford University. The M&O contractor is responsible for awarding and managing all subcontracts related to this project. The M&O contractor will evaluate various acquisition alternatives and project delivery methods prior to achieving CD-1. Potential acquisition and project delivery methods include, but are not limited to, firm fixed price contracts for design-bid-build and design-build. The M&O contractor will also evaluate potential benefits of using a single or multiple contracts to procure materials, equipment, construction, commissioning and other project scope elements. Project performance metrics for SLAC will be included in the M&O contractor's annual performance and evaluation measurement plan.

15-SC-78, Integrative Genomics Building
Lawrence Berkeley National Laboratory (LBNL), Berkeley, California
Project is for Design and Construction

1. Significant Changes and Summary

Significant Changes

This Construction Project Data Sheet (CPDS) is an update of the FY 2015 CPDS and does not include a new start for the budget year.

Summary

The first DOE O 413.3B Critical Decision (CD) is CD-0, Approve Mission Need*,* was approved on September 17, 2013. The preliminary Total Estimated Cost (TEC) range for this project is $84,900,000 to $90,000,000. The preliminary Total Project Cost (TPC) range for this project is $86,400,000 to $91,500,000.

A Federal Project Director with the appropriate certification level has been assigned to this project and has approved this CPDS.

The revised tailoring of CDs no longer reflects Phases A and B but only start of construction under CD-3.

The budgeted amount for PED funds in FY 2015 is reduced by $2,500,000 to $9,590,000 to reflect a slightly less conservative cost estimate for preliminary and final design.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	CD-3B	D&D Complete	CD-4
FY 2015	9/17/2013	N/A	1Q FY 2015[a]	3Q FY 2016[a]	4Q FY 2016[a]	3Q FY 2016[a]	1Q FY 2017[a]	N/A	1Q FY 2021[a]
FY 2016	9/17/2013	1Q FY 2015	2Q FY 2015[a]	2Q FY 2016[a]	3Q FY 2016[a]	4Q FY 2016[a]	N/A	N/A	1Q FY 2021[a]

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3– Approve Start of Construction
CD-4 – Approve Project Completion

[a] This project is pre-CD-2, and the schedule is preliminary. Construction funds will not be executed without appropriate CD approvals.

	Performance Baseline Validation[a]
FY 2015	N/A
FY 2016	N/A

3. Project Cost History

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC[b] Except D&D	OPC, D&D	OPC, Total	TPC
FY 2015	12,090	77,910[c]	90,000[c]	1,500	0	1,500[b]	91,500[c]
FY 2016	9,590	80,410[a]	90,000[c]	1,500	0	1,500[b]	91,500[c]

4. Project Scope and Justification

Scope

This project will fill the present capability gaps by providing a state-of-the-art facility for biosciences research and other programs. Preliminary tailoring of project scope includes an initial site preparation (Phase A) and main building construction (Phase B) which will be determined at CD-2. Additional supporting functions such as utilities or site modifications may be included in the project, if they are deemed necessary.

This project has not yet received CD-1 approval; therefore Key Performance Parameters (KPPs) are to be determined. The table below outlines preliminary KPPs.

Key Performance Parameters (Preliminary)

Description	Threshold Value (Minimum)	Objective Value (Maximum)
Biosciences and other research space	75,000 gross square feet	95,000 gross square feet

Justification

The mission need of this project is to increase the synergy and efficiency of biosciences and other research at Lawrence Berkeley National Laboratory (LBNL). LBNL has grown from a pioneering particle and nuclear physics laboratory into a multidisciplinary research facility with broad capabilities in physical, chemical, computational, biological, and environmental systems research in support of the Department of Energy (DOE) mission. Portions of the biosciences program at LBNL are located off-site, away from the main laboratory, and dispersed across several locations approximately twenty miles apart. This arrangement has produced research and operational capability gaps that limit scientific progress, in genomics-based biology related to energy and the environment.

[a] This project is pre-CD-2, and the schedule is preliminary. Construction funds will not be executed without appropriate CD approvals.
[b] Other project costs (OPC) are funded through laboratory overhead.
[c] This project has not received CD-2 approval; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC range for this project is $84,900,000 to $90,000,000. The preliminary TPC range for this project is $86,400,000 to $91,500,000.

FY 2015 funds will be used for preliminary and final design, project management and support activities, and construction. FY 2016 funds will be used for construction and project management and support activities.

The project has an exemption from the project management requirements in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets; however, the project is being conducted in accordance with the project management requirements in DOE O 413.3B, and all appropriate project management requirements have been met.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
Design			
FY 2015	9,590	9,590	4,795
FY 2016	0	0	4,795
Total, Design	9,590	9,590	9,590
Construction			
FY 2015	2,500	2,500	0
FY 2016	20,000	20,000	4,000
FY 2017	25,064	25,064	16,410
FY 2018	32,846	32,846	24,000
FY 2019	0	0	24,000
FY 2020	0	0	12,000
Total, Construction	80,410	80,410	80,410
TEC			
FY 2015	12,090	12,090	4,795
FY 2016	20,000	20,000	8,795
FY 2017	25,064	25,064	16,410
FY 2018	32,846	32,846	24,000
FY 2019	0	0	24,000
FY 2020	0	0	12,000
Total, TEC[a]	90,000	90,000	90,000

[a] This project has not received approval of CD-2; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC range is $84,900,000 to $90,000,000. The preliminary TPC range is $86,400,000 to $91,500,000.

(dollars in thousands)

	Appropriations	Obligations	Costs
Other Project Cost (OPC)[a]			
OPC except D&D			
FY 2014	1,500	1,500	1,145
FY 2015	0	0	355
Total, OPC	1,500	1,500	1,500
Total Project Cost (TPC)			
FY 2014	1,500	1,500	1,145
FY 2015	12,090	12,090	5,150
FY 2016	20,000	20,000	8,795
FY 2017	25,064	25,064	16,410
FY 2018	32,846	32,846	24,000
FY 2019	0	0	24,000
FY 2020	0	0	12,000
Total, TPC[a]	91,500	91,500	91,500

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design			
Design	8,590	10,590	N/A
Contingency	1,000	1,500	N/A
Total, Design	9,590	12,090	N/A

[a] Other Project Costs (OPC) are funded through laboratory overhead.

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Construction			
Construction	68,210	61,410	N/A
Contingency	12,200	16,500	N/A
Total, Construction	80,410	77,910	N/A
Total, TEC[a]	90,000	90,000	N/A
Contingency, TEC	13,200	18,000	N/A
Other Project Cost (OPC)[b]			
OPC except D&D			
Conceptual Planning	400	400	N/A
Conceptual Design	1,000	500	N/A
Startup	0	200	N/A
Contingency	100	400	N/A
Total, OPC	1,500	1,500	N/A
Contingency, OPC	100	400	N/A
Total, TPC[a]	91,500	91,500	N/A
Total, Contingency	13,300	18,400	N/A

7. Schedule of Appropriation Requests

($K)

Request Year		FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	Total
FY 2015	TEC	0	12,090	17,299	30,148	30,463	0	90,000[a]
	OPC[b]	1,300	0	0	0	0	200	1,500
	TPC	1,300	12,090	17,299	30,148	30,463	200	91,500[a]

[a] This project has not received approval of CD-2; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC range is $84,900,000 to $90,000,000. The preliminary TPC range is $86,400,000 to $91,500,000.
[b] Other Project Costs (OPC) are funded through laboratory overhead.

Request Year		FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	Total
				($K)				
FY 2016	TEC	0	12,090	20,000	25,064	32,846	0	90,000[a]
	OPC[b]	1,500	0	0	0	0	0	1,500
	TPC	1,500	12,290	20,000	25,064	32,846	0	91,500[a]

8. Related Operations and Maintenance Funding Requirements

Not Applicable

9. D&D Information

The new area that will be constructed in this project will not replace existing facilities.

	Square Feet
New area being constructed by this project at *Lawrence Berkeley National Laboratory*	75,000 to 95,000
Area of D&D in this project at *Lawrence Berkeley National Laboratory*	None
Area at *Lawrence Berkeley National Laboratory* to be transferred, sold, and/or D&D outside the project including area previously "banked"	75,000 to 95,000
Area of D&D in this project at other sites	None
Area at other sites to be transferred, sold, and/or D&D outside the project including area previously "banked"	None
Total area eliminated	None

Lawrence Berkeley National Laboratory will comply via space previously "banked." Lawrence Berkeley National Laboratory net banked square footage for future one-for-one offset as reported in the last FIMS update of September 26, 2013 stands at 165,000 SF.

10. Acquisition Approach

Acquisition for this project will be performed by the LBNL Management and Operating (M&O) contractor, University of California. The M&O contractor is responsible for awarding and managing all subcontracts related to this project. The M&O contractor will evaluate various acquisition alternatives and project delivery methods prior to achieving CD-1. Potential acquisition and project delivery methods include, but are not limited to, firm fixed price contracts for design-bid-build and design-build. The M&O contractor will also evaluate potential benefits of using a single or multiple contracts to procure materials, equipment, construction, commissioning and other project scope elements. Project performance metrics for LBNL will be included in the M&O contractor's annual performance and evaluation measurement plan.

[a] This project has not received approval of CD-2; funding estimates are consistent with the high end of the preliminary cost ranges. The preliminary TEC range is $84,900,000 to $90,000,000. The preliminary TPC range is $86,400,000 to $91,500,000.
[b] Other Project Costs (OPC) are funded through laboratory overhead.

Safeguards and Security

Overview

The Office of Science (SC) Safeguards and Security (S&S) program is designed to ensure appropriate security measures are in place to support the SC mission requirement of open scientific research and to protect critical assets within SC laboratories. This is accomplished by providing physical controls that will mitigate possible risks to the laboratories' employees, nuclear and special materials, classified and sensitive information, and facilities. The SC S&S program also provides funding for cyber security for the laboratories' information technology systems to protect electronic data while enabling the SC mission.

Highlights of the FY 2016 Budget Request

Ensuring adequate security for the special nuclear material housed in Building 3019 at the Oak Ridge National Laboratory (ORNL) is the highest priority for the SC S&S Program, and SC is proactive in evaluating and improving security at that facility. Security reviews conducted at Building 3019 since the 2012 security breach at the Y-12 complex have concluded that the materials housed there are properly protected; however, they also highlighted opportunities for improvement, which are currently being implemented. These improvements include clarification of roles and responsibilities, delegation of local Officially Designated Federal Security Authorities, formation of a corrective action team led by a member of SC senior leadership, enhancement of physical security systems, improvement of governance documentation, establishment of a comprehensive S&S Survey Program, and coordination with the DOE Ombudsman to improve the local security culture. The FY 2016 request includes funding to continue providing security at this important facility.

The FY 2016 request also includes an increase in cyber security investments. A review of the SC Cyber Security program was conducted to ensure the full scope of cyber security needs at each laboratory was being captured. The review determined that an increased level of funding was needed. This increase will ensure the Cyber Security Program has the funds needed to defend against cyber security compromises, minimize future losses of protected information, and detect repeated attempts to access information technology assets critical to support the SC mission.

Within the FY 2016 OMB Budget Request, S&S supports the Cyber Security Departmental Crosscut. DOE is engaged in three categories of cyber-related activities: protecting the DOE enterprise from a range of cyber threats that can adversely impact mission capabilities; bolstering the U.S. Government's capabilities to address cyber threats; 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 for incident response and the implementation of Department-wide Identity Credential and Access Management.

FY 2016 Crosscuts ($K)

	Cyber Security	Total
Safeguards and Security	33,156[a]	33,156

[a] Cybersecurity amount includes $6,086,000 for CyberOne through the Working Capital Fund (WCF).

The Department is continuing its strategy for managing enterprise-wide cyber-security and identity authentication for DOE IT systems, referred to as “CyberOne.” The CyberOne strategy provides improved Department-wide capabilities for incident management and logical access to federal IT systems. SC continues support of this Department-wide investment at the FY 2015 level. DOE’s cybersecurity policy establishes line management accountability for ensuring protection of information and information systems through senior DOE management, including the Department’s Under Secretaries. Departmental elements will provide sufficient direct funding to (or contractually direct) DOE labs and sites to implement cybersecurity, site-specific incident response capabilities, and the Department’s risk management approach.

Description

The S&S program is organized into seven functional areas: Protective Forces, Security Systems, Information Security, Cyber Security, Personnel Security, Material Control and Accountability, and Program Management.

<u>Protective Forces</u>

The Protective Forces element supports security officers, access control officers, and security policy officers assigned to protect S&S interests, along with their related equipment and training. Activities within this element include access control and security response operations as well as physical protection of the Department’s critical assets and SC facilities. The Protective Forces mission includes providing effective response to emergency situations, random prohibited article inspections, security alarm monitoring, and performance testing of the protective force response to various event scenarios.

<u>Security Systems</u>

The Security Systems element provides physical protection of Departmental personnel, material, equipment, property, and facilities, and includes fences, barriers, lighting, sensors, surveillance devices, entry control devices, access control systems, and power systems operated and used to support the protection of DOE property, classified information, and other interests of national security.

<u>Information Security</u>

The Information Security element provides support to ensure that sensitive and classified information is accurately, appropriately, and consistently identified, reviewed, marked, protected, transmitted, stored, and ultimately destroyed. Specific activities within this element include management, planning, training, and oversight for maintaining security containers and combinations, marking documents, and administration of control systems, operations security, special access programs, technical surveillance countermeasures, and classification and declassification determinations.

<u>Cyber Security</u>

The Cyber Security element provides appropriate staffing levels, risk management tools, training, and security controls to protect the sensitive and classified data electronically processed, transmitted, or stored on SC IT systems. This element provides site-specific security as well as enterprise-wide security through CyberOne. Risk management controls ensure that IT systems, including the data contained within these systems, maintain confidentiality, integrity, and availability in a manner consistent with the SC mission and federal requirements.

<u>Personnel Security</u>

The Personnel Security element encompasses the processes for employee suitability and security clearance determinations at each site to ensure that individuals are trustworthy and eligible for access to classified information or matter. This element also includes the management of security clearance programs, adjudications, security education, and awareness programs for Federal and contractor employees, and processing and hosting approved foreign visitors.

<u>Material Control and Accountability (MC&A)</u>

The MC&A element provides assurance that Departmental materials are properly controlled and accounted for at all times. This element supports administration, including testing performance and assessing the levels of protection, control, and accountability required for the types and quantities of materials at each facility; documenting facility plans for materials control and accountability; assigning authorities and responsibilities for MC&A functions; and establishing programs to detect and report occurrences such as material theft, the loss of control or inability to account for materials, or evidence of malevolent acts.

Program Management

The Program Management element coordinates the management of Protective Forces, Security Systems, Information Security, Personnel Security, Cyber Security, and MC&A to achieve and ensure appropriate levels of protections are in place.

Safeguards and Security Funding
($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Protective Forces	38,502	38,502	38,095	38,805	+710
Security Systems	13,580	13,580	12,601	12,019	-582
Information Security	4,407	4,407	4,252	4,416	+164
Cyber Security	16,074	16,074	24,118[a]	33,156[a]	+9,038
Personnel Security	5,416	5,416	5,267	5,412	+145
Material Control and Accountability	2,522	2,522	2,223	2,454	+231
Program Management	6,499	6,499	6,444	6,738	+294
Total, Safeguards and Security	**87,000**	**87,000**	**93,000**	**103,000**	**+10,000**

[a] Cybersecurity amount includes $7,351,000 in FY 2015 and $6,086,000 in FY 2016 for CyberOne through the Working Capital Fund (WCF).

Safeguards and Security

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Protective Forces $38,095,000	**$38,805,000**	**+$710,000**
Provides funding to maintain protection levels, equipment, and training needed to ensure proper protection and effective performance at all SC laboratories.	The FY 2016 Request will provide funding to support contracts that must adhere to cost of living adjustments required by collective bargaining agreements and to also maintain proper protection levels, equipment, and technical training needed to ensure effective performance at all SC laboratories.	The increase for protective forces across 12 sites and facilities is indicative of sustained levels of operations.
Security Systems $12,601,000	**$12,019,000**	**-$582,000**
Provides funding to maintain the security systems currently in place and to support investments in SC laboratory physical security systems. .	The FY 2016 Request will provide funding to properly maintain security systems and to support modest investments in upgrades to SC physical security monitoring, detection and access control systems.	The decrease reflects completion of prior year physical security upgrades.
Information Security $4,252,000	**$4,416,000**	**+$164,000**
Provides funding for personnel, equipment, and systems necessary to ensure sensitive and classified information is properly safeguarded at SC laboratories.	The FY 2016 Request will provide funding for personnel, equipment, and systems necessary to ensure sensitive and classified information is properly safeguarded at SC laboratories.	The increase for the SC-wide information security program across 12 sites and facilities is indicative of sustained levels of operations.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Cyber Security $24,118,000	**$33,156,000**	**+$9,038,000**
Maintains proper protection of SC laboratory computer resources and data and also supports SC's contribution of the Department's CyberOne strategy, which is managed through the Working Capital Fund. CyberOne is the Department's solution for managing enterprise-wide identity management and cyber-security for DOE systems and data. CyberOne will consolidate and streamline Department-wide systems and business processes to mitigate the risk of intrusion and the threat such intrusions pose to high-valued national assets. CyberOne will integrate various tools at headquarters and across the DOE complex to secure both data transmission and data repositories at these diverse sites.	The FY 2016 request will support proper protection of the SC laboratories' computer resources and sensitive data. A review of the SC Cyber Security program was conducted to ensure the full scope of cyber security needs at each laboratory was being captured. The review determined that, in order to properly protect each SC laboratory from cyber threats, increased funding for the program was needed. In FY 2016, Cyber Security will also continue to support the Department's CyberOne strategy.	The increase supports the full scope of Cyber Security tools, licenses, and FTE requirements across 12 sites and facilities.
Personnel Security $5,267,000	**$5,412,000**	**+$145,000**
Maintains Personnel Security efforts at SC laboratories.	FY 2016 funding will maintain Personnel Security efforts at SC laboratories.	Funding increases slightly in response to increased requests across all sites for required personnel security investigations and increased visitor control activities at SC sites and facilities.
Material Control and Accountability $2,223,000	**$2,454,000**	**+$231,000**
Maintains proper protection of material at SC laboratories.	Funding in FY 2016 will maintain proper protection of material at SC laboratories and supports required staffing levels needed to ensure the sites' baseline levels of MC&A operations can be achieved.	The increase is to accommodate required staffing level needs to ensure proper levels of MC&A operations can be achieved.
Program Management $6,444,000	**$6,738,000**	**+$294,000**
Provides funding for the oversight, administration, and planning for security programs at SC laboratories and to ensure security procedures and policy support SC Research missions.	The FY 2016 Request will provide funding for the oversight, administration, and planning for security programs at SC laboratories and to ensure security procedures and policy support SC Research missions.	The increase is indicative of sustained levels of operations.

Estimates of Cost Recovered for Safeguards and Security Activities ($K)

In addition to the direct funding received from the Safeguards and Security Program, sites recover Safeguards and Security costs related to Work for Others (WFO) activities from WFO customers, including the cost of any unique security needs directly attributable to the customer. Estimates of those costs are shown below.

	FY 2014 Planned Costs	FY 2015 Enacted Costs	FY 2015 Planned Costs	FY 2016 Planned Costs	FY 2016 vs. FY 2015
Ames National Laboratory	80	80	80	80	0
Argonne National Laboratory	1,470	1,100	1,100	1,100	0
Brookhaven National Laboratory	800	800	800	800	0
Lawrence Berkeley National Laboratory	733	733	733	733	0
Oak Ridge Institute for Science and Education	595	595	595	595	0
Oak Ridge National Laboratory	4,500	4,500	4,500	4,500	0
Pacific Northwest National Laboratory	4,800	4,633	4,633	4,204	-429
Princeton Plasma Physics Laboratory	50	50	50	40	-10
SLAC National Accelerator Laboratory	69	76	76	76	0
Total, Security Cost Recovered	13,097	12,567	12,567	12,128	-439

Program Direction

Overview

The Office of Science (SC) Program Direction (PD) supports a skilled Federal workforce to develop and oversee SC investments in world-leading research and scientific user facilities. SC investments deliver scientific discoveries and major scientific tools that transform our understanding of nature and advance the energy, economic, and national security of the United States. In addition, SC provides public access to DOE scientific findings to further leverage the Federal science investment and advance the scientific enterprise.

SC requires highly skilled scientific and technical program and project managers, as well as experts in areas such as acquisition, finance, legal, construction and infrastructure management, human resources, and environmental, safety, and health oversight. SC plans, executes, and manages science programs that address critical national needs. Overcoming national challenges in energy, environmental stewardship, and nuclear security, as well as enabling continued U.S. innovation and scientific competitiveness, requires transformational basic research. Oversight of DOE's basic research portfolio, which includes grants and contracts supporting nearly 22,000 researchers located at 300 universities and 17 national laboratories, as well as supervision of major construction projects, is a Federal responsibility. SC also enables world-leading research by providing and maintaining state-of-the-art scientific user facilities—the large machines of modern science—supporting nearly 31,000 users. These facilities offer unique capabilities and place U.S. researchers and industries at the forefront of science, technology, and innovation.

<u>Headquarters (HQ):</u>

SC HQ Federal staff provide program execution and program oversight, and policy, strategy, and resource management for the SC enterprise. The following activities are performed:

- Create and maintain a balanced research portfolio that includes high-risk, high-reward research to achieve mission goals and objectives.
- Conduct scientific program and research infrastructure planning, execution, and management across a broad spectrum of scientific disciplines and program offices; directly engage the scientific community to identify research opportunities and to communicate priorities.
- Assure rigorous external merit review of research proposals, selection of appropriate peer review experts, development of award recommendations informed by peer review, and regular evaluation of research programs. Each year, SC typically receives between 5,000 and 6,000 new and renewal proposals that require peer review, and manages over 6,000 laboratory, university, non-profit, and private industry research awards already in progress.
- Provide oversight and management of all SC user facilities and other current research infrastructure investments.
- Provide oversight and management of all line item and other construction projects.
- Provide oversight and management of the maintenance and operational integrity of the ten SC national laboratories.
- Provide policy, strategy, and resource management in the areas of information technology, grants and contracts, budget, and human capital.
- Respond to information requests from Congress, the Executive Office of the President, other executive branch offices, and the public.

<u>Site Offices:</u>

SC Site Office Federal staff maintain the business and management infrastructure required to support the scientific mission at 10 SC national laboratories. This includes conducting day-to-day business transactions of contract management activities, approvals to operate hazardous facilities, safety and security oversight, leases, property transfers, sub-contracts, and activity approvals required by laws, regulations, and DOE policy. As part of this, the Site Offices:

- Maintain a comprehensive contract management program to assure contractual mechanisms are managed effectively and consistently with guidelines and regulations, supporting over $3 billion per year of SC mission work performed by contractors at 10 SC national laboratories.
- Evaluate complex integrated laboratory activities including nuclear, radiological, and other complex hazards.

- Provide Federal project directors to facilitate execution of line item and other construction projects.

Integrated Support Center (ISC):

The ISC, located at the Chicago and Oak Ridge Offices, provides the business infrastructure to support the SC enterprise. These functions include legal and technical support; financial management; grant and contract processing; safety, security, and health management; labor relations, intellectual property and patent management; environmental compliance; facility infrastructure operations and maintenance; and information systems development and support. As part of this, the ISC:

- Manages the multi-appropriation, multi-program allotments for all SC national laboratories through administration of laboratory Management and Operating (M&O) contracts and is responsible for over 90% of SC funds awarded to laboratories and universities.
- Provides support to SC and other DOE programs for solicitations and funding opportunity announcements, as well as the negotiation, award, administration, and closeout of contracts and financial assistance awards using certified contracting officers and professional acquisition staff.

Office of Scientific and Technical Information (OSTI):

OSTI fulfills the Department's responsibilities for public access to the unclassified results of its research investments, as well as the collection and secured access to DOE's classified and sensitive scientific and technical information. In addition to ensuring long-term preservation, OSTI develops and maintains publicly-accessible web products offering access to technical reports, conference papers, patents, accepted manuscripts, videos, and datasets produced through the research of DOE's national laboratories and grantees. DOE researchers typically produce 30,000-40,000 research papers and reports annually, and OSTI's physical and electronic collections exceed 1 million research papers and reports. OSTI developed and is responsible for executing DOE's public access mandate consistent with the memorandum issued by the Office of Science and Technology Policy (OSTP) in February 2013. The DOE policy outlined in the Public Access Plan in response to the OSTP memorandum ensures that peer-reviewed publications (either accepted manuscripts or the version of record) resulting from DOE funding to grantees and laboratories will be made available to the public within 12 months from the date of publication. DOE's model is a cost-effective solution to this requirement because it leverages existing systems and processes for collecting and providing access to other forms of scientific and technical information. In FY 2015, the Advanced Scientific Computing Advisory Committee (ASCAC) will conduct a Committee of Visitors review of the OSTI program.

Highlights of the FY 2016 Budget Request

- The FY 2016 Request of $187,400,000 is an increase of $3,700,000 from the FY 2015 Enacted Appropriation and supports a total FTE level of 945.
- Consistent with Executive Order 13539, as amended December 19, 2011, the FY 2016 request supports the President's Council of Advisors on Science and Technology (PCAST), providing $855,000 for salaries and benefits for 2 FTEs, committee member travel, meeting planning support, and other related expenses.

Science Program Direction
Funding ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Washington Headquarters					
Salaries and Benefits	52,460	49,756	51,962	52,657	+695
Travel	1,766	1,666	1,866	1,775	-91
Support Services	14,450	16,735	13,472	14,651	+1,179
Other Related Expenses	14,955	14,035	15,870	15,050	-820
Total, Washington Headquarters	**83,631**	**82,192**	**83,170**	**84,133**	**+963**
Office of Scientific and Technical Information					
Salaries and Benefits	6,110	6,144	6,181	6,251	+70
Travel	76	75	78	120	+42
Support Services	1,284	1,654	1,522	1,366	-156
Other Related Expenses	961	897	1,000	855	-145
Total, Office of Scientific and Technical Information	**8,431**	**8,770**	**8,781**	**8,592**	**-189**
Field Offices					
Chicago Office					
Salaries and Benefits	22,100	22,672	22,355	22,815	+460
Travel	248	314	305	248	-57
Support Services	810	1,402	800	914	+114
Other Related Expenses	2,344	1,784	1,958	2,275	+317
Total, Chicago Office	**25,502**	**26,172**	**25,418**	**26,252**	**+834**

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Oak Ridge Office					
Salaries and Benefits	23,819	23,630	23,302	24,034	+732
Travel	324	381	300	345	+45
Support Services	2,136	2,182	1,469	1,660	+191
Other Related Expenses	3,785	4,473	3,434	4,025	+591
Total, Oak Ridge Office	**30,064**	**30,666**	**28,505**	**30,064**	**+1,559**
Ames Site Office					
Salaries and Benefits	437	400	441	450	+9
Travel	20	20	24	22	-2
Support Services	2	0	2	2	0
Total, Ames Site Office	**459**	**420**	**467**	**474**	**+7**
Argonne Site Office					
Salaries and Benefits	3,496	3,364	3,531	3,565	+34
Travel	66	82	107	80	-27
Support Services	52	73	158	165	+7
Other Related Expenses	6	0	39	21	-18
Total, Argonne Site Office	**3,620**	**3,519**	**3,835**	**3,831**	**-4**
Berkeley Site Office					
Salaries and Benefits	3,597	3,373	3,465	3,586	+121
Travel	59	50	75	59	-16
Support Services	223	459	384	361	-23
Other Related Expenses	75	45	131	87	-44
Total, Berkeley Site Office	**3,954**	**3,927**	**4,055**	**4,093**	**+38**

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Brookhaven Site Office					
Salaries and Benefits	4,290	3,985	4,329	4,368	+39
Travel	129	123	115	125	+10
Support Services	246	579	610	358	-252
Other Related Expenses	218	78	165	195	+30
Total, Brookhaven Site Office	**4,883**	**4,765**	**5,219**	**5,046**	**-173**
Fermi Site Office					
Salaries and Benefits	2,258	2,318	2,280	2,265	-15
Travel	61	50	75	75	0
Support Services	28	61	73	55	-18
Other Related Expenses	13	5	44	41	-3
Total, Fermi Site Office	**2,360**	**2,434**	**2,472**	**2,436**	**-36**
New Brunswick Laboratory					
Salaries and Benefits	4,104	3,814	3,575	3,552	-23
Travel	80	95	80	125	+45
Support Services	296	543	296	300	+4
Other Related Expenses	983	1,104	983	1,034	+51
Total, New Brunswick Laboratory	**5,463**	**5,556**	**4,934**	**5,011**	**+77**
Oak Ridge National Laboratory Site Office					
Salaries and Benefits	5,619	5,374	5,600	5,964	+364
Travel	95	71	110	100	-10
Support Services	240	312	281	461	+180
Other Related Expenses	15	15	30	30	0
Total, Oak Ridge National Laboratory Site Office	**5,969**	**5,772**	**6,021**	**6,555**	**+534**

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Pacific Northwest Site Office					
Salaries and Benefits	4,725	4,773	4,641	4,760	+119
Travel	131	123	125	133	+8
Support Services	41	43	38	48	+10
Other Related Expenses	14	67	104	83	-21
Total, Pacific Northwest Site Office	**4,911**	**5,006**	**4,908**	**5,024**	**+116**
Princeton Site Office					
Salaries and Benefits	1,450	1,476	1,505	1,510	+5
Travel	39	34	30	38	+8
Support Services	16	50	10	16	+6
Other Related Expenses	43	6	88	44	-44
Total, Princeton Site Office	**1,548**	**1,566**	**1,633**	**1,608**	**-25**
SLAC Site Office					
Salaries and Benefits	2,204	2,219	2,052	2,088	+36
Travel	50	37	59	50	-9
Support Services	40	163	138	148	+10
Other Related Expenses	33	22	57	33	-24
Total, SLAC Site Office	**2,327**	**2,441**	**2,306**	**2,319**	**+13**
Thomas Jefferson Site Office					
Salaries and Benefits	1,818	1,720	1,836	1,860	+24
Travel	48	48	50	60	+10
Support Services	6	20	49	10	-39
Other Related Expenses	6	6	41	32	-9
Total, Thomas Jefferson Site Office	**1,878**	**1,794**	**1,976**	**1,962**	**-14**

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Total Field Offices					
Salaries and Benefits	79,917	79,118	78,912	80,817	+1,905
Travel	1,350	1,428	1,455	1,460	+5
Support Services	4,136	5,887	4,308	4,498	+190
Other Related Expenses	7,535	7,605	7,074	7,900	+826
Total, Field Offices	**92,938**	**94,038**	**91,749**	**94,675**	**+2,926**
Total Program Direction					
Salaries and Benefits	138,487	135,018	137,055	139,725	+2,670
Travel	3,192	3,169	3,399	3,355	-44
Support Services	19,870	24,276	19,302	20,515	+1,213
Other Related Expenses	23,451	22,537	23,944	23,805	-139
Total, Program Direction	**185,000**	**185,000**	**183,700**	**187,400**	**+3,700**
Federal FTEs	956	929	940	945	+5
Technical Support					
Development of specifications	482	1,315	714	489	-225
System review and reliability analyses	682	222	700	732	+32
Surveys or reviews of technical operations	384	708	365	440	+75
Total, Technical Support	**1,548**	**2,245**	**1,779**	**1,661**	**-118**
Management Support					
Automated data processing	7,110	9,482	8,273	7,960	-313
Training and education	692	658	724	802	+78
Reports and analyses, management, and general administrative services	10,520	11,891	8,526	10,092	+1,566
Total, Management Support	**18,322**	**22,031**	**17,523**	**18,854**	**+1,331**
Total, Support Services	**19,870**	**24,276**	**19,302**	**20,515**	**+1,213**

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Other Related Expenses					
Rent to GSA	975	708	900	1,104	+204
Rent to others	1,679	1,914	1,556	1,893	+337
Communications, utilities, and miscellaneous	3,381	2,523	2,624	2,763	+139
Printing and reproduction	30	11	21	1	-20
Other services	1,917	254	1,834	1,361	-473
Operation and maintenance of equipment	103	340	103	143	+40
Operation and maintenance of facilities	1,029	1,933	1,044	1,333	+289
Supplies and materials	586	514	776	689	-87
Equipment	3,751	3,740	3,586	3,668	+82
Working Capital Fund	10,000	10,600	11,500	10,850	-650
Total, Other Related Expenses	**23,451**	**22,537**	**23,944**	**23,805**	**-139**

Program Direction

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Program Direction $183,700,000	**$187,400,000**	**+$3,700,000**
Salaries and Benefits $137,055,000	**$139,725,000**	**+$2,670,000**
The FY 2015 Enacted Appropriation supports 940 FTEs to perform scientific oversight, project management, essential operations support associated with science program portfolio management, and administration of PCAST. The FY 2015 appropriation allows SC to continue implementation of its succession planning strategy and allows backfill hiring for essential SC positions. Support for expenses such as increases in GS schedule pay rates, health insurance costs and retirement allocations in the Federal Employees Retirement System are included.	The FY 2016 Request will support 945 FTEs to perform scientific oversight, project management, essential operations support associated with science program portfolio management, and administration of PCAST. Support for expenses such as increases in GS schedule pay rates, health insurance costs and retirement allocations in the Federal Employees Retirement System are included.	Additional FTEs in FY 2016 are requested to fill essential SC positions that have become vacant due to retirements and other separations. Increased funding for salaries and benefits is requested based on current projections for SC's grade distribution and annual pay/step increases.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Travel $3,399,000	**$3,355,000**	**-$44,000**
Staff travel is required to ensure scientific management, compliance, safety oversight, and external review of research funding across all SC programs, since SC senior program managers are not co-located with grantees or at national laboratories. Travel is also required for facility visits where the use of electronic telecommunications is not practical for mandated on-site inspections and operations reviews. Travel is also included to support meetings of the PCAST, scheduled for six times per year with additional meetings called at the discretion of the President. PCAST is an advisory group to the President and Executive Office of the President. SC Federal Advisory Committee travel is supported, which includes over 170 representatives from universities, national laboratories, and industry, representing a diverse balance of disciplines, professional experience, and geography. Each of the six advisory committees provides valuable, independent advice to the Department regarding the complex scientific and technical issues that arise in the planning, management, and implementation of SC programs.	Staff travel is required to ensure scientific management, compliance, safety oversight, and external review of research funding across all SC programs, since SC senior program managers are not co-located with grantees or at national laboratories. Travel is also required for facility visits where the use of electronic telecommunications is not practical for mandated on-site inspections and operations reviews. Travel is included to support meetings of the PCAST, scheduled for six times per year with additional meetings called at the discretion of the President. PCAST is an advisory group to the President and Executive Office of the President. SC Federal Advisory Committee travel is supported, which includes over 170 representatives from universities, national laboratories, and industry, representing a diverse balance of disciplines, professional experience, and geography. Each of the six advisory committees provides valuable, independent advice to the Department regarding the complex scientific and technical issues that arise in the planning, management, and implementation of SC programs.	A small reduction in travel is due to budgeted travel estimates.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Support Services $19,302,000	**$20,515,000**	**+$1,213,000**
Technical expertise and business services sustain the following: maintenance, operation, and cyber security management of SC mission-specific information technology systems and infrastructure as well as SC-corporate Enterprise Architecture and Capital Planning Investment Control management; administration of the Small Business Innovation Research/Small Business Technology Transfer program; grants and contract processing and close-out activities; accessibility to DOE's corporate multi-billion dollar R&D program through information systems managed and administered by OSTI; operations and maintenance of the Searchable Field Work Proposal system to provide HQ and Field organizations a tool to search and monitor field work proposals; selected routine administrative services including travel processing and Federal staff training and education to maintain appropriate certification and update skills; select reports or analyses directed toward improving the effectiveness, efficiency, and economy of services and processes; and safeguards and security oversight functions.	Technical expertise and business services sustain the following: maintenance, operation, and cyber security management of SC mission-specific information technology systems and infrastructure as well as SC-corporate Enterprise Architecture and Capital Planning Investment Control management; administration of the Small Business Innovation Research/Small Business Technology Transfer program; grants and contract processing and close-out activities; accessibility to DOE's corporate multi-billion dollar R&D program through information systems managed and administered by OSTI; operations and maintenance of the Searchable Field Work Proposal system to provide HQ and Field organizations a tool to search and monitor field work proposals; selected routine administrative services including travel processing and Federal staff training and education to maintain appropriate certification and update skills; select reports or analyses directed toward improving the effectiveness, efficiency, and economy of services and processes; and safeguards and security oversight functions.	
The FY 2015 Enacted Appropriation funds essential information technology infrastructure and safety management support, as well as training for the SC workforce. The FY 2015 appropriation incorporates the IT Modernization Plan, which is expected to be fully implemented by the end of FY 2015. This will result in a common operating environment across SC Headquarters and Integrated Support Center (Chicago and Oak Ridge). Funding for a single consolidated IT support service contract is included.	The FY 2016 Request will fund essential information technology infrastructure, ongoing operations and maintenance of IT systems and safety management support, as well as training for the SC workforce. The FY 2016 request will continue to support the IT Modernization Plan.	Increased requirements are due to ongoing operations and maintenance of IT systems.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Other Related Expenses $23,944,000	**$23,805,000**	**-$139,000**
SC contribution to the Department's Working Capital Fund (WCF) provides for common administrative services at HQ including: rent and building operations, telecommunications, network connectivity, supplies, printing/graphics, mail, purchase card surveillance, health centers, and interagency transfers associated with E-gov initiatives. In addition to increases to support salary and benefit costs for staff administering the WCF, also included are fixed requirements in the Field Offices not funded through the WCF associated with rent, utilities, and telecommunications, building and grounds maintenance, computer/video maintenance and support, equipment leases, purchases, maintenance, and site-wide health care units. Also funded are SC-wide assessments for payroll processing and the Corporate Human Resource Information System. The FY 2015 Enacted Appropriation includes $11,500,000 to support fixed costs, rent, and other WCF requirements. WCF costs represent 48% of Other Related Expenses and is an estimate based on projected usage.	SC contribution to the Department's Working Capital Fund (WCF) provides for common administrative services at HQ including: rent and building operations, telecommunications, network connectivity, supplies, printing/graphics, mail, purchase card surveillance, health centers, and interagency transfers associated with E-gov initiatives. In addition to increases to support salary and benefit costs for staff administering the WCF, also included are fixed requirements in the Field Offices not funded through the WCF associated with rent, utilities, and telecommunications, building and grounds maintenance, computer/video maintenance and support, equipment leases, purchases, maintenance, and site-wide health care units. Also funded are SC-wide assessments for payroll processing and the Corporate Human Resource Information System. The FY 2016 Request includes $10,850,000 to support fixed costs, rent, and other WCF requirements. WCF costs represent 46% of the Other Related Expenses Request and is an estimate based on projected usage.	A small reduction in other related expenses is due to budgeted estimates.

Science
Facilities Maintenance and Repair

The Department's Facilities Maintenance and Repair activities are tied to its programmatic missions, goals, and objectives. The Facilities Maintenance and Repair activities funded by the budget and displayed below and are intended to ensure that the scientific community has the facilities required to conduct cutting edge scientific research now and in the future to meet Department of Energy goals and objectives.

Costs for Direct-Funded Maintenance and Repair (including Deferred Maintenance Reduction) ($K)

	FY 2014 Actual Cost	FY 2014 Planned Cost	FY 2015 Planned Cost	FY 2016 Planned Cost
Brookhaven National Laboratory	6,103	5,515	5,953	6,132
Fermi National Accelerator Laboratory	255	142	147	151
Notre Dame Radiation Laboratory	140	80	170	170
Oak Ridge National Laboratory	16,331	15,816	14,000	14,280
Oak Ridge Office	2,554	2,581	2,989	3,228
Office of Scientific and Technical Information	372	372	383	392
Pacific Northwest National Laboratory	2,070	2,358	0	0
SLAC National Accelerator Laboratory	3,323	3,545	2,774	2,871
Thomas Jefferson National Accelerator Facility	109	67	69	71
Total, Direct-Funded Maintenance and Repair	**31,257**	**30,476**	**26,485**	**27,295**

General purpose infrastructure includes multiprogram research laboratories, administrative and support buildings, as well as cafeterias, power plants, fire stations, utilities, roads, and other structures. Together, the SC laboratories have over 1,400 operational buildings and real property trailers, with nearly 20 million gross square feet of space.

Generally, facilities maintenance and repair expenses are funded through an indirect overhead charge. In some cases, however, a laboratory may charge maintenance directly to a specific program. One example would be when maintenance is performed in a building used only by a single program. Such direct-funded charges are not directly budgeted.

Costs for Indirect-Funded Maintenance and Repair (including Deferred Maintenance Reduction) ($K)

	FY 2014 Actual Cost	FY 2014 Planned Cost	FY 2015 Planned Cost	FY 2016 Planned Cost
Ames Laboratory	1,712	1,696	1,835	1,825
Argonne National Laboratory	50,071	43,400	46,600	47,500
Brookhaven National Laboratory	39,275	37,722	38,510	40,846
Fermi National Accelerator Laboratory	17,488	17,158	17,738	18,234
Lawrence Berkeley National Laboratory	18,164	17,000	21,859	30,948
Lawrence Livermore National Laboratory	2,828	2,828	2,885	2,943
Los Alamos National Laboratory	121	121	123	125

	FY 2014 Actual Cost	FY 2014 Planned Cost	FY 2015 Planned Cost	FY 2016 Planned Cost
Oak Ridge Institute for Science and Education	644	433	434	444
Oak Ridge National Laboratory	57,918	59,627	56,933	58,072
Oak Ridge National Laboratory facilities at Y-12	864	761	761	761
Pacific Northwest National Laboratory	2,781	1,809	4,521	4,838
Princeton Plasma Physics Laboratory	6,656	6,730	6,800	7,000
Sandia National Laboratories	2,649	2,649	2,701	2,755
SLAC National Accelerator Laboratory	7,737	8,208	8,504	9,089
Thomas Jefferson National Accelerator Facility	4,562	5,500	5,700	5,800
Total, Indirect-Funded Maintenance and Repair	**213,470**	**205,642**	**215,904**	**231,180**

Facilities maintenance and repair activities funded indirectly through overhead charges at SC laboratories are displayed. Since this funding is allocated to all work done at each laboratory, the cost of these activities is allocated to SC and other DOE organizations, as well as other Federal agencies and other entities doing work at SC laboratories. Maintenance reported to SC for non-SC laboratories is also shown. The figures are total projected expenditures across all SC laboratories.

Institutional General Plant Projects ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Argonne National Laboratory	13,090	12,458	12,140	12,247	+107
Brookhaven National Laboratory	7,740	7,159	6,739	9,655	+2,916
Lawrence Berkeley National Laboratory	6,000	2,392	3,974	4,978	+1,004
Oak Ridge National Laboratory	14,300	10,700	16,000	12,000	-4,000
Pacific Northwest National Laboratory	16,149	9,068	11,837	11,643	-194
SLAC National Accelerator Laboratory	4,344	959	7,040	6,254	-786
Total, IGPP	**61,623**	**42,736**	**57,730**	**56,777**	**-953**

Institutional General Plant Projects are construction projects that are less than $10 million and cannot be allocated to a specific program. IGPPs fulfill multi-programmatic and/or inter-disciplinary needs and are funded through site overhead. The table displays total IGPP funding across all SC laboratories by site.

Report on FY 2014 Expenditures for Maintenance and Repair

This report responds to the requirements established in Conference Report (H.Rep. 108-10) accompanying Public Law 108-7 (pages 886-887), which requires the Department of Energy to provide an annual year-end report on maintenance expenditures to the Committees on Appropriations. This report compares the actual maintenance expenditures in FY 2014 to the amount planned for FY 2014, including Congressionally directed changes.

Science

Total Costs for Maintenance and Repair ($K)

	FY 2014 Actual Costs	FY 2014 Planned Costs
Ames Laboratory	1,712	1,696
Argonne National Laboratory	50,071	43,400
Brookhaven National Laboratory	45,378	43,237
Fermi National Accelerator Laboratory	17,743	17,300
Lawrence Berkeley National Laboratory	18,164	17,000
Lawrence Livermore National Laboratory	2,828	2,828
Los Alamos National Laboratory	121	121
Notre Dame Radiation Laboratory	140	80
Oak Ridge Institute for Science and Education	644	433
Oak Ridge National Laboratory	74,249	75,443
Oak Ridge National Laboratory facilities at Y-12	864	761
Oak Ridge Office	2,554	2,581
Office of Scientific and Technical Information	372	372
Pacific Northwest National Laboratory	4,851	4,167
Princeton Plasma Physics Laboratory	6,656	6,730
Sandia National Laboratories	2,649	2,649
SLAC National Accelerator Laboratory	11,060	11,753
Thomas Jefferson National Accelerator Facility	4,671	5,567
Total, Maintenance and Repair	244,727	236,118

Science
Research and Development ($K)

	FY 2014 Current[a]	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Basic	4,013,904	4,045,611	4,166,560	+125,049
Applied	64,666	0	0	0
Subtotal, R&D	4,078,570	4,045,611	4,166,560	+125,049
Equipment	160,576	157,867	180,501	+22,634
Construction	484,578	476,687	552,702	+71,915
Total, R&D	**4,723,724**	**4,680,165**	**4,899,763**	**+219,598**

[a] Funding reflects the SBIR/STTR amounts transferred to the Office of Science.

Science
Small Business Innovative Research/Small Business Technology Transfer (SBIR/STTR) ($K)

	FY 2014 Reprogrammed/ Transferred	FY 2015 Projected	FY 2016 Request	FY 2016 vs. FY 2015 Projected
Office of Science				
Advanced Scientific Computing Research				
SBIR	13,291	15,457	18,450	+2,993
STTR	1,899	2,132	2,767	+635
Basic Energy Sciences				
SBIR	43,074	44,182	47,561	+3,379
STTR	6,153	6,094	7,134	+1,040
Biological and Environmental Research				
SBIR	16,943	17,034	18,238	+1,204
STTR	2,420	2,348	2,735	+387
Fusion Energy Sciences				
SBIR	7,719	8,906	7,743	-1,163
STTR	1,103	1,228	1,162	-66
High Energy Physics				
SBIR	18,901	18,273	18,381	+108
STTR	2,700	2,521	2,757	+236
Nuclear Physics				
SBIR	12,544	13,024	14,271	+1,247
STTR	1,792	1,796	2,141	+345
Total, Office of Science SBIR	**112,472**	**116,876**	**124,644**	**+7,768**
Total, Office of Science STTR	**16,067**	**16,119**	**18,696**	**+2,577**

	FY 2014 Reprogrammed/ Transferred	FY 2015 Projected	FY 2016 Request	FY 2016 vs. FY 2015 Projected
Other DOE				
Nuclear Energy				
SBIR	9,524	TBD	TBD	TBD
STTR	1,360	TBD	TBD	TBD
Electricity Delivery & Energy Reliability				
SBIR	2,657	TBD	TBD	TBD
STTR	380	TBD	TBD	TBD
Energy Efficiency & Renewable Energy				
SBIR	27,403	TBD	TBD	TBD
STTR	3,362	TBD	TBD	TBD
Environmental Management				
SBIR	619	TBD	TBD	TBD
STTR	88	TBD	TBD	TBD
Defense Nuclear Nonproliferation				
SBIR	6,975	TBD	TBD	TBD
STTR	997	TBD	TBD	TBD
Fossil Energy				
SBIR	9,888	TBD	TBD	TBD
STTR	1,413	TBD	TBD	TBD
Total, Other DOE SBIR	**57,066**	**TBD**	**TBD**	**TBD**
Total, Other DOE STTR	**7,600**	**TBD**	**TBD**	**TBD**
Total, DOE SBIR	**169,538**	**116,876**	**124,644**	**+7,768**
Total, DOE STTR	**23,667**	**16,119**	**18,696**	**+2,577**

Science
Safeguards and Security Crosscut ($K)

	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Protective Forces	38,502	38,095	38,805	+710
Physical Security Systems	13,580	12,601	12,019	-582
Information Security	4,407	4,252	4,416	+164
Cyber Security	16,074	24,118	33,156	+9,038
Personnel Security	5,416	5,267	5,412	+145
Material Control and Accountability	2,522	2,223	2,454	+231
Program Management	6,499	6,444	6,738	+294
Total, Safeguards and Security Crosscut	**87,000**	**93,000**	**103,000**	**+10,000**

Isotope Production and Distribution Program Fund

Overview

The Department of Energy's Isotope Program produces and sells radioactive and stable isotopes, byproducts, surplus materials, and related isotope services world-wide and operates under a revolving fund established by the 1990 Energy and Water Development Appropriations Act (Public Law 101–101), as amended by the 1995 Energy and Water Development Appropriations Act (Public Law 103–316). The combination of an annual direct appropriation and collections from isotope sales are deposited in the Isotope Production and Distribution Program Fund; both are needed to maintain the Isotope Program's viability. This revolving fund allows continuous and smooth operations of isotope production, sales, and distribution independent of the federal budget cycle and fluctuating sales revenue. An independent cost review of the fund's revenues and expenses is conducted annually.

The annual appropriation is requested as Isotope Development and Production for Research and Applications in the Office of Science Nuclear Physics program. Appropriated funds are used to maintain mission-readiness of facilities by supporting the core scientists and engineers needed to carry out the Isotope Program and the maintenance of isotope facilities to assure reliable production. In addition, the appropriation provides support for R&D activities associated with development of new production and processing techniques for isotopes, production of research isotopes, and training of new personnel in isotope production. Each site's production expenses for processing and distributing isotopes are offset by revenue generated from sales. About 80 percent of the resources in the revolving fund are used for operations, maintenance, isotope production, and R&D for new isotope production techniques, with approximately 20 percent available for process improvements, unanticipated changes in volume, and purchases of small capital equipment, such as assay equipment and shipping containers needed to ensure on-time deliveries.

The Department has supplied isotopes and related services to the Nation since the Atomic Energy Act of 1954 specified the role of the U.S. Government in isotope distribution. Substantial national and international scientific, medical, and research infrastructure relies upon the use of isotopes and is strongly dependent on the Department's products and services. Isotopes are now used for hundreds of applications that benefit society every day, such as diagnostic medical imaging, cancer therapy, smoke detectors, neutron detectors for homeland security applications, explosives detection, oil exploration, and tracers for climate-related research. For example, radioisotopes are used in the diagnosis or treatment of about one-third of all patients admitted to hospitals.[a] More than 17 million Americans undergo nuclear medicine procedures each year for a variety of conditions, including cancer, cardiovascular disease, neurological conditions, and other physiological problems.[b] Such nuclear procedures are among the safest and most effective diagnostic tests available and enhance patient care by avoiding exploratory surgery and other invasive procedures. The Isotope Program continuously assesses isotope needs to inform program direction; for example, in FY 2014, the Isotope Program organized its third annual Federal workshop to assess stakeholder requirements in order to optimize the utilization of resources and assure the greatest availability of isotopes.

Isotopes are primarily produced and processed at three facilities stewarded by the Isotope Program: the Brookhaven Linac Isotope Producer (BLIP) and associated processing labs at Brookhaven National Laboratory (BNL), the Isotope Production Facility (IPF) and associated processing labs at Los Alamos National Laboratory (LANL), and processing facilities at Oak Ridge National Laboratory (ORNL). In addition, production and distribution activities are supported at the Advanced Test Reactor (ATR) at Idaho National Laboratory, the High Flux Isotope Reactor (HFIR) at ORNL, Pacific Northwest National Laboratory, the Y-12 National Security Complex, and the Savannah River Site. IPF and BLIP provide accelerator production capabilities, while HFIR and ATR provide reactor production capability. HFIR has the highest neutron flux available for isotope production in the United States. The Isotope Program is broadening capability by including university-supported accelerator and reactor facilities used for research, education, and isotope production that can provide cost-effective and unique production

[a] http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/med-use-radioactive-materials.html
[b] http://www.snmmi.org/NewsPublications/NewsDetail.aspx?ItemNumber=9953

capabilities, including facilities at the University of Washington, Duke University, Washington University, Texas A&M University, the University of California at Davis, and the Missouri University Research Reactor. Most of these facilities reside in university medical departments.

In FY 2014, a total of $59.7 million was deposited in the revolving fund in FY 2014. This consisted of $19.4 million of direct FY 2014 appropriations from the Nuclear Physics program, plus collections of $40.3 million to recover costs related to isotope production and isotope services. Collections in FY 2014 included sales of californium-252, helium-3, selenium-75, and strontium-82. Californium-252 has a variety of industrial applications; helium-3 is used in neutron detectors for national security; selenium-75 is used as a radiography source; and strontium-82 has gained world-wide acceptance for use in heart imaging. In FY 2014, the Isotope Program served 137 customers including major pharmaceutical companies, industrial users, and researchers at hospitals, national laboratories, other Federal agencies, universities, and private companies, with the sale of 190 different radioactive and stable isotopes. Among the isotopes produced, seven were high-volume, moderately priced isotopes; the remaining were low-volume research isotopes, which are more expensive to produce. Commercial isotopes are priced to recover full cost or the market price, whichever is higher.

Program Accomplishments

Production of lead-212 to support medical research. Lead-212 and its radioactive decay product bismuth-212 are being used in research to develop pharmaceuticals for treating cancer. The approach is to use biomolecules for targeted delivery of these isotopes to cancer cells; the alpha particles generated by radioactive decay of these isotopes are highly effective in killing cancer cells while sparing nearby healthy cells due to the short distance traveled by alpha particles in vivo. Successful development of such pharmaceuticals would offer more effective treatment of cancers with fewer side effects relative to conventional therapies. Lead-212 became unavailable in June 2013 due to the termination of production by the sole U.S. supplier, so the Office of Nuclear Physics' Isotope Program established production capability at the Oak Ridge National Laboratory and now supplies lead-212 to medical researchers.

Highlights of the FY 2016 Budget Request

For FY 2016, the Department foresees moderate growth in isotope demand. Revolving fund resources will be used to support efforts to increase radioisotope production capabilities and availability, including the re-establishment of a Federal stable isotope enrichment capability as recommended by the Nuclear Science Advisory Committee. The U.S. government has not had an isotope enrichment capability since 1998. Since that time, inventories of some enriched stable isotopes have been depleted, forcing researchers to rely upon uncertain international supplies. Developing a U.S. enrichment capability at ORNL will assure the supply of enriched stable isotopes to researchers as well as assuring a domestic supply of enriched stable isotopes needed for national security applications. Investments in infrastructure and equipment will increase radioisotope production capabilities to meet demand, and include the development of higher power isotope production targets for IPF and a system to more effectively utilize the proton beam at BLIP.

Department of Energy
FY 2016 Congressional Budget Funding
By Appropriation By Site
($K)

	(dollars in thousands)		
	FY 2014 Current	**FY 2015 Approp.**	**FY 2016 Request**
Science			
Ames Laboratory			
Advanced Scientific Computing Research	96	80	80
Basic Energy Sciences	20,943	19,251	19,251
Biological and Environmental Research	338	0	0
Fusion Energy Sciences	192	0	0
Workforce Development for Teachers and Scientists	514	0	0
Safeguards and Security	993	993	1,219
Total, Ames Laboratory	**23,076**	**20,324**	**20,550**
Ames Site Office			
Program Direction	420	467	474
Argonne National Laboratory			
Advanced Scientific Computing Research	90,114	103,028	90,569
Basic Energy Sciences	229,817	233,325	240,273
Biological and Environmental Research	30,774	26,514	27,366
Fusion Energy Sciences	50	0	0
High Energy Physics	19,832	16,926	15,717
Nuclear Physics	29,782	27,489	28,778
Workforce Development for Teachers and Scientists	954	0	0
Science Laboratories Infrastructure	0	7,000	27,510
Safeguards and Security	8,858	8,858	8,858
Total, Argonne National Laboratory	**410,181**	**423,140**	**439,071**
Argonne Site Office			
Program Direction	3,519	3,835	3,831
Berkeley Site Office			
Program Direction	3,927	4,055	4,093

Brookhaven National Laboratory			
Advanced Scientific Computing Research	250	310	0
Basic Energy Sciences	231,256	180,477	187,573
Biological and Environmental Research	17,345	12,451	10,645
High Energy Physics	63,713	55,026	57,112
Nuclear Physics	182,736	181,853	192,887
Workforce Development for Teachers and Scientists	1,777	0	0
Safeguards and Security	11,959	11,959	12,151
Total, Brookhaven National Laboratory	**509,036**	**442,076**	**460,368**
Brookhaven Site Office			
Program Direction	4,765	5,219	5,046
Chicago Operations Office			
Advanced Scientific Computing Research	54,691	18,799	19,407
Basic Energy Sciences	315,047	301,734	307,303
Biological and Environmental Research	137,405	96,705	75,647
Fusion Energy Sciences	161,198	114,004	95,694
High Energy Physics	127,704	111,429	109,842
Nuclear Physics	136,018	160,178	171,291
Workforce Development for Teachers and Scientists	8,700	0	0
Science Laboratories Infrastructure	1,385	1,713	1,713
Safeguards and Security	42	44	45
Program Direction	26,172	25,418	26,252
Small Business Innovative Research	168,538	0	0
Small Business Technology Transfer Pilot Program	23,667	0	0
Total, Chicago Operations Office	**1,160,567**	**830,024**	**807,194**

Fermi National Accelerator Laboratory			
Advanced Scientific Computing Research	458	356	0
Basic Energy Sciences	45	630	0
High Energy Physics	385,930	367,549	373,783
Nuclear Physics	781	255	25
Workforce Development for Teachers and Scientists	714	0	0
Science Laboratories Infrastructure	34,900	0	9,000
Safeguards and Security	3,518	3,433	5,064
Total, Fermi National Accelerator Laboratory	**426,346**	**372,223**	**387,872**
Fermi Site Office			
Program Direction	2,434	2,472	2,436
Golden Field Office			
Workforce Development for Teachers and Scientists	670	0	0
Idaho National Engineering Laboratory			
Fusion Energy Sciences	2,790	2,610	2,700
Workforce Development for Teachers and Scientists	377	0	0
Total, Idaho National Engineering Laboratory	**3,167**	**2,610**	**2,700**
Lawrence Berkeley National Laboratory			
Advanced Scientific Computing Research	141,630	132,558	131,486
Basic Energy Sciences	158,078	147,501	151,412
Biological and Environmental Research	147,723	143,452	141,323
Fusion Energy Sciences	2,268	0	0
High Energy Physics	66,061	62,505	70,400
Nuclear Physics	19,047	17,931	19,089
Workforce Development for Teachers and Scientists	1,330	0	0
Science Laboratories Infrastructure	0	12,090	20,000
Safeguards and Security	5,658	5,658	7,085
Total, Lawrence Berkeley National Laboratory	**541,795**	**521,695**	**540,795**

Lawrence Livermore National Laboratory			
Advanced Scientific Computing Research	37,388	56,975	13,212
Basic Energy Sciences	2,968	2,964	2,964
Biological and Environmental Research	18,286	19,895	20,161
Fusion Energy Sciences	10,487	7,912	7,537
High Energy Physics	5,565	4,645	2,155
Nuclear Physics	1,440	794	798
Workforce Development for Teachers and Scientists	340	0	0
Total, Lawrence Livermore National Laboratory	**76,474**	**93,185**	**46,827**
Los Alamos National Laboratory			
Advanced Scientific Computing Research	8,778	7,380	4,746
Basic Energy Sciences	33,721	25,107	25,562
Biological and Environmental Research	24,992	25,308	23,657
Fusion Energy Sciences	3,563	2,192	1,986
High Energy Physics	3,095	2,035	1,950
Nuclear Physics	10,226	7,996	9,518
Workforce Development for Teachers and Scientists	434	0	0
Total, Los Alamos National Laboratory	**84,809**	**70,018**	**67,419**
National Energy Technology Laboratory			
Basic Energy Sciences	150	150	150
National Renewable Energy Laboratory			
Advanced Scientific Computing Research	266	266	173
Basic Energy Sciences	14,055	12,955	12,955
Biological and Environmental Research	1,029	880	785
Workforce Development for Teachers and Scientists	140	0	0
Total, National Renewable Energy Laboratory	**15,490**	**14,101**	**13,913**

Nevada Operations Office			
Advanced Scientific Computing Research	234	0	0
Basic Energy Sciences	1,066	0	0
Biological and Environmental Research	258	0	0
Fusion Energy Sciences	167	0	0
High Energy Physics	350	0	0
Nuclear Physics	239	0	0
Total, Nevada Operations Office	**2,314**	**0**	**0**
New Brunswick Laboratory			
Science Laboratories Infrastructure	900	4,900	1,200
Program Direction	5,556	4,934	5,011
Total, New Brunswick Laboratory	**6,456**	**9,834**	**6,211**
Oak Ridge Institute for Science and Education			
Advanced Scientific Computing Research	122	2,400	0
Basic Energy Sciences	2,264	250	250
Biological and Environmental Research	3,096	1,385	1,865
Fusion Energy Sciences	1,161	744	444
High Energy Physics	1,356	0	0
Nuclear Physics	786	425	792
Workforce Development for Teachers and Scientists	8,144	0	0
Science Laboratories Infrastructure	0	1,000	1,000
Safeguards and Security	1,645	1,645	1,883
Total, Oak Ridge Institute for Science and Education	**18,574**	**7,849**	**6,234**
Oak Ridge National Laboratory			
Advanced Scientific Computing Research	105,968	115,932	101,585
Basic Energy Sciences	305,034	304,839	316,747
Biological and Environmental Research	80,783	74,633	74,484
Fusion Energy Sciences	219,027	164,288	162,759
Nuclear Physics	18,914	16,938	18,541
Science Laboratories Infrastructure	0	0	12,000
Safeguards and Security	13,329	9,316	12,374
Total, Oak Ridge National Laboratory	**743,055**	**685,946**	**698,490**

Oak Ridge Operations Office			
Advanced Scientific Computing Research	29	0	225
Basic Energy Sciences	276	85	0
Biological and Environmental Research	304	0	0
Fusion Energy Sciences	50	0	0
High Energy Physics	244	0	0
Nuclear Physics	359	0	437
Science Laboratories Infrastructure	5,751	5,777	6,177
Safeguards and Security	21,659	19,282	21,017
Program Direction	30,666	28,505	30,064
Small Business Innovative Research	500	0	0
Total, Oak Ridge Operations Office	**59,838**	**53,649**	**57,920**
Office of Science and Technical Information			
Advanced Scientific Computing Research	180	276	183
Basic Energy Sciences	319	138	138
Biological and Environmental Research	379	0	205
Fusion Energy Sciences	178	138	0
High Energy Physics	211	138	124
Nuclear Physics	198	138	143
Workforce Development for Teachers and Scientists	280	0	0
Science Laboratories Infrastructure	200	200	200
Safeguards and Security	497	497	609
Program Direction	8,770	8,781	8,592
Total, Office of Science and Technical Information	**11,212**	**10,306**	**10,194**
ORNL Site Office			
Program Direction	5,772	6,021	6,555

Pacific Northwest National Laboratory			
Advanced Scientific Computing Research	6,158	6,052	4,296
Basic Energy Sciences	25,529	24,062	24,062
Biological and Environmental Research	112,324	105,504	102,257
Fusion Energy Sciences	1,735	1,313	1,313
High Energy Physics	10,119	3,045	2,450
Nuclear Physics	100	83	83
Workforce Development for Teachers and Scientists	848	0	0
Safeguards and Security	11,317	11,317	13,126
Total, Pacific Northwest National Laboratory	**168,130**	**151,376**	**147,587**
Pacific Northwest Site Office			
Program Direction	5,006	4,908	5,024
Princeton Plasma Physics Laboratory			
Advanced Scientific Computing Research	368	295	295
Basic Energy Sciences	1,300	435	435
Fusion Energy Sciences	84,246	73,435	71,562
High Energy Physics	225	200	200
Workforce Development for Teachers and Scientists	568	0	0
Science Laboratories Infrastructure	0	25,000	0
Safeguards and Security	2,407	2,407	2,477
Total, Princeton Plasma Physics Laboratory	**89,114**	**101,772**	**74,969**
Princeton Site Office			
Program Direction	1,566	1,633	1,608
Sandia National Laboratories			
Advanced Scientific Computing Research	14,398	13,074	5,906
Basic Energy Sciences	35,149	32,926	33,416
Biological and Environmental Research	8,454	9,464	8,763
Fusion Energy Sciences	2,710	2,155	1,355
Workforce Development for Teachers and Scientists	100	0	0
Total, Sandia National Laboratories	**60,811**	**57,619**	**49,440**

Savannah National Laboratory			
Basic Energy Sciences	417	417	417
Biological and Environmental Research	236	0	0
Total, Savannah National Laboratory	**653**	**417**	**417**
SLAC National Accelerator Laboratory			
Advanced Scientific Computing Research	486	357	374
Basic Energy Sciences	279,185	338,854	400,159
Biological and Environmental Research	6,725	4,725	3,900
Fusion Energy Sciences	4,168	4,250	4,750
High Energy Physics	85,889	92,356	96,512
Nuclear Physics	134	0	0
Workforce Development for Teachers and Scientists	270	0	0
Science Laboratories Infrastructure	25,482	21,920	34,800
Safeguards and Security	2,972	2,972	4,096
Total, SLAC National Accelerator Laboratory	**405,311**	**465,434**	**544,591**
SLAC Site Office			
Program Direction	2,441	2,306	2,319
Thomas Jefferson National Accelerator Facility			
Advanced Scientific Computing Research	279	279	284
Basic Energy Sciences	500	500	500
Biological and Environmental Research	455	40	0
High Energy Physics	898	50	785
Nuclear Physics	132,544	124,694	118,696
Workforce Development for Teachers and Scientists	310	0	0
Science Laboratories Infrastructure	29,200	0	0
Safeguards and Security	1,732	1,732	2,563
Total, Thomas Jefferson National Accelerator Facility	**165,918**	**127,295**	**122,828**
Thomas Jefferson Site Office			
Program Direction	1,794	1,976	1,962

Washington Headquarters			
Advanced Scientific Computing Research	1,579	82,583	248,173
Basic Energy Sciences	5,583	106,600	125,733
Biological and Environmental Research	2,704	71,044	121,342
Fusion Energy Sciences	1,865	94,459	69,900
High Energy Physics	3,728	50,096	56,970
Nuclear Physics	21,498	56,726	63,522
Workforce Development for Teachers and Scientists	30	19,500	20,500
Safeguards and Security	414	12,887	10,433
Program Direction	82,192	83,170	84,133
Small Business Innovative Research	500	0	0
Total, Washington Headquarters	**120,093**	**577,065**	**800,706**
Total, Science	**5,134,884**	**5,071,000**	**5,339,794**

Advanced Research Projects Agency-Energy

Advanced Research Projects Agency-Energy

Advanced Research Projects Agency–Energy (ARPA–E)

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Advanced Research Projects Agency - Energy
Proposed Appropriation Language

For Department of Energy expenses necessary in carrying out the activities authorized by section 5012 of the America COMPETES Act (Public Law 110-69), as amended, [$280,000,000] *$325,000,000*, to remain available until expended: Provided, That [$28,000,000] *$29,250,000* shall be available until September 30, [2016] *2017* for program direction.

Explanation of Changes

The $325,000,000 request for FY 2016 is a $45,000,000 increase over the FY 2015 enacted level. The increase in funding will enable ARPA-E to fund additional early-stage innovative programs as well as exploit the technological opportunities developed in previous ARPA-E programs, leading to transformational energy technologies.

Public Law Authorizations

P.L. 95-91, "Department of Energy Organization Act" (1977)
P.L. 109-58, "Energy Policy Act of 2005"
P.L. 110-69, "America COMPETES Act of 2007"
P.L. 111-358, "America COMPETES Reauthorization Act of 2010"

Advanced Research Projects Agency - Energy

($K)

FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request
280,000	280,000	279,982	325,000

Overview

The Advanced Research Projects Agency-Energy (ARPA-E) catalyzes and accelerates energy technologies that will enhance the economic and energy security of the United States through the development of transformational technologies that reduce imports of energy from foreign sources, increase energy efficiency, and reduce energy-related emissions, including greenhouse gas emissions. ARPA-E funds high-potential, high-impact energy projects that are too early for private sector or other Department of Energy (DOE) program office investment and could lead to entirely new ways to generate, store, and use energy.

ARPA-E focuses on energy technologies that can be meaningfully advanced with a modest investment over a defined period of time. ARPA-E's rigorous program design, close coordination with other DOE offices and federal agencies, competitive project selection process, and hands-on engagement, ensure thoughtful expenditures while empowering America's energy researchers with funding, technical assistance, and market awareness.

ARPA-E was established by the America COMPETES Act of 2007 following a recommendation by the National Academies in the *Rising above the Gathering Storm* report. As of January 2015, ARPA-E has funded over 400 projects with approximately $1.1 billion through 25 focused programs and open funding solicitations.

Highlights and Major Changes in the FY 2016 Budget Request

In FY 2016, ARPA-E expects to release funding opportunity announcements (FOA) for 7 – 10 focused technology programs. In FY 2015, ARPA-E released a third open funding opportunity announcement (OPEN 2015); however, in keeping with a multi-year cycle for OPEN solicitations (2009, 2012, and 2015), ARPA-E does not anticipate an open solicitation in FY 2016. In FY 2016, ARPA-E will continue its stand-alone Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program to provide additional support to small businesses beyond the significant number of awards that go to small businesses via ARPA-E's standard FOA process.

FY 2014 Key Accomplishments

The success of ARPA-E programs and projects will ultimately be measured by impact in the marketplace. As the projects ARPA-E funds seek to create transformational energy technologies that do not exist today and funding is for a limited duration, ARPA-E looks at various metrics to measure progress towards eventual market adoption. ARPA-E gauges success by project hand-offs, including the formation of new companies and fostering public and private partnerships to ensure projects continue to move towards the market. In FY 2014, ARPA-E saw continued traction across several key indicators, including multiple teams launching demonstration projects in partnership with public and private entities, as well as four ARPA-E funded small companies being acquired by strategic industry partners. ARPA-E awardee Sun Catalytix was purchased by Lockheed Martin becoming Lockheed Martin Advanced Energy Storage LLC, awardee SolarBridge was acquired by SunPower, awardee Empirion was acquired Altera, and awardee Allilyx was acquired by Evolva.

Program Roadmaps

- In accordance with the America COMPETES Act, Public Law 110-69, section 5012(g)(2)(2007) as amended, which has been codified as 42 U.S.C. § 16538(h)(2), ARPA-E's Strategic Vision Report can be found at: http://arpa-e.energy.gov/sites/default/files/ARPA-E_Strategic_Vision_Report_101713.pdf.

Advanced Research Projects Agency - Energy
Funding by Congressional Control ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
ARPA-E Projects	252,000	252,000	252,000	295,750	+43,750
Program Direction	28,000	28,000	28,000	29,250	+1,250
Subtotal, Advanced Research Projects Agency - Energy	**280,000**	**280,000**	**280,000**	**325,000**	**+45,000**
Rescission of Prior Year Balance	0	0	-18	0	+18
Total, Advanced Research Projects Agency - Energy	**280,000**	**280,000**	**279,982**	**325,000**	**+45,018**
Federal FTEs	**49**	**49**	**49**	**56**	**+7**

SBIR/STTR:

- FY 2014 Current: $9,374,993 total (SBIR $7,649,993 / STTR $1,725,000)
- FY 2015 Projected: $9,759,750 total (SBIR $8,576,750 / STTR $1,183,000)
- FY 2016 Request: $10,203,375 total (SBIR $8,872,500 / STTR $1,330,875)

ARPA-E Projects

Overview

The Advanced Research Projects Agency-Energy (ARPA-E) catalyzes and accelerates energy technologies that will enhance the economic and energy security of the United States through the development of transformational technologies that reduce imports of energy from foreign sources, increase energy efficiency, and reduce energy-related emissions, including greenhouse gas emissions. ARPA-E funds high-potential, high-impact energy projects that are too early for private sector or other Department of Energy (DOE) program office investment.

ARPA-E has created a nimble and adaptive structure that allows the Agency to quickly develop and execute programs, recruit a highly talented and experienced technical team, and provide awardees with technical assistance and market awareness to help projects succeed.

ARPA-E focused programs provide a unique bridge from basic science to early stage technology. These programs draw from the latest scientific discoveries and envision a viable path to commercial implementation through firm grounding in the economic realities and changing dynamics of the marketplace. The concept for a new focused program is developed through engagement with diverse science and technology communities, including some that may not have traditionally been involved in the topic area, and by learning from the outcomes of current ARPA-E programs and projects.

The ARPA-E program development cycle is primarily about identifying gaps where high-impact, high-potential investment by ARPA-E could lead to transformational technologies enabling entirely new ways to generate, store, and use energy. New programs are carefully constructed by Program Directors, working in an environment of constructive criticism where every aspect of a proposed program is intensely scrutinized for technical and economic viability, as well as impact on ARPA-E's mission. The program development cycle also involves careful coordination with ongoing research and development efforts in other DOE program offices, other federal agencies, and industry. For example, The *Reliable Electricity Based on Electrochemical Systems* (REBELS) program launched in FY 2014, which is aimed at developing fuel cell technology for distributed power generation, has been closely coordinated with other Department of Energy elements working on fuel cell technology, along with the work of industry stakeholders.

Each ARPA-E project includes clearly defined technical and commercial milestones that awardees are required to meet throughout the life of a project. Program Directors work closely with each awardee, through regular meetings and onsite visits, to ensure that milestones are being achieved in a timely fashion. When a project is not achieving the goals of the program, ARPA-E works with the awardee to rectify the issue or, in cases where the issue cannot be corrected, ARPA-E discontinues funding for the project.

The final element of the ARPA-E model is the Technology-to-Market program. Awardees are required to provide a Technology-to-Market plan prior to receiving an award and work closely with ARPA-E's Technology-to-Market advisors throughout the project to develop customized commercialization strategies. These include practical training and critical business information to equip projects with a clear understanding of market needs and thereby help guide technical development. In addition, ARPA-E facilitates relationships with investors, government agencies, small and large companies, and other organizations that are necessary to move awardees to the next stage of their project development.

Highlights of the FY 2016 Budget Request

In FY 2016 ARPA-E expects to release funding opportunity announcements (FOA) for 7 – 10 focused programs each funded at approximately $10 - $40 million. The inherent design of ARPA-E makes it impossible to predict in detail the specific technologies that will garner investment in FY 2016. ARPA-E envisions building from existing learning, often in a nonlinear and unexpected fashion, with a focus on both transportation and stationary energy. As ARPA-E fully funds projects at the time of award, FY 2016 funds will be primarily used for new programs and projects. A portion of FY 2016 funding is likely to be used to supplement ongoing ARPA-E projects where a small amount of additional funding from ARPA-E could catalyze a substantial technological development and potentially lead to future support from outside ARPA-E that will help advance the technology towards the market. ARPA-E will also continue its stand-alone Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program to provide additional support to small businesses beyond the significant number of awards to small businesses through ARPA-E's standard, non-SBIR/STTR solicitations. ARPA-E will continue the use of Innovative Development in Energy-Related Applied Science (IDEAS), a small, rolling, open solicitation to rapidly support innovative applied energy research that has the potential to lead to new focused programs or that may complement portfolios in ongoing focused programs.

ARPA-E Projects
Funding ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
ARPA-E Projects					
Transportation Systems	100,800	100,800	126,000	118,300	-7,700
Stationary Power Systems	151,200	151,200	126,000	177,450	+51,450
Total, ARPA-E Projects	**252,000**	**252,000**	**252,000**	**295,750**	**+43,750**

SBIR/STTR:

- FY 2014 Current: $9,374,993 total (SBIR $7,649,993 / STTR $1,725,000)
- FY 2015 Projected: $9,759,750 total (SBIR $8,576,750 / STTR $1,183,000)
- FY 2016 Request: $10,203,375 total (SBIR $8,872,500 / STTR $1,330,875)

ARPA-E Projects
Explanation of Major Changes ($K)

	FY 2016 vs FY 2015
Transportation Systems: Based upon five years of experience in the development of focused technology programs and noting the distribution of applications to and awards made in the first two competitive OPEN solicitations in 2009 and 2012, ARPA-E anticipates a shift from an equal funding distribution between Stationary Power Systems and Transportation Systems to approximately a 60:40 split in FY 2016.	**-7,700**
Stationary Power Systems: Based upon five years of experience in the development of focused technology programs and noting the distribution of applications to and awards made in the first two competitive OPEN solicitations in 2009 and 2012, ARPA-E anticipates a shift from an equal funding distribution between Stationary Power Systems and Transportation Systems to approximately a 60:40 split in FY 2016.	**+51,450**
Total, ARPA-E Projects	**+43,750**

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
$252,000,000	**$295,750,000**	**+ $43,750,000**
In FY 2015, ARPA-E released a third open funding opportunity announcement (OPEN 2015). ARPA-E anticipates new programs in both Transportation Systems and Stationary Power Systems in one or more of the following areas:	In FY 2016,ARPA-E plans to release funding opportunity announcements for 7 – 10 focused programs.	The number of focused programs expected to be released in FY 2016 will increase because ARPA-E will not release a large, open funding opportunity announcement. ARPA-E plans to release open funding solicitations every two-to-three years to maximize the quality of applications and to explore focused programs based on learning from previous ARPA-E projects.
	ARPA-E anticipates new focused programs in both Transportation Systems and Stationary Power Systems in the general areas below. New ARPA-E programs are increasingly taking advantage of key learnings and technological developments from previous ARPA-E focused programs and OPEN solicitation portfolios. These programs have built new communities of scientists and engineers that are approaching the many challenges of energy technology in new and exciting ways, with the potential for amplification of learning through crossovers between programs.	The inherent design of ARPA-E makes it impossible to predict in detail the specific technologies that will garner future investment. ARPA-E envisions building from existing learning, often in a nonlinear and unexpected fashion, with a focus on both transportation and stationary energy. ARPA-E works to quickly leverage new scientific breakthroughs and market developments. ARPA-E explores uncharted territories of energy technology and the intersections of those territories in order to create options for entirely new paths to accelerate the pace of innovation.
Transportation Fuels: The utility and energy storage capacity of liquid fuels suggest that they will remain in our transportation infrastructure for years to come. The challenge lies in finding innovative ways to produce fuels from an ever increasing variety of feedstocks. Novel routes to create fuels from carbon-neutral feedstocks (biomass or carbon dioxide) offer the potential for transformative reductions in greenhouse gas emissions associated with transportation. ARPA-E continues to use advances in bio-engineering and biochemistry to develop photosynthetic and non-photosynthetic routes to carbon-neutral fuels.	**Transportation Fuels and Feedstocks:** The utility and energy storage capacity of liquid fuels suggest that they will remain in our transportation infrastructure for years to come. The challenge lies in finding innovative ways to produce fuels from an ever increasing variety of feedstocks. Novel routes to create fuels from carbon-neutral feedstocks offer the potential for transformative reductions in greenhouse gas emissions associated with transportation. ARPA-E will continue to explore innovative ways to improve the yield of current and newly developed biofuel crops and to use advances in bio-engineering and biochemistry to develop photosynthetic and non-photosynthetic routes to carbon-neutral fuels. This	

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
	area of technology focus is applicable to Transportation Systems.	
Energy Materials and Processes: Advanced materials are central to the development of innovative energy conversion processes that improve efficiency in the generation and use of energy, with concomitant reduction in greenhouse gas emissions. ARPA-E continues to build upon new discoveries in fundamental material science to develop a broad range of materials for energy: catalysts, photovoltaics, structural materials, thermoelectrics, intelligent materials, semiconductors, magnetic materials, membranes, and others. Many of these new materials are well tailored for specific function at the nanoscale level, but pathways for their cost-effective manufacture at the scale needed for energy technology does not yet exist. ARPA-E continues to invest in research and development devoted to moving nanoscale materials from the realm of scientific discovery into real-world processes for improved energy utilization in a variety of technologies, including engines, heating and air conditioning units, electric motors, power electronics, solar cells, wind turbines, and other technologies that are only beginning to be envisioned for energy applications.	**Energy Materials and Processes:** Advanced materials are central to the development of innovative energy conversion processes that improve efficiency in the generation and use of energy, with concomitant reduction in greenhouse gas emissions. Increasingly, such technologies must also have minimal impact on important natural resources, such as critical minerals or water. ARPA-E will continue to build upon new discoveries in fundamental material science to develop a broad range of materials for energy: catalysts, photovoltaics, structural materials, thermoelectrics, intelligent materials, semiconductors, magnetic materials, membranes, and others. Many of these new materials are well tailored for specific function at the nanoscale level, but pathways for their cost-effective manufacture at the scale needed for energy technology does not yet exist. ARPA-E will continue to invest in research and development devoted to moving nanoscale materials from the realm of scientific discovery into real-world processes for improved energy utilization in a variety of technologies, including engines, heating and air conditioning units, electric motors, power electronics, solar cells, wind turbines, power plant cooling systems, gas separations, and other technologies that are only beginning to be envisioned for energy applications. This area of technology focus is applicable to both Transportation Systems and Stationary Power Systems.	
Energy Storage: Effective, inexpensive, reversible conversion of electrical energy to a more easily stored form, such as chemical, mechanical, and thermal	**Dispatchable Energy:** Energy storage remains a central challenge to the widespread adoption of electric vehicles and the increased penetration of	

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
energy, remains a central challenge to the widespread adoption of electric vehicles and the increased penetration of intermittent renewable energy sources onto the electric grid. ARPA-E plans to build upon previous investments in electrical energy storage for both transportation and the grid. These programs have built new communities of scientists and engineers that are approaching the challenge of energy storage in new and exciting ways. Moreover, these projects exhibit an amplification of learning through crossovers between programs. Because of these new insights, ARPA-E continues to envision new technology approaches as well as additional areas where efficient and inexpensive energy storage technologies are required.	intermittent renewable energy sources onto the future electric grid. Recognizing that electricity in the future will be derived from many sources at a variety of scales, ARPA-E will continue to explore technologies that enable the cost-effective production and storage of electricity suitable to a more flexible electric grid that may feature substantial distributed generation. Such efforts will focus on improving the dispatchability of electricity through effective, inexpensive, and reversible conversion of electrical energy to a more easily stored form, such as chemical, mechanical, and thermal energy. This area of technology focus is applicable to both Transportation Systems and Stationary Power Systems.	
Sensors, Information, and Integration: As energy technology meets the information age, the need to collect, analyze, standardize, and protect energy information will grow and diversify over many energy systems. The transition to smart and resilient energy systems will be enabled by reliable and inexpensive sensors to provide essential data, analytical tools capable of dealing with the vast amounts of data created, and sophisticated control algorithms to optimize system performance. ARPA-E has invested in building the innovative new components that need to be integrated into larger systems to achieve full impact and now sees a broad opportunity in the combination of sensor technology, informatics, and system integration. ARPA-E currently invests in the development of advanced sensors and control technologies for battery management and control algorithms for the power grid. ARPA-E plans to explore the further development of hardware and software tools needed to characterize, optimize, and control additional smart, integrated energy systems of	**Sensors, Information, and Integration:** As energy technology meets the information age, the need to collect, analyze, standardize, and protect energy information will grow and diversify over many energy systems. The transition to smart and resilient energy systems will be enabled by reliable and inexpensive sensors to provide essential data, analytical tools capable of dealing with the vast amounts of data created, and sophisticated control algorithms to optimize the performance of increasingly automated energy systems. ARPA-E has invested in building the innovative new components that need to be integrated into larger systems to achieve full impact and now sees a broad opportunity in the combination of sensor technology, informatics, and system integration. ARPA-E will continue to invest in the development of advanced sensors and control technologies for battery management and control algorithms for the power grid. ARPA-E plans to explore the further development of hardware and software tools needed to characterize, optimize, and	

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
the future. Future investments in systems integration will not replicate scale-up and manufacturing issues that are best addressed by the Department of Energy applied technology programs or private industry.	control an even broader range of smart, integrated energy systems of the future. Future investments in systems integration will not replicate scale-up and manufacturing issues that are best addressed by the Department of Energy applied technology programs or private industry. This area of technology focus is applicable to both Transportation Systems and Stationary Power Systems.	

Program Direction

Overview

Program direction provides ARPA-E with the necessary resources to execute ARPA-E's mission. Program direction funds are utilized for salaries and benefits of federal staff; travel; support services contracts to provide technical advice and assistance; and other related expenses, including the DOE Working Capital Fund.

The key components of the ARPA-E model are the team, particularly the Agency's Program Directors and Technology-to-Market advisors, and hands-on engagement with awardees. ARPA-E Program Directors provide awardees with technical guidance that combines scientific expertise and real-world experience. ARPA-E Technology-to-Market advisors supply critical business insight and direction to enable awardees to develop strategies to move technologies towards the market. Each ARPA-E project includes clearly defined technical and commercial milestones that awardees are required to meet throughout the life of a project. Program Directors work closely with each awardee, through regular meetings and on-site visits, to ensure that milestones are being achieved in a timely fashion. When a project is not achieving its milestones or the goals of the program, ARPA-E works with the awardee to rectify the issue or, in cases where the issue cannot be corrected, ARPA-E discontinues funding for the project. To ensure the efficiency of ARPA-E's hands-on engagement with awardees, ARPA-E has in-house legal, procurement, and contracting staff, co-located with the Program Directors, to provide direct access and timely communication. Finally, to help enable ARPA-E to rapidly move into new technology areas in response to scientific discoveries, breakthroughs, and opportunities, ARPA-E utilizes technical support contractors for technical advice and program management assistance.

Highlights of the FY 2016 Budget Request

ARPA-E Program Directors and Technology-to-Market Advisors serve limited terms. The FY 2016 program direction request therefore supports recruitment of sufficient staff and support service contractors to manage ARPA-E programs funded in FY 2016 and provide quality program oversight of new and ongoing projects. Since additional focused programs are expected to be developed in FY 2016, the increase in funding and FTEs support the additional staff required to develop new programs and manage a larger number of projects. ARPA-E will continue to build its Technology-to-Market team to ensure that appropriate resources are available to work closely with all ARPA-E awardees. Starting in FY 2014, ARPA-E's program direction funds also support embedded procurement staff; the costs of which are included in the FY 2016 request.

Program Direction
Funding ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
Program Direction Summary					
Washington Headquarters					
Salaries and Benefits	8,880	8,880	9,315	10,103	+788
Travel	1,003	1,003	1,003	1,316	+313
Support Services	13,330	13,330	12,895	12,858	-37
Other Related Expenses	4,787	4,787	4,787	4,973	+186
Total, Program Direction	**28,000**	**28,000**	**28,000**	**29,250**	**+1,250**
Federal FTEs	**49**	**49**	**49**	**56**	**+7**
Support Services and Other Related Expenses					
Support Services					
Technical Support	4,665	4,665	4,513	4,465	-48
Management Support	8,665	8,665	8,382	8,393	+11
Total, Support Services	**13,330**	**13,330**	**12,895**	**12,858**	**--37**
Other Related Expenses					
Rental payments to GSA	2,202	2,202	2,202	2,283	+81
Communications, utilities, and misc. charges	500	500	500	550	+50
Printing and reproduction	10	10	10	10	0
Other services from non-Federal sources	465	465	465	475	+10
Other goods and services from Federal sources	1,510	1,510	1,510	1,550	+40
Supplies and materials	100	100	100	105	+5
Total, Other Related Expenses	**4,787**	**4,787**	**4,787**	**4,973**	**+186**

Program Direction

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs FY 2015
Program Direction $28,000,000	**$29,250,000**	**+$1,250,000**
Salaries and Benefits		
At the FY 2015 enacted level ARPA-E will fund 49 FTEs.	At the FY 2016 request level ARPA-E anticipates needing up to 56 Federal FTEs.	+$788 The increase in funding and FTEs support the additional staff required to develop new programs and manage a larger number of projects.
Travel		
At the FY 2015 enacted level ARPA-E Program Directors and Technology-to-Market advisers will continue visit performers regularly as part of ARPA-E's hands-on engagement, which is the primary component of ARPA-E travel.	At the FY 2016 request level ARPA-E Program Directors and Technology-to-Market advisers will continue to visit performers regularly. The number of site visits will continue to be commensurate with the number of ongoing projects.	+$313 The increase in travel is commensurate with increased projects and FTEs.
Support Services		
At the FY 2015 enacted level ARPA-E anticipates a continued level of support commensurate to the number of ongoing and anticipated projects.	At the FY 2016 request level ARPA-E anticipates maintaining the use of support service contractors, at a slightly reduced level, to support ARPA-E federal staff in the management and oversight of projects and other required functions. The level of support commensurate to the number of ongoing and anticipated projects. ARPA-E will continue to optimize federal staff and contractor support based on funding levels and the number of projects under management.	-$37 The amount for support services is reduced in FY 2016 as ARPA-E continues to optimize contractor support based on federal staffing and program requirements.
Other Related Expenses		
The FY 2015 enacted level for other related expenses reflects the anticipated costs for these activities based on the number of ongoing and anticipated projects.	The FY 2016 request level for other related expenses primarily consists of Working Capital Fund and Information Technology support costs, which are commensurate with the level of FTEs and support services requested.	+$186 The increase in other related expenses is commensurate with management of a larger number of projects and increased FTEs.

Advanced Research Projects Agency - Energy
Research and Development ($K)

	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
Basic	0	0	0	0
Applied	126,000	126,000	147,875	+21,875
Development	126,000	126,000	147,875	+21,875
Subtotal, R&D	252,000	252,000	295,750	+43,750
Equipment	0	0	0	0
Construction	0	0	0	0
Total, R&D	**252,000**	**252,000**	**295,750**	**+43,750**

Advanced Research Projects Agency - Energy
Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) ($K)

	FY 2014 Current	FY 2015 Enacted	FY 2016 Request[1]	FY 2016 vs FY 2015 Projected
ARPA-E Projects				
SBIR	7,650	8,577	8,872	+295
STTR	1,725	1,183	1,331	+148
Total, SBIR/STTR	**9,375**	**9,760**	**10,203**	**+443**

[1] In FY 2016, ARPA-E will continue its stand-alone Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program to provide additional support to small businesses beyond the significant number of awards to small businesses via ARPA-E's standard non-SBIR/STTR solicitations.

ARPA-E Projects
Performance Measures

In accordance with the GPRA Modernization Act of 2010, the Department sets targets for, and tracks progress toward, achieving performance goals for each program.

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**Award Funding** - Cumulative percentage of award funding committed 45 days after award selections are announced.		
Target	70%	70%	70%
Result	Met	Not applicable	Not applicable
Endpoint Target	No endpoint – continuous measure of efficiency in awarding funds		
Performance Goal (Measure)	**New Company Formation** – Number of new companies formed as a direct result of ARPA-E funding. This was a new performance measure for ARPA-E in FY 2015. As of the end of FY 2013 ARPA-E funded research has led to the formation of at least 24 new companies. That is the baseline from which we would expect to add at least 3 new companies per year.		
Target	≥+3	≥+3	≥+3
Result	Met	Not applicable	Not applicable
Endpoint Target	No endpoint – continuous measure of impact of ARPA-E awards on creating new jobs and industries		

Department Of Energy
FY 2016 Congressional Budget
Funding By Appropriation By Site
($K)

Advanced Researched Projects Agency-Energy	FY 2014 Current	FY 2015 Enacted	FY 2016 Request
Washington Headquarters			
Advanced Researched Projects Agency-Energy			
Projects	252,000	252,000	295,750
Program Direction	28,000	28,000	29,250
Total, Advanced Researched Projects Agency-Energy	**280,000**	**280,000**	**325,000**
Total, Washington Headquarters	**280,000**	**280,000**	**325,000**
Total, Advanced Researched Projects Agency-Energy	**280,000**	**280,000**	**325,000**

GENERAL PROVISIONS – DEPARTMENT OF ENERGY
(INCLUDING TRANSFER [AND RESCISSIONS] OF FUNDS)

SEC. 301. (a) No appropriation, funds, or authority made available by this title for the Department of Energy shall be used to initiate or resume any program, project, or activity or to prepare or initiate Requests For Proposals or similar arrangements (including Requests for Quotations, Requests for Information, and Funding Opportunity Announcements) for a program, project, or activity if the program, project, or activity has not been funded by Congress.

(b)(1) Unless the Secretary of Energy notifies the Committees on Appropriations of the House of Representatives and the Senate at least 3 full business days in advance, none of the funds made available in this title may be used to—

(A) make a grant allocation or discretionary grant award totaling $1,000,000 or more;

(B) make a discretionary contract award or Other Transaction Agreement totaling $1,000,000 or more, including a contract covered by the Federal Acquisition Regulation;

(C) issue a letter of intent to make an allocation, award, or Agreement in excess of the limits in subparagraph (A) or (B); or

(D) announce publicly the intention to make an allocation, award, or Agreement in excess of the limits in subparagraph (A) or (B).

(2) The Secretary of Energy shall submit to the Committees on Appropriations of the House of Representatives and the Senate within 15 days of the conclusion of each quarter a report detailing each grant allocation or discretionary grant award totaling less than $1,000,000 provided during the previous quarter.

(3) The notification required by paragraph (1) and the report required by paragraph (2) shall include the recipient of the award, the amount of the award, the fiscal year for which the funds for the award were appropriated, the account and program, project, or activity from which the funds are being drawn, the title of the award, and a brief description of the activity for which the award is made.

(c) The Department of Energy may not, with respect to any program, project, or activity that uses budget authority made available in this title under the heading "Department of Energy—Energy Programs", enter into a multiyear contract, award a multiyear grant, or enter into a multiyear cooperative agreement unless—

(1) the contract, grant, or cooperative agreement is funded for the full period of performance as anticipated at the time of award; or

(2) the contract, grant, or cooperative agreement includes a clause conditioning the Federal Government's obligation on the availability of future year budget authority and the Secretary notifies the Committees on Appropriations of the House of Representatives and the Senate at least 3 days in advance.

(d) Except as provided in subsections (e), (f), and (g), the amounts made available by this title shall be expended as authorized by law for the programs, projects, and activities specified in the "Final Bill" column in the "Department of Energy" table included under the heading "Title III—Department of Energy" in the explanatory statement described in section 4 (in the matter preceding division A of this consolidated Act).

(e) The amounts made available by this title may be reprogrammed for any program, project, or activity, and the Department shall notify the Committees on Appropriations of the House of Representatives and the Senate at least 30 days prior to the use of any proposed reprogramming which would cause any program, project, or activity funding level to increase or decrease by more than $5,000,000 or 10 percent, whichever is less, during the time period covered by this Act.

(f) None of the funds provided in this title shall be available for obligation or expenditure through a reprogramming of funds that—

(1) creates, initiates, or eliminates a program, project, or activity;

(2) increases funds or personnel for any program, project, or activity for which funds are denied or restricted by this Act; or

(3) reduces funds that are directed to be used for a specific program, project, or activity by this Act.

(g)(1) The Secretary of Energy may waive any requirement or restriction in this section that applies to the use of funds made available for the Department of Energy if compliance with such requirement or restriction would pose a substantial risk to human health, the environment, welfare, or national security.

(2) The Secretary of Energy shall notify the Committees on Appropriations of the House of Representatives and the Senate of any waiver under paragraph (1) as soon as practicable, but not later than 3 days after the date of the activity to which a requirement or restriction would otherwise have applied. Such notice shall include an explanation of the substantial risk under paragraph (1) that permitted such waiver.

SEC. 302. The unexpended balances of prior appropriations provided for activities in this Act may be available to the same appropriation accounts for such activities established pursuant to this title. Available balances may be merged with funds in the applicable established accounts and thereafter may be accounted for as one fund for the same time period as originally enacted.

SEC. 303. Funds appropriated by this or any other Act, or made available by the transfer of funds in this Act, for intelligence activities are deemed to be specifically authorized by the Congress for purposes of section 504 of the National Security Act of 1947 (50 U.S.C. 414) during fiscal year **[**2015**]***2016* until the enactment of the Intelligence Authorization Act for fiscal year **[**2015**]***2016*.

SEC. 304. None of the funds made available in this title shall be used for the construction of facilities classified as high-hazard nuclear facilities under 10 CFR Part 830 unless independent oversight is conducted by the Office of **[**Independent**]** Enterprise Assessments to ensure the project is in compliance with nuclear safety requirements.

SEC. 305. None of the funds made available in this title may be used to approve critical decision-2 or critical decision-3 under Department of Energy Order 413.3B, or any successive departmental guidance, for construction projects where the total project cost exceeds $100,000,000, until a separate independent cost estimate has been developed for the project for that critical decision.

[SEC. 306. (a) SECRETARIAL DETERMINATIONS.—In this fiscal year, and in each subsequent fiscal year, any determination (including a determination made prior to the date of enactment of this Act) by the Secretary of Energy under section 3112(d)(2)(B) of the USEC Privatization Act (110 Stat. 1321–335), as amended, shall be valid for not more than 2 calendar years subsequent to such determination.

(b) CONGRESSIONAL NOTIFICATION.—In this fiscal year, and in each subsequent fiscal year, not less than 30 days prior to the provision of uranium in any form the Secretary of Energy shall notify the Committees on Appropriations of the House of Representatives and the Senate of the following—

(1) the provisions of law (including regulations) authorizing the provision of uranium;
(2) the amount of uranium to be provided;
(3) an estimate by the Secretary of Energy of the gross fair market value of the uranium on the expected date of the provision of the uranium;
(4) the expected date of the provision of the uranium;
(5) the recipient of the uranium;
(6) the value the Secretary of Energy expects to receive in exchange for the uranium, including any adjustments to the gross fair market value of the uranium; and
(7) whether the uranium to be provided is encumbered by any restriction on use under an international agreement or otherwise.**]**

SEC. **[**307**]***306*. Notwithstanding section 301(c) of this Act, none of the funds made available under the heading "Department of Energy—Energy Programs—Science" may be used for a multiyear contract, grant, cooperative agreement, or Other Transaction Agreement of $1,000,000 or less unless the contract, grant, cooperative agreement, or Other Transaction Agreement is funded for the full period of performance as anticipated at the time of award.

[SEC. 308. In fiscal year 2015 and subsequent fiscal years, the Secretary of Energy shall submit to the congressional defense committees (as defined in U.S.C. 101(a)(16)) a report, on each major warhead refurbishment program that reaches the Phase 6.3 milestone, that provides an analysis of alternatives. Such report shall include—

(1) a full description of alternatives considered prior to the award of Phase 6.3;
(2) a comparison of the costs and benefits of each of those alternatives, to include an analysis of trade-offs among cost, schedule, and performance objectives against each alternative considered;
(3) identification of the cost and risk of critical technology elements associated with each alternative, including technology maturity, integration risk, manufacturing feasibility, and demonstration needs;
(4) identification of the cost and risk of additional capital asset and infrastructure capabilities required to support production and certification of each alternative;
(5) a comparative analysis of the risks, costs, and scheduling needs for any military requirement intended to enhance warhead safety, security, or maintainability, including any requirement to consolidate and/or integrate warhead systems or mods as compared to at least one other feasible refurbishment alternative the Nuclear Weapons Council considers appropriate; and
(6) a life-cycle cost estimate for the alternative selected that details the overall cost, scope, and schedule planning assumptions.**]**

[SEC. 309. (a) Unobligated balances available from prior year appropriations are hereby rescinded from the following accounts of the Department of Energy in the specified amounts:
(1) "Energy Programs—Energy Efficiency and Renewable Energy", $9,740,000.
(2) "Energy Programs—Electricity Delivery and Energy Reliability", $331,000.
(3) "Energy Programs—Nuclear Energy", $121,000.
(4) "Energy Programs—Fossil Energy Research and Development", $10,413,000.
(5) "Energy Programs—Science", $3,262,000.
(6) "Energy Programs—Advanced Research Projects Agency—Energy", $18,000.
(7) "Energy Programs—Departmental Administration", $928,000.
(8) "Atomic Energy Defense Activities—National Nuclear Security Administration— Weapons Activities", $6,298,000.
(9) "Atomic Energy Defense Activities—National Nuclear Security Administration— Defense Nuclear Nonproliferation", $1,390,000.
(10) "Atomic Energy Defense Activities—National Nuclear Security Administration— Naval Reactors", $160,000.
(11) "Atomic Energy Defense Activities—National Nuclear Security Administration—Office of the Administrator", $413,000.
(12) "Environmental and Other Defense Activities—Defense Environmental Cleanup", $9,983,000.
(13) "Environmental and Other Defense Activities—Other Defense Activities", $551,000.
(14) "Power Marketing Administrations—Construction, Rehabilitation, Operation and Maintenance, Western Area Power Administration", $1,632,000.
(b) No amounts may be rescinded by this section from amounts that were designated by the Congress as an emergency requirement pursuant to a concurrent resolution on the budget or the Balanced Budget and Emergency Deficit Control Act of 1985. **]**

[SEC. 310. (a) None of the funds made available in this or any prior Act under the heading "Defense Nuclear Nonproliferation" may be made available to enter into new contracts with, or new agreements for Federal assistance to, the Russian Federation.
(b) The Secretary of Energy may waive the prohibition in subsection (a) if the Secretary determines that such activity is in the national security interests of the United States. This waiver authority may not be delegated.
(c) A waiver under subsection (b) shall not be effective until 15 days after the date on which the Secretary submits to the Committees on Appropriations of the House of Representatives and the Senate, in classified form if necessary, a report on the justification for the waiver. **]**

[SEC. 311. Of the funds authorized by the Secretary of Energy for laboratory directed research and development, no individual program, project, or activity funded by this or any subsequent Act making appropriations for Energy and Water Development for any fiscal year may be charged more than the statutory maximum authorized for such activities: *Provided*, That this section shall take effect not earlier than October 1, 2015.**]**

[SEC. 312. (a) DOMESTIC URANIUM ENRICHMENT.—None of the funds appropriated by this or any other Act or that may be available to the Department of Energy may be used for the construction of centrifuges for the production of enriched uranium for national security needs in fiscal year 2015.

(b) The Department shall provide a report to the Committees on Appropriations of the House of Representatives and the Senate not later than April 30, 2015 that includes:

(1) an accounting of the current and future availability of low-enriched uranium, highly-enriched uranium, and tritium to meet defense needs; and

(2) a cost-benefit analysis of each of the options available to supply enriched uranium for defense purposes, including a preliminary cost and schedule estimate to build a national security train.]

[SEC. 313. None of the funds made available in this Act may be used—

(1) to implement or enforce section 430.32(x) of title 10, Code of Federal Regulations; or

(2) to implement or enforce the standards established by the tables contained in section 325(i)(1)(B) of the Energy Policy and Conservation Act (42 U.S.C. 6295(i)(1)(B)) with respect to BPAR incandescent reflector lamps, BR incandescent reflector lamps, and ER incandescent reflector lamps.]

[SEC. 314. None of the funds made available by this Act may be used in contravention of section 3112(d)(2)(B) of the USEC Privatization Act (42 U.S.C. 2297h-10(d)(2)(B)) and all public notice and comment requirements under chapter 6 of title 5, United States Code, that are applicable to carrying out such section.]

[SEC. 315. (a) NOTIFICATION OF STRATEGIC PETROLEUM RESERVE DRAWDOWN.—None of the funds made available by this Act or any prior Act, or funds made available in the SPR Petroleum Account, may be used to conduct a drawdown (including a test drawdown) and sale or exchange of petroleum products from the Strategic Petroleum Reserve unless the Secretary of Energy provides notice, in accordance with subsection (b), of such exchange, or drawdown (including a test drawdown) to the Committees on Appropriations of the House of Representatives and the Senate.

(b) (1) CONTENT OF NOTIFICATION.—The notification required under subsection (a) shall include at a minimum—

(A) The justification for the drawdown or exchange, including—

(i) a specific description of any obligation under international energy agreements; and

(ii) in the case of a test drawdown, the specific aspects of the Strategic Petroleum Reserve to be tested;

(B) the provisions of law (including regulations) authorizing the drawdown or exchange;

(C) the number of barrels of petroleum products proposed to be withdrawn or exchanged;

(D) the location of the Strategic Petroleum Reserve site or sites from which the petroleum products are proposed to be withdrawn;

(E) a good faith estimate of the expected proceeds from the sale of the petroleum products;

(F) an estimate of the total inventories of petroleum products in the Strategic Petroleum Reserve after the anticipated drawdown;

(G) a detailed plan for disposition of the proceeds after deposit into the SPR Petroleum Account; and

(H) a plan for refilling the Strategic Petroleum Reserve, including whether the acquisition will be of the same or a different petroleum product.

(2) TIMING OF NOTIFICATION.—The Secretary shall provide the notification required under subsection (a)—

(A) in the case of an exchange or a drawdown, as soon as practicable after the exchange or drawdown has occurred; and

(B) in the case of a test drawdown, not later than 30 days prior to a test drawdown.

(c) POST-SALE NOTIFICATION.—In addition to reporting requirements under other provisions of law, the Secretary shall, upon the execution of all contract awards associated with a competitive sale of petroleum products, notify the Committees on Appropriations of the House of Representatives and the Senate of the actual value of the proceeds from the sale.

(d) (1) NEW REGIONAL RESERVES.—The Secretary may not establish any new regional petroleum product reserve—

(A) unless funding for the proposed regional petroleum product reserve is explicitly requested in advance in an annual budget submission and approved by the Congress in an appropriations Act; or

(B) until 90 days after notification of, and approval by, the Committees on Appropriations of the House of Representatives and the Senate.

(2) The budget request or notification shall include—

(A) the justification for the new reserve;

(B) a cost estimate for the establishment, operation, and maintenance of the reserve, including funding sources;

(C) a detailed plan for operation of the reserve, including the conditions upon which the products may be released;

(D) the location of the reserve; and

(E) the estimate of the total inventory of the reserve.

(e) REPORT ON REFINED PETROLEUM PRODUCTS.—Not later than 180 days after the enactment of this Act, the Secretary shall submit to the Committees on Appropriations of the House of Representatives and the Senate a detailed plan for operation of the refined petroleum products reserve, including funding sources and the conditions upon which refined petroleum products may be released.

(f) REPORT ON STRATEGIC PETROLEUM RESERVE EXPANSION.—

(1) The Secretary, through the Office of Energy Policy and Systems Analysis, shall submit to the Committees on Appropriations of the House of Representatives and the Senate not later than 180 days after enactment of this Act the report required in Public Law 111–8 (123 Stat. 617) regarding the expansion of the Strategic Petroleum Reserve.

(2) The report required in paragraph (1) shall include an analysis of the impacts of Northeast Regional Refined Petroleum Product Reserve on the domestic petroleum market. **]** *(Energy and Water Development and Related Agencies Appropriations Act, 2015.)*

TITLE V – GENERAL PROVISIONS

SEC. 501. None of the funds appropriated by this Act may be used in any way, directly or indirectly, to influence congressional action on any legislation or appropriation matters pending before Congress, other than to communicate to Members of Congress as described in 18 U.S.C. 1913.

[SEC. 502. (a) None of the funds made available in title III of this Act may be transferred to any department, agency, or instrumentality of the United States Government, except pursuant to a transfer made by or transfer authority provided in this Act or any other appropriations Act for any fiscal year, transfer authority referenced in the explanatory statement described in section 4 (in the matter preceding division A of this consolidated Act), or any authority whereby a department, agency, or instrumentality of the United States Government may provide goods or services to another department, agency, or instrumentality.

(b) None of the funds made available for any department, agency, or instrumentality of the United States Government may be transferred to accounts funded in title III of this Act, except pursuant to a transfer made by or transfer authority provided in this Act or any other appropriations Act for any fiscal year, transfer authority referenced in the explanatory statement described in section 4 (in the matter preceding division A of this consolidated Act), or any authority whereby a department, agency, or instrumentality of the United States Government may provide goods or services to another department, agency, or instrumentality.

(c) The head of any relevant department or agency funded in this Act utilizing any transfer authority shall submit to the Committees on Appropriations of the House of Representatives and the Senate a semiannual report detailing the transfer authorities, except for any authority whereby a department, agency, or instrumentality of the United States Government may provide goods or services to another department, agency, or instrumentality, used in the previous 6 months and in the year-to-date. This report shall include the amounts transferred and the purposes for which they were transferred, and shall not replace or modify existing notification requirements for each authority.**]**

SEC. **[**503**]***502*. None of the funds made available by this Act may be used in contravention of Executive Order No. 12898 of February 11, 1994 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations). (*Energy and Water Development Related Agencies Appropriations Act, 2015*).