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Department of Energy
FY 2012 Congressional Budget Request

Science

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Volume 4

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The Department of Energy's Congressional Budget justification is available on the Office of Chief Financial Officer, Office of Budget homepage at http://www.cfo.doe.gov/crorg/cf30.htm.

DEPARTMENT OF ENERGY
Appropriation Account Summary
(dollars in thousands - OMB Scoring)

	FY 2010 Current Approp.	FY 2011 Cong. Request	FY 2011 Annualized CR	FY 2012 Congressional Request	FY 2012 vs. FY 2010 $	FY 2012 vs. FY 2010 %
Discretionary Summary By Appropriation						
Energy And Water Development, And Related Agencies						
Appropriation Summary:						
Energy Programs						
Energy efficiency and renewable energy	2,216,392	2,355,473	2,242,500	3,200,053	+983,661	+44.4%
Electricity delivery and energy reliability	168,484	185,930	171,982	237,717	+69,233	+41.1%
Nuclear energy	774,578	824,052	786,637	754,028	-20,546	-2.7%
Fossil energy programs						
Fossil energy research and development	659,770	586,583	672,383	452,975	-206,795	-31.3%
Naval petroleum and oil shale reserves	23,627	23,614	23,627	14,909	-8,718	-36.9%
Strategic petroleum reserve	243,823	138,861	243,823	121,704	-122,119	-50.1%
Northeast home heating oil reserve	11,300	11,300	11,300	10,119	-1,181	-10.5%
Northeast home heating oil reserve oil sale	0	0	0	-79,000	-79,000	N/A
Total, Fossil energy programs	938,520	760,358	951,133	520,707	-417,813	-44.5%
Uranium enrichment D&D fund	573,850	730,498	573,850	504,169	-69,681	-12.1%
Energy information administration	110,595	128,833	110,595	123,957	+13,362	+12.1%
Non-Defense environmental cleanup	254,673	225,163	244,673	219,121	-35,552	-14.0%
Science	4,963,887	5,121,437	4,903,710	5,416,114	+452,227	+9.1%
Energy transformation acceleration fund	0	299,966	0	550,011	+550,011	N/A
Nuclear waste disposal	98,400	----	98,400	0	-98,400	-100.0%
Departmental administration	168,944	169,132	168,944	128,740	-40,204	-23.8%
Inspector general	51,927	42,850	51,927	41,774	-10,153	-19.6%
Title 17 - Innovative technology loan guarantee program	0	500,000	-15,000	200,000	+200,000	N/A
Section 1705 temporary loan guarantee program	0	----	0	0	——	——
Advanced technology vehicles manufacturing loan	20,000	9,998	20,000	6,000	-14,000	-70.0%
Better building pilot loan guarantee initiative for Universities, Schools, and Hospitals	0	0	0	105,000	+105,000	N/A
Total, Energy Programs	10,340,250	11,353,690	10,309,351	12,007,391	+1,667,145	+16.1%
Atomic Energy Defense Activities						
National nuclear security administration:						
Weapons activities *	6,386,371	7,008,835	7,008,835	7,629,716	+620,881	+8.9%
Defense nuclear nonproliferation *	2,131,382	2,687,167	2,136,709	2,549,492	-137,675	-5.1%
Naval reactors *	945,133	1,070,486	945,133	1,153,662	+83,176	+7.8%
Office of the administrator *	410,754	448,267	410,754	450,060	+1,793	+0.4%
Total, National nuclear security administration	9,873,640	11,214,755	10,501,431	11,782,930	+568,175	+5.1%
Environmental and other defense activities:						
Defense environmental cleanup	5,640,371	5,588,039	5,642,331	5,406,781	-233,590	-4.1%
Other defense activities	847,468	878,209	847,468	859,952	+12,484	+1.5%
Defense nuclear waste disposal	98,400	0	98,400	0	-98,400	-100.0%
Total, Environmental & other defense activities	6,586,239	6,466,248	6,588,199	6,266,733	-319,506	-4.9%
Total, Atomic Energy Defense Activities	16,459,879	17,681,003	17,089,630	18,049,663	+248,669	+1.5%
Power marketing administrations:						
Southeastern power administration	0	0	0	0	——	——
Southwestern power administration	13,076	12,699	13,076	11,892	-1,184	-9.1%
Western area power administration	109,181	105,558	109,181	95,968	-13,213	-12.1%
Falcon & Amistad operating & maintenance fund	220	220	220	220	——	——
Colorado River Basins	-23,000	-23,000	-23,000	-23,000	——	——
Total, Power marketing administrations	99,477	95,477	99,477	85,080	-14,397	-14.5%
Federal energy regulatory commission	0	0	0	0	——	——
Subtotal, Energy And Water Development and Related Agencies	26,899,606	29,130,170	27,498,458	30,142,134	+1,901,417	+6.7%
Uranium enrichment D&D fund discretionary payments	-463,000	-696,700	-463,000	0	+463,000	+100.0%
Excess fees and recoveries, FERC	-10,933	-29,111	-28,886	-25,072	-14,139	-129.3%
Subtotal, Discretionary Funding	26,425,673	28,404,359	27,006,572	30,117,062	+2,350,278	+8.5%
Strategic petroleum reserve sale	0	0	0	-500,000	-500,000	N/A
Cancellation of prior year unobligated balances	0	0	0	-70,332	-70,332	N/A
Total, Discretionary Funding **	26,425,673	28,404,359	27,006,572	29,546,730	+3,121,057	+11.8%

NOTE: * FY12 is compared against the FY11 Request. This exception has been implemented for NNSA only.
** The Total, Discretionary Funding, FY12 vs FY10 "$" and "%" columns, reflects a comparison of FY12 Request vs. FY10 Current Approp for all programs including NNSA

Science

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 49 passenger motor vehicles for replacement only, including one ambulance and one bus, $5,416,114,000, to remain available until expended.

Office of Science

Overview

Appropriation Summary by Program

	(dollars in thousands)		
	FY 2010 Current Appropriation	FY 2011 Continuing Resolution	FY 2012 Request
Office of Science			
Advanced Scientific Computing Research	383,199		465,600
Basic Energy Sciences	1,598,968		1,985,000
Biological and Environmental Research	588,031		717,900
Fusion Energy Sciences	417,650		399,700
High Energy Physics	790,811		797,200
Nuclear Physics	522,460		605,300
Workforce Development for Teachers and Scientists	20,678		35,600
Science Laboratories Infrastructure	127,600		111,800
Safeguards and Security	83,000		83,900
Science Program Direction	189,377		216,863
Small Business Innovation Research (SBIR)/ Small Business Technology Transfer (STTR) (SC funding)	107,352[a]		0
Subtotal, Office of Science	4,829,126		5,418,863
Congressionally directed projects	74,737		0
SBIR/STTR (Other DOE funding)	60,177[b]		0
Use of prior year balances	-153		-2,749
Total, Science Appropriation	4,963,887	4,903,710[c]	5,416,114

Preface

The FY 2012 budget request supports the Administration's *Strategy for American Innovation*, and is consistent with the goal of doubling funding at key basic research agencies, including the Office of Science. The FY 2012 Office of Science budget request supports the following objectives from the *Strategy*, including:

- Unleash a clean energy revolution
- Strengthen and broaden American leadership in fundamental research

[a] Reflects funding reprogrammed within the Science total to support the SBIR and STTR programs.
[b] Reflects funding transferred from other DOE appropriation accounts to support the SBIR and STTR programs.
[c] The FY 2011 Continuing Resolution (CR) column reflects a funding level for the P.L. 111–322 CR through March 4, 2011, annualized to cover a full year. Funding is equal to the FY 2010 appropriation level prior to transfers into the SBIR and STTR programs.

- Develop an advanced information technology ecosystem
- Educate the next generation with 21st century skills and create a world-class workforce

The Office of Science has long been a leader of U.S. scientific discovery and innovation. Over the decades, Office of Science investments have driven the modern biotechnology revolution and the transition in the 20th century from observational science to the science of control and directed design at the nanoscale. We have pushed the frontiers of our understanding of the origins of matter and the universe, and built and operated the large-scale scientific facilities that collectively form a major pillar of the current U.S. scientific enterprise. These investments and accomplishments have led to new technologies and created new businesses and industries, making significant contributions to our Nation's economy and quality of life.

In FY 2012, the Office of Science continues to support fundamental research for scientific discovery, and today our country needs to move strongly to solve our energy problems. Therefore, the central theme of this year's budget is research directed at approaches to creating new technologies for a clean energy future that address competing demands on our environment. These efforts, coordinated with the DOE technology programs and with input from the scientific community and industry, will emphasize research underpinning advances in non-carbon emitting energy sources, carbon capture and sequestration, transportation and fuel switching, transmission and energy storage, end-use efficiency, and critical materials for energy applications.

In the area of advancing non-carbon energy sources, the FY 2012 budget request will provide for new investments in the science of interfaces and degradation relevant to solar photovoltaics, basic actinide chemistry research relevant to advanced nuclear fuel cycles, and research in materials under extreme environments relevant to extreme nuclear technology environments. Carbon capture and sequestration research will focus on novel molecular design for materials and multiscale dynamics of flow and plume migration, respectively. The Office of Science will initiate an energy systems simulation research effort focused on predictive modeling of combustion in an evolving fuel environment in support of the Department's efforts in transportation and alternative fuels, as well as genomics-based research on biological design principles and synthetic biology tools to underpin bio-based energy solutions. Also underpinning transportation and fuel switching, as well as energy storage, the FY 2012 request will support an Energy Innovation Hub for Batteries and Energy Storage. Research in enabling materials sciences will support needs of future electricity transmission systems and novel building materials to improve building efficiencies.

The FY 2012 budget request also provides for foundational science in condensed matter and materials physics, chemistry, biology, climate and environmental sciences, applied mathematics, computational and computer science, high energy physics, nuclear physics, plasma physics, and fusion energy sciences; and provides for research facilities and capabilities that keep U.S. researchers at the forefront of science. FY 2012 request supports targeted increases in areas such as computational materials and chemistry by design, nanoelectronics, and advanced scientific applications and integrated application-hardware-software co-design for exascale, which position the U.S. to secure a competitive advantage in high-tech industries and maintain international leadership in scientific computing. Underlying these investments is the education and training of thousands of scientists and engineers who contribute to the skilled scientific workforce needed for the 21st century innovation economy.

Mission

The Office of Science mission is the delivery of scientific discoveries and major scientific tools to transform our understanding of nature and to advance the energy, economic, and national security of the United States.

Benefits

The Office of Science accomplishes its mission and advances national goals by supporting:

- *The Frontiers of Science*, focused on unraveling nature's mysteries—from the study of subatomic particles, atoms, and molecules that make of the materials of our everyday world to DNA, proteins, cells, and entire biological systems;
- *Energy and Environmental Science*, focused on advancing a clean energy agenda through basic research on energy production, storage, transmission, and use; and advancing our understanding of the Earth's climate through basic research in atmospheric and environmental sciences and climate change; and
- *The 21st Century Tools of Science*, national scientific user facilities providing the Nation's researchers with the most advanced tools of modern science including accelerators, colliders, supercomputers, light sources and neutron sources, and facilities for studying the nanoworld.

Program Overview

The Office of Science is the largest federal sponsor of basic research in the physical sciences, supporting about 27,000 investigators at about 300 U.S. academic institutions and at all of the DOE laboratories. The Office of Science also provides the Nation's researchers with state-of-the-art user facilities—the large machines of modern science. These facilities offer capabilities unmatched anywhere in the world and enable U.S. researchers and industries to remain at the forefront of science, technology, and innovation. About 26,000 researchers from universities, national laboratories, industry, and international partners are expected to use the Office of Science scientific user facilities in FY 2012.

The Office of Science is responsible for the oversight of ten DOE national laboratories: Ames National Laboratory, Argonne National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Princeton Plasma Physics Laboratory, SLAC National Accelerator Laboratory, and Thomas Jefferson National Accelerator Laboratory.

The Office of Science has ten programs: Advanced Scientific Computing Research (ASCR), Basic Energy Sciences (BES), Biological and Environmental Research (BER), Fusion Energy Sciences (FES), High Energy Physics (HEP), Nuclear Physics (NP), Workforce Development for Teachers and Scientists (WDTS), Science Laboratories Infrastructure (SLI), Safeguards and Security (S&S), and Science Program Direction (SCPD).

The *Advanced Scientific Computing Research* program supports research to discover, develop, and deploy the computational and networking capabilities to analyze, model, simulate, and predict complex phenomena important to DOE. Today, advances in mathematics and computing are providing the foundation for models and simulations that permit scientists to gain new insights into problems ranging from bioenergy and climate change to exploring the inner workings of a supernova. ASCR supports research in applied mathematics, computer science, advanced networking, and computational partnerships (Scientific Discovery through Advanced Computing, or SciDAC); research and evaluation prototypes; and the operation of forefront high performance computing systems and networks. A particular challenge of this program is fulfilling the science potential of emerging computing systems and other novel computing architectures. Delivering on the promise of exascale computing will require significant modifications to today's tools and techniques. The FY 2012 ASCR budget focuses on coordinated efforts to address the fundamental changes taking place in the computing industry to deliver hybrid, multi-core computing systems up to the exascale: positioning the U.S. to maintain international leadership in scientific computing and simulation over the next decade. In FY 2012, ASCR supports new co-design research efforts in Computational Partnerships; these efforts are aimed at developing applications capable of utilizing multi-petaflop resources while influencing the development of exascale resources to ensure these systems meet the demands of science and engineering applications. New research efforts will also be supported in key application areas in energy, environment, and national security. The FY 2012 request supports continued operations of the Oak Ridge Leadership Computing Facility, one of the world's most powerful computers at 2.33 petaflops, and the Argonne Leadership Computing Facility, which will be upgraded in FY 2012 to the next generation IBM Blue Gene/Q, with peak capability of approximately 10 petaflops. The National Energy Research Scientific Computing (NERSC) facility at Lawrence Berkeley National Laboratory will provide a total capacity of just over one petaflop. The Energy Sciences network (ESnet) will begin to deliver 100–400 gigabit per second connections among the Office of Science laboratories in FY 2012.

The *Basic Energy Sciences* program 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 and to support the DOE mission in energy, environment, and national security. BES-supported research disciplines—condensed matter and materials physics, chemistry, geosciences, and aspects of physical biosciences—provide the knowledge base for the control of the physical and chemical transformations of materials and the discovery and design of new materials with novel structures, functions, and properties. These disciplines drive new solutions and technologies in virtually every aspect of energy resources, production, conversion, transmission, storage, and efficiency. BES also plans, designs, constructs, and operates scientific user facilities that provide researchers unique tools to advance a wide range of sciences. These large-scale user facilities consist of a complementary set of intense x-ray sources, neutron scattering centers, electron beam characterization capabilities, and research centers for nanoscale science 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 science questions. In FY 2012, BES will expand basic research efforts in focused areas that underpin advances in non-carbon emitting energy sources, carbon capture and sequestration, transportation and fuel switching, transmission and energy storage, efficiency, and critical materials for energy applications, aligned with the President's commitment to clean energy R&D. BES will also support two interagency coordinated initiatives—computational materials and chemistry by design and nanoelectronics. In FY 2012, BES continues support for the Energy Frontier Research Centers initiated in FY 2009 and the Fuels from Sunlight Hub initiated in FY 2010, and will initiate a new Hub on Batteries and Energy Storage. Construction of the National Synchrotron Light Source II (NSLS-II) at Brookhaven National Laboratory continues in FY 2012 and will be fully supported. In addition to supporting the continuation of two ongoing major item of equipment (MIE) projects at the Spallation Neutron Source, BES will initiate three new MIEs in FY 2012—the NSLS-II Experimental Tool project; the Advanced Photon Source Upgrade; and the Linac Coherent Light Source Expansion (LCLS-II) to improve the x-ray spectral range of the LCLS and expand the experimental capacity.

The *Biological and Environmental Research* program supports fundamental research focused on three scientific drivers: exploring the frontiers of genome-enabled biology; discovering the physical, chemical, and biological drivers and environmental impacts of climate change; and seeking the geological, hydrological, and biological determinants of environmental sustainability and stewardship. BER-supported systems biology 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 to contribute to new strategies for producing new biofuels, cleaning up legacy waste, and sequestering carbon dioxide (CO_2). BER plays a critical role in supporting research on atmospheric processes, climate modeling, interactions between ecosystems and greenhouse gases (especially CO_2), and analysis of impacts of climatic change on energy production and use. BER's subsurface biogeochemistry research seeks to understand the role that subsurface biogeochemical processes play in determining the fate and transport of contaminants including heavy metals and radionuclides. In FY 2012, increased funding will support new research to identify, characterize, and articulate general biological design principles, and for the development of new synthetic molecular toolkits improved understanding of natural systems in order to predict, design, construct, and test new, multiscale natural and hybrid biological systems for clean energy and environmental solutions. Support continues for the three DOE Bioenergy Research Centers and for the Joint Genome Institute, which will support grand challenge projects related to large scale genome comparisons in soil environments and plant-microbe associations. In FY 2012, BER will expand its arctic climate research activities, including developing new observation capabilities for clouds, aerosols, and the terrestrial carbon cycle in this globally important and climatically sensitive region, which will support existing BER atmospheric process studies and modeling activities for evaluating and improving climate simulations. A new Atmospheric Radiation Measurement Climate Research Facility (ARM) fixed site will be developed in the Azores to provide critical long-term observations for marine clouds and aerosols. The Environmental Molecular Sciences Laboratory (EMSL) equipment refresh will continue to keep EMSL at the state of the art, including enhancement of leading capabilities in proteomics and advanced magnetic resonance.

The *Fusion Energy Sciences* program supports research 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 by studying plasma and its interactions with its surroundings across wide ranges of temperature and density, developing advanced diagnostics to make detailed measurements of its properties, and creating theoretical and computational models to resolve the essential physics principles. FES is the primary supporter of U.S. research in the field of plasma physics. FES operates scientific user facilities to enable world-leading research programs in high-temperature, magnetically confined plasmas and leads the U.S. participation in the design and construction of ITER, the world's first facility for studying a sustained burning plasma. FES also supports enabling R&D to improve the components and systems that are used to build fusion facilities. The FY 2012 budget request funds the U.S. Contributions to the ITER project, including research and development of key components, long-lead procurements, and personnel and funds to the ITER Organization. Research at the major experimental facilities in the FES program—the DIII-D tokamak, the Alcator C-Mod tokamak, and the National Spherical Torus Experiment—will continue to focus on providing solutions to high-priority technical issues and build a firm physics basis for ITER design and operation. FES provides a modest increase in FY 2012 for materials research related to near-term and longer term fusion devices and for U.S. participation in magnetic fusion research overseas to leverage international investments in unique facilities. FES also continues to support the joint program in high energy density laboratory plasmas with the National Nuclear Security Administration.

The *High Energy Physics* program supports research towards understanding how the universe works at its most fundamental level. This understanding is gained 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 supports research focused on three scientific frontiers: the Energy Frontier, the Intensity Frontier, and the Cosmic Frontier. Research includes theoretical and experimental studies by individual investigators and large collaborative teams, some who gather and analyze data from accelerator facilities in the U.S. and around the world and others who develop and deploy ultra-sensitive ground- and space-based instruments to detect particles from space and observe astrophysical phenomena. The Tevatron Collider at Fermilab completes its planned program. In FY 2012, HEP will support the analysis needs of researchers to exploit the data obtained from the Tevatron's record-breaking performance over the past few years. Support for Large Hadron Collider (LHC) detector operations, maintenance, computing, and R&D continues in FY 2012 in order to maintain a significant U.S. role in the LHC program. The Neutrinos at the Main Injector (NuMI) beamline at Fermilab will operate in its current configuration through mid-FY 2012 for ongoing experiments before a year-long beam power upgrade begins for the NuMI Off-Axis Neutrino Appearance (NOνA) experiment. In FY 2012, HEP will support project engineering and design for the Long Baseline Neutrino Experiment (LBNE) and the Muon to Electron (Mu2e) experiment that will use the NuMI beam and other auxiliary beamlines before the end of the next decade. Several projects to pursue questions in dark matter, dark energy, and neutrino properties continue in FY 2012, including endeavors with the National Science Foundation (such as VERITAS, Auger, DES, BOSS, and CDMS) and the National Aeronautics and Space Administration (Fermi Gamma-ray Space Telescope and AMS). In FY 2012, funding is requested for R&D and conceptual design efforts in support of new dark energy and dark matter experiments, in collaboration with other agencies. HEP also continues support for advanced accelerator and detector R&D to foster world-leading research in physics of particle beams and particle detection necessary for continued progress in high energy physics.

The *Nuclear Physics* program supports research to discover, explore, and understand all forms of nuclear matter. NP is the largest federal sponsor of basic research in nuclear science, supporting experimental and theoretical research—along with the development and operation of particle accelerators and advanced technologies—to create, detect, and describe the different forms and complexities of nuclear matter that can exist in the universe, including those that are no longer found naturally. The program also supports basic research to advance important nuclear science applications, the development of advanced instrumentation and accelerator technology, and analytical and computational techniques that are needed for nuclear science research. The FY 2012 request includes investments in forefront facilities for new research capability, including the construction of the Continuous Electron Beam Accelerator Facility (CEBAF) 12 GeV Upgrade project and the continued engineering and design and long-lead procurements for the Facility for Rare Isotope Beams (FRIB). The request provides for near optimal levels of operations at three NP scientific user facilities: CEBAF, the Relativistic Heavy Ion Collider (RHIC), and the Argonne Tandem Linac Accelerator System (ATLAS); and supports funding for several ongoing MIE projects that address compelling scientific opportunities. NP also provides stewardship of isotope production, and the Isotope Development and Production for Research Applications program will continue focus on production of isotopes needed by stakeholders and research isotope priorities identified by the community. Funding is provided, along with support from HEP, to maintain options for the far detector for the Long Baseline Neutrino Experiment.

The *Workforce Development for Teachers and Scientists* program supports a range of activities for students and educators in science, technology, engineering, and mathematics (STEM) that help develop the skilled scientific workforce needed for the Office of Science mission and the Nation. WDTS programs focus on graduate research fellowships, undergraduate research internship programs that place students in world class research environments at the DOE laboratories, professional development opportunities for STEM educators, and a Nation-wide competition at the middle school and high school levels, the National Science Bowl®. In FY 2012, WDTS will support a new cohort of graduate fellows and increased participation in the undergraduate research internship programs. In response to the recommendation from the 2010 Committee of Visitors' review, the DOE Academies Creating Teacher Scientists and Pre-Service Teachers programs are discontinued in FY 2012 as WDTS reevaluates effective mechanisms of STEM teacher training.

The *Science Laboratories Infrastructure* program's focus is to ensure the continued mission readiness of Office of Science laboratories and facilities to maintain the capability of those assets to enable delivery of each laboratory's and facility's assigned scientific mission. In FY 2009, the Office of Science began an Infrastructure Modernization initiative to revitalize Office of Science laboratories over ten years with the goal of providing the modern laboratory infrastructure needed to deliver advances in science the Nation requires to remain competitive in the 21^{st} century. Through this initiative, the Office of Science is ensuring its laboratories have state-of-the-art facilities and utilities that are flexible, reliable, and sustainable, with environmentally stable research space and high performance computing space needed to support scientific discovery. New and renovated buildings and utilities will include the latest temperature and humidity controls, clean power, and isolation from vibration and electromagnetic interference where needed. Facility designs will consider human factors to ensure collaborative and interactive work environments and allow for the integration of basic to applied research and development. The initiative includes a portfolio of projects funded through the SLI budget that will provide modern laboratory space, renovate space that does not meet research needs, replace facilities that are no longer cost effective to renovate or operate, modernize utility systems to prevent failures and ensure efficiency, and/or remove excess facilities to allow safe and efficient operations. The investments will not only improve the Office of Science's mission readiness but will also reduce the deferred maintenance backlog thereby improving the overall asset condition index across Office of Science laboratories.

American Recovery and Reinvestment Act

The Office of Science received $1,669,248,000 under the American Recovery and Reinvestment Act of 2009 (Recovery Act). The Office of Science based Recovery Act funding decisions on two of the primary goals articulated in the Recovery Act's statement of purpose: to provide investments needed to increase economic efficiency by spurring technological advances in science, and to preserve and create jobs and promote economic recovery. The Office of Science's Recovery Act projects have the characteristics of being "shovel-ready," enhancing research infrastructure, supporting high-priority R&D, and minimizing outyear mortgages. Recovery Act projects include acceleration of ongoing line-item construction projects, acceleration of major items of equipment, upgrades to Office of Science scientific user facilities, laboratory general plant projects, and scientific research. The Office of Science successfully obligated of its Recovery Act funds before the funds expired on September 31, 2010. Additionally, the Office of Science met its goal of costing 50 percent of Recovery Act funds by the end of calendar year 2010. More information on Office of Science Recovery Act supported activities can be found at the Department of Energy Recovery Act website (http://www.energy.gov/recovery/).

Office of Science Early Career Research Program

The Office of Science Early Career Research Program supports the development of individual research programs of outstanding scientists early in their careers and stimulates research careers in the areas supported by the Office of Science. This program provides competitively selected five-year research awards to researchers who have received a Ph.D. within the past ten years and who are untenured tenure-track assistant or associate professors in U.S. academic institutions or full-time employees in DOE national laboratories. Early career researchers may apply to any of the Office of Science research programs. Proposed research topics must fall within the Office of Science programmatic priorities, which are provided in an annual program announcement. This program addresses recommendations from multiple Committee of Visitors' reviews and reports such as the National Academies' 2005 study, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*.

Awards are based on merit review by external experts. FY 2010 was the first year of this program, with support for 69 research awards provided mostly through Recovery Act funds. The FY 2010 award abstracts can be found at http://science.doe.gov/SC-2/early_career.htm. In FY 2012, the Office of Science will support additional early career research awards. Those Office of Science program offices with similar early career research award programs prior to FY 2010, such as the Outstanding Junior

Investigator awards programs, are gradually integrating these programs into the Office of Science Early Career Research Program.

High-Risk, High-Reward Research[a]

The need for fundamental scientific and technological breakthroughs to accomplish DOE mission goals requires that the Office of Science support high-risk, high-reward research ideas that challenge current thinking yet are scientifically sound. The Office of Science programs incorporate high-risk, high-reward basic research elements in all of its research portfolios; each Office of Science research program considers a significant proportion of its supported research as high-risk, high-reward. Because advancing the frontiers of science also depends on the continued availability of state-of-the-art scientific facilities, the Office of Science constructs and operates national scientific facilities and instruments that comprise the world's most sophisticated suite of research capabilities.

The Office of Science's basic research is integrated within program portfolios, projects, and individual awards; as such, it is not possible to quantitatively separate the funding contributions of particular experiments or theoretical studies that are high-risk, high-reward from other mission-driven research in a manner that is credible and auditable. The Office of Science focuses on cultivating and improving the program management practices and policies that foster support for this aspect of its research portfolio. Effective program management is critical to the support of high-risk, high-reward research. The Office of Science program managers are experts in their respective fields and communicate program research priorities and interests to the scientific community; select proposal reviewers that are open to bold ideas; provide guidance to merit reviewers—including guidance on consideration of high-risk, high-reward research; and make recommendations on proposal selection, weighing inputs from peer review with programmatic relevance, potential impact, and overall portfolio balance. Committees of Visitors review program portfolios triennially to assess, among other things, the balance and impact of the portfolios, including an assessment of high-risk, high-reward research.

Likewise, several mechanisms are used by the Office of Science to identify and develop "high-reward" research topics, including Federal advisory committees, program and topical workshops, interagency working groups, National Academy studies, and special Office of Science program solicitations. These activities have identified opportunities for new, compelling research. As examples, some of these opportunities are captured in the following reports: *Research at the Intersection of the Physical and Life Sciences*, by the National Academies (2010); *New Worlds, New Horizons in Astronomy and Astrophysics,* the astronomy and astrophysics decadal survey (Astro2010 report), by the National Research Council; *Next-Generation Photon Sources for Grand Challenges in Science Energy*, by the Basic Energy Sciences Advisory Committee (2009); *Accelerators for Americas Future* workshop report (2009); *Advancing the Science of High Energy Density Laboratory Plasmas* by the Fusion Energy Sciences Advisory Committee (2009); *New Science for a Secure and Sustainable Energy Future*, by the Basic Energy Sciences Advisory Committee (2008); *Identifying Outstanding Grand Challenges in Climate Change Research* workshop report (2008); *U.S. Particle Physics: Scientific Opportunities, A Strategic Plan for the Next Ten Years*, by the High Energy Physics Advisory Panel; and *The Frontiers of Nuclear Science*, by the Nuclear Sciences Advisory Committee (2007).

In 2011, the Office of Science will work with other Federal agencies to identify best practices for encouraging and supporting high-risk, high-reward basic research.

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[a] In compliance with the reporting requirements in the America COMPETES Act of 2007 (P.L. 110–69, section 1008).

Basic and Applied R&D Coordination

Coordination between the Department's basic research and applied technology programs is a high priority for the Secretary of Energy. The Department has a responsibility to coordinate its basic and applied research programs to effectively integrate R&D conducted by the science and technology communities (e.g., national laboratories, universities, and private companies) that support the DOE mission. The Department's efforts have focused on improving communication and collaboration between federal program managers and increasing opportunities for collaborative efforts among researchers targeted at the interface of scientific research and technology development to ultimately accelerate DOE mission and national goals. Coordination between the basic and applied programs is enhanced through activities such as joint planning meetings and technical community workshops, joint annual contractor/awardee meetings, joint research solicitations, jointly-funded scientific facilities, and the program management activities of the DOE Small Business Innovation Research and Small Business Technology Transfer programs. Additionally, co-funding research activities and facilities at the DOE laboratories and funding mechanisms that encourage broad partnerships are also means by which the Department facilitates greater communication and 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 Office of Science program budget justification narrative.

Energy Innovation Hubs

The Office of Science oversees one of the three existing DOE Energy Innovation Hubs. The Hubs—large, multi-disciplinary, highly-collaborative teams of scientists and engineers working over a longer time frame to achieve a specific high priority goal—are built to accelerate the pace of scientific discovery and technology development; each is managed by a scientist-leader with the authority to assess results quickly and redirect funding within the Hub. The Hubs are designed to be large-scale efforts; funding over five years enables each Hub to mount R&D assaults on the scale required to make rapid progress towards development of transformative energy technology.

The Department's first three Energy Innovation Hubs, awarded in FY 2010, are tackling several challenges. The Office of Science's Fuels from Sunlight Hub is focused on developing the scientific knowledge and engineering tools to derive fuels directly from sunlight efficiently and economically. The mission of this Hub is to demonstrate a scalable and cost-effective solar fuels generator that, without use of wires or rare materials robustly produces fuel from the sun 10 times more efficiently than typical current crops. The Hub's integrated systems approach to the artificial photosynthesis challenge will consistently drive efforts towards the practical assembly and scale-up of these components to a working prototype. The Office of Nuclear Energy's Energy Innovation Hub for Modeling and Simulation is using modeling and simulation technologies to make leaps forward in nuclear reactor design and engineering. The Office of Energy Efficiency and Renewable Energy's Energy Efficient Building Systems Hub is working to develop and demonstrate highly efficient building components, systems, and models that are applicable to both retrofit and new construction.

The Department expects each Hub to become the unquestioned locus of scientific expertise in its given area. The Hubs are a central component of the Secretary of Energy's strategy to achieve the President's goals to reduce our dependence on foreign oil and our greenhouse gas emissions. The Hubs also embody the Secretary's goal to improve coordination between basic research and technology development. Additional information on the Hubs can be found at http://www.energy.gov/hubs/index.htm.

In FY 2012, the Office of Science will initiate a Hub on Batteries and Energy Storage based on the same open, competitive award process used for the first three Hubs. The objective of this Hub is to develop electrochemical energy storage systems that will safely approach theoretical energy and power density limits, while also achieving very high cycle life. The Hub will result in new materials, systems, and knowledge that will be critical to developing a robust industrial base leading to the next generation of energy storage technology. Additional information on the Batteries and Energy Storage Hub is found in the Basic Energy Sciences detailed budget justification.

Isotope Development, Production, and Research

Isotope production at the Department of Energy is primarily the responsibility of the Office of Science with three exceptions: plutonium-238 production by the Office of Nuclear Energy (NE), helium-3 production by NNSA, and molybdenum-99 production supported by NNSA's Global Threat Reduction Initiative (GTRI).

The Isotope Development and Production for Research and Applications (Isotope) program located in the Office of Science's Nuclear Physics program offers more than 120 stable and radioactive isotopes for use in basic research and in medical diagnostics and treatment, national security, energy, and industrial applications. The Isotope program produces isotopes only where there is no U.S. private sector capability or where other production capacity is insufficient to meet U.S. needs. Isotope production for commercial use or repackaging is on a full-cost recovery basis, while isotopes produced solely for non-proprietary research purposes are provided below cost. The Isotope program works in close collaboration with other federal agencies and the isotope-using communities to develop priorities for production. In April 2009, the Nuclear Science Advisory Committee issued its report establishing priorities for the production of research isotopes. A long-term strategic plan for the program came out in November 2009. Both reports were developed with federal, commercial, and research community input. The Isotope program has recently broadened its suite of production facilities to include university and other federal sites to optimize the availability of isotopes.

For nearly 50 years, NE's Space and Defense Power Systems program has been responsible for the design, development, production, and safe deployment of plutonium-238 radioisotope power systems. Science missions to explore the solar system and other government applications use plutonium-238 power systems. With a limited existing plutonium-238 stockpile, NE is working with NASA to re-establish domestic plutonium-238 production in order to assure continued availability of these power systems.

A current priority is the production of helium-3, used in neutron detection and cryogenics. Historically, helium-3 has been a by-product of tritium production for the U.S. weapons program. With the reduction in nuclear weapons, tritium production is at a low level and current demand for helium-3 has drawn down supplies. U.S. and international efforts are underway to address the helium-3 supply shortfall.

Molybdenum-99, or Mo-99, is widely used in medical diagnosis and has been produced commercially with reactors using highly enriched uranium (HEU) fuel. Because of the nonproliferation mission to remove HEU from use, NNSA's GTRI program has the lead for Mo-99. As part of its nuclear nonproliferation mission, and in light of the current Mo-99 supply shortage, GTRI is working to accelerate the establishment of commercial Mo-99 production in the United States, without the use of HEU. GTRI is implementing projects to demonstrate the viability of non-HEU based technologies for large-scale commercial Mo-99 production, including accelerator technology, low-enriched uranium (LEU) target technology, LEU solution reactor technology, and neutron capture technology.

Scientific Workforce

The Office of Science (and its predecessors) has an over 50-year history in supporting the education and training of the skilled scientific workforce needed to tackle some of our Nation's most important societal challenges. Through its six research programs, the Office of Science supports the training of undergraduates, graduate students, and postdoctoral researchers as an integral part of the ongoing sponsored research activities at universities and the DOE national laboratories. Office of Science programs also support the development of individual research programs of outstanding scientists early in their careers to stimulate research careers in disciplines supported by the Office of Science.

In addition, the Office of Science research programs support activities targeted towards undergraduate and graduate students, postdoctoral researchers, and K–12 science and math educators to educate and encourage new talent into fields important to the program-specific missions. These activities, which complement the activities supported within the Workforce Development for Teachers and Scientists program, provide opportunities that draw U.S. talent into science, technology, engineering, and mathematics; create the skilled scientific and technical workforce needed to develop solutions to our energy and environmental challenges in the 21st century; and enable the U.S. to continue to be a leader in science and innovation.

Undergraduate activities include short intensive research training internships in specific areas such as geophysics, radiochemistry, nuclear science, computer science and computational-based sciences, plasma and fusion energy sciences, and climate science; and short courses in emerging areas in the physical sciences and engineering, including opportunities for groups underrepresented in the physical sciences. Graduate student level activities include support for short courses and lecture series as part of scientific professional society meetings; summer courses, lecture series, and experimental training courses in areas such as neutron and x-ray scattering, high energy physics, and genomic sciences; and summer graduate research internships in targeted areas such as genomic science, radiochemistry, accelerator physics, and nuclear physics. Opportunities directed towards K–12 educators, carried out primarily through the DOE national laboratories, include workshops, classroom presentations, and summer training programs that provide educators with content knowledge, materials, and activities related to the physical sciences and mathematics to use in the classroom.

Office of Science Education Crosscut

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Undergraduate Programs		
Advanced Scientific Computing Research	250	300
Basic Energy Sciences	391	406
Biological and Environmental Research	100	100
Fusion Energy Sciences	365	395
High Energy Physics	0	0
Nuclear Physics	103	125
Workforce Development for Teachers and Scientists	5,261	8,000
Total, Undergraduate Programs	6,470	9,326
Graduate Programs		
Advanced Scientific Computing Research	6,014	6,014
Basic Energy Sciences	895	616
Biological and Environmental Research	1,499	105

	(dollars in thousands)	
	FY 2010 Current Appropriation FY	2012 Request
Fusion Energy Sciences	1,371	864
High Energy Physics	823	755
Nuclear Physics	148	165
Workforce Development for Teachers and Scientists 5,106		16,100
Total, Graduate Programs	15,856	24,619
Educator Programs, K-12 Students		
Basic Energy Sciences	0	10
Biological and Environmental Research	250	250
Fusion Energy Sciences	839	852
High Energy Physics	745	666
Workforce Development for Teachers and Scientists	8,671	5,500
Total, Educator Programs	10,505	7,278
Office of Science		
Advanced Scientific Computing Research	6,264	6,314
Basic Energy Sciences	1,286	1,032
Biological and Environmental Research	1,849	455
Fusion Energy Sciences	2,575	2,111
High Energy Physics	1,568	1,421
Nuclear Physics	251	290
Workforce Development for Teachers and Scientists	19,038	29,600
Total, Office of Science	32,831	41,223

Office of Science

Funding by Site by Program

(dollars in thousands)

	FY 2010 Current Approp. FY	2012 Request
Ames Laboratory		
Advanced Scientific Computing Research	900	0
Basic Energy Sciences	21,613	18,808
Biological and Environmental Research	675	675
Workforce Development for Teachers and Scientists	544	313
Safeguards and Security	1,185	950
Total, Ames Laboratory	24,917	20,746
Ames Site Office		
Science Program Direction	528	599
Argonne National Laboratory		
Advanced Scientific Computing Research	60,640	66,315
Basic Energy Sciences	212,919	246,726
Biological and Environmental Research	30,353	21,689
Fusion Energy Sciences	193	40
High Energy Physics	16,503	13,162
Nuclear Physics	29,643	28,935
Workforce Development for Teachers and Scientists	2,400	2,328
Science Laboratories Infrastructure	8,000	40,000
Safeguards and Security	9,163	8,983
Total, Argonne National Laboratory	369,814	428,178
Argonne Site Office		
Science Program Direction	3,418	4,149
Berkeley Site Office		
Science Program Direction	4,459	4,415

	(dollars in thousands)	
	FY 2010 Current Approp. FY	2012 Request
Brookhaven National Laboratory		
Advanced Scientific Computing Research	1,180	300
Basic Energy Sciences	243,541	272,943
Biological and Environmental Research	21,118	17,152
High Energy Physics	61,487	44,044
Nuclear Physics	182,314	195,334
Workforce Development for Teachers and Scientists	1,200	2,123
Science Laboratories Infrastructure	44,387	15,500
Safeguards and Security	11,898	12,857
Total, Brookhaven National Laboratory	567,125	560,253
Brookhaven Site Office		
Science Program Direction	5,132	5,235
Chicago Office		
Advanced Scientific Computing Research	61,892	20,019
Basic Energy Sciences	290,554	243,241
Biological and Environmental Research	173,442	159,190
Fusion Energy Sciences	154,541	137,156
High Energy Physics	137,323	129,634
Nuclear Physics	88,854	71,538
Workforce Development for Teachers and Scientists	473	149
Science Laboratories Infrastructure	809	1,385
Safeguards and Security	988	133
Science Program Direction	35,961	32,238
Congressionally Directed Projects	73,765	0
SBIR/STTR 1	67,529	0
Total, Chicago Office	1,186,131	794,683

	(dollars in thousands)	
	FY 2010 Current Approp. FY	2012 Request
Fermi National Accelerator Laboratory		
Advanced Scientific Computing Research	827	315
Basic Energy Sciences	183	35
High Energy Physics	412,737	393,425
Nuclear Physics	881	0
Workforce Development for Teachers and Scientists	483	146
Science Laboratories Infrastructure	0	0
Safeguards and Security	2,991	3,564
Total, Fermi National Accelerator Laboratory	418,102	397,485
Fermi Site Office		
Science Program Direction	2,279	2,601
Golden Field Office		
Workforce Development for Teachers and Scientists	485	161
Idaho National Laboratory		
Basic Energy Sciences	1,723	1,822
Biological and Environmental Research	1,972	1,310
Fusion Energy Sciences	2,242	2,222
Workforce Development for Teachers and Scientists	166	336
Congressionally Directed Projects	972	0
Total, Idaho National Laboratory	7,075	5,690
Lawrence Berkeley National Laboratory		
Advanced Scientific Computing Research	107,730	94,372
Basic Energy Sciences	152,988	162,019
Biological and Environmental Research	127,688	132,255
Fusion Energy Sciences	4,907	4,590
High Energy Physics	59,848	45,932
Nuclear Physics	31,249	20,244
Workforce Development for Teachers and Scientists	810	1,201
Science Laboratories Infrastructure	34,027	12,975
Safeguards and Security	5,184	5,096
Total, Lawrence Berkeley National Laboratory	524,431	478,684

	(dollars in thousands)	
	FY 2010 Current Approp. FY	2012 Request
Lawrence Livermore National Laboratory		
Advanced Scientific Computing Research	16,765	4,257
Basic Energy Sciences	4,847	3,973
Biological and Environmental Research	17,240	12,880
Fusion Energy Sciences	12,902	12,577
High Energy Physics	1,877	739
Nuclear Physics	3,330	1,300
Workforce Development for Teachers and Scientists	161	273
Total, Lawrence Livermore National Laboratory	57,122	35,999
Los Alamos National Laboratory		
Advanced Scientific Computing Research	6,582	1,920
Basic Energy Sciences	41,077	42,379
Biological and Environmental Research	12,210	18,194
Fusion Energy Sciences	5,313	2,842
High Energy Physics	648	255
Nuclear Physics	12,930	15,528
Workforce Development for Teachers and Scientists	223	130
Total, Los Alamos National Laboratory	78,983	81,248
National Energy Technology Laboratory		
Workforce Development for Teachers and Scientists	678	275
National Renewable Energy Laboratory		
Advanced Scientific Computing Research	522	0
Basic Energy Sciences	13,231	12,611
Biological and Environmental Research	1,136	878
Workforce Development for Teachers and Scientists	65	501
Total, National Renewable Energy Laboratory	14,954	13,990
Nevada Site Office		
Basic Energy Sciences	244	244
New Brunswick Laboratory		
Science Program Direction	6,132	6,720
Safeguards and Security	33	0
Total, New Brunswick Laboratory	6,165	6,720

	(dollars in thousands)	
	FY 2010 Current Approp. FY	2012 Request
Oak Ridge Institute for Science and Education		
Advanced Scientific Computing Research	1,765	0
Basic Energy Sciences	5,473	150
Biological and Environmental Research	7,653	4,170
Fusion Energy Sciences	1,935	1,450
High Energy Physics	1,137	0
Nuclear Physics	1,086	608
Workforce Development for Teachers and Scientists 9,418		18,278
Safeguards and Security	1,626	1,642
Science Program Direction	8	0
Total, Oak Ridge Institute for Science and Education	30,101	26,298
Oak Ridge National Laboratory		
Advanced Scientific Computing Research	104,871	96,955
Basic Energy Sciences	343,956	350,862
Biological and Environmental Research	74,024	70,777
Fusion Energy Sciences	153,756	118,716
High Energy Physics	79	0
Nuclear Physics	34,864	38,483
Workforce Development for Teachers and Scientists	0	21
Safeguards and Security	9,320	9,053
Total, Oak Ridge National Laboratory	720,870	684,867
Oak Ridge National Laboratory Site Office		
Science Program Direction	4,619	4,416
Oak Ridge Office		
Science Laboratories Infrastructure	5,214	5,493
Safeguards and Security	19,708	20,604
Science Program Direction	38,714	40,510
Total, Oak Ridge Office	63,636	66,607

	(dollars in thousands)	
	FY 2010 Current Approp. FY	2012 Request
Office of Scientific and Technical Information		
Advanced Scientific Computing Research	204	0
Basic Energy Sciences	389	83
Biological and Environmental Research	491	392
Fusion Energy Sciences	198	125
High Energy Physics	255	122
Nuclear Physics	216	125
Workforce Development for Teachers and Scientists	390	200
Safeguards and Security	508	465
Science Program Direction	11,501	9,277
Total, Office of Scientific and Technical Information	14,152	10,789
Pacific Northwest National Laboratory		
Advanced Scientific Computing Research	6,908	2,274
Basic Energy Sciences	25,337	23,423
Biological and Environmental Research	111,578	120,460
Fusion Energy Sciences	1,396	3,838
Nuclear Physics	849	104
Workforce Development for Teachers and Scientists	1,224	499
Safeguards and Security	11,840	11,520
Total, Pacific Northwest National Laboratory	159,132	162,118
Pacific Northwest Site Office		
Science Program Direction	5,463	5,771
Princeton Plasma Physics Laboratory		
Advanced Scientific Computing Research	478	0
Fusion Energy Sciences	75,362	70,517
High Energy Physics	292	227
Workforce Development for Teachers and Scientists	505	193
Safeguards and Security	2,265	2,222
Total, Princeton Plasma Physics Laboratory	78,902	73,159
Princeton Site Office		
Science Program Direction	1,747	1,981

	(dollars in thousands)	
	FY 2010 Current Approp. FY	2012 Request
Sandia National Laboratories		
Advanced Scientific Computing Research	10,697	7,236
Basic Energy Sciences	45,386	41,079
Biological and Environmental Research	1,674	4,148
Fusion Energy Sciences	3,786	2,414
Workforce Development for Teachers and Scientists	255	196
Total, Sandia National Laboratories	61,798	55,073
Savannah River National Laboratory		
Basic Energy Sciences	500	500
Biological and Environmental Research	363	0
Workforce Development for Teachers and Scientists	75	80
Total, Savannah River National Laboratory	938	580
SLAC National Accelerator Laboratory		
Advanced Scientific Computing Research	300	100
Basic Energy Sciences	188,672	218,324
Biological and Environmental Research	4,660	4,215
High Energy Physics	93,783	76,771
Workforce Development for Teachers and Scientists	170	305
Science Laboratories Infrastructure	6,900	24,110
Safeguards and Security	3,293	2,709
Total, SLAC National Accelerator Laboratory	297,778	326,534
SLAC Site Office		
Science Program Direction	2,871	2,845
Thomas Jefferson National Accelerator Facility		
Advanced Scientific Computing Research	100	0
Basic Energy Sciences	900	900
Biological and Environmental Research	600	600
High Energy Physics	2,354	1,232
Nuclear Physics	113,864	160,370
Workforce Development for Teachers and Scientists	488	273
Science Laboratories Infrastructure	27,687	12,337
Safeguards and Security	1,445	1,448
Total, Thomas Jefferson National Accelerator Facility	147,438	177,160

	FY 2010 Current Approp. FY	2012 Request
	(dollars in thousands)	
Thomas Jefferson Site Office		
Science Program Direction	2,069	2,098
Washington Headquarters		
Advanced Scientific Computing Research	838	171,537
Basic Energy Sciences	5,435	344,878
Biological and Environmental Research	1,154	148,915
Fusion Energy Sciences	1,119	43,213
High Energy Physics	2,488	91,657
Nuclear Physics	22,380	72,731
Workforce Development for Teachers and Scientists	465	7,619
Science Laboratories Infrastructure	576	0
Safeguards and Security	1,553	2,654
Science Program Direction	64,476	94,008
Total, Washington Headquarters	100,484	977,212
Total, Science	4,964,040	5,418,863

Office of Science

Major Changes or Shifts by Site

Argonne National Laboratory

- **Advanced Scientific Computing Research**: The Leadership Computing Facility will be undergoing site preparations, acquisition, installation, and testing of the IBM Blue Gene/Q for the 10-petaflop upgrade, while continuing to provide open high-performance computing capability with low electrical power consumption to enable scientific advances.

Fermi National Accelerator Laboratory

- **High Energy Physics**: The Tevatron Collider program is planned to complete operations in 2011 after a very successful run extending over a decade. The Fermilab accelerator complex will be shutdown for 6 months to install upgrades to the Neutrinos at the Main Injector beamline as well as reconfigure some elements of the Tevatron complex for the future Intensity Frontier research program. Fabrication and design for experiments which will make use of this new accelerator capabilities will be a major effort of the laboratory.

Oak Ridge National Laboratory

- **Nuclear Physics**: The funding increases required for the construction of two high priority major projects, the 12 GeV CEBAF Upgrade and the Facility for Rare Isotope Beams, have required strategic decisions within the Nuclear Physics program that include the closure of the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL in FY 2012.

SLAC National Accelerator Laboratory

- **High Energy Physics**: In FY 2012, SLAC's program in electron accelerator-based research will continue to be phased out as the laboratory's experimental high energy physics focus shifts largely towards non-accelerator-based projects. The laboratory's expertise in developing and deploying advanced detector systems, high-speed electronics, and data acquisition systems will be preserved to the extent possible and applied to these new efforts.
- **Science Laboratories Infrastructure:** The SLAC Science and User Support building is initiated. This facility will serve as the main entrance to the laboratory, the first stop for all visitors and users at SLAC, and will bring together many of the laboratory's visitors, users, and administrative services. This will enhance the scientific productivity and collaboration that supports the laboratory's cutting-edge discoveries and exceptional user research program.

Site Description

Ames Laboratory

The Ames Laboratory is a program dedicated laboratory (Basic Energy Sciences). The laboratory is located on the campus of the Iowa State University, in Ames, Iowa, and consists of 12 buildings (327 thousand gross square feet). The average age of the buildings is 42 years. DOE does not own the land. Ames conducts fundamental research in the physical, chemical, and mathematical sciences associated with energy generation and storage. Ames is home to the **Materials Preparation Center**, which is dedicated to the preparation, purification, and characterization of rare-earth, alkaline-earth, and refractory metal and oxide materials.

- **Advanced Scientific Computing Research**: Ames conducts research in computer science and participates on Scientific Discovery through Advanced Computing (SciDAC) science application teams.
- **Basic Energy Sciences**: Ames supports experimental and theoretical research on rare earth elements in novel mechanical, magnetic, and superconducting materials. Ames scientists are experts on magnets, superconductors, and quasicrystals that incorporate rare earth elements. Ames also conducts research in focused areas within chemical and biochemical sciences.
- **Safeguards and Security**: The Safeguards and Security (S&S) program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets at Ames. S&S provides planning, policy, implementation, and oversight in the areas of program management, access control officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

Ames Site Office

The Ames Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at the Ames Laboratory. The site office is responsible for project management of construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principal representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Argonne National Laboratory

The Argonne National Laboratory (ANL) in Argonne, Illinois, is a multiprogram laboratory located on 1,500 acres in suburban Chicago. The laboratory consists of 99 buildings (4.6 million gross square feet). The average age of the buildings is 37 years.

- **Advanced Scientific Computing Research**: ANL conducts research in applied mathematics and computer science, as well as research in advanced computing software tools relevant to hybrid, multi-core computing systems including future exascale systems. ANL also participates in a spectrum of SciDAC activities. The ANL Leadership Computing Facility provides the computational science community with a world-leading computing capability dedicated to breakthrough science and engineering. The Leadership Computing Facility will be upgraded to a 10 petaflop IBM Blue Gene/Q system, which make computationally-intensive projects of the largest scales possible.
- **Basic Energy Sciences**: ANL is home to research activities in broad areas of materials and chemical sciences. It is also the site of three user facilities—the Advanced Photon Source (APS), the Center for Nanoscale Materials (CNM), and the Electron Microscopy Center (EMC) for Materials Research.
    - The **Advanced Photon Source** is one of only three third-generation, hard x-ray synchrotron radiation light sources in the world. The 1,104-meter circumference facility—large enough to house a baseball park in its center—includes 34 bending magnets and 34 insertion devices, which generate a capacity of 68 beamlines for experimental research. Instruments on these beamlines attract researchers to study the structure and properties of materials in a variety of disciplines, including condensed matter physics, materials sciences, chemistry, geosciences, structural biology, medical imaging, and environmental sciences.
    - The **Center for Nanoscale Materials** provides capabilities for developing new methods for self assembly of nanostructures, exploring the nanoscale physics and chemistry of nontraditional electronic materials, and creating new probes for exploring nanoscale phenomena. The Center is organized around six scientific themes: nanomagnetism, bio-inorganic hybrids, nanocarbon, complex oxides, nanophotonics, and theory and simulation.
    - The **Electron Microscopy Center for Materials Research** has an emphasis on in-situ capabilities and measurements, including observation of samples in magnetic fields, under ion beam irradiation, and within a range of environments. A variety of instruments and approaches are available including an electron microscope with unique capabilities for correction of chromatic lens aberrations, which affords users the possibility of pursuing 3-D chemical imaging for characterization of buried interfaces and the study of hard/soft materials at low voltages below the displacement damage threshold. Research at EMC includes microscopy based studies on high-temperature superconducting materials, irradiation effects in metals and semiconductors, phase transformations, and processing related structure and chemistry of interfaces in thin films.
- **Biological and Environmental Research**: ANL conducts genomic, metagenomics, and computational research in microbes and soil microbial communities to understand the molecular-level processes that influence the mobility and transformations of contaminants or regulate carbon cycling and environmental interactions. ANL's Structural Biology Center operates beamlines for macromolecular crystallography at the APS.

In support of climate change research, ANL is a member of a multi-laboratory team that coordinates the overall infrastructure operations of Atmospheric Radiation Measurement Climate Research Facility (ARM) sites and mobile facilities. ANL manages the development and operation of an ARM mobile facility. ANL conducts research on aerosol processes and properties, and develops and applies software to enable efficient long-term climate simulations on distributed-memory multiprocessor computing platforms.

- **Fusion Energy Sciences**: ANL contributes a small effort in basic plasma science. In addition, ANL has participated in the two-year planning study of the Fusion Simulation Program, contributing in the areas of algorithm development, code verification, software standards, and workflow needs and tools determination.
- **High Energy Physics**: ANL has unique capabilities in the areas of engineering, detector technology, and advanced accelerator and computing techniques. Major ANL activities include working on the ATLAS (A Large Toroidal LHC Apparatus) experiment at the Large Hadron Collider, participating in the Fermilab neutrino program, completing the analysis of Tevatron data, developing new detector technologies for future experiments, advancing accelerator R&D using the Argonne Wakefield Accelerator, and partnering with Fermilab in the development of superconducting radio frequency technology for future accelerators.
  - The **Argonne Wakefield Accelerator** is an R&D testbed that focuses on the physics and technology of high-gradient, dielectric-loaded structures for accelerating electrons. Two approaches are being pursued: a collinear, electron-beam driven dielectric-loaded wakefield accelerator and a two-beam accelerator. The goal is to identify and develop techniques which may lead to more efficient, compact, and inexpensive particle accelerators for future HEP applications. Research activities at this facility include the development of materials/coatings for high gradient research, dielectric-loaded and photonic band gap accelerating structures, left-handed meta-materials, high-power/high-brightness electron beams, and advanced beam diagnostics.
- **Nuclear Physics**: ANL operates the Argonne Tandem Linac Accelerator System national user facility, the world's premiere stable beam facility, and supports its R&D program. ANL nuclear scientists have expertise in detector development, computational techniques, and advanced accelerator technology. Other activities include an on-site program of research using laser techniques (Atom Trap Trace Analysis); research programs at the Thomas Jefferson National Accelerator Facility (TJNAF), Fermilab, and RHIC; development and fabrication support for the Facility for Rare Isotope Beams (FRIB); theoretical calculations and investigations in subjects supporting the experimental research programs in medium energy and low energy physics; research in the production of radioisotopes for medical applications; data compilation and evaluation activities as part of the National Nuclear Data program; and, in collaboration with the Office of Nuclear Energy, measurement of actinide reaction rates and cross sections for nuclear fuel irradiated in the Idaho Advanced Test Reactor.
  - The **Argonne Tandem Linac Accelerator System** national user facility provides variable energy and precision beams of stable ions from protons through uranium at energies near the Coulomb barrier (up to 10 MeV per nucleon) using a superconducting linear accelerator. Most work is performed with stable heavy-ion beams, as well as a percentage of rare isotope beams. The facility features a wide array of experimental instrumentation, including a world-leading ion-trap apparatus, the Advanced Penning Trap. The Gammasphere detector, coupled with the Fragment Mass Analyzer, is a unique world facility for measurement of nuclei at the limits of angular

momentum (high-spin states). The facility nurtures a core competency in accelerator expertise with superconducting radiofrequency cavities for heavy ions that is relevant to the next generation of high-performance proton and heavy-ion linacs, and important to the SC mission and international stable and radioactive ion beam facilities. The combination of versatile beams and powerful instruments enables about 430 users annually to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies. The capabilities are being augmented by the fabrication of the Californium Rare Ion Beam Upgrade (CARIBU), which is being commissioned in FY 2011, as a source to provide new capabilities in neutron-rich radioactive beams. The Helical Orbital Spectrometer, employs a new concept to study reactions with radioactive beams from CARIBU.

- **Science Laboratories Infrastructure**: The SLI program supports DOE research initiatives by funding the line item construction needed to maintain mission ready infrastructure at ANL. The SLI program is currently funding the Energy Sciences Building project, which is constructing new, environmentally stable, specialized, and flexible space to replace some of the oldest and least effective research space for energy-related sciences.
- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets at ANL. S&S provides planning, policy, implementation, and oversight in the areas of program management, access control officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

Argonne Site Office

The Argonne Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at the Argonne National Laboratory. The site office is responsible for project management of line-item and other construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principal representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Berkeley Site Office

The Berkeley Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at the Lawrence Berkeley National Laboratory. The site office is responsible for project management of line-item and other construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principal representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Brookhaven National Laboratory

The Brookhaven National Laboratory (BNL) is a multiprogram laboratory located on 5,300 acres in Upton, New York. The laboratory consists of 331 SC buildings (4.0 million gross square feet of space). The average age of the buildings is 39 years. BNL operates major facilities that are available to university, industrial, and government personnel for basic and applied research in the physical, biomedical, and environmental sciences, and in selected energy technologies.

- **Advanced Scientific Computing Research**: BNL conducts research in applied mathematics and advanced networking. It also participates in a limited spectrum of SciDAC activities.
- **Basic Energy Sciences**: BNL conducts research efforts in materials sciences with emphasis on advanced scattering techniques, chemical sciences, and physical biosciences. It is also the site of two BES supported user facilities—the National Synchrotron Light Source and the Center for Functional Nanomaterials.
  - The **National Synchrotron Light Source** consists of two distinct electron storage rings. The x-ray storage ring is 170 meters in circumference and can accommodate 60 beamlines or experimental stations, and the vacuum-ultraviolet (VUV) storage ring can provide 25 additional beamlines around its circumference of 51 meters. Synchrotron light from the x-ray ring is used to determine the atomic structure of materials using diffraction, absorption, and imaging techniques. Experiments at the VUV ring help understand the atomic and electronic structure as well as the magnetic properties of a wide array of materials. Construction of a new synchrotron light source at BNL (the National Synchrotron Light Source II) is underway.
  - The **Center for Functional Nanomaterials** focuses on understanding the chemical and physical response of nanomaterials to make functional materials such as sensors, activators, and energy-conversion devices. It also provides clean rooms, general laboratories, and wet and dry laboratories for sample preparation, fabrication, and analysis. It includes equipment needed for laboratory and fabrication facilities for e-beam lithography, transmission electron microscopy, scanning probes and surface characterization, material synthesis and fabrication, and spectroscopy.
- **Biological and Environmental Research**: BNL operates beam lines for macromolecular crystallography at the National Synchrotron Light Source for use by the national biological research community and research into new technologies for biological structure determination. BNL conducts molecular radiochemistry and imaging and instrumentation research, developing advanced technologies for biological imaging.

  Climate change research includes the operation of the Atmospheric Radiation Measurement Climate Research Facility (ARM) External Data resource that provides atmospheric system research investigators with data from non-ARM sources, including satellite and ground-based systems. BNL is the lead for multi-institution research to address issues of model evaluation, development, and understanding of atmospheric processes.

  Scientists at BNL continue final analysis and closeout of the Free-Air Carbon Dioxide Enrichment (FACE) experiment at the Duke Forest which explored how plants respond to elevated carbon dioxide concentrations in the atmosphere.
- **High Energy Physics**: BNL has unique resources in the engineering and technology for future accelerators and detectors, advanced computational resources, and the Accelerator Test Facility. BNL serves as the host laboratory for the U.S. ATLAS collaboration, which participates in the research of the ATLAS detector at the Large Hadron Collider. BNL manages the program of maintenance and operations for the ATLAS detector, operates the primary U.S. analysis facility for ATLAS data, and is developing an analysis support center for U.S. based users. The group also contributes to the leadership and management of the U.S. International Linear Collider R&D effort and is a member of the Tevatron research collaboration at Fermilab.

  BNL researchers have a leadership role in the Reactor Neutrino experiment in Daya Bay, China. BNL physicists are also involved in other neutrino physics efforts including research at the Neutrinos at the Main Injector (NuMI) facility with the Main Injector Neutrino Oscillation experiment at Fermilab and R&D and planning for future accelerator-based neutrino experiments, particularly the Long Baseline Neutrino Experiment.

- The BNL **Accelerator Test Facility** is a user facility that supports a broad range of advanced accelerator R&D with many and varied scientific applications. The core capabilities include a high-brightness photoinjector electron gun, a 70-MeV linac, high power lasers synchronized to the electron beam at a picosecond level, four beam lines, and a sophisticated computer control system. Experiments carried out in this facility are proposal-driven and are typically in the areas involving interactions of high power electromagnetic radiation and high brightness electron beams, including laser acceleration of electrons and free-electron lasers. Other topics include the development of extremely high brightness electron beams, photo-injectors, electron beam and radiation diagnostics, and computer controls.

▪ **Nuclear Physics**: Research activities include: use of relativistic heavy ion beams and polarized protons in the Relativistic Heavy Ion Collider (RHIC) to investigate hot, dense nuclear matter and to understand the internal "spin" structure of the proton; development of future detectors for RHIC; core competencies in accelerator R&D of beam-cooling techniques aimed at increasing the RHIC beam luminosity and of importance to other SC projects; R&D and calibration efforts directed towards research with neutrinos; a theory program emphasizing RHIC heavy ion and "spin" physics; data compilation and evaluation at the National Nuclear Data Center (NNDC), the central U.S. site for these national and international efforts; operations of the Brookhaven Linac Isotope Producer (BLIP), which produces research and commercial isotopes in short supply; and a research and development effort of new isotope production and processing techniques.

- The **Relativistic Heavy Ion Collider** facility uses accelerators to inject beams into two rings of superconducting magnets of almost 4 kilometers circumference with 6 intersection regions where the beams can collide. RHIC can accelerate and collide a variety of heavy ions, including gold beams, up to an energy of 100 GeV per nucleon. RHIC is being used to search for and characterize hot dense nuclear matter and has seen signs of the same quark-gluon plasma that is believed to have existed microseconds after the big bang. It can also collide polarized protons with beams of energy up to 250 GeV per nucleon—a unique capability. Two detectors are supported to provide complementary measurements, with some overlap in order to cross-calibrate the measurements: the Solenoidal Tracker at RHIC and the Pioneering High-Energy Nuclear Interacting Experiment. Accelerator and detector upgrades continue to support second generation measurements to more fully understand and characterize the matter produced in RHIC collisions.

- The **Alternating Gradient Synchrotron** (AGS) accelerator is the injector of (polarized) proton and heavy-ion beams into RHIC, and its operations are supported by the NP Heavy Ion subprogram as part of the RHIC facility. The AGS is also utilized for radiation damage studies of electronic systems for NASA-supported work and work for other agencies. In addition, it has the capability to provide high intensity pulsed proton beams up to 33 GeV on fixed targets.

- The **Booster Synchrotron** accelerator, part of the RHIC injector, provides heavy-ion beams to a dedicated beam line (NASA Space Radiation Laboratory) for biological and electronic systems radiation studies funded by NASA.

- The **Electron Beam Ion Source** (EBIS) accelerator and linac system were completed in FY 2010 and are replacing the Tandem Van de Graaff accelerators that served as injectors for the Booster Synchrotron. EBIS, which was supported as a joint DOE/NASA project, promises greater efficiency, greater reliability, and lower maintenance costs as well as the potential for future upgrades.

- The **National Nuclear Data Center** is the central U.S. site for national and international nuclear data and compilation efforts. The U.S. Nuclear Data program is the United States' repository for information generated in low- and intermediate-energy nuclear physics research worldwide. This information consists of both bibliographic and numeric data. The Center is a resource for a very broad user community in basic nuclear science research and in all aspects of nuclear technology, with relevance to homeland security and advanced fuel cycles for nuclear reactors. Nuclear Data program-funded scientists at U.S. national laboratories and universities contribute to the Center's activities and responsibilities.
- The **Brookhaven Linac Isotope Producer** at BNL uses a linear accelerator that injects 200 MeV protons into the 33 GeV Alternating Gradient Synchrotron. The isotopes produced by BLIP, such as strontium-82, germanium-68, copper-67, and others, are used in medical diagnostic and therapeutic applications and other scientific research. The BLIP can operate in dedicated mode or in conjunction with RHIC operations. The BLIP is also used to perform irradiation tests for neutrino experiments.

▪ **Science Laboratories Infrastructure**: The SLI program supports DOE research initiatives by funding the line item construction needed to maintain mission ready infrastructure at BNL. SLI is currently funding the Renovate Science Laboratories, Phase II project that will modernize unsuitable laboratory space in buildings 510 (Physics) and 555 (Chemistry), allowing them to continue supporting research in Basic Energy Sciences, Nuclear Physics, and High Energy Physics. Final funding for construction of the Interdisciplinary Science Building, Phase I project was provided in FY 2010. This project will provide high accuracy laboratories (equipped with precise temperature, humidity, and vibration controls), offices, and support space for energy-related research and development in a new interdisciplinary facility.

▪ **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets at BNL. S&S provides planning, policy, implementation, and oversight in the areas of program management, protective force officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

Brookhaven Site Office

The Brookhaven Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at the Brookhaven National Laboratory. The site office is responsible for project management of line-item and other construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principal representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Chicago Office

The Chicago (CH) Office provides support (procurement, legal, financial management, human resources, and facilities and infrastructure) to headquarters program sponsors and to site offices responsible for program management oversight of six management and operating laboratories—the

Ames Laboratory, Argonne National Laboratory, Lawrence Berkeley National Laboratory, Brookhaven National Laboratory, Fermilab, and Princeton Plasma Physics Laboratory—and one government-owned and government-operated Federal laboratory, the New Brunswick Laboratory. The administrative, business, and technical expertise of CH is shared SC-wide through the Integrated Support Center concept. CH also serves as SC's Financial Assistance center, administering grants to about 300 colleges and universities in all 50 states, Washington, D.C., and Puerto Rico.

- **Advanced Scientific Computing Research**: Funds research at over 70 academic institutions located in 34 states.
- **Basic Energy Sciences**: Funds research at 170 academic institutions located in 50 states.
- **Biological and Environmental Research**: Funds research at over 200 institutions, including colleges, universities, private industry, and other Federal and private research institutions located in 48 states and Washington, D.C.
- **Fusion Energy Sciences**: Funds research grants and cooperative agreements at more than 60 colleges, universities, and industries located in approximately 30 states.
- **High Energy Physics**: Supports research groups at more than 100 colleges and universities located in 36 states, Washington, D.C., and Puerto Rico.
- **Nuclear Physics**: Funds research grants at 90 colleges and universities located in 35 states and Washington, DC.
- **Safeguards and Security**: S&S provides funding to the Chicago Office for federal field personnel security investigations.

Fermi National Accelerator Laboratory

Fermi National Accelerator Laboratory is a program-dedicated laboratory (High Energy Physics) located on a 6,800-acre site in Batavia, Illinois. The laboratory consists of 355 buildings (2.3 million gross square feet of space). The average age of the buildings is 43 years. Fermilab is the largest U.S. laboratory for research in high-energy physics and, world-wide, is second only to CERN–the European Laboratory for Particle Physics in size. About 2,000 scientific users—scientists from universities and laboratories throughout the U.S. and around the world—use Fermilab for their research. Fermilab's mission is that of the high-energy physics program: to understand matter at its deepest level, to identify its fundamental building blocks, and to understand how the laws of nature determine their interactions.

- **Advanced Scientific Computing Research**: Fermilab participates in SciDAC science application teams relevant to physics research, accelerator modeling, and distributed data. Fermilab also participates in advanced networking research.
- **High Energy Physics**: Fermilab is the principal HEP experimental facility in the Nation. Fermilab operates the **Tevatron** accelerator and colliding beam facility, which consists of a four-mile ring of superconducting magnets and two large multi-purpose detectors and is capable of accelerating protons and antiprotons to an energy of one trillion electron volts (1 TeV). The laboratory supports two Tevatron experiments, CDF and D-Zero, together home to about 1,400 physicists from Fermilab and other national laboratories, U.S. universities, and foreign universities and research institutes. The Tevatron Collider program is planned to complete operations in 2011 after a very successful run that extended over a decade. The Fermilab accelerator complex will run in FY 2012 for six months supporting the neutrino program and then be shutdown for 6 months to install upgrades and reconfigure some elements of the Tevatron complex for the future Intensity Frontier research program.

- The Tevatron complex includes the **Neutrinos at the Main Injector** (NuMI) beamline, the world's highest intensity neutrino beam facility. NuMI provides a controlled beam of neutrinos to the Main Injector Neutrino Oscillation (MINOS) experiment located in the Soudan Mine in Minnesota and the Main Injector Neutrino ν-A (MINERνA) experiment located onsite at Fermilab. The NuMI Off-Axis Neutrino Appearance (NOνA) project will upgrade the NuMI beamline in FY 2012 and exploit the increased beam power to make further discoveries in neutrino physics. NOνA is under construction and will be in full operation in 2014.
- Fermilab is host laboratory for the U.S. Compact Muon Solenoid (CMS) collaboration, which conducts research using the CMS detector at the LHC. Fermilab manages the program of maintenance and operations for the CMS detector and operates the primary U.S. data analysis center for CMS. Fermilab is also the host laboratory for the LHC Accelerator Research Program which manages U.S. accelerator physicists' efforts on the commissioning, operations, and upgrades of the LHC.
- Fermilab is also a leading national laboratory for research and development of future particle accelerator technologies. For example, the large scale infrastructure needed for the fabrication, processing, and testing of superconducting radio frequency cavities and cryomodules is being built at Fermilab. This includes horizontal and vertical test stands for cavity testing, high quality clean rooms and well-equipped rigging areas for assembly of cryomodules. Fermilab is the lead U.S. laboratory coordinating the national R&D program in this area.
- With an active program in particle astrophysics and cosmology, Fermilab has led the development and fabrication of a camera to be used in the Dark Energy Survey. It has significant participation in research on the direct detection of dark matter and ultra high energy cosmic rays, and is conducting R&D towards next generation dark energy and dark matter experiments.
- Fermilab also has a significant program for R&D on advanced detector components for a variety of physics applications. The laboratory also maintains and operates a fixed target beam for testing of detector elements that hosts university, national laboratory, and international R&D groups.

▪ **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets at Fermilab. S&S provides planning, policy, implementation, and oversight in the areas of program management, access control officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

Fermi Site Office

The Fermi Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at Fermilab. The site office is responsible for project management of line-item and other construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principle representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Idaho National Laboratory

Idaho National Laboratory (INL) is a multiprogram laboratory located on 572,000 acres in Idaho Falls, Idaho. Within the laboratory complex are nine major applied engineering, interim storage, and research and development facilities.

- **Basic Energy Sciences**: INL supports studies on materials sciences for nuclear fuels and the relationship of microstructure to materials properties.
- **Biological and Environmental Research**: INL is conducting subsurface biogeochemical research related to clean up of the nuclear weapons complex with an emphasis on understanding the control of mineral precipitation reaction fronts and coupled processes affecting contaminant transport.
- **Fusion Energy Sciences**: Research at INL focuses on the safety aspects of magnetic fusion concepts for existing and future machines, such as a burning plasma experiment, and further development of the domestic fusion safety database using existing collaborative arrangements to conduct work on international facilities. In addition, INL has expanded its research and facilities capabilities to include tritium science activities at the Safety and Tritium Applied Research (STAR) national user facility—a small tritium laboratory where the fusion program can conduct tritium material science, chemistry, and safety experiments. INL also coordinates safety codes and standards within the ITER program.
- **Nuclear Physics:** The Advanced Test Reactor (ATR) is supported for the production of select isotopes for the Isotope Program, such as gadolinium-153, an important isotope for applications such as positron emission tomography imaging. In collaboration with the Office of Nuclear Energy, nuclear fuel irradiated in the ATR is being analyzed at ANL to provide accurate data on actinide reaction rates and cross sections as part of the National Nuclear Data program.

Lawrence Berkeley National Laboratory

The Lawrence Berkeley National Laboratory (LBNL) is a multiprogram laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. The laboratory consists of 106 buildings (1.7 million gross square feet of space). The average age of the buildings is 40 years. LBNL is dedicated to performing leading-edge research in the biological, physical, materials, chemical, energy, and computer sciences. The land is leased from the University of California.

- **Advanced Scientific Computing Research**: LBNL conducts research in applied mathematics and computer science, as well as research in advanced computing software tools relevant to hybrid multi-core computing systems including future exascale systems. LBNL manages the Energy Sciences network (ESnet), one of the world's most effective and progressive science-related computer networks, which provides worldwide access and communications to Department of Energy facilities. LBNL is the site of the National Energy Research Scientific Computing Center (NERSC), which provides a range of high-performance, state-of-the-art computing resources that are a critical element in the success of many SC research programs. LBNL also participates in a spectrum of SciDAC activities.
- **Basic Energy Sciences**: LBNL is home to major research efforts in materials sciences with emphasis on nanoscience, chemical sciences, geosciences, biosciences, and solar fuels research. It is also the site of three Basic Energy Sciences supported user facilities—the Advanced Light Source (ALS), the National Center for Electron Microscopy, and the Molecular Foundry.
  - The **Advanced Light Source** provides vacuum-ultraviolet light and x-rays for probing the electronic and magnetic structure of atoms, molecules, and solids, such as those for high-

temperature superconductors. The high brightness and coherence of the ALS light are particularly suited for soft x-ray imaging of biological structures, environmental samples, polymers, magnetic nanostructures, and other inhomogeneous materials. Other uses of the ALS include holography, interferometry, and the study of molecules adsorbed on solid surfaces. The pulsed nature of the ALS light offers special opportunities for time resolved research, such as the dynamics of chemical reactions. Shorter wavelength x-rays are also used at structural biology experimental stations for x-ray crystallography and x-ray spectroscopy of proteins and other important biological macromolecules.

- The **National Center for Electron Microscopy** provides instrumentation for high-resolution, electron-optical microcharacterization of atomic structure and composition of metals, ceramics, semiconductors, superconductors, and magnetic materials. This facility includes, and provides users with access to the TEAM I instrument, the most advanced scanning transmission electron microscope in the world with unparalleled lateral spatial resolution of under 50 picometers. NCEM's focus and major impact is in the following areas of research: defects and deformation; mechanisms and kinetics of phase transformations in materials; nanostructured materials; surfaces, interfaces and thin films; and microelectronics materials and devices.

- The **Molecular Foundry** provides users with instruments, techniques, and collaborators to enhance the study of the synthesis, characterization, and theory of nanoscale materials. Its focus is on the multidisciplinary development and understanding of both "soft" (biological and polymer) and "hard" (inorganic and microfabricated) nanostructured building blocks and the integration of these building blocks into complex functional assemblies. Scientific themes include inorganic nanostructures; nanofabrication; organic, polymer, and biopolymer nanostructures; biological nanostructures; imaging and manipulation of nanostructures; and theory of nanostructures. The facility offers expertise in a variety of techniques for the study of nanostructures, including electronic structure and excited-state methods, *ab initio* and classical molecular dynamics, quantum transport, and classical and quantum Monte Carlo approaches.

▪ **Biological and Environmental Research**: LBNL is the lead national laboratory managing the **Joint Genome Institute** (JGI), the principal goal of which is high-throughput genome sequencing and analysis techniques. LBNL also operates BER-supported beamlines for life science applications, emphasizing small-angle x-ray scattering, infrared spectromicroscopy, x-ray tomography, and soft x-ray spectroscopy at the ALS for use by the national and international biological research community. LBNL plays a key role in the science supporting climate and environmental system prediction, and on biological and ecological responses to climate and atmospheric changes.

- LBNL conducts systems-level research to advance fundamental understanding of DOE-relevant microbes and environmental interactions and how subsurface biogeochemical processes impact contaminant transport and behavior across multiple spatial and temporal scales. LBNL research on carbon cycling involving terrestrial ecosystems contributes towards understanding the processes controlling the exchange of CO_2 between terrestrial ecosystems and the atmosphere.

- The laboratory also develops scalable implementation technologies that allow widely used climate models to run effectively and efficiently on massively parallel processing supercomputers. LBNL leads a multi-laboratory activity to study and quantify the risks of abrupt climate change during the 21^{st} century. LBNL conducts research on regional climate modeling, including efforts to advance aerosol and cloud parameterizations, and carry out model diagnostics and evaluations.

- The **Joint BioEnergy Institute** (JBEI) at LBNL, one of three DOE Bioenergy Research Centers, is focused on developing systems biology approaches for production of next generation (i.e. non-ethanol) liquid biofuels using well characterized microbes such as *E. coli* and yeast that lend themselves to metabolic engineering. JBEI researchers also study the basic characteristics of biomass synthesis pathways in model plant species, prospect rainforest soils for more efficient cellulose degrading enzymes and microorganisms, and examine the potential of ionic liquids for biomass deconstruction.

- **Fusion Energy Sciences**: LBNL has been conducting research in developing ion beams for applications to high energy density laboratory plasmas (HEDLP) and inertial fusion energy sciences. Currently the laboratory has two major experimental systems for doing this research: the Neutralized Drift Compression Experiment (NDCX) and the High Current Experiment. Both experiments are directed at answering the question of how ion beams can be produced with the intensity required for research in HEDLP and inertial fusion energy sciences. LBNL is currently upgrading the Neutralized Drift Compression Experiment from its present configuration to NDCX-II. The NDCX-II facility will advance the science of drift compression of an ion beam to intensify the beam, and enhance the energy on target of the ion beam by a factor of 100. LBNL conducts this research together with the Lawrence Livermore National Laboratory and Princeton Plasma Physics Laboratory through the Heavy Ion Fusion Science Virtual National Laboratory.

- **High Energy Physics**: LBNL has unique capabilities in the areas of superconducting magnet R&D, engineering and detector technology, the design of advanced electronic devices, computational resources, and the design of modern, complex software codes for HEP experiments. LBNL had a leading role in developing and implementing advanced particle detectors for the ATLAS experiment at the LHC, and now participates in the research program of the ATLAS detector. LBNL also has a leading role in providing the software and computing infrastructure for ATLAS. LBNL staff is also involved in neutrino physics research using reactor-produced neutrinos, and provides management expertise to the Reactor Neutrino experiment at Daya Bay, China.

  - The Laser Optics and Accelerator Systems Integrated Studies group has begun work on the Berkeley Lab Laser Accelerator (BELLA) project whose goal is the development of the 10 GeV laser-wakefield accelerator module using a petawatt laser.

  - LBNL also has an active program in particle astrophysics and cosmology, providing leadership in the development of innovative detector technologies and in the application of high energy physics analysis methods to astronomical observations. LBNL physicists lead ongoing studies of dark energy using supernovae and baryon acoustic oscillations, and continues R&D for a space-based dark energy mission. LBNL operates the Microsystems Laboratory, where new detector technologies have been developed for collider physics research and new devices to study dark energy and the cosmic microwave background. LBNL is also host to the Particle Data Group, which annually coordinates compilation and synthesis of high-energy physics experimental data into compendia which summarize the status of all major subfields of HEP.

- **Nuclear Physics**: LBNL supports a variety of activities focused primarily on NP's low energy and heavy ion subprograms. This include fabrication of a next-generation gamma-ray detector system, the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA); research with the STAR detector located at BNL's RHIC facility; and development and fabrication of major components for the STAR Heavy Flavor Tracker at RHIC. Also included are operation of the National Energy Research Scientific Computing Center's (NERSC) Parallel Distributed Systems Facility (PDSF) aimed at providing computation resources for the STAR heavy ion experiment at RHIC, a Tier-2

U.S. site on the computing grid to manage storage and processing of experimental data from the A Large Ion Collider Experiment (ALICE) experiment at the LHC, and low energy physics computation; fabrication of a detector upgrade for ALICE detector heavy ion program at the LHC; and analysis of data from the KamLAND detector in Japan that performed neutrino studies. In addition, development and fabrication of next generation neutrino detectors, including leading the effort on U.S. participation in the Cryogenic Underground Observatory for Rare events (CUORE) experiment in Italy, and a theory program with an emphasis on relativistic heavy ion physics are conducted. Data compilation and evaluation activities supporting the National Nuclear Data Center at BNL and R&D of electron-cyclotron resonance ion sources for the Facility for Rare Isotope Beams are also conducted at LBNL. The 88-Inch Cyclotron at LBNL is a facility for testing electronic circuit components for radiation "hardness" to cosmic rays, supported by the National Reconnaissance Office and the U.S. Air Force, and for a small in-house research program supported by NP.

- **Science Laboratories Infrastructure**: SLI supports DOE research initiatives by funding the line item construction needed to maintain mission ready infrastructure at LBNL. SLI is currently funding the Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II project at LBNL, which will replace seismically-poor buildings and trailers with a new general purpose laboratory/office building supporting multidisciplinary science, seismically upgrading the site-wide Hazardous Waste Handling Facility, and upgrading and modernizing an existing Life Sciences building (Building 74).
- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets at LBNL. S&S provides planning, policy, implementation, and oversight in the areas of program management, access control officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory (LLNL) is a multiprogram laboratory located on 821 acres in Livermore, California. This laboratory was built in Livermore as a weapons laboratory 42 miles from the campus of the University of California at Berkeley to take advantage of the expertise of the university in the physical sciences.

- **Advanced Scientific Computing Research**: LLNL conducts research in applied mathematics and computer science, as well as advanced computing software tools relevant to hybrid, multi-core computing systems including future exascale systems. LLNL also participates in a spectrum of SciDAC activities.
- **Basic Energy Sciences**: LLNL conducts research in focused areas related to extreme environments and the limits of length and time scales within materials sciences and geosciences.
- **Biological and Environmental Research**: LLNL is one of the major national laboratory partners supporting the Joint Genome Institute (JGI). LLNL is also a critical player to advance climate and environmental prediction systems. LLNL conducts research to study structure and function of microbial communities, including development of enabling novel technologies.
  - LLNL is improving model representation of the main processes—clouds, aerosols, and the cryosphere—that drive the rapid decrease in Arctic ice cover as well as examining the implications of those decreases on future climate. LLNL conducts research to develop metrics

and diagnostics for ultra-high resolution simulations. The laboratory also supports the ARM Climate Research Facility through the development and support of data sets designed for modelers. Through the Program for Climate Model Diagnosis and Intercomparision, LLNL provides the international leadership to develop and apply diagnostics tools to evaluate and improve the performance of climate models; every climate modeling center in the world participates in this unique program.

  - LLNL conducts subsurface biogeochemistry research on the fate and transport of plutonium and other actinide contaminants in the environment. LLNL is a partner in the LBNL-led Joint BioEnergy Institute.

- **Fusion Energy Sciences**: LLNL works with LBNL and PPPL through the Heavy-Ion Fusion Virtual National Laboratory in advancing the physics of heavy ion beams as a driver for high energy density laboratory plasmas and inertial fusion energy sciences. It also conducts research on fast ignition concepts for applications in research on high energy density physics and inertial fusion energy sciences. The LLNL program also includes collaborations with General Atomics on the DIII-D tokamak and benchmarking of fusion physics computer models with experiments such as DIII-D. LLNL carries out research in the simulation of turbulence and its effect on transport of heat and particles in magnetically confined plasmas. In addition, LLNL carries out research in support of plasma chamber and plasma-material interactions.

- **High Energy Physics**: HEP supports experimental physics research and technology R&D at LLNL, using unique capabilities of the laboratory primarily in the areas of engineering and detector technology and advanced accelerator R&D.

- **Nuclear Physics**: The LLNL program supports research in relativistic heavy ion physics as part of the PHENIX collaboration at RHIC and the ALICE experiment at LHC, in nuclear data and compilation activities, in R&D for neutrinoless double beta decay experiments, nuclear structure with radioactive ion beams, research on super heavy nuclei, and in theoretical studies in the areas of nuclear structure studies, low energy nuclear reactions, and lattice QCD. LLNL has partnered with LBNL's National Energy Research Scientific Computing Center (NERSC) to establish a Tier-2 U.S. site on the computing grid to manage storage and processing of experimental data from the ALICE experiment.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a multiprogram laboratory located on 30,413 acres in Los Alamos, New Mexico.

- **Advanced Scientific Computing Research**: LANL conducts research in applied mathematics and computer science and in advanced computing software tools relevant to hybrid, multi-core computing systems including future exascale systems. LANL also participates in a spectrum of SciDAC activities.

- **Basic Energy Sciences**: LANL is home to research efforts in materials sciences to control functionality, chemical sciences, and geosciences.

  LANL is also the site of two BES supported user facilities: the Manuel Lujan Jr. Neutron Scattering Center and the Center for Integrated Nanotechnologies (CINT).

  - The **Manuel Lujan Jr. Neutron Scattering Center** provides an intense pulsed source of neutrons to a variety of spectrometers for neutron scattering studies. The Lujan Center features instruments for measurement of high-pressure and high-temperature samples, strain measurement, liquid studies, and texture measurement. The facility has extensive experience in handling actinide samples. The Lujan Center is part of the Los Alamos Neutron Science Center (LANSCE), which includes a high-power 800 MeV proton linear accelerator, a proton storage ring, production targets to the Lujan Center and the Weapons Neutron Research facility, and a variety of associated experiment areas and spectrometers for national security research and civilian research.

- The **Center for Integrated Nanotechnologies** is devoted to establishing the scientific principles that govern the design, performance, and integration of nanoscale materials. Through its core facility in Albuquerque, New Mexico, and its gateways to both Sandia National Laboratories and Los Alamos National Laboratory, CINT provides access to tools and expertise to explore the continuum from scientific discovery to the integration of nanostructures into the microworld and the macroworld. CINT supports five scientific thrusts that serve as synergistic building blocks for integration research: nano-bio-micro interfaces, nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and theory and simulation.

▪ **Biological and Environmental Research**: LANL is one of the major national laboratory partners that support the JGI. LANL also participates in critical components designed to advanced climate and environmental predicition capabilities.

- LANL conducts research on the genomic analysis of complex microbial communities from environmental soil samples. Activities in structural biology include the operation of an experimental station for protein crystallography at LANSCE for use by the national biological research community.
- In support of BER's climate change research, LANL is a member of a multi-laboratory team that coordinates the overall infrastructure operations of Atmospheric Radiation Measurement Climate Research Facility (ARM) sites and mobile facilities. LANL manages the deployment and operation of an ARM mobile facility.
- LANL also has a crucial role in the development, optimization, and validation of coupled sea ice and oceanic models for implementation on massively parallel computers. The laboratory is improving representation of the main processes, clouds, aerosols and the cryosphere, that drive the rapid decrease in Arctic ice cover as well as examining the implications of those decreases on future climate.

▪ **Fusion Energy Sciences**: LANL has developed a substantial experimental system for research in magnetized target fusion, an important innovative confinement concept, and a thrust area in magnetized high energy density laboratory plasmas. The laboratory leads research in a high-density, compact plasma configuration called field reversed configuration. LANL supports the creation of computer codes for modeling the stability of magnetically confined plasmas, including tokamaks and innovative confinement concepts. The work also provides theoretical and computational support for the Madison Symmetric Torus experiment, a proof-of-principle experiment in reversed field pinch at the University of Wisconsin in Madison. LANL develops advanced diagnostics for fusion experiments, such as the rotating magnetic field as a current drive mechanism for the Field Reversed Configuration Experiment at the University of Washington in Seattle. LANL also supports the tritium processing activities needed for ITER.

▪ **High Energy Physics**: HEP supports theoretical and experimental physics research at LANL, using unique capabilities of the laboratory in high-performance computing for advanced simulations and expertise in particle astrophysics, neutrino physics, and advanced accelerator concepts.

- **Nuclear Physics**: NP supports a broad program of research at LANL. These activities include a research and development effort in relativistic heavy ions using the PHENIX detector at RHIC and leading the fabrication of the RHIC Forward Vertex Tracker (FVTX) detector for BNL; research on the quark substructure of the nucleon in experiments at Fermilab and the "spin" structure of nucleons at RHIC using polarized proton beams; measurement of oscillations of anti-neutrinos with the Mini Booster Neutrino Experiment (MiniBooNE); and R&D directed at future studies of the properties of neutrinos are also conducted. LANL scientists are participating in a modest program of neutron beam research that utilizes beams from the LANSCE facility for fundamental physics measurements are also conducted at LANL. A broad program of theoretical research, nuclear data, and compilation activities as part of the U.S. Nuclear Data program; operations of the Isotope Production Facility (IPF), which produces research and commercial isotopes in short supply; and a research and development effort of new isotope production and processing techniques are conducted as well.
    - At LANL, the 100 MeV **Isotope Production Facility** produces various radioactive isotopes, including germanium-68 (a calibration source for positron emission tomography PET scanners); strontium-82 (the parent of rubidium-82, used in cardiac PET imaging); and arsenic-73 (used as a biomedical tracer). The IPF is dependent on LANSCE operations and operates in parallel to LANSCE. NP also supports isotope production research using higher energy proton beams available at LANSCE (e.g., the production of actinium-225 by the irradiation of thorium-232 with 100-800 MeV protons).

National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) is an Energy Efficiency and Renewable Energy laboratory located on 632 acres in Golden, Colorado. NREL's focus is on renewable energy technologies such as photovoltaics and other means of exploiting solar energy. It is the world leader in renewable energy technology development. Since its inception in 1977, NREL's mission is to develop renewable energy and energy efficiency technologies and transfer these technologies to the private sector.

- **Advanced Scientific Computing Research**: NREL participates in SciDAC science application teams including efforts focused on computational nanoscience and computational biology.
- **Basic Energy Sciences**: NREL conducts fundamental research in the chemical sciences, biosciences, and materials sciences, which are primarily devoted to the conversion of solar energy to electricity and fuels.
- **Biological and Environmental Research:** NREL conducts research on the biological production of hydrogen and is a partner in the Oak Ridge National Laboratory-led Genomic Science BioEnergy Science Center.

New Brunswick Laboratory

The New Brunswick Laboratory (NBL), located at ANL in Illinois, is a government-owned, government-operated laboratory that serves as a DOE Center of Excellence in analytical chemistry and the science of measuring nuclear materials. In this role, NBL performs measurements of the elemental and isotopic compositions for a wide range of nuclear materials. NBL is the U.S. Government's Certifying Authority for nuclear reference materials and DOE's central technical authority for nuclear material measurements (primarily for safeguards purposes). NBL also functions as a Network Laboratory for the International Atomic Energy Agency. NBL is administered through and is a part of the Chicago Office (CH). NBL consists of one 52 year-old building (90 thousand gross square feet of space).

Oak Ridge Institute for Science and Education

The Oak Ridge Institute for Science and Education (ORISE), operated by Oak Ridge Associated Universities (ORAU), is located on a 179-acre site in Oak Ridge, Tennessee. ORISE has 12 buildings (116 thousand gross square feet of space). The average age of the buildings is 53 years. Established in 1946, ORAU is a university consortium leveraging the scientific strength of major research institutions to advance science and education by partnering with national laboratories, government agencies, and private industry. ORISE focuses on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists.

- **Advanced Scientific Computing Research**: ORISE provides administrative support for panel reviews, site reviews, and Advanced Scientific Computing Advisory Committee meetings. It also assists with the administration of topical scientific workshops.
- **Basic Energy Sciences**: ORISE provides administrative support for panel reviews and site reviews. It also assists with the administration of topical scientific workshops and provides administrative support for other activities such as for the reviews of construction projects.
- **Biological and Environmental Research**: ORISE coordinates activities associated with the peer review of research proposals and applications.
- **Fusion Energy Sciences**: ORISE supports the operation of the Fusion Energy Sciences Advisory Committee and administrative aspects of some Fusion Energy Sciences (FES) program peer reviews. It also acts as an independent and unbiased agent to administer the FES Postgraduate Fellowship programs.
- **High Energy Physics**: ORISE provides support in the area of program planning and review.
- **Nuclear Physics**: ORISE has supported the Holifield Radioactive Ion Beam Facility (HRIBF) and its research program through a close collaboration with university researchers using HRIBF; HRIBF operations cease in FY 2012. ORISE also provides support to the Nuclear Physics program in the area of merit peer review.
- **Workforce Development:** ORISE provides administrative support to the Office of Science Graduate Fellowship Program, including developing the on-line application and on-line review system, updating the program websites, and providing logistic support for the on-site review. ORISE provides administrative support to an interagency program by DOE, National Institute of Health (NIH), and National Science Foundation (NSF) for sponsoring U.S. graduate delegates to attend the Lindau Meeting with Nobel Laureates in Germany. ORISE also provides the administrative support for the National Science Bowl® and other WDTS programs, and serves as the education office for Oak Ridge National Laboratory
- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets at ORISE. S&S provides planning, policy, implementation, and oversight in the areas of program management, patrol and response officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

Oak Ridge National Laboratory

The Oak Ridge National Laboratory (ORNL) is a multiprogram laboratory located on a 24,000-acre reservation at Oak Ridge, Tennessee. The laboratory's 1,100-acre main site contains 237 buildings (3.7 million gross square feet of space). The average age of the buildings is 40 years.

- **Advanced Scientific Computing Research**: ORNL conducts research in applied mathematics and computer science, as well as research in advanced computing software tools relevant to hybrid, multi-core computing systems including future exascale systems. ORNL also participates in a spectrum of SciDAC activities. The Leadership Computing Facility at ORNL is operating one of the world's most powerful high performance computers, a two-petaflop Cray Baker system which makes computationally-intensive projects of the largest scales possible.
- **Basic Energy Sciences**: ORNL is home to major research efforts in materials and chemical sciences emphasizing fundamental understanding of materials behavior and interfacial phenomena with additional programs in geosciences. It is also the site of four BES supported user facilities—the Spallation Neutron Source (SNS), the High Flux Isotope Reactor (HFIR), the Shared Research Equipment User Facility, and the Center for Nanophase Materials Sciences.
  - The **Spallation Neutron Source** is a next-generation short-pulse spallation neutron source for neutron scattering that is significantly more powerful (by about a factor of 10) than any other spallation neutron source in existence. The SNS consists of a linac-ring accelerator system that delivers short (microsecond) proton pulses to a target/moderator system where neutrons are produced by a process called spallation. The neutrons produced are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations. There is initially one target station that can accommodate 24 instruments, but the potential exists for adding more instruments and a second target station.
  - The **High Flux Isotope Reactor** is a light-water cooled and moderated reactor to provide state-of-the-art facilities for neutron scattering, materials irradiation, and neutron activation analysis and is the world's leading source of elements heavier than plutonium for research, medicine, and industrial applications. The neutron scattering experiments at HFIR reveal the structure and dynamics of a wide range of materials. The neutron-scattering instruments installed on the four horizontal beam tubes are used in fundamental studies of materials of interest to solid-state physicists, chemists, biologists, polymer scientists, metallurgists, and colloid scientists. A number of improvements at HFIR have increased its neutron scattering capabilities to 12 state-of-the-art neutron scattering instruments on the world's brightest beams of steady-state neutrons.
  - The **Shared Research Equipment User Facility** (SHaRE) makes available state-of-the-art electron beam microcharacterization facilities for collaboration with researchers from universities, industry, and other government laboratories. Particular emphases include compositional analysis via spectroscopic and other techniques, including state-of-the-art atom probe tomography. Most SHaRE projects seek correlations at the microscopic or atomic scale between structure and properties in a wide range of metallic, ceramic, and other structural materials. Diverse research projects have been conducted, such as the characterization of magnetic materials, catalysts, semiconductor device materials, high Temperature superconductors, and surface-modified polymers.
  - The **Center for Nanophase Materials Sciences** integrates nanoscale science with neutron science; synthesis science; and theory, modeling, and simulation. Scientific themes include

macromolecular complex systems, functional nanomaterials, nanoscale magnetism and transport, catalysis and nano building blocks, and nanofabrication.

- **Biological and Environmental Research**: ORNL has a leadership role in research focused on both the ecological aspects of global environmental change and bioenergy.
  - The laboratory houses the Carbon Dioxide Information Analysis Center and Atmospheric Radiation Measurement Climate Research Facility (ARM) archive. ORNL leads a multi-laboratory activity to quantify and reduce critical uncertainties associated with carbon cycle-climate system feedback and to develop high resolution global climate simulations.
  - ORNL leads a multi-institutional effort to understand carbon cycling in permafrost soils and to predict the impact of a changing climate on cold region carbon budgets.
  - ORNL leads a multi-institutional team conducting field-scale research that is focused on understanding the coupled hydrologic, geochemical, and microbiological processes that control the mobility of mercury, uranium, technetium, and other contaminants across a range of scales.
  - ORNL is one of the major national laboratory partners that support the JGI, the principal goal of which is high-throughput genome sequencing and analysis. ORNL activities in structural biology include operation of a station for Small Angle Neutron Scattering at the High Flux Isotope Reactor for the national biological research community.
  - ORNL conducts Genomic Science microbial systems biology research in order to understand the interactions between plants and microbes, leading to development of more sustainable biofuel production.
  - The **BioEnergy Science Center** (BESC) at ORNL, one of three DOE Bioenergy Research Centers, is studying two prime candidate bioenergy feedstocks, the poplar tree and switchgrass, to understand plant properties that make biomass so resistant to deconstruction and identify less recalcitrant natural variants. BESC also emphasizes discovery and improvement of microbes capable of converting cellulosic biomass directly to ethanol or butanol while withstanding high temperatures and product toxicity involved in consolidated biomass processing approaches.
- **Fusion Energy Sciences**: ORNL develops a broad range of components that are critical for improving the research capability of fusion experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. The laboratory is a leader in fusion materials science, in the theory of heating of plasmas by electromagnetic waves, antenna design, and design and modeling of pellet injectors to fuel the plasma and control the density of plasma particles. The laboratory has also been the site of the Controlled Fusion Atomic Data Center and its supporting research programs, which are being closed out in FY 2012. ORNL is also a leader in stellarator theory. ORNL hosts the U.S. ITER Project Office and is the lead laboratory managing the U.S. Contributions to ITER major item of equipment project.
- **Nuclear Physics**: NP supports a diverse program of research at ORNL. These activities have included the research, development, and operations of the Holifield Radioactive Ion Beam Facility (HRIBF), which is closed in FY 2012, and a relativistic heavy ion group that is involved in a research program using the PHENIX detector at RHIC and ALICE at LHC. The development of and research with the Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source, a theoretical nuclear physics effort that emphasizes investigations of nuclear structure and astrophysics, and nuclear data and compilation activities that support the national nuclear data effort are also conducted. In addition, accelerator core competencies in rare isotope beam development and

high power targets; research on the possible existence of super heavy nuclei; R&D efforts in development of next-generation neutrinoless double beta decay experiments; isotope processing capabilities; R&D efforts associated with radioisotope and stable isotope production and processing; and the operations of the National Isotope Development Center are provided for. Enriched stable isotopes are processed at ORNL materials and chemical laboratories and radioactive isotopes are chemically processed and packaged in hot cells in a radiochemical laboratory and the Radiochemical Engineering Development Center. R&D to re-establish a stable isotope production capability is being pursued. The High Flux Isotope Reactor is supported for the production of select isotopes for the NP Isotope Program, including tungsten-188, an isotope with medical applications such as cancer therapy, and selenium-75, a commercial isotope used in radiography. The Isotope Program is responsible for programmatic activities in Building 4501, 7920, 7930, 3025E, and chemical and materials laboratories in Building 5500.

- **Holifield Radioactive Ion Beam Facility** is the only radioactive nuclear beam facility in the U.S. to using the Isotope-Separator On-Line method, and one of only three such facilities in the world. HRIBF has been used annually by about 260 scientists for studies in nuclear structure, dynamics, and astrophysics using radioactive beams. The HRIBF ceases operations in the FY 2012 in order to provide support for higher priority activities in NP, including the 12 GeV CEBAF Upgrade and the Facility for Rare Isotope Beams (FRIB). These strategic investments in new research capability, the first in over a decade, will maintain U.S. leadership in the scientific frontier of quantum chromodynamics (QCD), and secure U.S. leadership in nuclear structure and nuclear astrophysics. The 12 GeV CEBAF Upgrade will allow scientists to detect and study exotic and excited bound systems of quarks and gluons with unprecedented accuracy, illuminating the force which binds quarks and gluons into protons and neutrons. In the case of FRIB, the capability to study nuclear structure at the limits of nuclear existence, in particular for neutron rich nuclei, will be world leading, providing a major advance in research capability for the U.S. nuclear structure and nuclear astrophysics communities. The 12 GeV CEBAF Upgrade and FRIB construction were recognized as the two highest priorities for investments in new research capability by the nuclear science community in the 2007 NSAC Long Range Plan.
- **The Fundamental Neutron Physics Beamline** at the Spallation Neutron Source was completed in FY 2010 to provide high intensity pulsed beams of cold and ultracold neutrons for fundamental research with neutrons.
- The **National Isotope Development Center** (NIDC) is a virtual service organization that supports isotope development and production sites in the community supported by NP. NIDC coordinates the production, sales, and distribution of isotopes across the Nation, and the development and coordination of community outreach efforts. It also manages the Isotope Business Office which is located at ORNL.

- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets at ORNL. S&S provides planning, policy, implementation, and oversight in the areas of program management and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

Oak Ridge National Laboratory Site Office

The Oak Ridge National Laboratory Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at the Oak Ridge National Laboratory. The site office is responsible for project management of line-item and other construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principle representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Oak Ridge Office

The Oak Ridge (OR) Office directly provides corporate support (procurement, legal, financial management, human resources, and facilities and infrastructure) to site offices responsible for program management oversight of four major management and operating laboratories—Oak Ridge National Laboratory, Pacific Northwest National Laboratory, SLAC National Accelerator Laboratory, and Thomas Jefferson National Accelerator Facility. The administrative, business, and technical expertise of OR is shared SC-wide through the Integrated Support Center concept. The OR Manager is also the single Federal official with responsibility for contract performance at the Oak Ridge Institute for Science and Education (ORISE). The Manager provides on-site presence for ORISE with authority encompassing contract management, program and project implementation, Federal stewardship, and internal operations. OR also oversees the OR Reservation and other DOE facilities in the City of Oak Ridge. Together on the Reservation and in the City of Oak Ridge there are 35 buildings (237 thousand square feet). The average age of the buildings is 51 years.

- **Science Laboratories Infrastructure**: The Oak Ridge Landlord subprogram maintains Oak Ridge Reservation infrastructure such as roads outside plant fences as well as DOE facilities in the town of Oak Ridge, Payment in Lieu of Taxes (PILT), and other needs related to landlord responsibilities.
- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets and oversight in the areas of program management, protective force officers, and information security. S&S provides oversight for SC's only category I, special nuclear materials facility, building 3019. S&S also provides funding to the Oak Ridge Office for federal field personnel security investigations.

Office of Scientific and Technical Information

The Office of Scientific and Technical Information (OSTI) fulfills the Department's legislative mandate to provide public access to the unclassified results of DOE's research programs as well as the Open Government Directive to encourage collaboration and increase transparency. OSTI also collects, protects, and provides secure access to DOE's classified research outcomes. OSTI has built broad collaborations both within the U.S. and internationally to enable a single point of access to nearly 400 million pages of scientific information. Within the U.S., Science.gov offers simultaneous searching of Federal science databases and websites, while WorldWideScience.org performs the same functionality across the R&D results of over 65 countries. OSTI consists of one 63 year-old building (135 thousand gross square feet of space).

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory (PNNL) is a DOE multiprogram laboratory located in Richland, Washington that supports DOE's science, national security, energy, and homeland security missions.

PNNL consists of seven buildings (470 thousand gross square feet of space.) The average age of the buildings is three years.

- **Advanced Scientific Computing Research**: PNNL conducts research in applied mathematics and computer science, as well as research in advanced computing software tools relevant to hybrid, multi-core computing systems including future exascale systems. PNNL also participates in a spectrum of SciDAC activities.
- **Basic Energy Sciences**: PNNL supports research in interfacial and surface chemistry, inorganic molecular clusters, analytical chemistry, geosciences, and applications of theoretical chemistry. Materials research emphasizes synthesis science, mechanical properties, and radiation effects.
- **Biological and Environmental Research**: PNNL is home to the **Environmental Molecular Science Laboratory** (EMSL), a national scientific user facility that provides integrated experimental and computational resources. In addition, PNNL carries out research in support of climate, environmental, and genomic sciences.
  - EMSL supports discovery and technological innovation in the environmental molecular sciences. EMSL provides more than 50 leading-edge instruments and a supercomputer to users from academia, DOE laboratories, and industry. EMSL enables users to undertake molecular-scale experimental and theoretical research on aerosol chemistry, biological systems, biogeochemistry, and interfacial and surface science.
  - PNNL conducts research on the molecular mechanisms of cellular responses to low doses of radiation and the development of new technologies and high-throughput approaches for characterizing cellular components. PNNL conducts Genomic Science microbial systems biology research to gain a predictive understanding of the interactions and functions of associated bacterial species in natural environments. PNNL is one of the national laboratory partners that support the JGI, the principal goal of which is high-throughput DNA sequencing.
  - PNNL leads two multi-institutional field projects focused on developing a better understanding of the processes that impact reactive transport and mobility of contaminants such as uranium, technetium, and plutonium.
  - The Atmospheric Radiation Measurement Climate Research Facility (ARM) technical office is located at PNNL, and has the project management responsibility for all ARM engineering activity and the conduct of ARM fixed site-based field campaigns.
  - PNNL provides expertise in research on aerosol properties and processes and in field campaigns for atmospheric sampling and analysis of aerosols. PNNL research on climate modeling improves the simulations of precipitation and aerosols effects to represent human-earth system interdependencies and assess the impacts of climate change
- **Fusion Energy Sciences**: PNNL has focused on research on materials that can survive in a fusion neutron environment. Scientists and engineers at PNNL provide leadership in the evaluation of ceramic matrix composites for fusion applications and support work on ferrite steels as part of the U.S. fusion materials team.
- **Nuclear Physics**: NP supports modest R&D efforts aimed at exploring production mechanisms for isotopes, and for the processing of select isotopes important to the Nation. NP also supports R&D efforts towards a next generation detector to search for neutrinoless double beta decay.
- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or

destruction of Departmental assets at PNNL. S&S provides planning, policy, implementation, and oversight in the areas of program management, access control officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues. Protective force services are provided under a memorandum of understanding with the Department's Office of Environmental Management.

Pacific Northwest Site Office

The Pacific Northwest Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at PNNL. The site office is responsible for project management of line-item and other construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principal representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Princeton Plasma Physics Laboratory

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory located on 88 acres in Plainsboro, New Jersey. The laboratory consists of 34 buildings (754 thousand gross square feet of space). The average age of the buildings is 36 years.

- **Advanced Scientific Computing Research**: PPPL participates in SciDAC science application teams related to fusion science.
- **Fusion Energy Sciences**: PPPL is the only DOE laboratory devoted primarily to plasma and fusion science. The laboratory hosts experimental facilities used by multi-institutional research teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the **National Spherical Torus Experiment** (NSTX), which is an innovative toroidal confinement device, closely related to the tokamak. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks and the NSF Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas, as well as several large tokamak facilities abroad, including the Joint European Torus in the United Kingdom, and the Korean Superconducting Tokamak Reactor Advanced Research in Korea. Research is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL is a partner with ORNL in the U.S. Contributions to ITER Project with responsibility for design and fabrication of various plasma diagnostics and ITER's steady-state electric power system. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. PPPL has a large theory group that does research in the areas of turbulence and transport, equilibrium and stability, wave-plasma interaction, and heavy ion accelerator physics. PPPL, LBNL, and LLNL currently work together in advancing the physics of heavy ion drivers for research in high energy density laboratory plasmas through the Heavy Ion Fusion Science Virtual National Laboratory. Through its association with Princeton University, PPPL provides high quality education in fusion-related sciences, having produced more than 230 Ph.D. graduates since its founding in 1951.
- **High Energy Physics**: HEP supports a small theoretical research effort at PPPL using unique capabilities of the laboratory in the area of advanced accelerator R&D.
- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or

destruction of Departmental assets at PPPL. S&S provides planning, policy, implementation, and oversight in the areas of program management, access control officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

Princeton Site Office

The Princeton Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at the Princeton Plasma Physics Laboratory. The site office is responsible for project management of line-item and other construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principal representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Sandia National Laboratories

Sandia National Laboratories (SNL) is a multiprogram laboratory located on 3,700 acres in Albuquerque, New Mexico, with additional sites in Livermore, California and Tonopah, Nevada.

- **Advanced Scientific Computing Research**: SNL conducts research in applied mathematics and computer science, as well as research in advanced computing software tools relevant to hybrid, multi-core computing systems including future exascale systems. SNL also participates in a spectrum of SciDAC activities.
- **Basic Energy Sciences**: SNL is home to significant research efforts in materials and chemical sciences with additional programs in geosciences. SNL has a historic emphasis on electronic components needed for the Office of Defense Programs. The laboratory has very modern facilities in which unusual microcircuits and structures can be fabricated out of various semiconductors. It is also the site of the Center for Integrated Nanotechnologies (CINT).
  - The **Center for Integrated Nanotechnologies** is devoted to establishing the scientific principles that govern the design, performance, and integration of nanoscale materials. Through its core facility in Albuquerque, New Mexico, and its gateways to both SNL and LANL, CINT provides access to tools and expertise to explore the continuum from scientific discovery to the integration of nanostructures into the microworld and the macroworld. CINT supports five scientific thrusts that serve as synergistic building blocks for integration research: nano-bio-micro interfaces, nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and theory and simulation.
- **Biological and Environmental Research**: In support of BER's climate change research, SNL is a member of a multi-laboratory team that coordinates the overall infrastructure operations of Atmospheric Radiation Measurement Climate Research Facility (ARM) sites and facilities. SNL conducts climate modeling research to support new dynamical cores and improve its scalability for implementation on high-system computing systems. SNL is a partner in the LBNL-led Joint BioEnergy Institute.
- **Fusion Energy Sciences**: SNL plays a lead role in developing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interface of plasmas and the walls of fusion devices. Material samples and prototypes are tested in SNL's Plasma Materials Test Facility, which uses high-power electron beams to simulate the high heat fluxes expected in fusion environments. Materials and components are

exposed to tritium-containing plasmas in the Tritium Plasma Experiment located in the STAR facility at INL. Sandia supports a wide variety of domestic and international experiments in the areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing. SNL serves an important role in the design and analysis activities related to the ITER first wall components, including related R&D.

Savannah River National Laboratory

The Savannah River National Laboratory (SRNL) is a multiprogram laboratory located on approximately 34 acres in Aiken, South Carolina. SRNL provides scientific and technical support for the site's missions, working in partnership with the site's operating divisions. The laboratory is a partner with ORNL in the U.S. Contributions to ITER Project with responsibility for design and fabrication of ITER's tokamak exhaust processing system.

SLAC National Accelerator Laboratory

The SLAC National Accelerator Laboratory is located on 426 acres of Stanford University land in Menlo Park, California. SLAC is a multipurpose laboratory for photon science, accelerator and particle physics research and astrophysics. SLAC operates the final third of its two-mile linear accelerator for the Linac Coherent Light Source (LCLS). SLAC consists of 161 buildings (1.9 million gross square feet of space). The average age of the buildings is 32 years.

- **Basic Energy Sciences**: SLAC is home to research activities in materials and chemical sciences that build on ultrafast and advanced synchrotron techniques and include an emphasis on materials for energy. It is the site of two user facilities—the Linac Coherent Light Source (LCLS) and the Stanford Synchrotron Radiation Lightsource (SSRL).
  - The **Linac Coherent Light Source** is a user facility that provides laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak power and peak brightness than any existing coherent x-ray light source. The SLAC linac will provide high-current, low-emittance 5–15 GeV electron bunches at a 120 hertz repetition rate. A long undulator bunches the electrons and leads to self-amplification of the emitted x-ray radiation at the LCLS, which constitutes the world's first free electron laser user facility producing short pulses (from a few to 200 femtoseconds long) in the hard and soft x-ray regions. The x-ray laser light is utilized at several instruments located at six hutches to perform experiments in many areas of physics, chemistry, and biology.
  - The **Stanford Synchrotron Radiation Lightsource** is a DOE user facility for researchers from industry, government laboratories, and universities. These include astronomers, biologists, chemical engineers, chemists, electrical engineers, environmental scientists, geologists, materials scientists, and physicists. A research program is conducted at SSRL with emphasis in both the x-ray and ultraviolet regions of the spectrum. SSRL scientists are experts in photoemission studies of high-temperature superconductors and in x-ray scattering.
- **Advanced Scientific Computing Research**: SLAC participates in SciDAC science application teams relevant to physics research, accelerator modeling, and distributed data.
- **Biological and Environmental Research**: SLAC operates nine SSRL beamlines for structural molecular biology. This program involves synchrotron radiation-based research and technology developments in structural molecular biology that focus on protein crystallography, x-ray small angle scattering diffraction, and x-ray absorption spectroscopy for determining the structures of complex proteins of many biological consequences.

SLAC also investigates the fundamental molecular-scale mechanisms controlling the stability and fate of metal and radionuclide contaminants in the subsurface at DOE sites.

- **High Energy Physics**: SLAC participates in the accelerator-based research program of the ATLAS detector at the LHC, is leading several efforts at the Cosmic Frontier of particle astrophysics, and is one of the primary national laboratories for research and development of particle accelerator technologies.
  - SLAC led construction of the primary instrument for the **Fermi Gamma-ray Space Telescope (FGST)** which was launched into earth orbit in 2008, and is home to the data operations center that manages the scientific data collection from the satellite. SLAC physicists and a user community will analyze the FGST data for several years.
  - SLAC is leading the R&D for a camera to be used in the proposed **Large Synoptic Survey Telescope**, which incorporates a next-generation ground-based dark energy experiment as part of a broad program in astronomy and astrophysics. SLAC and Stanford University are also home to the Kavli Institute for Particle Astrophysics and Cosmology, which brings together researchers studying a broad range of fundamental questions about the universe, from theoretical astrophysics to dark matter and dark energy. HEP supports research at Kavli aimed primarily at exploring astrophysical phenomena to test new ideas in particle physics.
  - SLAC is the host for the **Facility for Advanced Accelerator Experimental Tests (FACET)**, which will study plasma acceleration, using short, intense pulses of electrons to create a plasma wakefield accelerator. The laboratory is at the forefront of damping ring and beam delivery designs, required to ensure the beam brightness and precision control needed for future accelerators. SLAC also represents the center of expertise for design, fabrication, and testing of radio frequency power systems used to energize the accelerator components. The laboratory also participates in R&D for advanced detector technologies, with emphasis on software, simulation, and electronics.
- **Science Laboratories Infrastructure**: SLI supports DOE research initiatives by funding the line item construction needed to maintain mission ready infrastructure at SLAC. SLI is currently funding the Research Support Building and Infrastructure Modernization project at SLAC to replace substandard modular buildings and trailers that are well beyond their intended useful life, and to modernize key existing buildings onsite.
- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or destruction of Departmental assets at SLAC. S&S provides planning, policy, implementation, and oversight in the areas of program management, access control officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

SLAC Site Office

The SLAC Site Office completes evaluation and acceptance of contractor deliverables and performs oversight and evaluation of contractor performance against contract requirements and ensures delivery of government required services, items, and approvals at the SLAC National Accelerator Laboratory. The site office is responsible for project management of line-item and other construction projects, as well as budget formulation, execution, and financial management and integrity. The site office also serves as the Department's principal representative for local, state, and regional Tribal government interactions and communications with other local stakeholders.

Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility (TJNAF) is a Nuclear Physics program-dedicated laboratory located on 206 acres in Newport News, Virginia, focused on the exploration of nuclear and nucleon structure. The laboratory consists of 61 buildings (685 thousand gross square feet of space). The average age of the buildings is 18 years.

- **Advanced Scientific Computing Research:** TJNAF participates in SciDAC science application teams relevant to physics research, accelerator modeling, and distributed data.
- **Basic Energy Sciences:** BES supports the development of superconducting radio frequency (SRF) cavities at TJNAF that will ultimately be used for the next generation light sources.
- **Biological and Environmental Research**: BER supports the development of advanced imaging instrumentation at TJNAF that will ultimately be used in next generation biological imaging systems.
- **High Energy Physics**: HEP supports an R&D effort at TJNAF on accelerator technology, using the unique expertise of the laboratory in the area of superconducting radiofrequency systems for particle acceleration.
- **Nuclear Physics**: The centerpiece of TJNAF is the **Continuous Electron Beam Accelerator Facility** (CEBAF), a unique international electron-beam user facility for the investigation of nuclear and nucleon structure based on the underlying quark substructure. The facility has an international user community of about 1,300 researchers. Polarized electron beams with energies of up to 6.0 GeV can be provided by CEBAF simultaneously to three different experimental halls. Hall A is designed for spectroscopy and few-body measurements. Hall B has a large acceptance detector, CLAS, for detecting multiple charged particles coming from a scattering reaction. Hall C is designed for flexibility to incorporate a wide variety of different experiments. Its core equipment consists of two medium resolution spectrometers for detecting high momentum or unstable particles. Also in Hall C, a new detector, Q-weak, will be used to measure the weak charge of the proton by a collaboration of laboratory and university groups, in partnership with the NSF. TJNAF supports a group that does theoretical calculations and investigations in subjects supporting the experimental research programs in medium energy physics. TJNAF research and engineering staff are world experts in superconducting radiofrequency accelerator technology. Their expertise is being used in the construction of the 12 GeV CEBAF Upgrade Project and has contributed to other SC facilities such as the SNS at Oak Ridge National Laboratory.
  - The **12 GeV CEBAF Upgrade Project** which started construction in FY 2009 and is scheduled to complete in FY 2015, will double the energy of the accelerator. In addition to upgrading the energy and the capability of the existing Halls A, B, and C, the project is constructing a new Hall D and detector, which will provide researchers with the opportunity to study quark confinement, one of the greatest mysteries of modern physics. Operations of the existing facility will be limited in FY 2012 to support project installation activities.
- **Science Laboratories Infrastructure**: SLI supports DOE research initiatives by funding the line item construction needed to maintain mission ready infrastructure at TJNAF. SLI is currently funding the Technology and Engineering Development Facility project that will construct new industrial assembly, laboratory, and office space, and renovate existing space in the Test Lab Building.
- **Safeguards and Security**: The S&S program supports DOE research missions by ensuring appropriate levels of protection against unauthorized access, theft, diversion, loss of custody, or

destruction of Departmental assets at TJNAF. S&S provides planning, policy, implementation, and oversight in the areas of program management, access control officers, and information security. In addition, the S&S program addresses cyber, personnel security, security systems, and material control and accountability issues.

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Washington Headquarters

SC Headquarters, located in the Washington, D.C. area, is responsible for the Federal funds awarded to about 300 universities, all 17 DOE national laboratories, and private research institutions. HQ Program and Project Managers are responsible for scientific program development and management across a broad spectrum of scientific disciplines and program offices, as well as oversight of the design, construction, and operation of large-scale scientific user facilities at laboratories and universities. Program management and oversight includes regular rigorous evaluation of research programs, facilities, and projects by external peer review. Additional HQ policy, technical, and administrative support staff are responsible for budget and planning; general administration; information technology; infrastructure management; construction management; safeguards and security; and environment, safety, and health within the framework set by the Department.

Advanced Scientific Computing Research

Funding Profile by Subprogram

(dollars in thousands)

FY	2010 Current Appropriation FY	2012 Request
Advanced Scientific Computing Research		
Mathematical, Computational, and Computer Sciences Research	153,545	174,033
High Performance Computing and Network Facilities	229,654	291,567
Total, Advanced Scientific Computing Research	383,199[a] 46	5,600

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 108–423, "Department of Energy High-End Computing Revitalization Act of 2004"
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

The mission of the Advanced Scientific Computing Research (ASCR) program is to discover, develop, and deploy computational and networking capabilities to analyze, model, simulate, and predict complex phenomena important to the Department of Energy (DOE). A particular challenge of this program is fulfilling the science potential of emerging computing systems and other novel computing architectures, which will require numerous significant modifications to today's tools and techniques to deliver on the promise of exascale science.

Background

Imagine exploring the inner workings of a supernova or traveling through time to observe Earth's global climate as it changes. Scientists today can explore these realms thanks to a 100 fold increase in computing power delivered over the past five years and to the software and algorithms developed to harness the power of these forefront computers.

Throughout history, as we have strived to comprehend the mysteries of the universe, mathematics has been an essential tool. It allowed Eratosthenes to determine the circumference of the earth. Newton invented calculus to understand the movement of the planets. Mathematical research in the 1800s laid the groundwork for Einstein's Theory of General Relativity.

Today, advances in mathematics and computing are providing the foundation for models and simulations, which permit scientists to gain new insights into problems ranging from bioenergy and climate change to Alzheimer's disease. ASCR and its predecessor programs have led these advances for the past thirty years by supporting the best applied math and computer science research, delivering world class scientific simulation facilities, and working with discipline scientists to deliver exceptional science.

[a] Total is reduced by $10,801,000, $9,643,000 of which was transferred to the Small Business Innovation Research (SBIR) program, and $1,158,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

"It is generally accepted that computer modeling and simulation offer substantial opportunities for scientific breakthroughs that cannot otherwise—using laboratory experiments, observations, or traditional theoretical investigations—be realized. At many of the research frontiers, computational approaches are essential to continued progress and will play an integral and essential role in much of twenty-first century science and engineering."[a] For the growing number of problems where experiments are impossible, dangerous, or inordinately costly, exascale computing will enable the solution of vastly more accurate predictive models and the analysis of massive quantities of data, producing advances in areas of science and technology that are essential to DOE and Office of Science missions and, in the hands of the private sector, drive U.S. competitiveness.

In FY 2009 and FY 2010, ASCR delivered petascale computing power to the open science community, making available two of the world's fastest computers for open-science. More than a dozen DOE applications have achieved sustained performance on these machines in excess of one petaflop revealing new details and nuances in areas such as biofuels, fusion energy, nanoelectronics, fluid dynamics, astrophysics, superconductors, and magnetic materials. These efforts advance critical technologies for the Department and the Nation. For example, the ASCR partnership with Basic Energy Sciences in computational materials have enabled high-density disk drives, new approaches to photovoltaic cells, and understanding of stress corrosion cracking and high-temperature superconductors that could transform our energy infrastructure. ASCR-supported high-performance machines are the culmination of a decade-long effort to build computing architectures with unprecedented speed and capability. At the same time, the development of new mathematical theories and algorithms contributed as much, or more, as the raw computational power of supercomputers to the speed at which difficult scientific problems can be solved computationally. Finally, to ensure that the science and engineering disciplines were ready to use Leadership Computing Facilities, ASCR fostered collaborations among research communities encompassing applied mathematics, computer science, physics, biology, chemistry, and other disciplines.

ASCR supports world-leading basic research in both applied mathematics and computer science focused on areas relevant to high performance computing. The results of this research are brought to the broader scientific community through the Scientific Discovery through Advanced Computing (SciDAC) program. SciDAC, established in 2001, accelerates progress in computational science by breaking down the barriers between disciplines and fostering more dynamic partnerships between applications—such as astrophysics or biology—and the ASCR-supported computer scientists and mathematicians who deeply understand the hardware and software available. Areas of focus for the SciDAC program to date include climate, astrophysics, materials, and fusion energy. These partnerships have been spectacularly successful, with documented improvements in code performance in excess of 10,000 percent.

The success of the SciDAC partnerships within the Office of Science has stimulated the development of new partnerships between ASCR and the Department's technology offices. ASCR-supported researchers are now focusing on the mathematical and computational challenges of the electricity grid and nuclear reactor modeling. In addition, the ASCR applied mathematics program is supporting research in complex natural and engineered systems and uncertainty quantification. This research has relevance to DOE applied programs such as carbon sequestration, wind energy, next generation nuclear reactors, Smart Grid, and fuels from sunlight. Additional partnerships will begin in FY 2012, broadening these efforts.

Science today is by nature increasingly collaborative. Today's collaborations require researchers not only to communicate with each other, but also to exchange large data sets, and often to run complex

[a] "*The Potential Impact of High-End Capability Computing on Four Illustrative Fields of Science and Engineering"* a 2008 report of the National Research Council of the National Academy of Sciences available on line at http://www.nap.edu/catalog.php?record_id=12451

calculations and experiments in locations remote from where the original data are collected or generated. To facilitate the best collaborations for science, ASCR has played a leading role in driving development of the high-bandwidth networks connecting researchers to each other and their data. The invisible glue that binds today's networks across the world together—effortlessly passing billions of searches and trillions of bits from one corner of the earth to another—has roots in ASCR-supported research. ASCR-supported researchers helped establish critical protocols such as TCP/IP on which the current Internet is based. ASCR advanced networking research makes international collaborations such as the Large Hadron Collider and ITER possible and underpins virtual meeting and other commercial collaboration tools.

Looking forward, major changes are underway in the computing industry due to the critical importance of power and energy efficiency in computing systems from the desktop to the exascale. To enable this transition, ASCR is adopting the strategy used by other SC programs and planning more direct involvement with the providers of high performance computing systems. Future computing systems will have thousands of processing units per chip and these units will be heterogeneous. The first generation of this type of high performance hybrid, multi-core computer has already become reality with the emergence of a machine in China that claimed the title of the world's fastest computer in November 2010. The promise of this new hybrid, multi-core architecture brings with it many new challenges. The Chinese machine contains hundreds of thousands of compute cores that share data and communicate with specialized chips that accelerate performance but make it more challenging to use. Soon, hybrid machines will have millions then billons of cores, which need to be managed and made to work effectively together. Communication, data movement, memory management, and fault detection and recovery will all become major challenges for applications. This is not unlike the change from operator run switchboards to computer-run communications except that the users will need to invent and make the change since industry investments to adapt these chips for the gaming and video-streaming markets will not deliver the software, operating systems, or tools needed for scientists to use high performance computers. ASCR must take on that challenge to continue progress in the computational research focused on the Department of Energy missions. However, U.S. scientists also require this capability to retain leadership in many other areas of research. Across computational science and engineering, continued progress will require the expertise of a team of computer scientists, applied mathematicians and computational scientists who deeply understand their needs as well as partnerships with the computer venders to ensure that these needs impact design of new hardware. In so doing, these teams create the software, tools, and methods that advance use of the technology and broaden the impact of its potential throughout the government and private sector.

ASCR will continue to be guided by science needs as it develops computers and networks at the leading edge of technology. ASCR has already initiated investments to address the challenges of hybrid, multi-core computing up to the exascale (capable of an exaflop, or 10^{18} floating point operations per second, a thousand-times faster than today's petascale computers). Like the path to petascale computing, this path is driven by the requirements of applications that are critical to the DOE and the nation as defined through a series of workshops.[a] However, unlike the path to petascale, there are technological challenges that must be addressed to reduce the energy demands and increase the memory available on exascale systems so that they will be useful for science and engineering. Addressing these challenges will result in not only exascale systems but also in affordable, energy efficient petascale systems and high-end desktops to drive scientific and engineering discovery across the country. With this integrated approach, ASCR will continue to deliver scientific insight to address national problems in energy and the environment, while advancing U.S. competitiveness in information technology and high-tech industry.

[a] Workshop reports can be found at http://www.science.doe.gov/ascr/ProgramDocuments/ProgDocs.html.

Subprograms

To accomplish its mission and address the challenges described above, the ASCR program is organized into two subprograms—Mathematical, Computational, and Computer Sciences Research and High Performance Computing and Network Facilities.

- The *Mathematical, Computational, and Computer Sciences Research* subprogram develops mathematical descriptions, models, methods, and algorithms to describe and understand complex systems, often involving processes that span a wide range of time and/or length scales. The subprogram also develops the software to make effective use of advanced networks and computers, many of which contain thousands of multi-core processors with complicated interconnections, and to transform enormous data sets from experiments and simulations into scientific insight.
- The *High Performance Computing and Network Facilities* subprogram delivers forefront computational and networking capabilities and contributes to the development of next-generation capabilities through support of prototypes and testbeds.

Effective scientific utilization of high-end capability computing requires dynamic partnerships among application scientists, applied mathematicians, computer scientists, and facility support staff. Therefore, close coordination both within and across ASCR subprograms and with partner organizations is key to the success of the ASCR program.

Benefits

The evolution of the ASCR program will enable the U.S. to take advantage of the changes in computer hardware technology and deliver computers and networks that are a thousand-fold more energy efficient than today, drive unprecedented improvements in the scientific understanding of areas critical to the future of the Country, and secure a competitiveness advantage in high-tech and information technology industries.

Because computer-based simulation is so important to research programs across SC and the Nation, in addition to its core research program, ASCR invests in partnerships to advance use of high end computing in a wide array of disciplines important to DOE and operates the Leadership Computing Facilities as open user facilities with access determined by merit evaluation of proposals. The next generation of ASCR partnerships will drive unprecedented scientific advances for SC and the Nation. Some examples of applications that rely on both ASCR facilities and research efforts and have important benefits to science and society at large include:

- Computational chemistry and simulation of nanomaterials relevant to energy applications. These applications are funded in partnership with the Basic Energy Sciences program.
- Next generation Earth System Models to dramatically improve our ability to predict changes in global climate. This work is funded in partnership with the Biological and Environmental Research program. ASCR also provides the majority of the computing and networking resources for the U.S. contributions to the Intergovernmental Panel on Climate Change.
- Simulations of fusion reactors. This work is jointly funded with the Fusion Energy Sciences program.
- Computer modeling of nuclear structure with relevance for science, nuclear energy, and nuclear weapons. These applications are through partnerships with both the Nuclear Physics program and the National Nuclear Security Administration.
- Analysis of massive amounts of data from experiments such as the Large Hadron Collider, and simulations, such as three dimensional simulations of supernovae events, which are only possible

with leadership computing resources. These works are supported through partnerships with the High Energy and Nuclear Physics programs and the National Nuclear Security Administration.

- Simulations of biological systems relevant for bioenergy applications and subsurface science research to characterize and predict changes in DOE's environmental management sites. This work also has implications for DOE's efforts in subsurface carbon sequestration. These applications are partnerships with the Biological and Environmental Research Program.

In addition to these benefits, establishing SC Leadership Computing Facilities has required partnerships with hardware vendors to develop the most appropriate architectures for scientific discovery and the software necessary to effectively use these powerful systems. These industrial partnerships benefit many sectors of the economy from high-tech industry and academic research to software development and engineering. Finally, ASCR's support of researchers and students (the next generation of researchers) is a benefit to the national research and development workforce.

Finally, through ASCR allocation mechanisms, including INCITE and the ASCR Leadership Computing Challenge (ALCC), industry researchers have used the leadership computing resources to conduct both proof of concept and validation simulations to advance fundamental understanding in their research and development efforts. These users have praised government support for such cutting edge resources and state that their results have helped them gain a competitive advantage by demonstrating the benefits of high performance computing to their companies. Industry applications are held to the same peer review and readiness criteria as academic and national laboratory applications and have come from Boeing, Corning, DreamWorks Animation, Fluent/ANSYS, inc., Ford, Gene Networks Systems, GE Global Research, General Atomics, General Motors Research and Development Center, IBM Research, Pratt and Whitney, Procter & Gamble and Smart Truck/BMI.

Program Planning and Management

ASCR has developed a system of planning and priority setting that strongly benefits from input by outside experts. ASCR has also instituted a number of peer review and oversight processes designed to assess the quality, relevance, and performance of the ASCR portfolio on a regular basis. One way ASCR ensures the integrity and effectiveness of the peer review processes is through the Advanced Scientific Computing Advisory Committee (ASCAC), which organizes Committees of Visitors (COVs) to review ASCR research management, the impact of ASCR scientific user facilities, and progress toward the long-term goals of the program. For example, a COV reviewed ASCR investments in Applied Mathematics in FY 2010 and found "the program to be very effective and well-managed".[a] In addition, ASCAC identifies scientific challenges and opportunities, including specific bottlenecks to progress in areas such as climate change or computational biology. In FY 2010, ASCAC was charged to analyze the opportunities and challenges for ASCR and the Office of Science associated with exascale computing. In response to this charge, ASCAC formed a subcommittee with experts in a wide range of fields. They considered the challenges and opportunities with primary impact in the Office of Science as well as those impacting DOE more broadly. The subcommittee submitted two interim reports[b] for review and discussion with ASCAC on the path to developing this final report which was unanimously accepted by ASCAC on November 9, 2010. The committee found that "The Exascale Initiative will be significant and transformative for Department of Energy missions and the economic competitiveness of the United States."

In addition to ASCAC, critical tools for managing the ASCR scientific user facilities include annual operational reviews and requirements workshops. For example, ESnet and NERSC both conduct

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[a] 2010 Applied Math Committee of Visitors report can be found at http://www.sc.doe.gov/ascr/ASCAC/Reports.html

[b] ASCAC *Challenges and Opportunities of Exascale Computing* report can be found at http://www.sc.doe.gov/ascr/ASCAC/Reports.html

requirements workshops each year with individual SC program offices. The purpose of each workshop is to accurately characterize the near-term, medium-term, and long-term requirements of the science conducted by each program office. With two workshops per year, ASCR refreshes the requirements information for each of the six program offices every three years.

Community-driven workshops are another critical means by which dialogues are facilitated and new research opportunities are identified. For example, there were a series of workshops in 2009 to identify key science opportunities in the disciplines important to DOE—nuclear energy, materials and chemistry, high energy and nuclear physics, climate change, biology, and cross-cutting areas—and the potential role of extreme scale computing in realizing those opportunities.[a]

Another important planning and coordination mechanism for ASCR is the National Science and Technology Council's (NSTC) subcommittee on Networking and Information Technology Research and Development (NITRD). ASCR is a major participant in the NITRD program,[b] which coordinates Federal research investments by the 11 member agencies in advanced information technologies such as computing, networking, and software through interagency working groups and coordinating groups. ASCR is a major participant and/or chair of the High End Computing Research and Development, Large Scale Networking, and High End Computing Infrastructure and Applications groups. A recent evaluation of NITRD by the President's Committee of Advisors on Science and Technology (PCAST) recommended balancing procurement of high performance computers with fundamental computer science and engineering research for next-generation technologies. Reports from industry and other mission agencies, such as DARPA, indicate that because of power constraints, data movement, rather than computational operations, will be the limiting factor for future systems petaflops to exaflops. ASCR will use both of these inputs to inform its computer science, and computational science research activities to utilize computing at extreme scales and to understand large scale data from both simulations and experiments, within the context of a mission agency.

In October 2008, the National Research Council published a study titled *"The Potential Impact of High-End Capability Computing (HECC) on Four Illustrative Fields of Science and Engineering"*[c] that identifies and categorizes important scientific questions and technology problems for which an extraordinary advancement in our understanding is difficult or impossible without leading edge scientific simulation capabilities. In all four fields studied—atmospheric sciences, astrophysics, separations chemistry, and evolutionary biology—the committee found continuing demand for more powerful high end computing and for large scale data management. The report outlined the major scientific challenges in the four fields and estimated the associated challenges in mathematics, computer science, and computing infrastructure. The conclusions of the report underscore the importance of balancing investments in high potential application areas, the high-end computing resources required by multiple fields, and the longer-term mathematics and computer science research that underpins continued progress. The report also emphasizes the added importance of linking these efforts: "In many cases HECC capabilities must continue to be advanced to maximize the value of data already collected…The committee foresees a growing need for computational scientists and engineers who can work with mathematicians and computer scientists to develop next-generation code."

Basic and Applied R&D Coordination

A cornerstone of the ASCR program is coordination across disciplines and programs. Partnerships within SC are mature and continue to advance the use of high performance computing and scientific

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[a] Workshop reports can be found at http://www.science.doe.gov/ascr/ProgramDocuments/ProgDocs.html.
[b] Information on the NITRD program can be found at http://www.nitrd.gov.
[c] The "The Potential Impact of High-End Capability Computing (HECC) on Four Illustrative Fields of Science and Engineering" can be found at http://www.nap.edu/catalog.php?record_id=12451

networks for science. In addition, ASCR continues to have a strong partnership with the National Nuclear Security Administration in areas of mutual interest including best practices for management of high performance computing facilities. Looking ahead, this partnership will be increasingly important to efforts to advance the development of exascale computing for critical Department mission applications. In FY 2012, ASCR and NNSA will further strengthen our partnership by coordinating relevant research activities and conducting a series of joint workshops to inform our planning. This coordination will be expanded in FY 2012 to provide for complementary and synergistic efforts among Federal agencies as part of a national strategy for leadership in high performance computing. Through NITRD, ASCR will be a part of a coordinated national effort to address hardware, firmware, and software challenges for exascale computing.

In discussions with the technology development programs throughout DOE, a key area of mutual interest continues to be in applied mathematics for the optimization of complex systems, control theory, and risk assessment. In March 2009, a workshop was organized, in partnership with the DOE Office of Electricity Delivery and Energy Reliability, which focused on the challenges of grid modernization efforts. This workshop is part of a series of workshops on basic research needs in applied R&D areas. Other workshops have covered advanced nuclear energy systems (with the Office of Nuclear Energy), subsurface science (with the Offices of Environmental Management, and Fossil Energy), cyber security (with the Office of Electricity Delivery and Energy Reliability), alternative and renewable energy (with the Office of Energy Efficiency and Renewable Energy) and the scientific challenges of exascale computing for national security (with the National Nuclear Security Administration). These workshops facilitate a dialogue between the ASCR research community and a specific applied R&D community and identify opportunities for new research. This research becomes part of the ASCR program through investigator driven research proposals and is coordinated with the applied efforts through program manager interactions and joint principal investigator meetings. In FY 2012, ASCR plans to conduct a competition under SciDAC for new applied energy partnerships.

Budget Overview

The architecture of future computing systems, from desktops to exascale, will be transformed by changes in the underlying semiconductor technology and will be constrained by the need for greater energy efficiency. Anticipated characteristics of future hybrid, multi-core systems include:

- Decreased clock frequencies to conserve power;
- Increased number of processing units on a single chip;
- Increased energy costs for moving data both on-chip and off-chip; and
- Decreased memory per flop (and dramatically reduced memory per processor).

Computational scientists will therefore face the following challenges:

- Total concurrency in the applications must rise by a factor of about a million;
- Current weak-scaling approaches will be problematic due to the reduced memory per processor;
- For both power and performance reasons, minimizing data movement will be much more important so flat cache hierarchies will no longer be helpful;
- The failure rates for components and manufacturing variability make it unreasonable to assume the computer is deterministic. This is true for performance today and will affect the results of computations by 2018 due to silent errors;

- Synchronization will be very expensive and the work required to manage synchronization will be high; and
- The I/O system at all levels—chip to memory, memory to I/O node, I/O node to disk—will be much harder to manage due to the relative speeds of the components.

These challenges represent a change in the computing cost model, from expensive compute operations coupled with almost free data movement, to nearly free compute operations coupled with increasingly more expensive data movement.

It is important to note that even though these barriers are the most severe for exascale systems, they impact the full spectrum of computing. Numerical algorithms, mathematical models, and scientific software codes must also be reformulated, perhaps radically, to take full advantage of these emerging computational platforms. New methods of data management and analysis must be developed to deal with the stricter constraints on data movement for visualization and analysis. Achieving the necessary improvements will require a closer cooperation between computer architects, domain scientists, application developers, applied mathematicians, and computer scientists.

The FY 2012 ASCR budget focuses on coordinated efforts to address the fundamental changes taking place in the computing industry to deliver on the promise of hybrid, multi-core computing systems up to the exascale: positioning the U.S. to maintain international scientific computing and simulation leadership to address our scientific and engineering challenges and secure a competitiveness advantage in high-tech and information technology industries. Since the challenges ahead will require major advances in hardware, software, methods, and tools, the request balances investments in high performance computing facilities, advanced networks, and research and evaluation prototypes with investments in applied mathematics, computer science, next generation networks for science, and computational partnerships. This balance should allow for continued progress in a wide array of fields important to DOE's science, energy and national security missions in FY 2012 and for years to come.

The FY 2012 budget request continues support for the Leadership Computing Facility at Oak Ridge National Laboratory (OLCF)—which runs a 2.33 petaflop, six-core Cray XT5 system, openly available to the scientific community through the Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program as well as the ASCR Leadership Computing Challenge (ALCC) allocations program. The OLCF will continue to provide access and assistance to tool and library developers and to researchers seeking to scale their application to this new realm of computing power. In addition, OLCF activities will support preparations at ORNL for a computing system 5-10 times more capable than current systems. These activities are critical to harnessing the complexity of this architecture and meeting challenges associated with hybrid, multi-core high performance computer systems with millions of multicore and specialized processors. OLCF efforts are also expected to build experience and tools for emerging architectures supported in part through ASCR's Research and Evaluation Prototypes activity.

The FY 2012 budget request also continues support for the Leadership Computing Facility at Argonne National Laboratory (ALCF), including an upgrade of this facility to a 10 petaflop IBM Blue Gene/Q. Development of this proposed machine is based on a joint ASCR-NNSA sponsored research project with IBM and the Argonne and Lawrence Livermore National Laboratories, supported from FY 2006 to FY 2010 through the Research and Evaluations Prototypes activity. This project focused on the development of power efficient high performance computing and meaningfully contributed to the IBM Blue Gene product line, which was recognized with the National Medal of Technology and Innovation in the Fall of 2009. The Blue Gene Q provides an alternative approach to high performance computing from the hybrid, multi-core approach being pursued at the OLCF. This diversity both broadens the user community to a wide range of applications important to the Department and also reduces the risk of future procurements. The ALCF is also openly available to the scientific community through INCITE and ALCC and will continue to provide access and assistance to tool and library developers and to researchers seeking to scale their applications. The National Energy Research Scientific Computing Center (NERSC) facility at Lawrence Berkeley National Laboratory will continue to operate at a capacity of over one petaflop in FY 2012 to meet ever growing demand from SC researchers. The focus will be on assisting researchers to effectively utilize the potential of this facility and preparing researchers to move beyond NERSC to the leadership computing machines.

The FY 2012 budget request supports operation of ESnet to continue to advance the next generation network capability that is critical to DOE applications and facilities. Building on the Recovery Act-supported Advanced Networking Initiative, ESnet will begin to deliver 100 gigabit per second (Gbps) connections to SC laboratories in FY 2012, with a goal of achieving 1,000 Gbps connectivity in 2016. The increases in bandwidth are timed to meet the requirements of the Office of Science to move massive amounts of data to and from the petascale computing facilities and from other research facilities such as the Large Hadron Collider and Spallation Neutron Source. The ESnet is also critical to effective utilization of the growing volume of data in climate research, nuclear structure, genomics, and proteomics that advance DOE’s energy and environment missions. These efforts also rely upon investments in Next Generation Networking for Science to ensure that facilities are able to fully utilize this expanded bandwidth.

The FY 2012 budget greatly expands research efforts under Computational Partnerships aimed at developing applications capable of utilizing high performance hybrid, multi-core computing resources while informing the development of exascale resources to ensure that the demands of these applications are well understood and helping to shape the new architectures under development. New Co-Design Centers will be supported in key applications critical to Department missions in energy, environment and national security. These Co-Design Centers will enable close coupling of applications, computer science and computer hardware architecture that is required for success at exascale. In addition, FY 2012 begins the third round of investments in Scientific Discovery through Advanced Computing (SciDAC). To make it easier for science and engineering applications to utilize and incorporate enabling technologies, the 14 assorted SciDAC Centers and Institutes, supported in FY 2010, will be replaced in FY 2012 with a few larger, more integrated, SciDAC Institutes that will develop and deploy the tools and capabilities needed by both the traditional Scientific Computation Application Partnerships, funded with the other SC programs, and expanded Department of Energy Computation Application Partnerships, funded with the Department’s applied programs, that enable scientists to refine and scale their codes to effectively utilize the capabilities of the Leadership Computing Facilities.

The FY 2012 budget continues the core research efforts in Applied Mathematics and Computer Science focused on long-term research necessary for continued progress in high performance computational science and engineering. These investments will be critical to meeting the challenges of high performance hybrid, multi-core computing systems and to realizing the potential of the exascale systems on the horizon. The Applied Mathematics activity will support new efforts in Uncertainty Quantification to enable predictive simulations. In networking, the focus will continue to be on developing the advanced tools that harness new optical technologies to meet the requirements of the ESnet and the SC research community.

Significant Program Shifts

The challenges of developing and utilizing high performance hybrid, multi-core computing systems on the path to exascale while meeting the demands of some critical DOE applications require us to enhance the long-term, coordinated research and hardware investments across the ASCR research portfolio that were initiated in FY 2010. The FY 2012 budget enhances these investments with significant new projects in the Research and Evaluations Prototypes activity that focus on understanding and influencing critical technology developments in areas such as memory and processor design to provide increased energy efficiency and performance. These projects also provide the U.S. research community with an opportunity to experiment with cutting-edge architectures and begin to develop tools and methods for harnessing their capabilities. The changes in computer architectures discussed above require increased innovation and collaboration for continued progress. By actively participating in the development of these next-generation machines, ASCR can ensure that appropriate architectures for science are developed while researchers better understand their inherent challenges and can begin to work on overcoming those challenges. This activity will prepare researchers to effectively utilize the next generation of scientific computers and will also reduce the risk of future major procurements. These investments are also important to continued U.S. leadership in information technology and high-tech industry as vendor partnerships ensure that the solutions developed for scientific computing are also incorporated into commercial offerings.

In FY 2012, SciDAC partnerships with DOE's applied technology offices will be expanded. The Computational Partnerships activity will also expand support for Co-Design Centers. The Applied Mathematics activity will support new efforts in Uncertainty Quantification to enable predictive simulations. The Argonne Leadership Computing Facility will be upgraded to approximately 10 petaflops. The Oak Ridge Leadership Computing Facility will prepare for a computing system 5-10 times more capable than the current Cray XT5.

Annual Performance Targets and Results

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget.

Mathematical, Computational, and Computer Sciences Research

Funding Schedule by Activity

	(dollars in thousands	
	FY 2010 Current Appropriation	FY 2012 Request
Mathematical, Computational, and Computer Sciences Research		
Applied Mathematics	43,698	48,973
Computer Science	45,936	47,400
Computational Partnerships	49,538	60,036
Next Generation Networking for Science	14,373	12,751
SBIR/STTR 0		4,873
Total, Mathematical, Computational, and Computer Sciences Research	153,545	174,033

Description

The Mathematical, Computational, and Computer Sciences Research subprogram supports activities aimed at effectively utilizing forefront computational 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 must be positioned to address scientifically challenging questions, such as:

- What new mathematics are required to more accurately model systems involving processes taking place on vastly different time and length scales such as the earth's climate and the behavior of living cells?
- Which computational architectures and platforms will deliver the most benefit for the science of today and the future?
- What computer science and algorithm innovations would increase the efficiency of supercomputer problem solving?
- What operating systems, data management, analyses, representation model development, user interfaces, and other tools are required to make effective use of future-generation supercomputers?
- What networking collaboration tools are needed to make all scientific resources readily available to scientists, regardless of whether they are in a university, national laboratory, or industrial setting?

FY 2010 Accomplishments

- *Mathematics for Reliable Real-Time Power Dispatch.* Since electricity cannot currently be effectively stored on a large scale, providers rely on usage forecasts to plan generating capacity. Mathematicians and computer scientists at Argonne National Laboratory have recently developed a program called PIPS for the electricity dispatch problem. PIPS combines information such as weather, loads, and renewable generation outputs (e.g., wind power) over wide geographical regions to enable electricity usage forecasts to ensure sufficient capacity at any given moment.

Preliminary numerical testing has demonstrated a 600-fold improvement in the time-to-solution for a dispatch problem with 27 million variables and 6,000 uncertain scenarios using 1,000 parallel cores.

- *New Programming Model for Achieving Scalability on Extreme-Scale Computing Systems.* A critical challenge for future high-performance computing systems is the effective management of the speed and expediency of communications among the extremely large number of processors. ASCR researchers have developed an approach that holds promise for circumventing message passing bottlenecks. Called the Asynchronous Dynamic Load Balancing Library (ADLB), this innovative programming model enables an application to reuse most of its highly tuned code and streamlines the way parallel programming resources are allocated. Although more research will be needed to fully explore the capability of ADLB, early results are promising. Using ADLB, the researchers have successfully run the first, full calculations of carbon-12—a specific target of the ASCR SciDAC Universal Nuclear Energy Density Functional project and one that addresses fundamental issues in the origin of the universe—on more than 130,000 processors of the Blue Gene/P at the Argonne Leadership Computing Facility.
- *New Algorithm Improves Performance and Accuracy on Extreme-Scale Computing Systems.* On modern computer architectures, communication between processors takes longer than the performance of a floating point arithmetic operation by a given processor. ASCR researchers have developed a new method, derived from commonly used linear algebra methods, to minimize communications between processors and the memory hierarchy, by reformulating the communication patterns specified within the algorithm. This method has been implemented in the TRILINOS framework, a highly-regarded suite of software, which provides functionality for researchers around the world to solve large scale, complex multi-physics problems.
- *Improving Community Code Performance for Nuclear Energy Application.* Nuclear reactor analysis requires accurate characterization of the neutron distribution in the reactor in order to determine power, safety, and fuel and component performance. In a steady-state operational reactor, the neutron field is characterized by six independent variables (three in space, two in angle, and one in energy), and the mean free path of low-energy neutrons are in the millimeter to centimeter range. Thus, high-resolution solutions of the transport equation require tremendous computational resources. Traditionally, computational resources have not been sufficient to attack this problem at full resolution; so multi-level approximation schemes have been employed. Denovo is a community code that serves as a general radiation transport application for nuclear and radiological sciences by finding accurate numerical solutions to the linear Boltzmann equation. This application area includes, but is not limited to, nuclear reactor analysis, fusion, radiation shielding and protection, nuclear safeguards, radiation detection, and radiation therapy, diagnostics, and treatment planning. Working with Denovo users, ASCR researchers made major improvements to traditionally used methods for decomposition and for solving the partial differential equations governing the power distribution in a full-scale reactor core. The core (height 4.2 m) has 17x17 (289) assemblies (height 3.6 m), of which 157 are fuel and 132 are reflector, with each fuel assembly consisting of 17x17 fuel pins. As a result, accuracy was dramatically improved by eliminating multi-level approximation schemes and the problem was solved in 11 minutes on the OLCF using over 50% of available computing power. The time to solution was a factor of 17 improvement over previous simulations.

- *Simulation Reveals Details in Cellulose for Bioenergy Alternatives.* ASCR researchers recently conducted cellulose simulations showing a structure change in cellulose when heated that may impact how hard it is to break cellulose apart. ASCR researchers also developed new methods to measure the intrinsic work for an enzyme to pull a single cellulose chain out of a crystal of cellulose—a key measure of the intrinsic toughness of cellulose. Cellulose is the most common organic compound on Earth and is a primary target for bioenergy. Nature has evolved to protect plants from invaders by making cellulose very difficult for enzymes to deconstruct. Individual cellulose chains pack together into fibrils, similar to how small threads are combined to form a rope or cable. Experiments are limited in what they can tell us about this structure, so we rely on molecular simulation to investigate the detailed structure of cellulose fibrils. The simulation results will allow us to quantify the effects of pretreatment strategies on cellulose structure with significant implications for advancing development of cellulosic bio-ethanol.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Applied Mathematics	**43,698**	**48,973**

Over the past half-century, ASCR-supported researchers from universities, national laboratories, and industry have made significant enduring advances in applied mathematics, such as laying the foundations for Computational Fluid Dynamics and developing Adaptive Mesh Refinement for tracking important, fine-scale structures within a simulation. These have been essential enablers of modern computational science and engineering and have become ubiquitous in industry and throughout the government. The challenges of the Department's missions and those from high performance hybrid, multi-core computing will require significant innovation from our applied mathematicians and a dedicated focus throughout our portfolio. These anticipated results will transform computational and applied mathematics and will be critical to continued leadership in computational science. As the computing industry moves toward hybrid, multi-core computing architectures, the applied mathematics-supported researchers will be working with the software industry to continue progress at all levels of computing with implications throughout our economy and our daily lives.

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. Applied Mathematics research underpins all of DOE's modeling and simulation efforts. The research falls into several general categories:

- Numerical methods research for equations related to problems such as fluid flow, magneto-hydrodynamics, wave propagation, and other natural or physical processes.
- Computational meshing research for developing ways in which physical domains can be efficiently partitioned into smaller, possibly geometrically complex, regions as part of a larger-scale simulation.

- Advanced linear algebra research for fast and efficient numerical solutions of linear algebraic equations that often arise when simulating physical processes. Because a large fraction of the time in many simulations is spent doing this type of computation, advances here have enormous leverage across science.
- Optimization research for mathematical methods for minimizing energy or cost, finding the most efficient solutions to engineering problems, or discovering physical properties and biological configurations. This includes optimization, control, and risk assessment in complex systems with relevance for DOE missions in energy, national security, and environment.
- Multiscale mathematics and multiphysics computations for connecting the very large with the very small, the very long with the very short, and multiple physical models in a single simulation.
- In FY 2010, the Multiscale Mathematics area of research began to explicitly include Uncertainty Quantification. For FY 2012, this area is expanded to a somewhat separate research area owing to its importance for predictive science at the exascale.
- Joint Applied Mathematics-Computer Science Institutes for the development of efficient new mathematical models, algorithms, libraries, and tools for next generation computers.
- Mathematics for the analysis of extremely large datasets for identifying key features, determining relationships between the key features, and extracting scientific insights.
- Mathematics of cyber security from a basic research perspective for addressing the understanding and discovery of anomalies in existing network data, modeling of large-scale networks, and understanding dynamics and emergent behavior on networks. This leverages on-going efforts in the mathematics of optimization and risk assessment in complex systems.

In FY 2012, basic research activities will continue for fundamental mathematical advances and computational breakthroughs across DOE and Office of Science missions—including model formulation and algorithm development for emerging computing systems. FY 2012 supports significant growth in support for Uncertainty Quantification research, deemed critical to realizing the potential of exascale computing for predictive science. For many problems in the fields of natural sciences and engineering, incomplete descriptions, measurements, and data for these problems introduce uncertainties as researchers attempt to understand complex phenomena through computer modeling and simulation. As we increase the use of computing to study such problems, the development of more sophisticated techniques for the incorporation and quantification of uncertainties becomes key to our success. New efforts in the research and development of uncertainty quantification methodology and techniques will improve our overall understanding of complex scientific and engineering problems and allow us to make quantitative predictions about the behavior of these systems.

In FY 2012, the Computational Science Graduate Fellowship program, aimed at attracting the best graduate students in the scientific disciplines and educating them as the next generation of computational scientists, is continued at $6,000,000.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Computer Science	**45,936**	**47,400**

Computer Science research is conducted by universities, national laboratories, major information technology companies and small businesses. Their efforts have resulted in software, languages, libraries and tools that run on most of the world's high performance computing platforms and are used by many of the Nation's information technology and high-tech companies, as well as by all of the DOE scientific and national security application communities. As the computing industry moves toward hybrid, multi-core computing architectures, this work plays a critical role in ensuring that these machines are useful tools for all levels of scientific computing.

The Computer Science activity supports research to utilize computing at extreme scales and to understand extreme scale data from both simulations and experiments. Industry reports indicate that because of power constraints, data movement, rather than computational operations, will be the limiting factor for future systems petaflops to exaflops. Memory per core is expected to decline sharply while the performance of storage systems will continue to lag far behind the computational capability of the systems. Multi-level storage architectures that span multiple types of hardware are anticipated and will require new approaches to run-time data management and analysis. To address these challenges the Computer Science portfolio includes:

- Operating and file systems for extreme scale computers with many thousands of multi-core processors with complicated interconnection networks.
- Performance and productivity tools for extreme scale systems that enable users to diagnose and monitor the performance of software and scientific application codes to enable users to improve performance and get scientific results faster.
- Programming models that enable today's computations and discover new models that scale to hundreds of thousands of processors to simplify application code development for petascale computing.
- Approaches to simulate and understand the impact of advanced computer architectures on scientific applications critical to the Department.
- Data management and visualization to transform extreme scale data into scientific insight through investments in visualization tools that scale to multi-petabyte datasets and innovative approaches to indexing and querying data.
- Joint Applied Mathematics-Computer Science Institutes for the development of efficient new mathematical models, algorithms, libraries, and tools for next generation computers. Leading edge developers to directly address the new challenges from the next generation of computers and transfer this insight to key DOE application developers.

A fundamental challenge for the Computer Science activity is enabling science applications to harness computer systems with increasing scale and increasing complexity that take advantage of technology advances such as multicore chips. This challenge will require more dynamic behavior of system software (operating systems, file systems, compilers, and performance tools) than historically developed to deal with time varying power and resilience requirements. Substantial innovation is

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

needed to provide essential system software functionality in a timeframe consistent with the anticipated availability of hardware.

Another fundamental challenge is enabling scientists to effectively manage, analyze, and visualize the petabytes of data resulting from extreme scale simulations and experimental facilities. Substantial innovation in computer science and applied mathematics is needed to provide essential system and application functionality in a timeframe consistent with the anticipated availability of hardware.

In FY 2012, the Computer Science activity will continue to focus on the challenges of emerging high performance hybrid, multi-core computing architectures containing as many as a billion cores with hybrid processors. The research efforts, begun in FY 2010, will continue to focus on advanced architectures and related technologies for hybrid, multi-core computing up to the exascale and the associated software including significant investments to improve our ability to simulate future systems.

Computational Partnerships	**49,538**	**60,036**

Over the past decade, the Scientific Discovery through Advanced Computing (SciDAC) has influenced and shaped the development of a distinct approach to science and engineering research through high performance computation. The influence of this program can best be seen by the world-wide interest in replicating the SciDAC approach. SciDAC focuses on the very high-end of high performance computational science and engineering and faces two distinct challenges: to broaden the community and thus the impact of this approach, particularly to address the Department's missions, and to ensure that further progress at the forefront is enhanced rather than curtailed by the emergence of hybrid, multi-core architectures. A decade of effort has uniquely enabled this program to be ready to simultaneously meet both of these important challenges. These efforts have shown U.S. industry new ways to use their computing to improve competitiveness. The Computational Partnerships activity supports the SciDAC program to use results from applied mathematics and computer science research on scientific applications sponsored by other SC programs. 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. To address challenges of the future, SciDAC has been expanded to include Co-Design Centers/partnerships focused on developing the applications that need exascale computing systems and informing the design of the hardware.

The next round of SciDAC investments, scheduled for competition in FY 2012, will address the challenges from emerging hardware to ensure continued progress in computational science in support of the Department's missions and broadening the benefits of high end computation to the Department's applied programs. The key components of the program are SciDAC Institutes, Computation Application Partnerships, and Co-Design Centers.

- *SciDAC Institutes* will be the keystone for applied math and computer science efforts to systematically address technical challenges that are inherent to the scale of new architectures or common across applications. The formulation of these Institutes is based on our lessons-learned from nearly a decade of SciDAC Centers for Enabling Technology and University-based Institutes. The re-formulated SciDAC Institutes will be responsible for developing new methods, algorithms and libraries; new methodologies for achieving portability and interoperability of complex

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

scientific software packages; software tools and support for application performance; and tools for feature identification, data management, and visualization spanning the full range of SciDAC applications. The SciDAC Institutes will provide a more integrated approach for managing outreach to new communities and deployment of SciDAC-developed software and techniques.

- *Scientific Computation Application Partnerships* with other SC programs will build on past successes to dramatically improve the ability of SC researchers to effectively and confidently utilize multi-petaflop computing systems to advance science. These partnerships support research between applied mathematicians and computer scientists (supported by ASCR) with domain scientists (supported by the other SC programs) to refine and apply computational techniques and tools that address the specific problems of a particular research effort, such as modeling the reactive transport of contaminants through groundwater or developing an Earth System model that fully simulates the coupling between the physical, chemical, and biogeochemical processes in the global climate.
- *Department of Energy Computation Application Partnerships* with the Department's applied programs will be formed to transfer SciDAC technologies and improve the ability of DOE researchers to effectively utilize petascale and emerging extreme scale computing systems to advance their mission goals. These partnerships support collaborative research between applied mathematicians and computer scientists (supported by ASCR) with application researchers (supported by the other DOE programs) to refine and apply computational techniques and tools that address the specific problems of a particular research effort, such as modeling the complete nuclear fuel cycle or the electricity grid; developing a predictive model that accurately simulates conditions at DOE contaminated sites and allows the Department to optimize remediation strategies; and predictive, long-term simulations of carbon sequestration options. ASCR has had workshops with NE to inform these partnerships and is currently planning workshops with EERE, OE, and FE to develop these efforts.
- *Co-Design Centers* will continue the close coupling of applications, computer science, and computer hardware architecture that is required for success at exascale. They ensure that future architectures are well-suited for DOE target applications and that major DOE scientific problems can take advantage of the emerging hybrid, multi-core computing architectures. These centers of computational science need to be formally engaged in the hardware, software, numeric methods, algorithms, and applications co-design process that will be responsible for making key tradeoffs in the design of exascale systems. It is anticipated that these Co-Design Centers will need to address: application formulation, advanced programming languages, integrated uncertainty quantification, validation and verification, new mathematics and approaches to implementing multi-physics problems that naturally express parallelism and locality, and data management analysis, including visualization, all in the context of a scientific problem area important to the DOE.

In FY 2012, the request supports new Co-Design efforts and new Department of Energy Computation Application Partnerships with the Department's applied programs for energy and the environment.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Next Generation Networking for Science	**14,373**	**12,751**

To facilitate the best collaborations for science, ASCR has played a leading role in driving development of the high-bandwidth networks connecting researchers to each other and their data. The invisible glue that binds today's networks across the world together—effortlessly passing billions of searches and trillions of bits from one corner of the earth to another—has roots in ASCR-supported research, ASCR-supported researchers helped establish critical protocols such as TCP/IP on which the current Internet is based. ASCR advanced networking research makes international collaborations such as the Large Hadron Collider and ITER possible and underpins virtual meeting and other commercial collaboration tools. The Next Generation Networking for Science activity builds on results from Computer Science and Applied Mathematics to develop integrated software tools and advanced network services to enable large-scale scientific collaboration and to utilize the new capabilities of ESnet to advance DOE missions. The research falls into two general categories:

- Distributed systems software including scalable and secure tools and services to facilitate large-scale national and international scientific collaboration, and high-performance software stacks to enable the management, and distribution of extremely large data sets generated by simulations or by science experiments such the Large Hadron Collider, the Intergovernmental Panel on Climate Change, and ITER; and
- Advanced network technologies including dynamic optical network services, scalable cyber security technologies, and multi-domain, multi-architecture performance protocols to seamlessly interconnect and provide access to distributed computing resources and science facilities.

In FY 2012, research will continue to focus on developing the software, middleware and hardware that delivers 99.999% reliability up to and beyond one petabyte per second while allowing the successful products of prior research such as the Open Science Grid and the Earth Systems Grid to transition into operational services supported by their users. The Next Generation Networking research program will continue to make critical investments in several areas including (1) new protocols that allow hosts to rapidly and efficiently adapt to network conditions to maximize the available bandwidth; (2) new routing algorithms that can improve the performance of routers and switches; (3) a rich suite of secure collaboration tools and services; and (4) advanced simulation environments that duplicate real networks to ensure that science communities achieve their goals, and in so doing, underpin commercial offerings to broaden the opportunities for other government agencies, U.S. industry and the American people.

Small Business Innovative Research (SBIR)/ Small Business Technology Transfer (STTR)	**0**	**4,873**

In FY 2010, $4,113,000 and $494,000 were transferred to the SBIR and STTR programs respectively. The FY 2012 amount shown is the estimated requirement for continuation of the SBIR and STTR programs.

Total, Mathematical, Computational, and Computer Sciences Research	**153,545**	**174,033**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Applied Mathematics	
This increase will support new efforts in Uncertainty Quantification to enable predictive scientific simulation and the continued development of new and improved applied mathematical models, methods, and algorithms to understand complex systems.	+5,275
Computer Science	
The increase will support new efforts focused on the challenges of hybrid, multi-core computing.	+1,464
Computational Partnerships	
The increase, in addition to the completion of several projects, will support new partnerships with DOE applied programs and Co-Design Centers.	+10,498
Next Generation Networking for Science	
This decrease reflects a phase out of support for the Open Science Grid and Earth Systems Grid which are moving into production.	-1,622
SBIR/STTR	
SBIR/STTR increases as research funding is increased.	+4,873
Total Funding Change, Mathematical, Computational, and Computer Sciences Research	**+20,488**

High Performance Computing and Network Facilities

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
High Performance Computing and Network Facilities		
High Performance Production Computing	54,900	57,800
Leadership Computing Facilities	128,788	156,000
Research and Evaluation Prototypes	15,984	35,803
High Performance Network Facilities and Testbeds	29,982	34,500
SBIR/STTR 0		7,464
Total, High Performance Computing and Network Facilities	229,654	291,567

Description

The High Performance Computing and Network Facilities subprogram delivers forefront computational and networking capabilities to scientists nationwide. These include high performance production computing at the National Energy Research Scientific Computing Center (NERSC) facility at LBNL and Leadership Computing Facilities at Oak Ridge (OLCF) and Argonne (ALCF) National Laboratories. 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 subprogram also invests in long-term needs through the Research and Evaluation Prototypes activity which will play a critical role in achieving exascale computing.

Computing resources are allocated through competitive processes. Up to eighty percent of the processor time on the Leadership Computing Facilities is allocated through the Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program, which is open to all researchers and results in awards to 20–30 projects per year, each requiring a substantial amount of the available resources. The high performance production computing facilities at NERSC are predominately allocated to researchers supported by SC programs. In addition to INCITE, all of the ASCR scientific computing facilities allocated ten to thirty percent of computing resources through the ASCR Leadership Computing Challenge program. This program is open year-round to scientists from the research community in academia and industry for special situations of interest to DOE with an emphasis on high-risk, high-payoff simulations in areas directly related to the DOE's energy mission, for national emergencies, or for broadening the community of researchers capable of using leadership computing resources.

ASCR facilities provide critical resources for the scientific community following the public access model used by other Office of Science scientific user facilities including light sources, accelerators and microscopes. In addition, ASCR facilities provide a crucial testbed for U.S. industry to deploy the most advanced hardware and have it tested by the leading scientists across the country in universities, national laboratories, and industry.

FY 2010 Accomplishments

- *Oak Ridge Supercomputers Delivers Petascale Science*. Using the additional computing capability from the FY 2009 upgrade to 2.33 petaflops, researchers using the Oak Ridge Leadership Computing Facility (OLCF) were able for the first time to predict the flux of contaminants into the Columbia River basin at the Hanford 300 waste disposal site in Washington State. The team's application was able to model the complex nonlinear chemistry and transient fluid flow caused by fluctuations in the Columbia River to inform the Department's efforts for the remediation of the aging underground contaminant storage facilities. Another project run on the OLCF looked at lifted flames from a direct injection diesel-engine jet and, for the first time, performed a three-dimensional simulation capable of fully resolving flame and ignition features such as chemical composition, temperature profile, and turbulence flow. In yet another project, researchers performed the largest simulation to date of turbulent dispersion, informing the development of more efficient engines.
- *Argonne Supercomputer Explains How Impurities Cause Embrittlement of Materials.* Simulations run at the Argonne Leadership Computing Facility have answered a fundamental question encompassing chemistry, mechanics, and materials science: how minute impurities in the grain boundaries of a material alter its fracture behavior. Sulfur segregation-induced embrittlement of nickel is an important problem for the design of the next-generation nuclear power plants. Although experiments had identified an essential role of sulfur in the embrittlement, there was little understanding of how the sulfur had effect. Through simulation, researchers found that the impurities led to an order-of-magnitude reduction of grain-boundary shear strength and tensile-strength reduction, which allow crack tips to find an easy propagation path. This mechanism explains experimental observations and elucidates the experimentally found link between sulfur impurities and embrittlement. Results were published in *Physics Review Letters*.
- *Argonne Supercomputer Speeds up Research in Response to Pandemic Flu.* The rapid turnaround of huge protein structure campaigns at the Argonne Leadership Computing Facility allowed researchers seeking to computationally design protein-based inhibitors towards pathogens like the H1N1 influenza to develop and test new algorithms that speed up research. The acceleration provided by use of leadership computing resources allowed researchers to quickly identify two candidate inhibitors for the pandemic strain of H1N1 in response to the global emergency. Conventional protein structure determination from nuclear magnetic resonance (NMR) data is labor intensive and prone to error. Researchers used the ALCF to develop simplified approaches without losing accuracy. These approaches were incorporated into the Rosetta3 protein structure modeling methodology—the most popular software tool for protein structure prediction. This enhancement enables routine NMR structure determination for larger proteins. Results were published in *Science* and the *Journal of Molecular Biology*.
- *National Energy Research Scientific Computing (NERSC) Clears Cloud Modeling*. Researchers, using supercomputers at NERSC, developed a new global cloud resolving model which is designed to reduce the uncertainty in current climate models. Combined with these powerful systems of the future, the model will allow scientists to simulate climate down to the one-kilometer scale—the scale at which the effects of clouds will be more accurately represented. Clouds have powerful effects on the Earth's climate, both cooling the planet by reflecting heat from the sun and warming it by trapping heat near the surface. Today's models, at best, use parameterizations, or statistical representations, of clouds and their effects in climate models—one of the main reasons different

climate models produce different results. In fact, cloud parameterizations are one of the greatest sources of uncertainty in today's climate models.

- *Energy Sciences Network (ESnet) Delivers*. When the Large Hadron Collider started operations in FY 2010, ESnet flawlessly handled the doubled traffic over two months, transmitting over 8.6 petabytes of data per month. More than half of this traffic is now using the software developed by ESnet to establish virtual circuits that provide carrier-class network reliability and services. ESnet has also deployed a test and measurement infrastructure that significantly increased data transfer performance for the climate community, DOE supercomputer centers and leadership facilities in support of the Intergovernmental Panel on Climate Change (IPCC) 5th assessment report (AR5) expected in 2014.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
High Performance Production Computing	**54,900**	**57,800**

This activity supports the NERSC facility located at LBNL. NERSC delivers high-end capacity computing services for the SC research community. Annually, nearly 3,200 computational scientists in about 400 projects use NERSC to perform basic scientific research across a wide range of disciplines including astrophysics, chemistry, climate modeling, materials, high energy and nuclear physics, and biology. NERSC enables teams to prepare to use the ALCF and OLCF as well as to perform the calculations that are required by the missions of the SC programs. NERSC users are supported by SC programs with about 60% based in universities, 30% in national laboratories, and 10% in other government laboratories and industry. NERSC's large and diverse user base requires an extremely agile support staff.

FY 2012 funding will support operation of the NERSC high-end capability systems (NERSC-5 and NERSC-6), lease payments, and user support. The total capacity of NERSC in FY 2012 will be more one petaflop. The NERSC computational resources are integrated by a common high performance file storage system that enables users to easily migrate to any of the available resources. With approximately 60 petabytes of storage and an average transfer rate in the hundreds of megabytes per second, this system is critical to effective use of the facility and allows users to easily move data into and out of the NERSC.

The NERSC facility is a vital resource for the Office of Science research community and is consistently oversubscribed with requests exceeding capacity by a factor of 3-10. NERSC regularly gathers requirements from the Office of Science programs through a robust process that informs upgrade plans. Regular upgrades attempt to keep pace with demand but scientific demand for computing continues to outpace available resources. NERSC is also a vital resource for ASCR because it has a large and diverse user community. NERSC staff are adept at meeting the needs of such a diverse community including both savvy and novice users. This feedback is vital to SciDAC and to ASCR efforts to broaden the impact of its research results particularly as the computing industry moves toward hybrid, multi-core computing.

(dollars	in thousands)
FY 2010 Current Appropriation	FY 2012 Request

	FY 2010	FY 2012
Achieved Operating Hours	8,585	N/A
Planned Operating Hours	8,585	8,585
Optimal Hours	8,585	8,585
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	1%	1%
Number of Users	3,100	3,500

Leadership Computing Facilities **128,788 156,000**

The Leadership Computing Facilities (LCF) activity enables open scientific applications to harness the potential of leadership computing to advance science. In June, 2010, the Oak Ridge LCF was the most powerful computing system in the world at that time, according to the independent international Top 500 ranking of supercomputers. The era of petaflop science opens significant opportunities to dramatically advance research as simulations more realistically capture the behavior of, for example, materials and ITER scale fusion devices. The leadership facilities also provide experience and tools critical to continued progress in high performance computing. The success of this effort is built on the gains made in research and evaluation prototypes, the SciDAC program, and research in applied mathematics and computer science.

The costs for both the ALCF and OLCF fall into three general areas: lease payments, operations (space, power, cooling, maintenance, tapes, etc.), and staff.

- **Leadership Computing Facility at ORNL (OLCF)** **86,788** **94,000**

  In FY 2009, with Recovery Act funds, the OLCF's Cray XT5 system was upgraded to 2.33 petaflops—making it the most powerful computer in the world. In addition, the facility also continues to operate a 263 teraflop Cray XT4 machine, also available for INCITE projects, ASCR Leadership Computing Challenge projects, scaling tests, and tool and library developers.

  The facility staff continues to assist users to fully utilize the OLCF resources. As a result, several applications, such as combustion studies in diesel jet flame stabilization, simulations of neutron transport in fast reactor cores, and groundwater flow in porous media, are running at petascale.

  In FY 2012, the request supports staff, operations, and lease payments for the computer system at the facility. In addition, the OLCF will continue site preparations for a 5-10 times more capable computing system. Experience with this system is expected to inform ASCR investments in both exascale relevant research and in the Research and Evaluations Prototypes activity.

  The OLCF has a strong and successful partnership with its computing vendor. The OLCF's knowledgeable staff are versed in hardware, cutting edge tools and methods, and the needs of forefront computational science and engineering teams. It is this expertise that enabled the OLCF to deliver petascale science from day one of operations of the petascale computer. The OLCF then turned its focus on the specific challenges of hybrid, multi-core computing systems with particular attention to application requirements. Through INCITE and outreach, the OLCF transfers its expertise to industry and academic users to broaden the benefits for the Nation. For example, the OLCF worked with Ford on energy recovery technologies and is working with BMI/Smart Truck to improve the fuel efficiency of class 8 trucks.

	FY 2010	FY 2012
Achieved Operating Hours	7,008	N/A
Planned Operating Hours	7,008	7,008
Optimal Hours	7,008	7,008
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	1%	1%
Number of Users	550	625

- **Leadership Computing Facility at ANL (ALCF) 42,000 62,000**

The ALCF provides a high performance 556 teraflop peak capability IBM Blue Gene/P with low-electrical power requirements. It will be upgraded in FY 2012 to the next generation system, an IBM Blue Gene/Q, with peak capability of approximately 10 petaflops. The Blue Gene/Q was developed through a joint research project with NNSA, IBM, and ASCR's Research and Evaluation Prototypes activity. The ALCF and OLCF systems are architecturally distinct and this diversity of resources benefits the Nation's HPC user community. The ALCF supports many applications, including molecular dynamics and materials, for which it is better suited than the OLCF or NERSC. ALCF staff operates and maintains the computing resources and provides support to INCITE projects, ASCR Leadership Computing Challenge projects, scaling tests, and tool and library developers.

In FY 2012, the request supports acquisition, installation and testing of the IBM Blue Gene/Q. In addition, the ALCF activity will also support operation and INCITE allocation of the Blue Gene/P in FY 2012 and operation and early access to the Blue Gene/Q.

The ALCF also has a strong and successful partnership with its computing vendor. The ALCF's knowledgeable staff are versed in hardware, cutting edge tools and methods, and the needs of forefront computational science and engineering teams. When IBM received the National Medal of Technology and Innovation for its Blue Gene line of supercomputers in the Fall of 2009, the contributions of Argonne and Lawrence Livermore National Laboratory, from their research partnership with IBM, were also recognized. This experience will be critical to the success of industry partnerships to address the challenges of next-generation computing. Through INCITE, the ALCF also transfers its expertise to industry and academic users to broaden the benefits for the Nation. For example, the ALCF has worked with Pratt and Whitney to reduce emissions and improve operability in aircraft engine combustors and it is working with GE Global Research to reduce Aerodynamic noise in next-generation, low-emission aircraft propulsion and wind turbines.

(dollars in thousands)	
FY 2010 Current Appropriation	FY 2012 Request

	FY 2010	FY 2012
Achieved Operating Hours	7,008	N/A
Planned Operating Hours	7,008	7,008
Optimal Hours	7,008	7,008
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	1%	1%
Number of Users	200	350

	FY 2010 Current Appropriation	FY 2012 Request
Research and Evaluation Prototypes	**15,984**	**35,803**

The potential benefits from exascale computing capability have been documented through a series of workshops and town meetings. These workshops and detailed discussions with industry experts underscore that achieving exascale computing will require overcoming large technical challenges that cannot be accomplished with incremental improvements to current hardware and software. One of the most significant challenges will be reducing the amount of electrical power per operation by approximately 99.7% relative to today's systems. Memory design is a related challenge as future systems must dramatically reduce the amount of energy needed to move data between the memory devices and the processor. Another hardware challenge arises from the continued reduction of transistor dimensions which will cause many circuit failures. Techniques will be needed to manage the errors and it may be necessary for programming techniques and operating system designs to handle those errors that are behind hardware detection and correction mechanisms. Additional hardware challenges include the move to solid-state disk storage, the use of on-die voltage regulation, and the transition to photonic interconnection networks for moving the massive amount of information between processor-memory elements and between those elements and bulk storage and networking devices. All in all, the hardware challenges of exascale dwarf those faced in moving from gigascale to terascale in the 1990s and in moving from terascale to petascale in the last decade.

The Research and Evaluation Prototypes activity addresses these challenges of next generation computing systems. By actively partnering with industry in the development of these next-generation machines, ASCR can ensure that the most appropriate architectures for science are developed while application and software researchers gain a better understanding of future systems to get a head start in developing software and models to take advantage of the new capabilities. Thus Research and Evaluation Prototype activity will prepare researchers to effectively utilize the next generation of scientific computers and will also reduce the risk of future major procurements.

In FY 2012, the Research and Evaluation Prototypes activity will support efforts to explore architectures on the path toward exascale computing and pursue multiple paths to overcoming key barriers. These efforts will be closely coordinated with FY 2012 investments in the NNSA to ensure complementary and efficient use of resources. These efforts will also be tightly coupled with research supported by the Applied Mathematics activity, the Computer Science activity, the SciDAC Co-Design Centers supported by the Computational Partnerships activity, and experience at the computing facilities.

New Research and Evaluation Prototype investments will engage industry and leverage investments in the private sector as a partner in development. This is critical to ensuring that the demands of high performance computing for science and engineering are incorporated into commercial offerings and exascale capability. This effort will also provide the U.S. research community—from universities, national laboratories, and industry—with early access to emerging designs so as to inform their research efforts. Planned Research and Evaluation investments include partnerships with computer vendors to design the next generations of systems for science as well as focused partnerships to develop critical technologies:

- Initiation of two architectural development partnerships with U.S. computer vendors to develop hardware and low level software architectures which enable the creation of high performance scientific applications for these computers, as well as the smaller scale versions that will be ubiquitous in the scientific infrastructure; and
- Partnerships with U.S. memory vendors to deliver high bandwidth, power efficient memory technology for 2015 and 2018 computer systems. This is critical because the current commercial memory roadmaps indicate that memory power requirements will dominate the power budgets for computers targeted at scientific applications. Unless we invest in this area, the power requirements for exascale systems would be untenable. Low power, high speed memory with 10-100 fold improvement over current commercial offerings is required for science applications.

As the ASCAC report on exascale emphasized, "[f]or the information technology industry, leadership in hardware and software innovation for exascale computing will be accompanied by leadership in the full spectrum of computing from embedded computers and handheld mobile devices to laptop and desktop servers to departmental servers, all of which includes the use of high levels of intra-chip multithreaded parallelism. There is a critical need to find co-designed hardware and software solutions in this full spectrum (e.g., the power challenges for mobile devices bear a lot of similarity to those for nodes in an exascale systems) therefore whichever country leads in exascale computing will also enjoy technology leadership in the IT sector in general."[a]

High Performance Network Facilities and Testbeds	**29,982**	**34,500**

The costs for ESnet are dominated by operations which include refreshing hardware, such as switches and routers, on the schedule needed to ensure the 99.999% reliability that is required for large scale scientific data transmission.

The FY 2012 budget request supports operation of ESnet to continue to advance the next generation network capability that is critical to DOE applications and facilities. Building on the Recovery Act-supported Advanced Networking Initiative, ESnet will begin to deliver 100 gigabit per second (Gbps) connections to SC laboratories in FY 2012, with a goal of achieving 1,000 Gbps connectivity in 2016.

[a] *Opportunities and Challenges of Exascale Computing,* Advanced Scientific Computing Advisory Committee Subcommittee page 11, (http://www.science.doe.gov/ascr/ASCAC/Reports/Exascale-Subcommittee-Report.pdf).

(dollars in thousands)		
	FY 2010 Current Appropriation	FY 2012 Request

	FY 2010	FY 2012
Achieved Operating Hours	8,760	N/A
Planned Operating Hours	8,760	8,760
Optimal Hours	8,760	8,760
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	0.01%	0.01%
Number of Users[a]	N/A	N/A

	FY 2010 Current Appropriation	FY 2012 Request
Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR)	**0**	**7,464**

In FY 2010, $5,530,000 and $664,000 were transferred to the SBIR and STTR programs respectively. The FY 2012 amount shown is the estimated requirement for continuation of the SBIR and STTR programs.

	FY 2010 Current Appropriation	FY 2012 Request
Total, High Performance Computing and Network Facilities	**229,654**	**291,567**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
High Performance Production Computing	
The increase will support operation of the NERSC high-end capability systems (NERSC-5 and NERSC-6), lease payments, and user support.	+2,900
Leadership Computing Facilities	
▪ Leadership Computing Facility at ORNL	
Increase supports site preparations and acquisition of a prototype hybrid multi-core computing system for research and tool development.	+7,212
▪ Leadership Computing Facility at ANL	
The increase supports upgrade of the facility to a 10 petaflop IBM Blue Gene/Q.	+20,000
Total, Leadership Computing Facilities	**+27,212**

[a] The ESnet is a high performance scientific network that connects DOE facilities to researches around the world and it is therefore not possible to estimate users.

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research and Evaluation Prototypes	
The increase will support significant new research and development partnerships to advance exascale relevant prototypes and critical technologies that meet the needs of science applications.	+19,819
High Performance Network Facilities and Testbeds	
The increase will enable ESnet to plan for the installation and operation of a dedicated optical network to meet the growing requirements for DOE applications and facilities.	+4,518
SBIR/STTR	
Increase in SBIR/STTR due to increase in operating expenses.	+7,464
Total Funding Change, High Performance Computing and Network Facilities	**+61,913**

Supporting Information

Operating Expenses, Capital Equipment, and Construction Summary

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Operating Expenses	373,899	440,600
Capital Equipment	9,300	25,000
Total, Advanced Scientific Computing Research	383,199	465,600

Funding Summary

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	169,529 21	7,300
Scientific User Facility Operations	213,670 24	8,300
Total, Advanced Scientific Computing Research	383,199 46	5,600

Scientific User Facility Operations

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
NERSC 5	4,900	57,800
OLCF 8	6,788	94,000
ALCF 4	2,000	62,000
ESnet 2	9,982	34,500
Total, Scientific User Facility Operations	213,670	248,300

Facilities Users and Hours

	FY 2010 Current Appropriation FY	2012 Request
NERSC		
Achi eved Operating Hours	8,585	N/A
Planned Operating Hours	8,585	8,585
O ptimal Hours	8,585	8,585
Percent of Optimal Hours	100%	100%
Unsc heduled Downtime	1%	1%
Num ber of Users	3,100	3,500

	FY 2010 Current Appropriation FY	2012 Request
ESnet		
Achieved Operating Hours	8,760	N/A
Planned Operating Hours	8,760	8,760
Optimal Hours	8,760	8,760
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	0.01%	0.01%
Number of Users [a] N/A		N/A
OLCF		
Achieved Operating Hours	7,008	N/A
Planned Operating Hours	7,008	7,008
Optimal Hours	7,008	7,008
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	1%	1%
Number of Users	550	625
ALCF		
Achieved Operating Hours	7,008	N/A
Planned Operating Hours	7,008	7,008
Optimal Hours	7,008	7,008
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	1%	1%
Number of Users	200	350
Total		
Achieved Operating Hours	31,361	N/A
Planned Operating Hours	31,361	31,361
Optimal Hours	31,361	31,361
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	1%	1%
Number of Users	3,850	4,475

[a] The ESnet is a high performance scientific network that connects DOE facilities to researches around the world and it is therefore not possible to estimate users.

Scientific Employment

	FY 2010 Current Appropriation FY	2012 Request
# University Grants	210	215
Average Size	224,000	247,000
# Laboratory Projects	180	181
# Graduate Students (FTEs)	488	527
# Permanent Ph.D.s (FTEs)	756	807
# Other (FTEs)	246	288

Basic Energy Sciences

Funding Profile by Subprogram

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Basic Energy Sciences		
Materials Sciences and Engineering	353,423	459,952
Chemical Sciences, Geosciences, and Biosciences	287,480	394,717
Scientific User Facilities	803,825	978,931
Subtotal, Basic Energy Sciences	1,444,728	1,833,600
Construction	154,240	151,400
Total, Basic Energy Sciences	1,598,968[a]	1,985,000

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
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 Act of 2010"

Program Overview

Mission

The mission of the 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.

Background

Our ability to discover and transform the material resources that nature provides has shaped history and built civilizations. From prehistoric hunters and gatherers, who utilized wood-burning fires and fashioned tools from stone, to modern nations that run on processes powered primarily by coal and oil, progress has been marked by advanced technologies designed to make better use of Earth's resources. Today, science and technology are increasingly at the heart of many critical societal, political, and economic issues that surround the energy security and sustainability of our nation.

The energy challenges of the next century will fundamentally depend on scientific discovery and technological innovation. The lessons of the previous century illustrate that major breakthroughs in energy technologies are largely built on a deep foundation of basic research advances. Solar photovoltaic technology has its roots in Einstein's early twentieth-century paper on the photoelectric effect. The development of nuclear energy would have been impossible without the atomic science pioneered by Einstein and others. Even the electronics used to render today's internal combustion engine more efficient have their root in the transistor, whose development was critically dependent on concept of quantum mechanics. At the core of these advances is the ability to create new materials using

[a] Total is reduced by $37,532,000, $33,511,000 of which was transferred to the Small Business Innovation Research (SBIR) program, and $4,021,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

sophisticated synthetic and processing techniques, precisely define the atomic arrangements in matter, and control physical and chemical transformations.

The research disciplines that the BES program supports—condensed matter and materials physics, chemistry, geosciences, and aspects of physical biosciences—are those that discover new materials and design new chemical processes. These disciplines touch virtually every 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 serves as an agent of change in achieving the vision of a secure and sustainable energy future.

The BES program is one of the nation's largest sponsors of research in the natural sciences. In FY 2010, the program funded research in more than 170 academic institutions located in 50 states and in 14 DOE laboratories located in 12 states. Thus, approximately 40% of the BES program's research activities are sited at academic institutions. The BES program also supports world-class open-access scientific user facilities that provide outstanding capabilities for imaging; for characterizing materials of all kinds from metals, alloys, and ceramics to fragile biological samples; and for studying the chemical transformation of materials. These facilities are used to correlate the microscopic structure of materials with their macroscopic properties, which provides critical insights to their electronic, atomic, and molecular configurations, often at ultrasmall length and ultrafast time scales.

The energy systems of the future—whether they tap sunlight, store electricity, or make fuel from 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.

The 20^{th} century witnessed revolutionary advances in the physical sciences, bringing remarkable discoveries such as high-temperature superconductors, electron microscopy with atomic resolution, and carbon nanotubes that combine the strength of steel with the mass of a feather. Observational science is now giving birth to the science of control, where accumulated knowledge derived from observations is used to design, initiate, and direct the chemical and physical behavior of materials at atomic and nanoscale. BES-supported research stands at the dawn of an age in which materials can be built with atom-by-atom precision and computational models can predict the behavior of materials before they exist. These capabilities, unthinkable only a few decades ago, create unprecedented opportunities to revolutionize the future of sustainable energy applications and beyond, from information management to national security.

Subprograms

To accomplish its mission and address the scientific challenges outlined above, the BES program is organized into three subprograms: Materials Sciences and Engineering; Chemical Sciences, Geosciences, and Biosciences; and Scientific User Facilities.

The *Materials Sciences and Engineering* subprogram supports research that explores the origin of macroscopic material behaviors and their fundamental connections to atomic, molecular, and electronic structures. At the core of the subprogram is the quest for a paradigm shift for the deterministic design and discovery of new materials with novel structures, functions, and properties. To accomplish this goal, the portfolio stresses the need to probe, understand, and control the interactions of phonons, photons, electrons, and ions with matter to direct and control energy flow in materials systems over multiple time and length scales. Such understanding and control are critical to science-guided design of highly efficient energy conversion processes, such as new electromagnetic pathways for enhanced light emission in solid-state lighting and multi-functional nanoporous structures for optimum charge transport in batteries and fuel cells. This subprogram also seeks to conceptualize, calculate, and predict processes underlying physical transformations, tackling challenging real-world systems—for example, materials with many atomic constituents, with complex architectures, or that contain defects; systems that exhibit correlated emergent behavior; and systems that are far from equilibrium. Such understanding will be critical to developing predictive capability for complex systems behavior, such as in superconductivity and magnetism. The subprogram also supports the development and advancement of the experimental and computational tools and techniques that in turn enable the understanding of the behaviors of materials, especially their reactivity under the full range of extreme conditions and the ability to predict the structure and properties of formed phases. Finally, the subprogram exploits the interfaces between physical and biological sciences to explore bio-mimetic processes as new approaches to novel materials design.

The *Chemical Sciences, Geosciences, and Biosciences* subprogram supports research that explores fundamental aspects of chemical reactivity and energy transduction over an enormous range of scale and complexity. Phenomena are studied over spatial scales from the sub-nanometer, as defined by the structure of atoms and molecules, to kilometers, appropriate to the behavior of subsurface geological structures, and over time scales defined by the motions of electrons in atoms, attoseconds (10^{-18} seconds), to millennia over which geological change must be understood. At the heart of this research lies the quest to understand and control chemical reactions and the transformation of energy at the molecular scale in systems ranging from simple atoms and molecules, to active catalysts, to complex biochemical or geochemical substances. At the most fundamental level, the development and understanding of the quantum mechanical behavior of electrons, atoms, and molecules in the 20th century has now evolved into the ability to control and direct such behavior to achieve desired results, such as the optimal conversion of solar energy into electronic excitation in molecular chromophores or into the creation of multiple charge carriers in nanoscale semiconductors. This subprogram also seeks to extend this new era of control science to include the capability to tailor chemical transformations with atomic and molecular precision. Here, the goal is to achieve fully predictive assembly and manipulation of larger, more complex chemical systems, such as interfacial catalysis, at the same level of detail now known for simple molecular systems. Finally, this subprogram seeks ultimately to achieve a molecular level understanding and control of the emergent and highly non-equilibrium behavior of biological and geological systems through the application of state-of-the-art experimental and computational tools.

The *Scientific User Facilities* subprogram supports the operation of a geographically diverse suite of major facilities that provide researchers 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 of many disciplines from academia, national laboratories, and industry to utilize the facilities' unique capabilities and sophisticated instrumentation. These large-scale user facilities consist of a complementary set of intense x-ray sources, neutron scattering centers, electron beam characterization capabilities, and research centers for nanoscale science. These facilities probe materials in space, time, and energy with the appropriate resolutions that can interrogate the inner workings of matter—transport, reactivity, fields, excitations, and motion—to answer some of the most challenging grand science questions. 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. The subprogram recognizes that at the heart of scientific discovery lies advanced tools and instruments. The continual development and upgrade of the instrumental capabilities includes new x-ray and neutron experimental stations, improved core facilities, and new stand-alone instruments. The subprogram also manages a research portfolio in accelerator and detector development to explore technology options for developing the next generations of x-ray and neutron sources. Collectively, these user facilities and enabling tools produce a host of 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 offer critical scientific insights for the discovery and design of advanced materials and novel chemical processes with broad societal impacts, from energy applications to information and biomedical technologies.

Benefits

The BES program supports basic research that underpins a broad range of energy technologies. Research in materials sciences and engineering leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety of energy generation, conversion, transmission, storage, and use. For example, advances in superconductivity have been introduced commercially in a number of demonstration projects around the country. Improvements in alloy design for high temperature applications are used in commercial furnaces and in green technologies such as lead-free solder. Research in chemistry has led to advances such as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improved catalysts for the production of fuels and chemicals; and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. Research in geosciences results in advanced monitoring and measurement techniques for reservoir definition and an understanding of the fluid dynamics of complex fluids through porous and fractured subsurface rock. Research in the molecular and biochemical nature of photosynthesis aids the development of solar photo-energy conversion.

The BES program also plays a major role in enabling the nanoscale revolution. The importance of nanoscience to future energy technologies is clearly reflected by the fact that all of the elementary steps of energy conversion (e.g., charge transfer, molecular rearrangement, and chemical reactions) take place on the nanoscale. The development of new nanoscale materials, as well as the methods to characterize, manipulate, and assemble them, create an entirely new paradigm for developing new and revolutionary energy technologies.

Program Planning and Management

Inputs to program planning and prioritization include overall scientific opportunity, projected investment opportunity, DOE mission need, and Administration and Departmental priorities. Many long-range planning exercises for elements of the BES program are performed under the auspices of the Basic Energy Sciences Advisory Committee (BESAC). During the past few years, BESAC has provided advice on new directions in nanoscale science and complex systems; on the operation of the major scientific user facilities; on the need for new, next-generation facilities for x-ray, neutron, and electron-beam scattering; on performance measurement; on the quality of the BES program management and its consequent impacts on the program portfolio; on new directions in research relating to specific aspects of fundamental science such as catalysis, biomolecular materials, and computational modeling at the nanoscale; on the fundamental research challenges posed by the Department's energy missions; on a 20-year roadmap for BES facilities; and on theory and computation needs across the entire portfolio of BES research.

Of particular note is the 2003 BESAC report, *Basic Research Needs to Assure a Secure Energy Future*, which was the foundation for ten follow-on Basic Research Needs workshops supported by BES in the areas of the hydrogen economy, solar energy utilization, superconductivity, solid-state lighting, advanced nuclear energy systems, combustion of 21st century transportation fuels, electrical-energy storage, geosciences as it relates to the storage of energy wastes (the long-term storage of both nuclear waste and carbon dioxide), materials under extreme environments, and catalysis for energy applications. Together these workshops attracted over 1,500 participants from universities, industry, and DOE laboratories. BESAC was charged with summarizing the results of these ten workshops and relating this summary to the science themes identified in the 2007 BESAC Grand Challenges study. A report, entitled *New Science for a Secure and Sustainable Energy Future*, was released in December 2008. The report highlighted the magnitude of the challenges in the realm of energy and environment facing the U.S and the importance of fundamental science to finding transformational solutions.

As a follow up to the series of Basic Research Needs workshops, BESAC was charged to assess basic research opportunities that will have more immediate impact on energy applications, and specifically to address strengthening the linkages between the basic research and industry communities. The basic science needs of industry are often more narrowly focused on solving specific nearer-term roadblocks to progress in existing and emerging clean energy technologies. To better define these issues and identify specific barriers to progress, a wide cross-section of scientists and engineers from industry, universities, and national laboratories participated in a workshop to delineate the basic science Priority Research Directions most urgently needed to address the roadblocks and accelerate the innovation of clean energy technologies. A key conclusion of the report, entitled *Science for Energy Technology: Strengthening the Link between Basic Research and Industry*, is that in addition to the decadal challenges defined in the Basic Research Needs reports, specific research directions addressing industry roadblocks are ripe for further emphasis. Another key conclusion is that identifying and focusing on specific scientific challenges and translating the results to industry requires more direct feedback and communication and collaboration between industrial and BES-supported scientists. The report also recognized that the suite of BES scientific user facilities play a key role in advancing the science of clean energy technology.

Together these reports describe a continuum of research spanning the most fundamental questions of how nature works to the questions that address technological show-stoppers in the applied research programs supported by the DOE technology offices as well as by industry. Dealing with these issues requires breakthrough advances with new understanding, new materials, and new phenomena that will come from fundamental science. These reports will continue to inform the BES research agenda to bring frontier research to bear on addressing the Department's mission in science and energy.

Planning for the facilities of the BES program is also an ongoing activity. The BES program has a long tradition of planning, constructing, and operating facilities well. During the past ten years, the BES program has delivered nearly $2 billion of facilities and upgrades on schedule and within budget. Among others, this includes the Spallation Neutron Source, the complete reconstruction of the Stanford Synchrotron Radiation Lightsource, five Nanoscale Science Research Centers, the Linac Coherent Light Source, and numerous instrument fabrication projects. BESAC sponsored a workshop *Next-Generation Photon Sources for Grand Challenges in Science and Energy* to explore the scientific frontiers that could be tackled with next generation photon sources. The workshop identified new research opportunities in materials, chemistry, biology, medicine, environment, and physics for science and energy that can be addressed with diffraction, excitation, and imaging by photons. BES built on this foundation and conducted two follow-on workshops to assess the technical readiness of various approaches for 4^{th} generation light sources, including compact light sources, and the corresponding R&D needs in 2009 and 2010. It is expected that the output of these workshops will help set the course for photon science facilities for the next decade.

All research projects supported by BES undergo regular peer review and merit evaluation based on procedures set down in the Code of Federal Regulations, 10 CFR Part 605, for the extramural grant program and in an analogous process for the laboratory programs and scientific user facilities. The BES peer review process evaluates the following four criteria, in order of decreasing importance: scientific and/or technical merit of the project, appropriateness of the proposed method or approach, competency of the personnel and adequacy of proposed resources, and reasonableness and appropriateness of the proposed budget. The criteria for review may also include other appropriate factors established and announced by BES.

Facilities are reviewed using external, independent review committees operating according to the procedures established for peer review of BES laboratory programs and facilities. Important aspects of the reviews include assessments of the quality of research performed at the facility, the reliability and availability of the facility, user access policies and procedures, user satisfaction, facility staffing levels, R&D activities to advance the facility, management of the facility, and long-range goals of the facility. The outcomes of these reviews helped improve operations and develop new models of operation for all BES scientific user facilities.

Facilities that are in design or construction are reviewed according to procedures set down in DOE Order 413.3B "Program and Project Management for Capital Assets" and in the Office of Science "Independent Review Handbook." In general, once a project has entered the construction phase, it is reviewed with external, independent committees approximately biannually. These Office of Science construction project reviews enlist experts in the technical scope of the facility under construction and its costing, scheduling, and construction management.

BESAC also reviews the major elements of the BES program annually using Committees of Visitors (COVs). The first COV review of BES was conducted in 2002, and all elements of the BES program have been reviewed once every three years on a rotating schedule. COVs assess the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document proposal actions; and the quality of the resulting portfolio, specifically the breadth and depth of portfolio elements and the national and international standing of the elements. The latest COV was held on April 6–8, 2010, on the Scientific User Facilities subprogram, and the next COV will be in April 2011 on the Chemical Sciences, Geosciences, and Biosciences subprogram. All BES COV reports are available on the BES web site.

Information and reports for all of the above mentioned advisory and consultative activities are available on the BES website. Other studies are commissioned as needed using the National Academies' National Research Council and other independent groups.

Basic and Applied R&D Coordination

As is demonstrated by the depth and scope of the Basic Research Needs workshop series, the BES program is committed to R&D integration. These workshops and the follow-on solicitations seek to partner the BES program with its counterparts in the DOE technology offices and NNSA.

Many activities facilitate cooperation and coordination between BES and the applied research programs, including joint efforts in strategic planning, solicitation development, peer reviews, and program contractors meetings. For example, in hydrogen research, BES has actively engaged with the Offices of Energy Efficiency and Renewable Energy, Fossil Energy, and Nuclear Energy to coordinate activities such as budget submissions, solicitation topic selections and proposal reviews, posture plan development, and joint contractors meetings. BES participates in the DOE Hub Working Group, which meets regularly with representatives from the Office of Energy Efficiency and Renewable Energy and the Office of Nuclear Energy to provide integrated programmatic oversight and promote commonality across the three DOE Energy Innovation Hubs that were initiated in FY 2010—Fuels from Sunlight, Modeling and Simulation for Nuclear Reactors, and Energy Efficient Building Systems Design. BES also participates in interagency coordination activities, such as the Interagency Working Group on Hydrogen and Fuel Cells led by the White House Office of Science and Technology Policy; the Hydrogen Technical Advisory Committee (HTAC), a Federal Advisory Committee established by the Energy Policy Act of 2005 to advise the Secretary of Energy on issues related to hydrogen and fuel cell research, development, demonstration, and deployment; and the Hydrogen and Fuel Cell Interagency Task Force consisting of senior agency representatives across the Federal Government. BES also coordinates with the Office of Energy Efficiency and Renewable Energy and the Office of Electricity Delivery and Energy Reliability on electrical energy storage research for transportation and grid-level storage, respectively. BES has involved program managers in both offices in regular information exchange meetings and in developing a preliminary coordination plan in electrical energy storage. BES 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. Since FY 2007, BES has worked with the Office of Electricity Delivery and Energy Reliability to initiate SBIR awards in electrical energy storage for grid applications.

At the program manager level, there have been regular intra-departmental meetings for information exchange and coordination on solicitations, program reviews and project selections in research areas such as biofuels derived from biomass; solar energy utilization; hydrogen production, storage, and use; 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 technology offices and defense programs. DOE program managers have also established formal technical coordinating committees that meet on a regular basis to discuss R&D programs with wide applications for basic and applied programs. Additionally, technology offices staff participate in reviews of BES research, and BES staff participate in reviews of research funded by the technology offices and ARPA-E.

The Department's national laboratory system plays an important role in the ability of BES to effectively integrate research and development by providing opportunities to collocate activities at the laboratories. Co-funding and co-siting of research by BES and DOE technology programs at the same institutions, such as the DOE laboratories or universities, 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 of resources, expertise, and knowledge of research breakthroughs and program needs.

Budget Overview

In FY 2012, the BES program will support expanded efforts in basic research related to transformational clean energy technologies. These new directions derive from the series of "Basic Research Needs" workshop reports and the follow-on workshop reports by the Basic Energy Sciences Advisory Committee. As recognized in the series of workshop reports, clean energy technologies are in their infancy compared to traditional fossil fuel-based technologies, and they have many scientific and technological challenges to overcome in order to operate at their full potential. The reports have defined the decadal science challenges whose solutions will create comprehensive understanding and control of clean energy phenomena; they have also been instrumental in guiding the establishment of the 46 Energy Frontier Research Centers (EFRCs), which exemplify the pursuits of the broad-based science challenges for energy applications. Complementary to such broad-based research efforts are opportunities to focus more specifically on limitations of performance in existing clean energy technologies. The limitations can be overcome through targeted basic research efforts aimed at understanding the phenomena underlying performance limitations and contributing innovations based on scientific understanding that remove barriers to technological progress. The requested increases in FY 2012 for clean energy are primarily guided by the recent BESAC report *Science for Energy Technology: Strengthening the Link between Basic Research and Industry*, which stresses the importance of sustained efforts of testing new concepts, identifying roadblocks, and pursuing scientific and technical solutions to accelerate transformative advances for targeted impact on cost, reliability, and performance—in a way similar to the development of information technology, in which generations of innovative advances in silicon-based devices yielded Moore's Law and game-changing breakthroughs.

In order to achieve the President's challenge of generating 80% of America's electricity from clean energy sources by 2035, the FY 2012 budget request includes funding for integrated R&D activities across the Department's technology programs and the Office of Science. The DOE technology programs will manage applied research, development, and deployment efforts to gain and apply knowledge to achieve identified near-to-mid-term goals. The basic research work within BES is selected in clean energy areas where an understanding of the fundamental phenomena is necessary to achieve game-changing discoveries for mid-to-longer-term technological innovation.

Our science based approach for creating transformational improvements in clean energy technologies consists of increasing basic research on a set of interrelated energy issues: non-carbon sources, carbon capture and sequestration, transportation and fuel switching, transmission and energy storage, and efficiency. These basic research efforts will be conducted in coordination with the complementary R&D activities in the following DOE programs: Office of Energy Efficiency and Renewable Energy, Office of Nuclear Energy, Office of Electricity Delivery and Energy Reliability, Office of Fossil Energy, and the National Nuclear Security Administration. The FY 2012 budget contains increases to BES research in the following areas, as detailed in this budget submission and summarized below.

- ***Non-carbon Sources:***
  - *Solar Electricity from Photovoltaics – Fundamental Science of Interfaces and Degradation* (+$8,000,000). Many critical issues that surround the performance, cost, and reliability of solar photovoltaics (PV) are associated with interfaces: p-n junctions, device contacts, light and carrier reflectors, tunnel junctions, passivation and buffer layers, grain boundaries in polycrystalline semiconductors, and packaging materials. Technology development in PV interfaces has been largely empirical in nature. Greatly improved characterization tools provide a unique opportunity to probe PV interfaces in situ and enable new research opportunities for improved fundamental understanding of their behavior. Fundamental research is also required to improve the scientific basis for understanding the mechanisms by which PV modules are degraded. Particular emphasis will be place on degradation and the long-term effects of impurity diffusion processes.
  - *Advanced Nuclear Energy – Basic Actinide Chemistry Research for Fuel Cycles* (+$8,000,000). New research is proposed to significantly advance fundamental understanding of actinide molecules and their chemistry, with broad impacts for nuclear reactor fuels, waste forms, and separations techniques. Proposed research includes development of more sophisticated theoretical and experimental tools for the understanding of the structure and bonding of actinide species with an emphasis on separation chemistry addressing the multiplicity of chemical forms and oxidation states for actinides in fuels, solutions, and waste forms. New characterization and computational tools can play particularly important roles in addressing these challenges. These tools offer the opportunity to transform and accelerate the fundamental chemistry that underpins technology development for advanced nuclear energy systems.
  - *Materials under Extreme Environments* (+$15,000,000). The physical processes that occur in materials under extreme nuclear technology environments span time scales from femtoseconds to decades and proceed over length scales ranging from atomistic to meters. These processes must be understood for real, engineered materials including complex alloys, materials with defects and impurities, materials with complex microstructures, and ranging from actinides to metals to

composites. Research in this area will focus on understanding, modeling, and designing radiation-resistant materials that maintain all of the required physical properties after prolonged exposure. Materials discovery will include nanoscale design of new materials, including self-healing potential to limit the impact of defects generated in the extreme exposures in reactors. In situ experiments will be closely integrated with theoretical/computational efforts to develop a fundamental understanding of degradation mechanisms and kinetics over multiple length and time scales.

- ***Carbon Capture and Sequestration***

  - *Carbon Capture – Novel Molecular Design* (+$8,000,000). The objective of research in predictive modeling of carbon capture will be to gain significant advances in quantum chemical structure determination, intermolecular potentials, and molecular dynamics algorithms on CO_2 interactions with complex materials and minerals for efficient and cost-effect carbon capture and sequestration. Specific emphasis will be placed on the discovery and design of new materials that incorporate complex structures and functionalities tuned for optimum separation properties; understanding and controlling the atomic and molecular level interactions of the targeted species with the separation media; and tailored capture/release processes with alternative driving forces, taking advantage of a new generation of nanoscale materials.

  - *Carbon Sequestration – Multiscale Dynamics of Flow and Plume Migration* (+$8,000,000). Permanent storage of captured CO_2 through injection into deep underground geologic formations has been proposed as the most practical approach to store captured industrial scale carbon emissions. Significant scientific and technical challenges must be overcome to scale up sequestration methodologies reliably and safely to effective operational levels. A critical current limitation is the inaccuracy of models that seek to describe the migration of CO_2 in the subsurface, which require characterization over vast spatial scales under multiple geological sites. New research to improve field-scale models will emphasize the improved understanding of geologic processes and rates relevant to subsurface sequestration sites, including better understanding of reservoir-scale geochemistry; reactive flow and transport processes and rates; higher resolution geophysical measurement techniques; and more accurate simulation approaches for linking geochemical processes and geophysical responses across multiple spatial scales.

- ***Transportation and Fuel Switching***

  - *Energy Systems Simulation – Internal Combustion Engines (ESS-ICE).* (+$15,000,000). Research activities in this area will focus on predictive modeling of combustion in an evolving fuel environment, thus building on the science base for the development of simulation tools for advanced internal combustion engine design. Basic research in ESS-ICE will emphasize the development of two complementary, experimentally validated sets of codes: one for stochastic, in-cylinder engine processes and one that can reliably predict the temporal and spatial behavior of liquid fuel injection. These two areas have been identified as high priorities by the U.S. engine industry and lie on the critical path toward the complete transition from hardware-intensive, experience-based engine design to simulation-intensive, science-based design. This research will be particularly important for the economic design of high-efficiency, clean engines burning a variety of fuels, including biofuels.

  - *Batteries and Energy Storage Hub* (+$34,020,000). Initiated in FY 2010, the Energy Innovation Hubs are designed as a multidisciplinary effort that addresses critical science and technology issues in an integrated manner. A Hub focuses teams of researchers in separate but collaborative research areas on overcoming scientific barriers to development of a complete energy system with potential for implementation into a transformative energy technology. In FY 2012, BES will support the continuation of the Fuels from Sunlight Hub and will initiate a new Hub on Batteries and Energy Storage. The Hub is aimed at developing electrochemical energy storage systems that safely approach theoretical energy and power densities with very high cycle life. These are systemic challenges, and the Hub will result in new materials, systems, and knowledge critical to developing a robust industrial base leading the next generation of energy storage technology, including that for transportation (e.g., batteries for plug-in hybrid and all electric vehicles). Knowledge gained in the Batteries and Energy Storage Hub could also contribute to grid-level or stationary energy storage, as noted in the *Transmission and Energy Storage* section below.

- ***Transmission and Energy Storage***
  - *Electric Power Grid – Enabling Materials Sciences* (+$4,000,000). The research activities will include development of advanced materials for normal and superconducting power transmission lines and electronic components and devices to control and link complex high voltage direct current networks. Additional research will be initiated for developing nano-materials and novel deposition processes to achieve improved properties for cost-effective, high-capability electric power distribution.
  - *Power Electronics* (+$3,500,000). The Nation's future electric systems will need cost-effective, reliable, high-capability power electronic components and devices to control and link complex high voltage networks, measure and control flow, and reduce energy losses in long-distance transmission. Power electronics are particularly important in interfacing new, renewable electrical power sources to the existing grid distribution systems. In particular, wide bandgap materials that permit single devices to control current flows at higher voltages with high efficiency could make power electronics affordable and enable efficient tools to control and manage electricity. Focus areas in basic materials research will be initiated in low defect density, wide bandgap semiconductors; magnetic materials for high frequency inductors, including non-rare earth based materials; and next generation dielectrics.
  - *Batteries and Energy Storage Hub* (same Hub as above). The Hub is aimed at developing electrochemical energy storage systems that safely approach theoretical energy and power densities with very high cycle life. These are systemic challenges, and the Hub will result in new materials, systems, and knowledge critical to developing a robust industrial base leading the next generation of energy storage technology, including that for grid and other stationary energy storage applications. Knowledge gained in this Hub could also contribute to electrical energy storage for vehicle applications as noted in the *Transportation and Fuel Switching* section above.
- ***Efficiency***
  - *Advanced Solid-state Lighting – Novel Light Emitting Diodes* (+$8,000,000). Solid-state lighting is the direct conversion of electricity to visible white light using inorganic semiconductor materials, organic materials or hybrid combinations. By avoiding the indirect processes characteristic of traditional incandescent and fluorescent lighting that generate heat, solid state lighting can greatly improve the conversion efficiency. There is no known fundamental physical barrier to achieving ultrahigh efficiencies for visible white light. The proposed research will focus on the design of new materials to control the flow of electrons, including research on understanding light-emitting organic and inorganic (and hybrid) materials and nanostructures,

control of the materials and nanostructure properties, research on interfacial issues between semiconductors, metals and organic materials and the development of a fundamental understanding of the processes that mediate the competing conversion of electrons to light and heat.

- *Energy Efficiency – Enabling Materials Sciences* (+$4,000,000). Buildings are responsible for nearly 40 percent of US primary energy use and 70 percent of electricity demand. Significant opportunities exist to improve building efficiencies. These include research on the development of novel building materials using nano-materials, novel deposition processes to achieve improved properties. Research on reducing electrical energy needs will include materials with optical and thermal properties that respond passively or controllably to external conditions for reducing heating and cooling demands, windows with controllable optical properties, and new lighting devices.

In addition to the aforementioned basic research opportunities in clean energy technologies, BES will initiate a new program in methane hydrates, which are naturally occurring combinations of methane and water that form at low temperatures and high pressures.

- *Methane Hydrates* (+$10,000,000). The emphasis of this activity will be on expanding the research base to characterize the formation mechanisms of gas hydrates and to understand and ultimately predict the environmental stability of hydrates at the systems level. This activity supports theory, multi-scale modeling and simulation, and experimental research in areas such as: the intermolecular forces that govern the structure and properties of methane hydrates; multi-phase behavior of hydrate-sediment systems; and studies of methane hydrates in the natural environment.

Increases in research funding also are requested as part of two inter-agency coordinated initiatives – *Computational Materials and Chemistry by Design* and *Nanoelectronics*. Both of these initiatives will provide the broad knowledge foundations critical for clean energy and other advanced technologies.

- *Computational Materials and Chemistry by Design* (+$40,000,000). As described in the Office of Science Workshop on *Computational Materials Science and Chemistry for Innovation*, over the past two decades, the United States has developed and deployed the world's most powerful collection of tools for the synthesis, processing, characterization, and simulation and modeling of materials and chemical systems at the nanoscale, from dimensions of a few atoms to a few hundred atoms across. We are at the threshold of a new era where control of these processes will transform our ability to understand and design new materials and chemistries. In turn, this predictive capability will transform technological innovation by accelerating the development and deployment of new materials and processes in products and manufacturing. Harnessing the potential of computational science and engineering for the discovery and development of materials and chemical processes is likely to have significant impact on our future industrial competitiveness.

  Computational Materials and Chemistry by Design is a multi-agency effort. DOE will lead in the development of new software tools and data standards that catalyze a fully integrated approach from material discovery to applications. New research efforts will be initiated to design materials with targeted properties and advanced chemical processes with high efficiencies through theory, computation, and modeling, as validated by precise experimental characterization. The era of modern technology requires understanding the complexity of materials and chemical assemblies well beyond that of the past centuries and beyond the current capabilities offered by experimental approaches alone. The need to accelerate the innovation cycle by taking advantage of the significant growth in modeling and high performance computing, underscores the critical importance of this request. Coupled with the goal of materials and chemistry by design is another critical goal for accelerating advances in energy technologies—the ability to accurately predict changes in materials and their properties associated with their use in a specific application, incorporating the effects of fabrication of materials into system components, influence of the environment in which materials are used, and extend the lifetime of their usage. Discovery of new materials and chemical assemblies with totally new properties and accurate lifetime predictions are crucial to generation, use, and advances in energy technologies, as well as to virtually all industries that use materials, both structural and functional, in their infrastructure and products—crossing the spectrum of transportation, electronics, buildings, chemicals and pharmaceuticals, health, and consumer products. This request envisions assembling integrated teams focused on key scientific knowledge gaps to develop new theoretical models, including their realization in reusable and broadly-disseminated software. Special attention will be paid to the development of powerful abstraction methods to enable the distillation of new physical laws bridging multiple length and temporal scales. The ultimate goal is to provide the Nation with a science-based computational tool set to rationally predict and design materials and chemical processes to gain a global competitive edge in scientific discovery and innovation.

- *Nanoelectronics* (+$10,000,000). *Nanoelectronics* is one of the signature activities of the National Nanotechnology Initiative coordinated by the National Science and Technology Council's subcommittee on Nanoscale Science, Engineering and Technology. BES research will focus on overcoming fundamental physics limitations of semiconductor processing and memory devices in two thrust areas: exploring new or alternative "state variables" for computing, e.g., other alternatives to charge transfer exploited by conventional transistors such as spintronics, and exploiting nanoscale processes and phenomena for quantum information science. These activities require the development of novel fabrication, processing, and instrumentation techniques, and new theoretical and modeling tools. This research will be informed by and coordinated with applied research in industries to identify the next generation of logic device beyond mainstream silicon-based Complementary Metal-Oxide Semiconductor (Si/CMOS) technology.

In FY 2012, there also are a number of significant program milestones and increases in the areas of construction and Major Items of Equipment (MIE) projects. These efforts aim at ensuring that the BES-supported scientific tools and instrumentation stay at the technological forefront and continue to charter new paths for scientific pursuits.

- The Linac Coherent Light Source (LCLS) at SLAC National Accelerator Laboratory completed construction in FY 2010 within budget, ahead of schedule, and with capabilities meeting—and in some aspects exceeding—the designed technical specifications. The LCLS is the world's first hard X-ray free electron laser (FEL) and produces ultrafast pulses of X-rays millions of times brighter than even the most powerful synchrotron light sources. It provides scientists with a unique tool for studying the arrangement and motion of atoms and electrons in metals, semiconductors, ceramics, polymers, catalysts, plastics, and biological molecules with the potential to significantly impact advanced energy research and other fields. Capitalizing on LCLS's success, a new MIE project for LCLS expansion (LCLS-II) is initiated in FY 2012 (+$30,000,000) to extend the x-ray spectral range at the LCLS and expand the experimentation capacity to accommodate the fast growing number of users. The LCLS-II MIE will enable the U.S. maintain leadership in FEL science and keep pace with facilities under construction elsewhere in the world.
- Support is continued for construction and Other Project Costs (FY 2012 funding of $151,400,000 and $7,700,000, respectively) for the National Synchrotron Light Source-II (NSLS-II)—built as a

replacement for NSLS—to enable the study of material properties and functions, particularly materials at the nanoscale, at a level of detail and precision never before possible. The NSLS-II project provides funding for six experimental beamlines, which is only a fraction of the total capacity. Although some of the equipment can be reused from the NSLS instruments, in order to make full use of the scientific capabilities of the new machine, new state of the art instruments need to be designed, constructed, and commissioned. A new MIE, the NSLS-II Experimental Tools (NEXT), is requested in FY 2012 (+$12,000,000) to initiate the fabrication of approximately five to six additional instruments.

- The Advanced Photon Source (APS) at Argonne National Laboratory is one of the most productive light sources in the US, serving the largest number of users per year. It is a leading machine for physical sciences, having pioneered instruments and techniques in high-pressure science, x-ray photon correlation spectroscopy and inelastic x-ray scattering. Commissioned in 1996, many of the APS components—both accelerator and instruments—were designed in the early 1990s and are not optimized for today's needs. The Advanced Photon Source Upgrade (APS-U) project is to add new x-ray capabilities and increase the number of experiments that the APS can accommodate. The new APS-U MIE project (+$20,000,000) would provide significant technical enhancements in the source's entire hard x-ray range, particularly above 20 keV, both in source brightness and intensity. Such capabilities are critically needed to examine real materials, in real time, in real environments, especially in extreme conditions encountered in advanced energy applications.
- Transmission Electron Aberration-Corrected Microscope II (TEAM II) will produce a new microscope that incorporates many of the component innovations in the initial TEAM instrument that was completed and made available to users in FY 2009. The TEAM instrument was designed with an emphasis on extending spatial resolution to new limits by fully integrating the correction of lens aberrations. The new TEAM-II MIE project (+$18,000,000) will be optimized differently to provide complementary functionality following the recommendations of a BES workshop on *Future Science Needs and Opportunities for Electron Scattering: Next-Generation Instrumentation and Beyond*. Approaches being considered include: dramatic expansion of the range of in-situ conditions (temperatures, pressures, electromagnetic fields, fluid environments) under which materials can be studied, challenges of examining soft (such as polymeric and biological or biomimetic) materials and hard/soft interfaces, and improved temporal resolution for observation of dynamic processes. These capabilities will be especially critical for exploring the unit processes and phenomena involved in clean energy technologies.
- Funding (+$47,000,000) is requested to upgrade, enhance, and procure beamlines and instruments at light sources, neutron sources, and nanoscale science research centers. The funding will be competed amongst BES scientific user facilities with the goal of significantly advancing the synthesis and characterization capabilities for clean energy technologies. This may include capabilities to collect data at high or low extremes of temperature, at high pressure, in the presence of gasses or liquid, and/or at operating voltages in a working device; to engage in materials synthesis, including high throughput combinatorial synthesis for nanoscale materials discovery and design; and for the facilities to handle full scale devices, ranging from a solar panel to a battery that powers an electric vehicle. This supports one of the key priority research directions of the BESAC Science for Energy Technology report, in which "at scale" experiments on commercial materials/devices in real-world environments is highlighted as a key enabling cross-cutting capability.

Annual Performance Results and Targets

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget.

Materials Sciences and Engineering

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Materials Sciences and Engineering		
Materials Sciences and Engineering Research	353,423	447,583
SBIR/STTR	0	12,369
Total, Materials Sciences and Engineering	353,423	459,952

Description

This subprogram supports fundamental experimental and theoretical research to provide the knowledge base for the discovery and design of new materials with novel structures, functions, and properties.

Condensed matter and materials physics research includes activities in experimental condensed matter physics, theoretical condensed matter physics, materials behavior and radiation effects, and physical behavior of materials. The research goals are supported to understand, design, and control materials properties and function. These are achieved through studies of the relationships of materials structures to their electrical, optical, magnetic, surface reactivity, and mechanical properties and investigations of material response to external forces such as stress, chemical and electrochemical environments, radiation, and the proximity of surfaces and interfaces.

Scattering and instrumentation sciences research includes activities in neutron and x-ray scattering and electron and scanning microscopies. Research is supported on the fundamental interactions of photons, neutrons, and electrons with matter to understand the atomic, electronic, and magnetic structures and excitations of materials and the relationship of these structures and excitations to materials properties and behavior.

Materials discovery, design, and synthesis research includes activities in synthesis and processing science, materials chemistry, and biomolecular materials. Research is supported in the discovery and design of novel materials and the development of innovative materials synthesis and processing methods. This research is guided by applications of concepts learned from the interface among physics, chemistry, and biology and from nanoscale understanding of synthesis and structures.

Selected FY 2010 Accomplishments

- *Smallest Superconductor Discovered.* Scientists have found the world's smallest superconductor, a chain of four pairs of organic molecules less than one nanometer wide and only 3.5 nanometers long. In normal metals, the resistance of a wire increases as the size of the wire decreases, making it very difficult to make nanoscale metal wires because the increased resistance causes the wires to heat up and eventually melt. However, superconducting materials have no electrical resistance and can carry large electrical currents without power dissipation or heat generation. In this research, the organic superconductor $(BETS)_2GaCl_4$ (where BETS is *bis*(ethylenedithio)tetraselenafulvalene) continued to be superconducting as the molecular chains decreased from 50 nm to the length of only four pairs of molecules. This finding provides the first evidence of successful fabrication of nanoscale superconducting wires, opening up a new regime for superconductivity research that could potentially impact nanoscale electronic devices and energy applications.

- *Fractional Quantum Hall Effect Discovered in Graphene.* For the first time the fractional quantum Hall effect (FQHE) was observed in graphene, a form of carbon that has attracted attention recently because of its unusual electronic properties and potential for use in nano-electronics. Graphite is a layered material made up of 1 atom thick graphene sheets. In the FQHE, electrons interact strongly and behave collectively like new particles with a fraction of the electron's charge. Previously, the FQHE was only observed in ultrapure semiconductors at temperatures near absolute zero. These experiments confirmed the FQHE in graphene up to 20 degrees above absolute zero, indicating that electron-electron interactions are much stronger in graphene than in semiconductors. These results open the door for investigations of correlated electron behavior in graphene and have implications for future applications in electronics and quantum computing.
- *Advance in Semiconductor Nanocrystal Conductivity*: Cadmium-selenide nanorods hold promise as the active material in solar energy conversion devices. Attempts to characterize the electronic transport properties of the nanorods are extremely complicated since the addition of a metal contact alters the electronic structure of the nanorod at the metal-nanorod interface. A new synthesis technique has shown a dramatic improvement in the quality of the interface as observed by a 100,000 fold increase in the electrical conductivity of individual nanorods. Solution phase chemical deposition was used to grow gold tips on the ends of cadmium-selenide nanorods. Detailed measurements revealed that the conductivity increase is due to a 75 percent reduction of the barrier to electrical conduction. This result is attributed to maintaining an unaltered electronic structure in the semiconductor at the interface with the gold tips. These findings demonstrate the critical importance of innovative fabrication methods for the next generation of nano-sized solar photovoltaic, electronic, and optoelectronic devices.
- *Computational Design, Synthesis, and Characterization of Energy Relevant Materials.* Titanium dioxide (TiO_2) is a promising material for the conversion of sunlight into electricity. It is readily available, inexpensive and non-toxic. However, its use in photovoltaics is hampered by its relatively low absorption of visible light. Recent first principles calculations suggested that doping TiO_2 with a combination of chromium and nitrogen could vastly increase its absorption of solar radiation. The effect of the dopant is to reduce the bandgap and shift strong absorption in TiO_2 from ultraviolet to visible spectra. The calculations also predicted that the doped material was thermodynamically stable and could be synthesized. The theoretical predictions were confirmed by synthesis of doped nanometer-sized TiO_2 particles followed by characterization to confirm the properties and structure. The theoretical prediction of a material followed by the subsequent synthesis and characterization provides a rapid path to the discovery of new energy relevant materials.
- *First Identification of Individual Light Atoms by Electron Microscopy***.** For the first time, individual atoms of boron, carbon, nitrogen and oxygen have been resolved, identified, and located in materials made up of multiple elements. These light elements (with low Z, atomic number) are important components in materials for energy technologies including batteries and organic solar cells. The first atom-by-atom analysis of these light elements was made possible by an aberration-corrected scanning transmission electron microscope. The technique was used to examine a monolayer of boron nitride, revealing individual atomic substitutions involving carbon and oxygen impurity atoms. Careful analysis enabled construction of a detailed map of the atomic structure, with all the atoms of the four species resolved and identified. The new level of sensitivity is made possible by Z-contrast imaging at low operating voltages that distinguishes atoms of different Z values by their different scattering power.

- *Noble Element Xenon becomes Ignoble under Pressure.* Research showing the high pressure reactivity of otherwise inert xenon gas revolutionizes the understanding of xenon chemistry while opening up potential routes to synthesizing a new class of hydrogen storage materials. A novel compound has been discovered—$Xe(H_2)_7$—with the highest number of hydrogen molecules per molecular unit known to date. It forms at pressures of ~40,000 atmospheres and surprisingly remains stable to much higher pressures. High resolution structure of this compound reveals that the xenon atoms coalesce into pairs that are surrounded by hydrogen molecules. These experimental data show the first evidence of the weak forces that 'glue' these two elements together to form a solid—results that have attracted the attention of theorists around the world who are trying to determine the mechanisms for bonding in these novel compounds formed at high pressure.
- *New Mechanism for Design of Materials Resistant to Radiation Damage.* A new mechanism has been discovered that holds promise for reducing the damage experienced by materials in nuclear reactors by enhancing the "healing" of defects created by the exposure to energetic neutrons. Using a combination of modeling tools, the Energy Frontier Research Center for Materials under Irradiation and Mechanical Extremes examined the role of grain boundaries on damage production and defect evolution. Molecular dynamics calculations showed that the boundaries have a complex effect on damage production by reducing the number of defects remaining after the collision cascade. By examining the damaged structures at longer time scales with temperature-accelerated dynamics calculations, it was found that radiation-induced interstitial clusters of several atoms can emit from the boundary and annihilate nearby vacancies. This can take place over many atomic distances, and occurs much faster than alternative recombination mechanisms. This result may explain the increased radiation damage resistance found in nanostructured materials, which have a large number of grain boundaries, and could be used to design improved materials for reactor applications.
- *Making Silicon Solar Cells More Efficient and Less Expensive.* The Energy Frontier Research Center for Light-Material Interactions in Energy Conversion has demonstrated for the first time that the conventional light-trapping limit for solar absorbing materials can be surpassed. They have created a new type of flexible solar cell that enhances the absorption of sunlight and efficiently converts its photons into electrons using arrays of long, thin silicon wires embedded in a polymer substrate. The new silicon wire arrays are able to absorb about 85% of the photons from incident sunlight and convert between 90 and 100 percent of these into electrons. The silicon wires measure between 30 and 100 microns in length and only 1 micron in diameter. Just 2 percent of the light-capturing elements are made up of silicon wire arrays and remaining 98% is polymer, making these solar cells less expensive and easier to produce than current solar cells, potentially via a roll-to-roll manufacturing process.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Materials Sciences and Engineering Research	**353,423**	**447,583**
▪ **Experimental Condensed Matter Physics**	**46,621**	**58,621**

This activity supports experimental condensed matter physics emphasizing the relationship between the electronic structure and the properties of complex materials, often at the nanoscale. The focus is on systems whose behavior derives from strong correlation effects of electrons as manifested in superconducting, semi-conducting, magnetic, thermoelectric, and optical properties. Also supported is the development of new techniques and instruments for characterizing the electronic states and properties of materials under extreme conditions, such as in ultra low temperatures (millikelvin), in ultra high magnetic fields (100 Tesla), and at ultrafast time scales (femtosecond). Capital equipment is provided for scanning tunneling microscopes, electron detectors, superconducting magnets, and physical property measurement instruments.

Improving the understanding of the electronic behavior of materials on the atomistic scale is relevant to the DOE mission, as these structures offer enhanced properties and could lead to dramatic improvements in technologies for energy generation, conversion, storage, delivery, and use. Specifically, research efforts in understanding the fundamental mechanisms of superconductivity, the elementary energy conversion steps in photovoltaics, and the energetics of hydrogen storage provide the major scientific underpinnings for the respective energy technologies. This activity also supports basic research in semiconductor and spin-based electronics of interest for the next generation information technology and electronics industries.

In FY 2012, research will continue in complex and emergent behavior. The research activities will emphasize investigations of emergent behaviors that arise from the collective, cooperative behavior of individual components of a system such as atoms or electrons that lead to physical phenomena as diverse as phase transitions, high temperature superconductivity, colossal magnetoresistance, random field magnets, and spin liquids and glasses. New research will be initiated on nanomaterials and the influence of defects and interfaces on electron transport. Research would develop mechanistic understanding to push materials performance into new regimes, with potential to significantly reduce cost and enhance lifetimes. For photovoltaics, research will focus on quantitative understanding of phenomena including in situ assessments of the effects of dopants and grain boundaries on the materials' functionality (simultaneous electronic, optical, thermal, and mechanical behavior). Additional research will be initiated to improve the wavelength conversion for solid-state lighting, with emphasis on understanding the tailoring of excitation to desired wavelengths and enhanced quantum efficiencies, while extending high temperature performance and operation lifetimes. For the grid, opportunities lie in developing the next generation of superconductors by understanding votex pinning mechanisms and thermal fluctuations in a variety of promising superconducting materials, including multiband superconductors. Research will be initiated on understanding conductivity in new classes of nanomaterials and composites, considering the implications of coupling among electronic, thermal, and mechanical properties (e.g., sagging during use).

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **Theoretical Condensed Matter Physics**	**29,748**	**47,248**

This activity supports theoretical condensed matter physics with emphasis on the theory, modeling, and simulation of electronic correlations. A major thrust is nanoscale science, where links between the electronic, optical, mechanical, and magnetic properties of nanostructures and their size, shape, topology, and composition are poorly understood. Other major research areas include strongly correlated electron systems, quantum transport, superconductivity, magnetism, and optics. Development of theory targeted at aiding experimental technique design and interpretation of experimental results is also emphasized. This activity supports the Computational Materials and Chemical Sciences Network, which forms collaborating teams from diverse disciplines to address the increasing complexity of many current research issues. The activity also supports large-scale computation to perform complex calculations dictated by fundamental theory or to perform complex system simulations. Capital equipment funding will be provided for items such as computer workstations and clusters.

This activity provides the fundamental knowledge required to predict the reliability and lifetime of materials for current and future energy use and conversion technologies. Specific examples include inverse design of compound semiconductors for unprecedented solar photovoltaic conversion efficiency, solid-state approaches to improving capacity and kinetics of hydrogen storage, and ion transport mechanisms for fuel cell applications.

In FY 2012, research activities will continue to focus on enhancing the understanding of the nature and origin of highly correlated states in strongly interacting systems that have spin, charge, lattice, and orbital degrees of freedom and that are often intrinsically inhomogeneous on nanometer length scales. Research will include both theoretical and computational approaches capable of interrogating systems to gain direct insight on the mechanisms that lead to cooperative behavior. As part of *Computational Materials and Chemistry by Design*, this activity includes a significant funding increase for new research efforts to design and discover new materials with targeted properties through theory, computation, and modeling software, as validated by precise experimental characterization. Emphasis will be on the development of theory and software treating multiple length and time scales to understand dynamics, charge transport, and other properties in order to design new highly correlated materials, light-weight structural materials, metamaterials, and other advanced materials for energy applications. Simulating dynamical processes is central to modeling a wide variety of phenomena relating to materials synthesis, nanoscale, and properties in extreme environments of temperature, pressure, or radiation. Development and validation of ab initio methods and software are needed for the calculation of electronic structure, transport, phase diagrams, and evolution of structure and properties during materials use and eventual failure. Integration of correlated electronic-structure methods with quantum transport models would allow research to closely couple with electronics, materials fabrication, and energy industries.

▪ **Mechanical Behavior and Radiation Effects**	**17,487**	**32,487**

This activity supports basic research to understand defects in materials and their effects on the properties of strength, structure, deformation, and failure. Defect formation, growth, migration, and propagation are examined by coordinated experimental and modeling efforts over a wide range of spatial and temporal scales. Topics include deformation of ultra-fine scale materials, radiation-resistant material fundamentals, and intelligent microstructural design for increased strength, formability, and fracture resistance in energy relevant materials. The goals are to develop predictive models for the design of materials having superior mechanical properties and radiation resistance. Capital equipment funding is provided for microstructural analysis, nanoscale mechanical property measurement tools, and ion-beam processing instrumentation.

The ability to predict materials performance and reliability and to address service life extension issues is important to the DOE mission areas of robust energy storage systems; fossil, fusion, and nuclear energy conversion; radioactive waste storage; environmental cleanup; and defense. Among the key materials performance goals for these technologies are good load-bearing capacity, failure and fatigue resistance, fracture toughness and impact resistance, high-temperature strength and dimensional stability, ductility and deformability, and radiation tolerance. Since materials from large-scale nuclear reactor components to nanoscale electronic switches undergo mechanical stress and may be subjected to ionizing radiation, this activity provides the fundamental scientific underpinning to enable the advancement of high-efficiency and safe energy generation, use, and storage as well as transportation systems.

In FY 2012, core research activities will continue to focus on understanding defects in materials and their effects on the properties of strength, structure, deformation, and failure, including ultra-fine scale materials, fundamental radiation effects, and effects of interfaces. An increase in funding is requested to significantly expand research on the properties of materials under extreme environments such as the exposure to an energetic flux, chemical reactive stimulants, high temperature and pressure. The primary emphasis will be on discovering novel phenomena and materials for improved performance with superior functionality and to establish unified models to predict the mechanical and degradation behavior of solids over multiple length and time scales. Additional research will be initiated on understanding the complex interactions of radiation-induced defects with microstructure, and their effects on the functionalities of materials under extreme conditions, emphasizing those that will exist in future generation nuclear reactor environments. The research will focus on fundamental defect interactions including the effects of helium, atomistic modeling, and designing radiation-resistant materials. Materials discovery will include nanoscale design of new materials, including materials with self-healing potential to limit the impact of defects generated by extreme exposures in reactors. In situ experiments and associated atomistic modeling will develop a fundamental understanding of kinetics of the evolution of damage microstructures. This research will be coordinated among the Office of Science, Office of Nuclear Energy, and the National Nuclear Security Administration.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **Physical Behavior of Materials**	**28,533**	**46,033**

This activity supports basic research on the behavior of materials in response to external stimuli, such as temperature, electromagnetic fields, chemical environments, and the proximity effects of surfaces and interfaces. Emphasis is on the relationships between performance (such as electrical, magnetic, optical, electrochemical, and thermal performance) and the microstructure and defects in the material. Included within the activity are research to establish the relationship of crystal defects to semiconducting, superconducting, and magnetic properties; phase equilibria and kinetics of reactions in materials in hostile environments; and diffusion and transport phenomena. Basic

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

research is also supported to develop new instrumentation, including in situ experimental tools, and to probe the physical behavior in real environments encountered in energy applications. Capital equipment funding is provided for items such as physical property measurement tools that include spectroscopic and analytical instruments for chemical and electrochemical analysis.

The research supported by this activity is necessary for improving materials reliability in chemical, electrical, and electrochemical applications and for improving the ability to generate and store energy in materials. Materials in energy-relevant environments are increasingly being exposed to extreme temperatures, strong magnetic fields, and hostile chemical conditions. A detailed understanding of how materials behavior is linked to the surroundings and treatment history is critical to the understanding of corrosion, photovoltaics, fast-ion conducting electrolytes for batteries and fuel cells, novel magnetic materials for low magnetic loss power generation, magnetocaloric materials for high-efficiency refrigeration, and new materials for high-temperature gasification.

In FY 2012, this activity will support research on the fundamental science of photon-matter interactions, which is likely to play a significant role in the development of metamaterials and nano-plasmonics—materials that are expected to be extremely important for the development of technologies that enable low cost power conversion. The research will also include the search for photoconversion materials, such as polycrystalline, nanocrystalline, and organic materials to replace expensive single crystals; innovative design of interpenetrating photoconversion materials networks to improve charge separation and collection efficiency; and the development of novel processes to obtain extremely high photo-conversion efficiencies. Funding is requested for new research on power electronics, focused on developing an understanding of the influence of defects on the properties of wide bandgap semiconductors and discovery of new magnetic materials and new, high-temperature, high-breakdown-voltage dielectric materials. Additional funding is requested to support research for the *Nanoelectronics* initiative that will focus on overcoming fundamental physics limitations to develop novel innovative concepts for nanoelectronics, including investigations of novel interconnect approaches, integration of optical and electronic materials, and novel materials for quantum information systems. In addition, new research activities will support research on degradation mechanisms and the influence of impurity diffusion on the lifetime of photovoltaics. Research will focus on understanding of intermixing and diffusion across interfaces in the structures, emphasizing compound semiconductors and cadmium-based alloys. Also included in these assessments will be development of an understanding of interface inhomogeneities on the photovoltaic performance. A mechanistic understanding will evolve that will correlate transport properties with structural evolution, interface migration, and compositional changes.

This activity also includes funding for the U.S.-India Clean Energy Research Center.

▪ **Neutron and X-ray Scattering**	**40,024**	**42,524**

This activity supports basic research on the fundamental interactions of photons and neutrons with matter to achieve an understanding of the atomic, electronic, and magnetic structures and excitations of materials and the relationships of these structures and excitations to materials properties. The main emphasis is on x-ray and neutron scattering, spectroscopy, and imaging research, primarily at major BES-supported user facilities. The development and improvement of next-generation instrumentation, novel detectors, sample environments, data analysis, tools, and technology for producing polarized neutrons are key aspects of this activity. Instrumentation development and experimental research in ultrafast materials science, including research aimed at generating, manipulating, and detecting ultrashort and ultrahigh-peak-power electron, x-ray, and laser pulses to study ultrafast physical phenomena in materials, is an integral part of the portfolio. Capital equipment funding is provided for items such as detectors, monochromators, focusing mirrors, and beamline instrumentation at the facilities.

The increasing complexity of DOE mission-relevant materials such as superconductors, semiconductors, and magnets requires ever more sophisticated scattering techniques to extract useful knowledge and to develop new theories for the behavior of these materials. X-ray and neutron scattering probes are some of the primary tools for characterizing the atomic, electronic, and magnetic structures of materials. Additionally, neutrons play a key role in hydrogen research as they provide atomic- and molecular-level information on structure, diffusion, and interatomic interactions for hydrogen. They also allow access to the morphologies that govern useful properties in catalysts, membranes, proton conductors, and hydrogen storage materials. The activity is relevant to the behavior of matter in extreme environments, especially at high pressure.

In FY 2012, research will continue to support scattering research to take advantage of increased neutron and x-ray fluxes and optimized beamline optics at BES user facilities, combined with specialized instrumentation, to investigate electrochemical processes in real time. Emphasis will be on using elastic and inelastic neutron scattering to determine structure and local dynamics and on neutron reflectivity to examine electrode/electrolyte interfaces. Time-resolved measurements will be used to study phase transformation kinetics in both amorphous and crystalline phases. The new capabilities will be used to study materials under ultrahigh pressure and to identify novel phase and phenomena not accessible via ambient conditions. Continued emphasis will be placed on materials science research to take advantage of new x-ray and neutron sources to perform research designed to understand dynamic phenomena in real-time, including the physics of strongly correlated systems, spintronics, materials at extreme conditions, and nanostructured materials for energy technologies including carbon capture phenomena, nanomagnetism, and energy storage. New research will be initiated as part of *Computational Materials and Chemistry by Design* to provide targeted experimental support for the development of algorithms and software with predictive capabilities to aid the materials discovery and design. This research will take advantage of the in situ capabilities of national user facilities for neutron and x-ray scattering for research in the discovery of advanced materials for efficient photovoltaics, electrodes and electrolytes for the next generation energy storage systems, membranes for fuel cells, carbon dioxide sequestration, radiation resistant self healing materials, and better magnets. The goal will be to facilitate stronger interaction between the experiments and theory to ensure that the experimental and computational data on structure and dynamics of functional materials are available to accelerate development and enable validation of the software. In situ research can measure properties dynamically, during synthesis and use of materials in appropriate environments and operational conditions, yielding direct data for comparison to predictions.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **Electron and Scanning Probe Microscopies**	**29,790**	**30,290**

This activity supports basic research in condensed matter physics and materials physics using electron scattering and microscopy and scanning probe techniques. The research includes experiments and theory to understand the atomic, electronic, and magnetic structures of materials. This activity also supports the development and improvement of electron scattering and scanning probe instrumentation and techniques, including ultrafast diffraction and imaging techniques. Capital equipment funding is provided for items such as new scanning probes and electron microscopes as well as ancillary equipment including high resolution detectors.

Performance improvements for environmentally acceptable energy generation, transmission, storage, and conversion technologies likewise depend on a detailed understanding of the structural characteristics of advanced materials. Electron and scanning probe microscopies are some of the primary tools for characterizing the atomic, electronic, and magnetic structures of materials. The activity is relevant to hydrogen research through the structural determination of nanostructured materials for hydrogen storage and solar hydrogen generation.

In FY 2012, research will emphasize the development of tools that will dramatically improve spatial, time, and energy resolution to provide fundamental understanding of the electron and charge transfer processes and mechanisms by which ions interact with electrode materials. The effort will focus on studies of transient non-equilibrium nanoscale structures, including adsorbed species in both vacuum and electrochemical environments, with near-atomic spatial resolution and at the femtosecond time scale. Ultrafast electron scattering will be developed as a companion tool to ultrafast photon probes. New research under *Computational Materials and Chemistry by Design* will be initiated to utilize microscopy, especially evolving in situ, high resolution characterization of structure and charge transport in materials for next generation batteries, photovoltaics, thermoelectrics, magnetism, and superconductivity. Development of theory and software that can predictably discover materials with designed properties requires high resolution experimental data in appropriate length and time scales at relevant conditions for the validation and refinement. The wide range of electron microscopy techniques offer superior spatial resolution and chemical speciation information complementary to x-ray and neutron scattering. The joint computational and microscopy research will assess atomic level structure, analysis of composition, evaluation of interactions of critical microstructural features, transport measurements, and the evolution of these during in situ evaluation of deformation, at elevated temperature, under straining, and other environments.

▪ **Experimental Program to Stimulate Competitive Research (EPSCoR)**	**21,623**	**8,520**

This activity supports basic research spanning the broad range of science and technology programs at DOE in states that have historically received relatively less Federal research funding. The EPSCoR states are shown below. The research supported by EPSCoR includes 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, nuclear energy, and energy efficiency and renewable energy.

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The core activity interfaces with all other core activities within the Office of Science. It is also responsive to and supports the DOE mission in the areas of energy and national security and in mitigating their associated environmental impacts.

In FY 2012, efforts will continue spanning DOE missions in the Office of Science and science underpinning a number of technology programs including Fossil Energy, Nuclear Energy, and Energy Efficiency and Renewable Energy and enhancing collaboration between programs and collaboration with DOE user facilities. The FY 2012 request will continue basic research related to DOE mission areas and will enhance collaborative efforts with DOE user facilities.

The following table shows EPSCoR distribution of funds by state.

EPSCoR Distribution of Funds by State

Alabama	547	0
Alaska	2,257	0
Arkansas	0	0
Delaware	811	649
Hawaii	0	0
Idaho	540	0
Iowa	0	0
Kansas	514	0
Kentucky	650	0
Louisiana	1,444	0
Maine	0	0
Mississippi	0	0
Montana	450	0
Nebraska	555	0
Nevada	534	0
New Hampshire	700	700
New Mexico	1,345	0
North Dakota	0	0
Oklahoma	2,900	0
Puerto Rico	470	0
Rhode Island	546	0
South Carolina	0	0

	(dollars in thousands)	
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South Dakota	2,329	0
Tennessee	1,809	0
U.S. Virgin Islands	0	0
Utah	0	0
Vermont	0	0
West Virginia	554	0
Wyoming	2,445	0
Technical Support	223	460
Other[a]	0	6,711

- **Synthesis and Processing Science** **20,777 24,777**

This activity supports basic research for developing new techniques to synthesize materials with desired structure, properties, or behavior; to understand the physical phenomena that underpin materials synthesis such as diffusion, nucleation, and phase transitions; and to develop in situ monitoring and diagnostic capabilities. The emphasis is on the synthesis of complex thin films and nanoscale materials with atomic layer-by-layer control; preparation techniques for pristine single crystal and bulk materials with novel physical properties; understanding the contributions of the liquid and other precursor states to the processing of bulk nanoscale materials; and low energy processing techniques for large scale nanostructured materials. The focus of this activity on bulk synthesis and crystal and thin films growth via physical means is complementary to the Materials Chemistry and Biomolecular Materials activity, which emphasizes chemical and biomimetic routes to new materials synthesis and design. Capital equipment funding is provided for crystal growth apparatus, heat treatment furnaces, lasers, chemical vapor deposition and molecular beam epitaxial processing equipment, plasma and ion sources, and deposition instruments.

Synthesis and processing science is a key component in the discovery and design of a wide variety of energy relevant materials. In this regard, the activity supports DOE's mission in the synthesis of wide bandgap semiconductors for solid state lighting; light-weight metallic alloys for efficient transportation; novel materials such as metal organic frameworks for hydrogen storage; and structural ceramics and the processing of high temperature superconductors for near zero-loss electricity transmission. The research activity aims at providing synthesis and processing capabilities to enable the manipulation of individual spin, charge, and atomic configurations in ways to probe the atomistic basis for materials properties.

In FY 2012, research will seek to develop novel design rules for synthesizing nanostructured materials and assemblies for applications including solid-state lighting, solar energy conversion, and electrical energy storage. Research on advanced materials for electrical energy storage will include

[a] Uncommitted funds in FY 2011, and FY 2012 will be competed among all EPSCoR states.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

studies on the fundamental electrochemical characteristics of nanoscale building blocks with varying size and shape and in confined geometry. The development of new capabilities for synthesis will be emphasized including novel crystal growth techniques that will expand our ability to discover needed materials for advanced energy technologies, as well as to facilitate our understanding of new phenomena in energy generation and transport, including superconductivity, photovoltaics, and energy storage. In addition, new synthesis methods would be studied to manipulate microstructures (e.g., tailored nanoparticle dispersions) that allow enhancement of the dielectric properties of insulators and of the mechanical strength of conductors, thereby increasing the power that can be safely transmitted in the grid. Novel approaches would also be studied to create materials with increased functionality such as magnetism, but that rely on a reduced level of rare-earth additives, by understanding and controlling morphology, composition, and interfaces to understand their effects on macroscopic properties. Materials discovery research will focus on development of new materials that do not depend on rare earth additions for the desired properties.

▪ **Materials Chemistry and Biomolecular Materials**	**57,063**	**65,063**

This activity supports basic research in chemical and bio-inspired synthesis and discovery of new materials. In the materials chemistry area, discovery, design, and synthesis of novel materials with an emphasis on the chemistry and chemical control of structure and collective properties are supported. Major thrust areas include nanoscale chemical synthesis and assembly; solid state chemistry for exploratory synthesis and tailored reactivities; novel polymeric materials; surface and interfacial chemistry including electrochemistry; and the development of new, science-driven, laboratory-based analytical tools and techniques. In the biomolecular materials area, research supported includes biomimetic and bioinspired functional materials and complex structures, and materials aspects of energy conversion processes based on principles and concepts of biology. The focus on exploratory chemical and biomolecular formation of new materials is complementary to the emphasis on bulk synthesis, crystal growth, and thin films in the Synthesis and Processing Science activity. Capital equipment funding is provided for items such as advanced nuclear magnetic resonance and magnetic resonance imaging instruments and novel scanning probe microscopes.

Research supported in this activity underpins many energy-related technological areas such as batteries and fuel cells, catalysis, energy conversion and storage, friction and lubrication, high-efficiency electronic devices, hydrogen generation and storage, light-emitting materials, light-weight high-strength materials, and membranes for advanced separations.

In FY 2012, the emphasis will focus on developing a predictive understanding of the role of interfaces in the processes underpinning energy storage, photochemical, and catalytic technologies, devising experimental strategies for atom-by-atom synthesis or molecular assembly of structures, and exploring novel concepts for enhanced performance. The research will seek to advance the ability for materials to self-repair, regulate, clean, sequester impurities, and tolerate abuse. Bio-inspired materials discovery—linking physical and chemical synthesis with the synthesis strategies of biology—will be a focus to create new materials *in vitro* with altered morphologies and desired materials properties. Biological self-assembly occurs on both spatial and temporal scales and can be reversible, resulting in complex structures that are far from equilibrium, opening new avenues to materials with emergent behaviors. Additional funding will support new research to understand

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

carbon capture phenomena, including investigation of novel chemical and biomimetic approaches for efficient carbon capture and release with a focus on kinetics and environments that include contaminants found in flue gases. Another priority area for new funding is development of improved understanding of the mechanisms responsible for system losses in organic light emitting diodes (OLEDs) and, based on this understanding, design and identification of new, novel materials with improved performance. The focus would be on research to elucidate the mechanisms for molecular interactions among the layered structures, connectors, interfaces, impurities, contacts, and their environments in high excitation conditions. A critical aspect of life extension is discerning how to limit degradation of the molecular structure due to the collision and annihilation of higher energy (blue) excitons.

- **Energy Frontier Research Centers (EFRCs)[a] 58,000 58,000**

  The EFRCs established in late FY 2009 are multi-investigator and multi-disciplinary centers that foster, encourage, and accelerate basic research to provide the basis for transformative energy technologies of the future.[b] The EFRCs represent an important research modality for BES, bringing together the skills and talents of a critical mass of investigators to enable energy relevant, basic research of a scope and complexity that would not be possible with standard single-investigator or small-group awards. The scope and unique nature of the EFRC program requires special oversight, which is accomplished through a BES-wide, dedicated EFRC management team. This team has the direct management responsibility over all EFRCs and also coordinates EFRC research with the complementary research conducted within the BES core research areas.

  This activity supports those EFRCs that are best coordinated with and most suitably complement the ongoing core research activities within the Materials Science and Engineering subprogram. These EFRCs 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; that improve the conversion of electricity to light; that can be used to improve electrical energy storage; that are resistant to corrosion, decay, or failure in extreme conditions of temperature, pressure, radiation, or chemical exposures; that take advantage of emergent phenomena, such as superconductivity, to improve energy transmission; that optimize energy flow to improve energy efficiency; and that are tailored at the atomic level for catalytic activity.

  In FY 2012, existing EFRCs will continue their research toward these ends. In addition, ongoing efforts to bridge disciplines, generate new avenues of inquiry, and accelerate research within the broader community will continue via periodic all-hands meetings, joint symposia and workshops, summer schools, tool development, contractors' meetings, and interactions with BES program management. BES will provide further guidance to the EFRCs to help maximize their impact and effectiveness on the basis of peer reviews of their science to be conducted during FY 2012.

[a] A complimentary set of EFRCs is also included in the Chemical Sciences, Geosciences, and Biosciences subprogram.
[b] 16 of the 46 EFRCs awarded were forward funded for the five-year initial award period under the American Recovery and Reinvestment Act of 2009.

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
▪ **Energy Innovation Hub-Batteries and Energy Storage**	**0**	**34,020**

As an energy carrier, electricity has no rival with regard to its environmental cleanliness, flexibility in interfacing with multiple production sources and end uses, and efficiency of delivery. Electrical energy storage offers one of the most significant solutions to the effective use of electricity in energy management. Improved energy storage is critical for more efficient and reliable smart electric grid technologies; plug-in hybrid or all-electric vehicles in the transportation sector; and the deployment of intermittent renewable energy power sources such as solar, wind, and wave energy into the utility sector. Today's electrical energy storage approaches, such as batteries and electrochemical devices, suffer from limited energy and power capacities, lower-than-desired rates of charge and discharge, calendar and cycle life limitations, low abuse tolerance, high cost, and poor performance at high or low temperatures. These performance deficiencies adversely affect the successful use and integration of renewable, intermittent power sources such as solar, wind, and wave energy into the utility sector. These same fundamental problems have also limited broad consumer acceptance and market adaptation of hybrid and all-electric vehicles.

Recent developments in nanoscience and nanotechnology offer tantalizing clues on promising scientific directions that may enable conceptual breakthroughs. They include the abilities to synthesize novel nanoscale materials with architectures tailored for specific electrochemical performance, to characterize materials and dynamic chemical processes at the atomic and molecular level, and to simulate and predict structural and functional relationships using modern computational tools. Based on this, radically new concepts in materials design can be developed for producing storage devices with materials that are abundant and low in manufacturing cost, are capable of storing higher energy densities, have long cycle lifetimes, and have high safety and abuse tolerance.

Together, these new capabilities provide the potential for addressing the gaps in cost and performance separating the current electrical energy storage technologies and those required for sustainable utility and transportation needs.

Fundamental performance limitations of energy storage systems are rooted in the constituent materials making up an electrical energy storage device, and novel approaches are needed to develop multifunctional electrical energy storage materials that offer new self-healing, self-regulating, failure-tolerant, impurity-sequestering, and sustainable characteristics.

Energy Innovation Hubs are composed of a large team of investigators focused on a single critical national need identified by the Department. Hubs integrate across the full spectrum of basic and applied research and development and bring to bear a sustained effort on our most challenging energy problems. This Hub will address a number of specific areas of energy storage research that were identified in the BES workshop report *Basic Research Needs for Electrical Energy Storage*. These include:

- Efficacy of structure in energy storage—new approaches combining theory and synthesis for the design and optimization of materials architectures including self-healing, self-regulation, failure-tolerance, and impurity sequestration.

	(dollars in thousands)	
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- Charge transfer and transport—molecular scale understanding of interfacial electron transfer.
- Electrolytes—electrolytes with strong ionic solvation, yet weak ion-ion interactions, high fluidity, and controlled reactivity.
- Probes of energy storage chemistry and physics at all time and length scales—analytical tools capable of monitoring changes in structure and composition at interfaces and in bulk phases with spatial resolution from atomic to mesoscopic levels and temporal resolution down to femtoseconds.
- Multi-scale modeling—computational tools with improved integration of length and time scales to understand the complex physical and chemical processes that occur in electrical energy storage processes from the molecular to system scales.

One time funding of $10,000,000 will be provided for Hub start-up needs, excluding new construction.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **General Plant Projects (GPP)**	**3,757**	**0**

No funds are requested in FY 2012.

SBIR/STTR 0		**12,369**

In FY 2010, $8,516,000 and $1,022,000 were transferred to the SBIR and STTR programs, respectively. The FY 2012 amount shown is the estimated requirement for the continuation of the congressionally mandated SBIR and STTR programs.

Total, Materials Sciences and Engineering	**353,423**	**459,952**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Materials Sciences and Engineering Research	
▪ **Experimental Condensed Matter Physics**	
Increase funding for research on electron transport phenomena in materials for photovoltaics, solid state lighting, and integration of renewable technologies in the grid.	+12,000
▪ **Theoretical Condensed Matter Physics**	
Increased funding will support research for Computational Materials and Chemistry by Design for accurate design and discovery of new materials with desired functionality based on theoretical understanding using experimentally validated software.	+17,500

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Mechanical Behavior and Radiation Effects**	
Increased funding for enhanced research on the discovery of new materials and enhancement of the properties of materials used in extreme environments such as the exposure to an energetic neutron flux, chemical reactive stimulants, and high temperature and pressure.	+15,000
▪ **Physical Behavior of Materials**	
Increased funding for enhanced research on the fundamental science of defect physics and new materials to improve power electronics (+$3,500). Increased funding is provided for research on fundamental physics underpinning innovative concepts for nanoelectronics (+$10,000). Increased funding is requested for research on degradation, mechanisms, and impurity diffusion for photovoltaics (+$4,000).	+17,500
▪ **Neutron and X-ray Scattering**	
Increase funding will support in situ scattering research to validate computational models and software for the design of materials.	+2,500
▪ **Electron and Scanning Probe Microscopies**	
Increased funding will support utilization of microscopy and spectroscopy to validate computational methods for the design of materials.	+500
▪ **Experimental Program to Stimulate Competitive Research (EPSCoR)**	
Decrease to the FY 2010 requested level.	-13,103
▪ **Synthesis and Processing Science**	
Increased funding will support research to discover new materials for grid applications.	+4,000
▪ **Materials Chemistry and Biomolecular Materials**	
Increased funding will support research on novel materials and chemistries for carbon capture, critical research to prevent environmental carbon dioxide levels from growing to unacceptably high concentrations (+$4,000) and research to understand mechanism underlying system losses in organic light emitting diodes (+$4,000).	+8,000
▪ **Energy Innovation Hub – Batteries and Energy Storage**	
Funding is provided for the Batteries and Energy Storage Hub, to be coordinated with other DOE research and development activities for energy storage.	+34,020
▪ **GPP**	
No funds requested in FY 2012.	-3,757
Total, Materials Sciences and Engineering Research	**+94,160**

	FY 2012 vs. FY 2010 Current Approp. ($000)
SBIR/STTR	
Funding for SBIR/STTR increases relative to FY 2010 because of two issues: 1) the mandated SBIR/STTR set-asides that were transferred out of the program in FY 2010 are included in the FY 2012 request, and 2) an increase in total operating expenses from FY 2010 to FY 2012 increases the amount of the set-aside.	+12,369
Total Funding Change, Materials Sciences and Engineering	**+106,529**

Chemical Sciences, Geosciences, and Biosciences

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Chemical Sciences, Geosciences, and Biosciences		
Chemical Sciences, Geosciences, and Biosciences Research	287,480	384,272
SBIR/STTR	0	10,445
Total, Chemical Sciences, Geosciences, and Biosciences	287,480	394,717

Description

This subprogram supports experimental, theoretical, and computational research to provide fundamental understanding of chemical transformations and energy flow in systems relevant to DOE missions. This knowledge serves as a basis for the development of new processes for the generation, storage, and use of energy and for mitigation of the environmental impacts of energy use.

In fundamental interactions, basic research is supported in atomic, molecular, and optical sciences; gas-phase chemical physics; ultrafast chemical science; theoretical and computational chemistry; and condensed phase and interfacial molecular science. Emphasis is placed on structural and dynamical studies of atoms, molecules, and nanostructures, and the description of their interactions in full quantum detail, with the aim of providing a complete understanding of reactive chemistry in the gas phase, condensed phase, and at interfaces. Novel sources of photons, electrons, and ions are used to probe and control atomic, molecular, and nanoscale matter. Ultrafast optical and x-ray techniques are developed and used to study and direct molecular, dynamics, and chemical reactions.

In photochemistry and biochemistry, including solar photochemistry, photosynthetic systems, and physical biosciences, research is supported on the molecular mechanisms involved in the capture of light energy and its conversion into chemical and electrical energy through biological and chemical pathways. 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 encompasses organic and inorganic photochemistry, photo-induced electron and energy transfer, photo-electrochemistry, and molecular assemblies for artificial photosynthesis.

In chemical transformations, research themes include the characterization, control, and optimization of chemistry in many forms, including catalysis; separations and analysis; actinide chemistry; and geosciences. Catalysis science underpins the design of new catalytic methods for the clean and efficient production of fuels and chemicals and emphasizes inorganic and organic complexes; interfacial chemistry, nanostructured and supramolecular catalysts, photocatalysis and electrochemistry, and bio-inspired catalytic processes. Heavy element chemistry focuses on the spectroscopy, bonding, and reactivity of actinides and fission products. Complementary research on chemical separations focuses on the use of nanoscale membranes and the development of novel metal-adduct complexes. Chemical analysis research emphasizes laser-based and ionization techniques for molecular detection, particularly the development of chemical imaging techniques. Geosciences research covers analytical and physical geochemistry, rock-fluid interactions, and flow/transport phenomena.

Selected FY 2010 Accomplishments

- *Unpeeling an Atom from the Inside Out.* A team of scientists has explored the interaction of ultrashort, high-intensity x-ray pulses with simple atoms using the world's first x-ray free-electron laser, the Linac Coherent Light Source (LCLS) at the SLAC National Accelerator Laboratory. Understanding the fundamental interaction of ultra-intense x-ray radiation with a free atom is a critical first step towards application of the LCLS to the study of more complex material systems. The recent experiments revealed the nature of the electronic response in a neon atom exposed to LCLS x-ray pulses at various photon energies for all processes that are energetically feasible through absorption of a single x-ray photon. Because the LCLS pulse is so intense and hard x-rays interact preferentially with inner-shell electrons, the neon atom is stripped of all of its electrons, starting from the inner shell of electrons followed by the outer electrons in the valence shell, creating a novel state known as a "hollow atom." The extremely rapid ejection of inner-shell electrons causes the atom to become transparent to x-ray absorption while retaining its ability to coherently scatter x-rays. This result is particularly promising for the future study of single biomolecules and nanoscale objects using the LCLS, since the techniques for imaging these objects rely on minimizing x-ray absorption (a key source of sample damage) while maximizing coherent scattering (the source of signal fidelity).
- *Nanoscale Chemical Imaging.* Chemical imaging refers to analytical and microscopy techniques that use molecular spectroscopy and often temporal resolution to obtain images of chemically distinct species at nanoscale resolution. A team of scientists has obtained images of individual zinc oxide (ZnO) nanowires, which are proposed for solar energy conversion applications, by combining atomic force microscopy with near-field scanning optical microscopy. By concentrating laser excitation light on a sharp metal tip of a scanning probe microscope, images of the chemical modifications of the ZnO surface with a spatial resolution of 100 nm were recorded. Characterization of the chemistry in such a small domain is unprecedented and important because it can reveal the influence of local variation in the sample. This new technique adds to our arsenal of chemically selective imaging techniques that are needed for the characterization of chemical processes for solar energy conversion, electrical energy storage, and catalysis.
- *Catalysts for Making Biodiesel with High Efficiency and Less Waste.* Current industrial processes for the production of biodiesel use reactions between bio-oil feedstocks and methanol that are catalyzed by sodium or potassium hydroxide. These produce the desired fatty acid esters (biodiesel) and byproducts such as glycerol and soaps. Separation of the biodiesel from the byproducts requires neutralization of the un-reacted hydroxides by strong acids, removal and disposal of toxic and corrosive chemicals, and prodigious amounts of water. This post-treatment creates waste and contributes significantly to production costs. Researchers have recently developed heterogeneous catalysts that have high activity, are easily separated from the reaction mixture by filtration, are reusable, and do not require presence of strong bases, so the overall process cost is greatly reduced and waste is reduced. In the new catalysts, silicon is substituted for calcium in calcium oxide within the porous catalytic structure. By controlling the calcium to silicon ratio, the researchers can tune reactivity to optimize biodiesel production. These catalysts were first tested successfully in a pilot plant and have now been implemented in two industrial-scale biodiesel production plants.
- *Earth-abundant Catalysts for Solar Fuel Generation.* Generation of solar fuels on a scale needed to meet global fuel demands requires that water is used as an electron source to power subsequent fuel-formation reactions. To be viable in real systems, reaction catalysts must also be robust and made from earth-abundant materials. Both cobalt and manganese oxide-based catalysts are used by nature

to drive water splitting reactions in natural photosynthesis, but catalysts of similar activity had not been developed for use in inorganic systems prior to this work. Two new oxygen-evolving electrocatalysts have been developed based on embedding earth-abundant nanoparticles of cobalt or manganese oxide in mesoporous silica structures. The particles are arranged in vertical layers in the transparent silica to efficiently utilize incident sunlight even at maximum solar intensity. In laboratory tests, the new catalysts readily produce oxygen when illuminated by sunlight and remain stable in aqueous systems. The development of effective oxygen-evolving catalysts from earth-abundant materials is a critical step toward sustainable solar fuel generation.

- *Imaging Mineral Reactivity with X-rays.* The mineral-fluid interface is the principal site of low-temperature geochemical processes at and near the Earth's surface, and therefore exerts a powerful influence on natural geochemical cycles and the response of those cycles to man-made alterations. For example, the dissolution of silicate minerals is a process that buffers atmospheric CO_2. Researchers have developed a new capability to image interfacial reactivity using x-ray microscopy at the nanometer scale. This opens up the potential for real-time imaging of the chemistry of interfacial processes as it occurs and complements physical imaging approaches such as atomic force microscopy. The research explored the effect of elevated salinity, which is the amount of dissolved salt in groundwater, on the dissolution of the mineral feldspar. *In-situ* x-ray reflectivity measurements show that increased salinity greatly increases the overall dissolution rate and leads to a rougher surface than at lower salinities. Detailed images of the reacted surfaces show that inhomogeneous dissolution leads to micron-scale regions with locally increased roughness, which provides information on the lateral variation of mineral reactivity with potential impact on understanding soil and groundwater chemistry and their interactions with atmospheric gases like CO_2.
- *A Protein that Protects Photosynthetic Apparatus Critical to Algal Survival.* Plants and algae use photosynthesis to capture solar energy and convert it into a chemical form that can be used by the cell. Too much sunlight, however, can harm photosynthetic organisms, causing severe oxidative damage and even cell death. To protect themselves, both plants and algae have evolved an energy-quenching mechanism that releases excess light energy as heat and protects the photosynthetic apparatus from damage. Researchers recently found that an evolutionarily ancient light harvesting protein, called LHSCR, was critical for survival of the green algae *Chlamydomonas reinhardtii* in a fluctuating light environment. The research suggests that this single protein in algae may play a role in both dissipating excess energy from chlorophyll and in sensing light to turn off the dissipation mechanism at the appropriate time. In higher plants, however, one protein in the light harvesting complex dissipates the energy while a different protein acts as the light sensor. The study of LHSCR in algae presents an alternative view of how nature controls solar energy harvesting and provides new insight for the effective use of algae as a biofuels feedstock and for the design of artificial light harvesting complexes.
- *Enhancing the Efficiency of Organic Photovoltaics.* Large-scale penetration of photovoltaics (PV) into the commercial electricity sector requires the development of new PV materials that have improved conversion efficiency and lower production cost than silicon. While materials based on molecular and polymer building blocks have enormous potential for being cost effective, the demonstrated conversion efficiency of these materials is ten times smaller than that of silicon. Recently, two Energy Frontier Research Centers have collaborated to develop new morphologies for organic PV materials that optimally blend interpenetrating bilayers of organic dye molecules and functionalized fullerene-like molecules to achieve a conversion efficiency of 4.1%, a significant increase over the typical 2.7% efficiencies for such materials. Researchers were guided by optical

spectroscopy and microscopy that characterized the rate of charge migration in these materials, which critically determines their conversion efficiency, and found that during the film deposition process rough, disordered interfaces with specific concentration ratios yielded the optimal morphology. The flexible modification of the morphology of these materials offers great promise for their development into cheap and efficient organic photovoltaics.

Detailed Justification

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Chemical Sciences, Geosciences, and Biosciences Research	**287,480**	**384,272**
▪ **Atomic, Molecular, and Optical Science**	**23,011**	**24,011**

This activity supports theory and experiments to understand structural and dynamical properties of atoms, molecules, and nanostructures. The research emphasizes the fundamental interactions of these systems with photons and electrons to characterize and control their behavior. These efforts aim to develop accurate quantum mechanical descriptions of properties and dynamical processes of atoms, molecules, and nanoscale matter. The study of energy transfer within isolated molecules provides the foundation for understanding chemical reactivity, i.e., the process of energy transfer to ultimately make and break chemical bonds. Topics include the development and application of novel, ultrafast optical probes of matter, particularly x-ray sources; the interactions of atoms and molecules with intense electromagnetic fields; and studies of collisions and many-body cooperative interactions of atomic and molecular systems, including ultracold atomic and molecular gases. Capital equipment funding is provided for items such as lasers and optical equipment, unique ion sources or traps, position-sensitive and solid-state detectors, control and data processing electronics, and computational resources.

The knowledge and techniques produced by this activity form a science base that underpins several aspects of the DOE mission. New methods for using photons, electrons, and ions to probe matter lead to more effective use of BES synchrotron, nanoscience, and microcharacterization facilities. Similarly, the study of formation and evolution of energized states in atoms, molecules, and nanostructures provides a fundamental basis for understanding elementary processes in solar energy conversion and radiation-induced chemistry.

In FY 2012, research will emphasize the development and application of new ultrafast x-ray and optical probes of matter, including some of the first experiments to be performed on the Linac Coherent Light Source; theoretical and computational methods for the interpretation of ultrafast measurements; and the use of optical fields to control and manipulate quantum mechanical systems.

▪ **Chemical Physics Research**	**51,536**	**66,536**

This activity supports experimental and theoretical investigations in the gas phase, condensed phase, and at interfaces aimed at elucidating the molecular-scale chemical and physical properties and interactions that govern chemical reactivity, solute/solvent structure, and transport. Also supported are new opportunities to attain predictive understanding of chemical reactivity, including structural and dynamical studies that emphasize a complete understanding of reactive

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chemistry at full quantum detail. These approaches include the development and implementation of predictive computational modeling and simulation, incorporating advanced theory and experimental validation, for scientific discovery across multiple scales. Gas phase chemical physics research emphasizes studies of the dynamics and rates of chemical reactions at energies characteristic of combustion, the chemical and physical properties of key combustion intermediates, and development of experimental and theoretical tools. Combustion models are developed that incorporate complex chemistry with the turbulent flow and energy transport characteristics of real combustion processes. The overall aim is the development of a fundamental understanding of chemical reactivity enabling validated theories, models and computational tools for predicting rates, products, and dynamics of chemical processes involved in energy utilization by combustion devices. This activity includes support for the Combustion Research Facility (CRF), a multi-investigator research laboratory for the study of combustion science and technology. Condensed phase and interfacial molecular science research emphasizes chemical, physical, and electron-driven processes in aqueous media and at interfaces. Studies of reaction dynamics at well-characterized surfaces and clusters lead to the development of theories on the molecular origins of surface-mediated catalysis and heterogeneous chemistry. Studies of model condensed-phase systems target first-principles understandings of molecular reactivity and dynamical processes in solution and at interfaces. The approach confronts the transition from molecular-scale chemistry to collective phenomena in complex systems, such as the effects of solvation on chemical structure and reactivity. Research in computational and theoretical chemistry emphasizes integration and development of new and existing theoretical and computational approaches. Capital equipment funding is provided for items such as lasers and optical equipment, novel position-sensitive and temporal detectors, specialized vacuum chambers for gas-phase and surface experiments, spectrometers, and computational resources.

The impact of this activity on DOE missions is far reaching. The gas-phase portions contribute strongly to the DOE mission in the area of the efficient and clean combustion of fuels. The coupling of complex chemistry and turbulent flow has long challenged predictive combustion modeling. Truly predictive combustion models enable the design of new combustion devices (such as internal combustion engines, burners, and turbines) with maximum energy efficiency and minimal environmental consequences. In transportation, the changing composition of fuels, from those derived from light, sweet crude oil to biofuels and fuels from alternative fossil feedstocks, puts increasing emphasis on the need for science-based design of modern engines. The condensed-phase and interfacial portions impact a variety of mission areas by providing a fundamental basis for understanding chemical reactivity in complex systems, such as those encountered in catalysis and environmental processes, along with activity that provides fundamental underpinnings relevant to energy production and storage. Surface-mediated chemistry research in this activity complements more directed efforts in heterogeneous catalysis. Condensed-phase and interfacial chemical physics research on dissolution, solvation, nucleation, separation, and reaction provides important fundamental knowledge relevant to the environmental contaminant transport in mineral and aqueous environments. Fundamental studies of reactive processes driven by radiolysis in condensed phases and at interfaces provide improved understanding of radiolysis effects in nuclear fuel and waste environments.

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In FY 2012, research will continue to emphasize fundamental interfacial and condensed phase molecular science that underpins and complements other BES efforts in heterogeneous, rediolytic chemistry, and geosciences. Research in theoretical and computation chemistry will continue to emphasize the development and application of new approaches to treat complex chemical systems. Also in FY 2012, this activity will support a new initiative in Energy Systems Simulation – Internal Combustion Engines (ESS-ICE) in collaboration with the Vehicle Technologies Program (VTP) within the Office of Energy Efficiency and Renewable Energy. Science-based, predictive simulation of combustion was identified as the single grand challenge in the BES workshop report *Basic Research Needs for Clean and Efficient Combustion of 21st Century Transportation Fuels* (2007). In a follow-up series of focused workshops with the combustion science and technology community, with emphasis on participation by U.S. automotive and engine industries, two complementary sets of codes have been identified as critical for engine design: one for stochastic, in-cylinder engine processes and one that can reliably predict the temporal and spatial behavior of liquid fuel injection. These two topics lie on the critical path toward the transition from hardware-intensive, experience-based engine design to simulation-intensive, science-based design, which is particularly important for the economic design of high-efficiency engines that can burn a broad range of fuels (including biofuels) cleanly. The ability to accurately simulate stochastic properties will allow minimization of cycle-to-cycle variations inherent in engines and allow more rapid optimization of the overall air/fuel handling and combustion processes. The liquid fuel injection code, which would include orifice flow and cavitation, atomization, dense secondary break-up, dilute spray dynamics, and vaporization, is necessary to accurately model the fuel injection processes used by all modern engines. Delivery of these two code sets for advanced engine design requires a seamless integration of basic research, focused on fundamental understanding and model systems, and engineering development, focused on device-scale simulation and testing. BES fundamental research will stress the development and experimental validation of the target codes, including experimental and theoretical studies of the complex combustion chemistry of new fuels at the high pressures, multi-phase spray dynamics, cinematic imaging diagnostics, and benchmark numerical simulations of model combustion systems that make extensive use of Office of Science leadership class computational platforms. The complementary engineering development portion of ESS-ICE will be supported by VTP, building from the long-standing and successful collaboration in basic and applied combustion science and technology between BES and VTP.

▪ **Solar Photochemistry**	**40,241**	**52,741**

This activity supports molecular-level research on solar energy capture and conversion in the condensed phase and at interfaces. These investigations of solar photochemical energy conversion focus on the elementary steps of light absorption, electrical charge generation, and charge transport within a number of chemical systems, including those with significant nanostructured composition. Supported research areas include organic and inorganic photochemistry and photocatalysis, photoinduced electron and energy transfer in the condensed phase and across interfaces, photoelectrochemistry, and artificial assemblies for charge separation and transport that mimic natural photosynthetic systems. This activity, with its integration of physical and synthetic scientists devoted to solar photochemistry, is unique to DOE. Capital equipment funding

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is provided for items such as ultrafast laser systems, scanning tunneling microscopes, fast Fourier transform infrared and Raman spectrometers, and computational resources.

Solar photochemical energy conversion is an important option for generating electricity and chemical fuels and therefore plays a vital role in DOE's development of solar energy as a viable component of the nation's energy supply. Photoelectrochemistry provides an alternative to semiconductor photovoltaic cells for electricity generation from sunlight using closed, renewable energy cycles. Solar photocatalysis, achieved by coupling artificial photosynthetic systems for light harvesting and charge transport with the appropriate electrochemistry, provides a direct route to the generation of fuels such as hydrogen, methane, and complex hydrocarbons. Fundamental concepts derived from studying highly efficient excited-state charge separation and transport in molecular assemblies is also applicable to future molecular optoelectronic device development.

In FY 2012, continued emphasis will be placed on studies of semiconductor/polymer interfaces, multiple charge generation within semiconductor nanoparticles, dye-sensitized solar cells, inorganic/organic donor-acceptor molecular assemblies, and the use of nanoscale materials in solar photocatalytic generation of chemical fuels. As part of the *Computational Materials and Chemistry by Design* effort, an element of the *National Materials Initiative* with other federal agencies by the Office of Science and Technology Policy, this activity includes a significant increase for the development of software tools for the simulation of light harvesting and conversion of solar energy into electricity and chemical fuels. The complexity of the underlying science for solar energy conversion requires simultaneously developing and testing computational methods and theories. Emphasis will be placed on integration and further development of scalable methods for simulating the spatial and temporal evolution of electric excitations in molecular and nanoscale systems. While computational software exists for quantitatively determining the fundamental interactions that collectively mediate charge and energy transport, these need to be carefully woven together by scientific experts in a way that allows technically adept engineers to predict carrier transport through complex solids, liquids, polymers, and interfaces.

This activity also includes funding for the U.S.-India Clean Energy Research Center.

▪ **Photosynthetic Systems**	**17,773**	**17,773**

This activity supports fundamental research on the biological conversion of solar energy to chemically stored forms of energy. Topics of study include light harvesting, exciton transfer, charge separation, transfer of reductant to carbon dioxide, as well as the biochemistry of carbon fixation and carbon storage. Emphasized areas are those involving strong intersection between biological sciences and energy-relevant chemical sciences and physics, such as in self-assembly of nanoscale components, efficient photon capture and charge separation, predictive design of catalysts, and self-regulating/repairing systems. Capital equipment funding is provided for items such as ultrafast lasers, high-speed detectors, spectrometers, environmentally controlled chambers, high-throughput robotic systems, and computational resources.

The impact of research in this activity is to uncover the underlying structure-function relationships and to probe dynamical processes in natural photosynthetic systems to guide the development of robust artificial and bio-hybrid systems for conversion of solar energy into electricity or chemical fuels. The ultimate goal is the development of bio-hybrid systems in which

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the best features from nature are selectively used while the shortcomings of biology are bypassed. Achieving this goal would impact DOE's efforts to develop solar energy as an efficient, renewable energy source.

In FY 2012, research will emphasize understanding and control of the weak intermolecular forces governing molecular assembly in photosynthetic systems; understanding the biological machinery for cofactor insertion into proteins and protein subunit assemblies; adapting combinatorial, directed-evolution, and high-throughput screening methods to enhance fuel production in photosynthetic systems; characterizing the structural and mechanistic features of new photosynthetic complexes; and determining the physical and chemical rules that underlie biological mechanisms of repair and photo-protection.

▪ **Physical Biosciences**	**17,076**	**17,076**

This activity combines experimental and computational tools from the physical sciences with biochemistry and molecular biology. A fundamental understanding of the complex processes that convert and store energy in living systems is sought. Research supported includes studies that investigate the mechanisms by which energy transduction systems are assembled and maintained, the processes that regulate energy-relevant chemical reactions within the cell, the underlying biochemical and biophysical principles determining the architecture of biopolymers and the plant cell wall, and active site protein chemistry that provides a basis for highly selective and efficient bio-inspired catalysts. Capital equipment is provided for items including advanced atomic force and optical microscopes, lasers and detectors, equipment for x-ray or neutron structure determinations, and Fourier transform infrared and nuclear magnetic resonance spectrometers.

The research provides basic structure-function information necessary to accomplish solid-phase nanoscale synthesis in a targeted manner, i.e., controlling the basic architecture of energy-transduction and storage systems. This impacts numerous DOE interests, including improved biochemical pathways for biofuel production, next generation energy conversion/storage devices, and efficient, environmentally benign, sustainable catalysts.

In FY 2012, continued emphasis will be placed on probing the organizational principles of biological energy transduction and chemical storage systems using advanced molecular imaging and x-ray or neutron methods for structural determination. Of particular interest is the molecular scale characterization of the structure and chemistry of the biopolymers of the plant cell wall, knowledge that is required for the direct catalytic conversion of biomass into chemical fuels.

▪ **Catalysis Science**	**44,787**	**53,787**

This activity develops the fundamental scientific principles enabling rational catalyst design and chemical transformation control. Research includes the identification of the elementary steps of catalytic reaction mechanisms and their kinetics; construction of catalytic sites at the atomic level; synthesis of ligands, metal clusters, and bio-inspired reaction centers designed to tune molecular-level catalytic activity and selectivity; the study of structure-reactivity relationships of inorganic, organic, or hybrid catalytic materials in solution or supported on solids; the dynamics of catalyst structure relevant to catalyst stability; the experimental determination of potential energy landscapes for catalytic reactions; the development of novel spectroscopic techniques and

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structural probes for in situ characterization of catalytic processes; and the development of theory, modeling, and simulation of catalytic pathways. Capital equipment funding is provided for items such as ultrahigh vacuum equipment with various probes of interfacial structure, spectroscopic analytical instrumentation, and specialized cells for in situ synchrotron-based experiments, and computational resources.

Catalytic transformations impact an enormous range of DOE mission areas. Particular emphasis is placed on catalysis relevant to the conversion and use of fossil and renewable energy resources and the creation of advanced chemicals. Catalysts are vital in the conversion of crude petroleum and biomass into clean burning fuels and materials. They control the electrocatalytic conversion of fuels into energy in fuel cells and batteries and play important roles in the photocatalytic conversion of energy into chemicals and materials. Catalysts are crucial to creating new, energy-efficient routes for the production of basic chemical feedstocks and value-added chemicals. Environmental applications of catalytic science include minimizing unwanted products and transforming toxic chemicals into benign ones, such as the transformation of chlorofluorocarbons into environmentally acceptable refrigerants.

In FY 2012, research will focus on the chemistry of inorganic, organic, and hybrid porous materials; the nanoscale self-assembly of these systems; and the integration of functional catalytic properties into nanomaterials. New strategies for design of selective catalysts for fuel production from both fossil and renewable biomass feedstocks will be explored. Increased emphasis will be placed on the use of spectroscopy and microscopy to probe both model systems in vacuum and realistic catalytic sites. Research on catalytic cycles involved in electrochemical energy storage and solar photocatalytic fuel formation will receive increased emphasis. As part of the *Computational Materials and Chemistry by Design* effort, this activity includes an increase for the development of predictive simulation tools for photo-catalytic, fuel-forming reactions—a critically important way in which catalyst discovery for artificial photosynthesis can be accelerated. As a verification and validation complement to the discovery of new catalysts through simulation, this activity also includes an increase for the development of new experimental approaches to the synthesis of materials and new methods to probe catalytic reactivity in situ.

▪ **Separations and Analysis**	**14,386**	**18,848**

This activity supports fundamental research covering a broad spectrum of separation concepts, including membrane processes, extraction under both standard and supercritical conditions, adsorption, chromatography, photodissociation, and complexation. Also supported is work to improve the sensitivity, reliability, and productivity of analytical determinations and to develop new approaches to analysis in complex, heterogeneous environments, including techniques that combine chemical selectivity and spatial resolution to achieve chemical imaging. This activity is the nation's most significant long-term investment in the fundamental science underpinning actinide separations and mass spectrometry. The overall goal is to obtain a thorough understanding, at molecular and nanoscale dimensions, of the basic chemical and physical principles involved in separations systems and analytical tools so that their full utility can be realized. Capital equipment funding is provided for items such as lasers for use in sample

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ionization and chemical imaging, advanced mass spectrometers with nanoprobes, confocal microscopes for sub-diffraction limit resolution, and computational resources.

All effective chemical transformations require a medium to separate reactants from products. The separations of chemically distinct species and the related analytical determinations of their concentrations, often in complex environments and with extreme sensitivity, are relevant to many energy technologies. New separation media show tremendous potential for the efficient separation and subsequent capture of carbon dioxide in post-combustion gas streams and for the separation of oxygen from air required for oxy-combustion. Advanced separation membranes are also critical to the development of next-generation fuel cells. Measuring and separating contaminants from process streams in industry, or toxins from the environment, benefit from novel approaches to separations and increasingly sensitive chemical analysis.

In FY 2012, separations research will focus on fluid flow in nanoscale membranes and the formation of macroscopic separation systems via self-assembly of nanoscale building blocks. Chemical analysis research will emphasize the development of techniques with high spatial, temporal, and chemical resolution and simultaneous application of multiple analytical techniques. There is an increase for the development of new materials and methods for separation and capture of CO_2 from post-combustion gas streams and oxygen from air prior to oxy-combustion. New research in this area will include experimental and theoretical/computational studies of how weak intermolecular forces can be understood and controlled to achieve separations with high selectivity toward and capture of CO_2 with only modest energy requirements for subsequent release.

▪ **Heavy Element Chemistry**	**12,152**	**23,382**

This activity supports research in the chemistry of the heavy elements, including actinides and fission products. The unique molecular bonding of the heavy elements is explored using theory and experiment to elucidate electronic and molecular structures, bond strengths, and chemical reaction rates. Additional emphasis is placed on the chemical and physical properties of actinides to determine solution, interfacial, and solid-state bonding and reactivity; on determining chemical properties of the heaviest actinide and transactinide elements; and on bonding relationships among the actinides, lanthanides, and transition metals. Capital equipment funding is provided for items such as instruments used to characterize actinide materials (spectrometers, diffractometers, etc.) and equipment to handle the actinides safely in laboratories and at synchrotron light sources.

This activity represents the nation’s only comprehensive program that provides funding for basic research in actinide and fission product chemistry and is broadly relevant to the DOE mission. Knowledge of the chemical characteristics of actinide and fission-product materials under realistic conditions provides a basis for advanced fission fuel cycles and is coordinated with the more applied efforts within the Office of Nuclear Energy Fuel Cycle Research and Development Program. Fundamental understanding of the chemistry of these long-lived radioactive species is required to accurately predict and mitigate their transport and fate in environments associated with the storage of radioactive wastes.

In FY 2012, continued emphasis will be placed on bonding and reactivity studies in solutions,

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solids, nanoparticles, and interfaces, incorporating theory and modeling to understand, predict, and control the chemical bonding and reactivity of the heavy elements, especially under extreme conditions of temperature and radiation fields to be found in advanced nuclear energy systems. Increased study of organo-actinide chemistry may provide new insights into metal-carbon bonds with metals that have large ion sizes, f-orbital bonding, and multiple oxidation states. There is an increase for basic actinide chemistry research that is important for advanced nuclear fuel cycles with an emphasis on the complex separation chemistry addressing the multiplicity of chemical forms and oxidation states for actinides in fuels, solutions, and waste forms. The use of new characterization and computational tools, including DOE x-ray and neutron sources, nanoscale science research centers, and leadership computer platforms, will play an important enabling role in this new effort.

▪ **Geosciences Research**	**23,703**	**43,003**

This activity supports basic experimental and theoretical research in geochemistry and geophysics. Geochemical research emphasizes fundamental understanding of geochemical processes and reaction rates, focusing on aqueous solution chemistry, mineral-fluid interactions, and isotopic distributions and migration in natural systems. Geophysical research focuses on new approaches to understand the subsurface physical properties of fluids, rocks, and minerals and develops techniques for determining such properties at a distance; it seeks fundamental understanding of wave propagation physics in complex media and the fluid dynamics of complex fluids through porous and fractured subsurface rock units. Application of x-ray and neutron scattering using BES facilities plays a key role in the geochemical and geophysical studies within this activity. The activity also emphasizes incorporating physical and chemical understanding of geological processes into multiscale computational modeling. Capital equipment funding is provided for items such as x-ray and neutron scattering end stations at BES facilities for environmental samples and for augmenting experimental, field, and computational capabilities.

This activity provides the basic research in geosciences that underpins the nation's strategy for understanding and mitigating the terrestrial impacts of energy technologies and thus is relevant to the DOE mission in several ways. It develops the fundamental understanding of geological processes relevant to geological disposal options for byproducts from multiple energy technologies. Knowledge of subsurface geochemical processes is essential to determining the fate and transport properties of harmful elements from possible nuclear or other waste releases. Geophysical imaging methods are needed to measure and monitor subsurface reservoirs for hydrocarbon production or for carbon dioxide storage resulting from large-scale carbon sequestration schemes.

In FY 2012, continued emphasis will be placed on geochemical studies and computational analysis of complex subsurface fluids and solids, including nanophases; understanding the dynamics of fluid flow, particulate transport and associated rock deformation in the deep subsurface; and developing the ability to integrate multiple data types in predictions of subsurface processes and properties. There is an increase for research to improve field-scale models of the dynamics of flow and plume migration in carbon sequestration. This will emphasize better understanding of reservoir-scale geochemistry; reactive flow and transport processes and rates;

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higher resolution geophysical measurement techniques; and more accurate simulation approaches for linking geochemical processes and geophysical responses across multiple spatial scales. There is also an increase for a new effort to expand our understanding of the formation mechanisms of gas hydrates, and to understand and ultimately predict the environmental stability of hydrates at the systems level. This new hydrates effort will include simulation and experiment in areas including the intermolecular forces that govern the structure and properties of methane hydrates; multi-phase behavior of hydrate-sediment systems; and studies of methane hydrates in the natural environment.

▪ **Energy Frontier Research Centers (EFRCs)[a]**	**42,000**	**42,000**

The EFRCs established in late FY 2009 are multi-investigator and multi-disciplinary centers that foster, encourage, and accelerate basic research to provide the basis for transformative energy technologies of the future.[b] The EFRCs represent an important new research modality for BES, bringing together the skills and talents of a critical mass of investigators to enable energy relevant, basic research of a scope and complexity that would not be possible with the standard single-investigator or small-group award. The scope and unique nature of the EFRC program requires special oversight, which is accomplished through a BES-wide, dedicated EFRC management team. This team has the direct management responsibility over all EFRCs and also coordinates EFRC research with the complementary research conducted within the BES core research areas.

This activity supports those EFRCs that complement the ongoing core research activities within the Chemical Sciences, Geosciences and Biosciences subprogram. In general terms, these EFRCs are focused on the design, discovery, control, and characterization of 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; for the clean and efficient combustion of advanced transportation fuels; and for science-based carbon capture and geological sequestration. Unifying themes in the research include the fundamental understanding of interfacial phenomena underlying the transport of electrons, atoms, molecules, and energy at the nanoscale and the development and application of new experimental and theoretical tools for molecular-scale understanding of complex chemical, biochemical, and geological processes.

In FY 2012, existing EFRCs will continue their research toward these ends. In addition, ongoing efforts to bridge disciplines, generate new avenues of inquiry, and accelerate research within the broader community will continue via periodic all-hands meetings, joint symposia and workshops, summer schools, tool development, contractors' meetings, and interactions with BES program management. BES will provide further guidance to the EFRCs to help maximize their impact and effectiveness on the basis of peer reviews of their science to be conducted during FY 2012.

[a] A complementary set of EFRCs is also included in the Materials Sciences and Engineering subprogram.
[b] 16 EFRCs were forward funded for the five-year initial award period under the American Recovery and Reinvestment Act of 2009.

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▪ **Energy Innovation Hub—Fuels from Sunlight**	**0**	**24,300**

After nearly 3 billion years of evolution, nature can effectively convert sunlight into energy-rich chemical fuels using the abundant feedstocks of water and carbon dioxide. All fuels used today to power vehicles and create electricity, whether from fossil or biomass resources, are ultimately derived from photosynthesis. While biofuels are renewable resources that avoid the environmental consequences of burning the sequestered carbon of fossil fuels, their scalability and sustainability are ongoing issues. Furthermore, the overall energy efficiency of converting sunlight to plant material and then converting biomass into fuels is low. The natural photosynthetic apparatus is a remarkable machine, but plants and photosynthetic microbes were not designed to meet human energy needs—much of the energy captured from the sun is necessarily devoted to the life processes of the plants. Imagine the potential energy benefits if we could generate fuels directly from sunlight, carbon dioxide, and water in a manner analogous to the natural system, but without the need to maintain life processes. The impact of replacing fossil fuels with fuels generated directly by sunlight would be immediate and revolutionary.

Basic research has already provided enormous advances in our understanding of the subtle and complex photochemistry associated with the natural photosynthetic system. Similar advances have occurred using inorganic photo-catalytic methods to split water or reduce carbon dioxide. Yet, we still lack sufficient knowledge to design solar fuel generation systems with the required efficiency, scalability, and sustainability for economic viability. Energy Innovation Hubs are composed of a large set of investigators focused on a single critical national need identified by the Department. Hubs integrate across the full spectrum of basic and applied research and development and bring to bear a sustained effort on our most challenging energy problems. The Fuels from Sunlight Hub is intended to integrate over the technical components and the basic research to applied engineering required to ultimately develop a commercially viable solar energy to chemical fuel conversion system.

The Joint Center for Artificial Photosynthesis (JCAP) was established in FY 2010 as the DOE Fuels from Sunlight Hub through a competitive Funding Opportunity Announcement that was open to universities, DOE laboratories, for-profit companies, and nonprofit entities. JCAP aims at developing a cost-effective way to produce fuels, as plants do, by combining sunlight, water, and carbon dioxide, and would be a transformational advance in carbon-neutral energy technology. Its long-term objective is to develop and demonstrate a manufacturable solar-fuels generator, made of naturally abundant elements, that will take sunlight, water, and carbon dioxide as inputs, and robustly produce fuel from the sun 10 times more efficiently than typical current crops. Research and development in JCAP will emphasize both discovery of new components necessary to meet this objective, including new light harvesting materials and fuel-forming catalysts, and the benchmarking and integration of these components into a viable solar-fuels system.

(dollars in thousands)

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The Fuels from Sunlight Hub was initiated in FY 2010 with $22,000,000 provided through the Office of Energy Efficiency and Renewable Energy (EERE). SC/BES provided programmatic oversight for the establishment of the Fuels from Sunlight Hub, including management of the solicitation and its merit review process. In order to assess and guide the initial success of the Hub, it is subject to continuous management oversight by a dedicated Hub management team within BES. BES reviews all JCAP performance plans (space, conflict of interest, and intellectual property) and conducts monthly conference calls with JCAP to assess Hub progress. The Hub will submit formal quarterly progress reports to BES and will be subject to annual, external peer review, beginning in April 2011. BES continues to coordinate the activities of the Fuels from Sunlight Hub with the two other Energy Innovation Hubs initiated in FY 2010—Modeling and Simulation for Nuclear Reactors in the Office of Nuclear Energy and Energy Efficient Building Systems Design in EERE. In FY 2012, the Fuels from Sunlight Hub is funded at the planned annual level ($24,300,000), which will allow JCAP to function as an integrative Hub for DOE solar fuels research and to make timely progress on its objectives for the five-year award period.

▪ **General Plant Projects (GPP)**	**815**	**815**

GPP funding is provided for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems principally at the Ames Laboratory and the Combustion Research Facility at Sandia National Laboratories. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting requirements for safe and reliable facilities operation. Additional GPP funding is included in the Materials Sciences and Engineering subprogram and the Scientific User Facilities subprogram. The total estimated cost of each GPP project will not exceed $10,000,000 in FY 2012.

SBIR/STTR	**0 10,445**	

In FY 2010, $7,104,000 and $852,000 were transferred to the SBIR and STTR programs, respectively. The FY 2012 amount shown is the estimated requirements for the continuation of the congressionally mandated SBIR and STTR programs.

Total, Chemical Sciences, Geosciences, and Biosciences	**287,480**	**394,717**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Chemical Sciences, Geosciences, and Biosciences Research	
▪ **Atomic, Molecular, and Optical Science**	
Increase in funding to emphasize the development and application of new ultrafast x-ray and optical probes of matter.	+1,000

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Chemical Physics Research**	
Increase in funding to support the science-based Energy Systems Simulation - Internal Combustion Engines (ESS-ICE) initiative.	+15,000
▪ **Solar Photochemistry**	
Increase in funding to support the *Computational Materials and Chemistry by Design* effort for the development of computational methods and software tools for the simulation of light harvesting and conversion of solar energy into electricity and chemical fuels.	+12,500
▪ **Catalysis Science**	
Increase in funding to support the *Computational Materials and Chemistry by Design* effort for the development of computational methods and software tools for the simulation of photo-catalytic, fuel-forming reactions in artificial photosynthesis (+$5,000); for a complementary effort in catalytic synthesis and in situ characterization ($+2,000); and for research with focus on the chemistry of inorganic, organic, and hybrid porous materials (+$2,000).	+9,000
▪ **Separations and Analysis**	
Increased funding is provided for the development of new materials and methods for separation and capture of CO_2 from post-combustion gas streams and oxygen from air prior to oxy-combustion (+$4,000). Increase in funding to continue research with focus on fluid flow in nanoscale membranes and the formation of macroscopic separation systems (+$3,692). Decrease in funding due to realignment of projects between Separations and Analysis and Heavy Element Chemistry (-$3,230).	+4,462
▪ **Heavy Element Chemistry**	
Increase in funding for new research on actinide chemistry and separations relevant to advanced nuclear fuel cycles (+$8,000). Increase in funding due to realignment of projects between Heavy Element Chemistry and Separations and Analysis (+$3,230).	+11,230
▪ **Geosciences Research**	
Increase in funding for the research on the multiscale dynamics of flow and plume migration in carbon sequestration (+$8,000); for new research on the formation mechanism and environmental stability of methane hydrates (+$10,000); and to continue research on geochemical studies and computational analysis of complex subsurface fluids and solids (+$1,300).	+19,300

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Energy Innovation Hub – Fuels from Sunlight**	
Full annual funding is provided for the Fuels from Sunlight Hub, which has a long-term mission to develop and demonstrate a manufacturable solar-fuels generation system.	+24,300
Total, Chemical Sciences, Geosciences and Biosciences Research	**+96,792**
SBIR/STTR	
Funding for SBIR/STTR increases relative to FY 2010 because of two issues: the mandated SBIR/STTR set-asides that were transferred out of the program in FY 2010 are included in the FY 2012 request, and an increase in total operating expenses from FY 2010 to FY 2012 increases the amount of the set-aside.	+10,445
Total Funding Change, Chemical Sciences, Geosciences, and Biosciences	**+107,237**

Scientific User Facilities

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Scientific User Facilities		
Research	35,989	27,097
Major Items of Equipment	25,000	97,000
Facilities Operations	734,994	825,416
Other Project Costs	7,842	7,700
SBIR/STTR	0	21,718
Total, Scientific User Facilities	803,825	978,931

Description

This subprogram supports the R&D, planning, and operation of scientific user facilities for the development of novel nano-materials and for materials characterization through x-ray, neutron, and electron beam scattering; the former is accomplished through the Nanoscale Science Research Centers and the latter is accomplished through the world's largest suite of synchrotron radiation light source facilities, neutron scattering facilities, and electron-beam microcharacterization centers.

The BES-supported suite of facilities and research centers provides a unique set of analytical tools for studying the atomic structure and functions of complex materials. These facilities provide key capabilities to correlate the microscopic structure of materials with their macroscopic properties. The synchrotron light sources, producing photons largely over a very wide range of photon energies (from the infrared to hard x-rays), shed light on fundamental aspects of the physical world, investigating energy, momentum, and position using the techniques of spectroscopy, scattering, and imaging applied over various time scales. Neutron sources take advantage of the electrical neutrality and special magnetic properties of the neutron to probe atoms and molecules and their assembly into materials. Electron beam instruments provide the spatial resolution needed to observe individual nanostructures and even single atoms by exploiting the strong interactions of electrons with matter and the ability to readily focus beams of charged particles. The Nanoscale Science Research Centers provide the ability to fabricate complex nanostructures using chemical, biological, and other synthesis techniques, and to characterize, assemble, and integrate them into devices.

Annually, the BES user facilities are visited by more than 11,000 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. The light sources are an outstanding example of serving users from a diverse range of disciplines, including physical and life sciences. For example, the life sciences sector of the light sources users increased from less than 10% in the 1990s to approximately 40% in 2010. Also supported are research activities leading to the improvement of today's facilities and better detectors, paving the foundation for the development of next generation facilities.

Selected FY 2010 Accomplishments

- *2009 Chemistry Nobel Prize to BES Synchrotron Facilities' Users.* The 2009 Nobel Prize in Chemistry for studies on ribosome was performed at the BES supported synchrotron radiation facilities. The ribosome works as a protein factory in all life organisms. Specifically, the ribosome translates the genetic instructions encoded by DNA into chains of amino acids that make up proteins. Synchrotron radiation facilities provide intense x-rays and advanced instruments enabling the studies of ribosome structures in great details at atomic level that unlocked the secret of how this protein factory functions.
- *Linac Coherent Light Source Ready for Operation.* In June 2010, the Linac Coherent Light Source (LCLS), the world's first hard x-ray free electron laser facility became officially operational. The completion of this fourth generation Linac-based light source is a milestone for x-ray user facilities. LCLS's unique capabilities will complement that of the storage ring-based third generation synchrotron light sources. The early science program, conducting experiments during the commissioning period, has already produced world-class high-impact results such as the study of femtosecond electronic response of atoms to ultra intense x-rays led by scientists at Argonne National Laboratory (see also the FY 2010 highlight under the Chemical, Physical Biosciences, and Geosciences Program section). The first open call for proposals for LCLS beam time attracted 107 proposals involving 672 scientists from 22 countries for the fall 2010 operation period.
- *Top-off Operation at Stanford Synchrotron Radiation Light Source Delivered High Flux Stable X-rays.* The Stanford Synchrotron Radiation Light Source has recently completed a successful upgrade, making top-off operation available to user service. The top-off operation makes frequent injection of electrons into the storage ring to maintain the storage ring current at an almost constant level while continually delivering x-rays to users at all times without interruption. Instead of having two major injections of a large number of electrons per day followed by uninterrupted ring current decay, the top-off operation mode adds small number of electrons to the storage ring every few minutes to offset the ring current decay during that same period of time. The near-constant ring current enhances the flux and brightness of the radiation while simultaneously improving the thermal stability of the machine and the beamline optics. The result is more x-ray photons with better beam quality delivered to users.
- *Bilayer Graphene Gets a Bandgap.* Graphene is the two-dimensional crystalline form of carbon whose extraordinary electron mobility and other unique features hold great promise for nanoscale electronics and photonics. But without a bandgap—the fundamental physical feature that makes semiconductor electronics possible—graphene's promise can't be realized. As with monolayer graphene, bilayer graphene also has a zero bandgap and thus behaves like a metal. But a bandgap can be introduced if an electric displacement field is applied to the two layers; the material then behaves like a semiconductor. A team of researchers from Lawrence Berkeley National Laboratory has engineered a bandgap in bilayer graphene that can be precisely controlled from 0 to 250 meV. To achieve this goal they used spectroscopic data obtained at the Advanced Light Source. Coupling this newly-discovered precision bandgap control with the known ability to independently manipulate the electronic states of graphene through electrical doping makes dual-gated bilayer graphene a remarkably flexible material for the development of novel nanoscale electronic devices.
- *Discovery of Element 117.* An international team of scientists from Russia and the United States established the existence of element 117 from decay patterns observed following the bombardment of the radioactive berkelium target with calcium ions at the JINR U400 cyclotron in Dubna, Russia. The berkelilum target was produced at the High Flux Isotope Reactor. Element 117 was the only

missing element in row seven of the periodic table. This discovery provides important tests of nuclear theories and offers the possibility of further expansion of the periodic table with accompanying scientific advancements in the physics and chemistry of heavy elements.

- *More Neutrons Delivered to More Users at Spallation Neutron Source.* The Spallation Neutron Source, the world's most intense pulse accelerator based neutron source, has continued to ramp up in both capability and capacity for users. The machine is operating at one megawatt beam power with over 90% reliability. Six instruments have entered the user program, while seven additional instruments are in commissioning and six more under construction. The number of scientific proposals submitted for SNS instruments' access has doubled for FY 2010 compared with FY 2009, with a significant increase in the number of unique users in FY 2010.
- *Instrumentation Developments Advance Atom Probe Tomography at the Shared Research Equipment (SHaRE) user facility.* A novel instrument, adding a laser-pulsed evaporation capability to a modern local electrode atom probe, now makes it possible for large-band-gap insulators to be successfully analyzed. Non-conducting ceramics, such as alumina, and geological samples, such as olivine, have been successfully analyzed, surmounting the prior requirement for electrically-conducting materials and permitting the technique to be applied to most solid materials. Furthermore, a new database-dependent approach is being developed for the quantification of atom probe tomography data. The high mass resolving power of the instrument has enabled this method to be applied to resolve and identify all the peaks in the mass spectrum without user interaction, with successful application to several alloys. This new capability extends the reach of atom probe tomography to a broader range of materials, while at the same time significantly shortening the time needed for data analysis.
- *Modification of Nanowires at Center for Nanoscale Materials (CNM) Enables Catalysis with Visible Light.* Nanowires of silver are well-developed materials that have been evaluated for use as transparent conductive electrodes for photovoltaic and other electronic devices. Now research at CNM has led to an integrated processing approach to chemically convert these nanowires to silver chloride and decorate them with gold nanoparticles, changing their properties substantially and enabling them to decompose organic molecules when subjected to illumination in the visible spectrum. Ions of iron generated in the initial conversion step are utilized to reduce gold precursors, leading to the surface deposition of gold on the converted silver chloride nanowires. Resonant absorption of visible light by the metal nanoparticles then drives photocatalysis. Accelerated decomposition of the organic molecule methylene blue was documented under white-light illumination at room temperature, raising the prospect that organic contaminants could potentially be removed from water using a film of such nanowires in sunlight or under fluorescent illumination.
- *Mix-and-Match Inorganic Nanocomposites Synthesized by Solution Processing at the Molecular Foundry.* Nanocomposites that consist of ordered particle assemblies in a solid matrix can have properties and behavior that are dramatically dependent on the relative shapes, sizes, and arrangements of the constituents. Researchers at the Molecular Foundry have designed a new solution-phase chemistry approach, based on colloidal nanoparticles and soluble precursors, that is capable of producing nanoscale rods, spheres, tetrapods, and other shapes. These units can then be used to form a range of assemblies including ordered superlattices, binary assemblies of two different sizes and/or types of nanoparticles, and vertically oriented arrays of nanorods. This approach offers considerable flexibility in controlling the component materials and morphology as compared with conventional methods for nanocomposite synthesis, such as thermal- or reaction-induced microphase separation or growth of nanoparticles within a porous matrix. The team demonstrated the generality of the method by creating nanocomposites of more than 20 different

compositions, starting from assemblies of spherical or rod-shaped nanoparticles. Tailored choices of materials and nanoparticle shapes and structural assemblies can be used to address a wide range of applications, from thermoelectric energy conversion to photovoltaic cells, nanostructured battery electrodes, and data storage devices.

- *Advances in Modeling at the Center for Nanophase Materials Sciences (CNMS) Improve Calculations of Magnetic Properties of Materials*. A team led by CNMS researchers has developed code for modeling magnetic structure that has achieved 1.84 thousand trillion calculations per second (1.84 petaflops). This exceptional performance was recognized by the 2009 ACM Gordon Bell Prize, which honors the world's highest-performing scientific computing applications. The project centers on a scalable method for ab initio computation of free energies in nanoscale systems, allowing direct and accurate calculations of the temperature above which a material loses its magnetism (the Curie temperature). The approach, known as the Wang-Landau Locally Self-consistent Multiple Scattering (WL-LSMS) method, differs from earlier efforts because it sets aside empirical models and their attendant approximations to tackle the system through first-principles calculations. It builds on a combination of two methods—the locally self-consistent multiple scattering (LSMS) and a Monte Carlo method known as Wang-Landau. The combination allows extension of the calculations to technologically relevant temperatures. The project thus contributes to the search for enhanced properties and stronger, more stable magnets, with implications for advances in areas such as magnetic storage and the development of lighter, stronger motors for electric vehicles.

- *High Brightness Beams Obtained with Low Charge Injection.* Recent studies have demonstrated that high brightness photon beams can be produced by a free electron laser from electron bunches carrying small amounts of charge. These electron bunches have extremely low charge but are of very high quality, i.e., they are well collimated and packed in ultrashort intense bunches. The bunch duration is shorter than the time it takes for an atom to move a significant distance (less than 100 femtoseconds) and resulted in high brightness photon beam that can be used to take snapshots of the atomic structure of matter, opening new exciting possibilities in the understanding of novel materials. In addition, these beams alleviate the difficulties of transporting high charge electron bunches by producing high photon brightness with smaller amounts of charge. These results have contributed greatly to the successful operation of the Linac Coherent Light Source.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	**35,989**	**27,097**
▪ **Electron-beam Microcharacterization**	**11,536**	**11,536**

This activity supports three electron-beam microcharacterization centers, which operate as user facilities, work to develop next-generation electron-beam instrumentation, and conduct corresponding research. These centers are the Electron Microscopy Center for Materials Research at Argonne National Laboratory (ANL), the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory (LBNL), and the Shared Research Equipment program at Oak Ridge National Laboratory (ORNL). Operating funds are provided to enable expert scientific interaction and technical support and to administer a robust user program at these facilities, which are made

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

available to all researchers with access determined via peer review of brief proposals. Capital equipment funding is provided for instruments such as scanning, transmission, and scanning transmission electron microscopes; atom probes and related field ion instruments; related surface characterization apparatus and scanning probe microscopes; and/or ancillary tools such as spectrometers, detectors, and advanced sample preparation equipment.

Electron scattering has key attributes that give such approaches unique advantages and make them complementary to x-ray and neutron beam techniques. These characteristics include strong interactions with matter (allowing the capture of meaningful signals from very small amounts of material, including single atoms under some circumstances) and the ability to readily focus the charged electron beams using electromagnetic lenses. The net result is unsurpassed spatial resolution and the ability to simultaneously get structural, chemical, and other types of information from subnanometer regions, allowing study of the fundamental mechanisms of catalysis, energy conversion, corrosion, charge transfer, magnetic behavior, and many other processes. All of these are fundamental to understanding and improving materials for energy applications and the associated physical characteristics and changes that govern performance.

In FY 2012, full user operations continue at all three of these facilities, which are routinely available to users during normal working hours. The Transmission Electron Aberration Corrected Microscope (TEAM) instrument at the National Center for Electron Microscopy at LBNL is available to the research community 24 hours a day. It leads the world in spatial resolution and embodies the first chromatic aberration corrector in an instrument of this kind, and thus its availability opens new frontiers in imaging of materials on the nanoscale for the broad scientific community. Further research and technique development proceeds using this and other instruments at the Electron Beam Microcharacterization Centers on high-resolution imaging, atomic scale tomography, in situ experimentation within electron microscopes, strain and segregation in individual nanostructures, and many other related topics.

▪ **Accelerator and Detector Research**	**15,561**	**15,561**

This activity supports basic research in accelerator physics and x-ray and neutron detectors. Accelerator research is the corner stone for the development of new technologies that will improve performance of light sources and neutron spallation facilities. This research will explore new areas of science and technologies that will facilitate the construction of next generation accelerator-based user facilities. Detector research is a crucial, but often overlooked, component in the optimal utilization of user facilities. This research program is investing aggressively in research leading to a new and more efficient generation of photon and neutron detectors. Research includes studies on creating, manipulating, transporting, and performing diagnostics of ultra-high brightness beam behavior from its origin at a photocathode to its travel through undulators. Studies on achieving sub-femtosecond (hundreds of attoseconds) free electron laser (FEL) pulses will also be underway. Demonstration experiments will take place in advanced FEL seeding techniques, such as echo-enhanced harmonic generation and other optical manipulation to reduce the cost and complexity of seeding harmonic generation FELs. A very high frequency laser photocathode radio frequency (RF) gun using a room temperature cavity will be developed which can influence the design of linac-based FELs with megahertz rates. An application will be funded for construction and testing of a

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

superconducting RF electron gun that has the potential to be the cornerstone of a future high average power FEL that combines peak performance and high average flux. Research will be done on timing and synchronization of RF and laser sources for seeded Long-wave UV (LUV) or x-ray FELs and efficient generations of seed radiation. Studies will continue on collective electron effects, such as micro-bunch instabilities from coherent synchrotron and edge radiation; beam bunching techniques, such as magnetic compression or velocity bunching; fast instruments to determine the structure of femtosecond electron bunches; and detectors capable of acquiring x-ray and neutron scattering data at very high collection rates.

This activity interacts with BES scientific research that employs synchrotron and neutron sources. It also coordinates with other DOE offices, especially in the funding of capabilities whose cost and complexity require shared support. Research at the Accelerator Test Facility at Brookhaven National Laboratory is jointly funded by the High Energy Physics and BES programs. There is also planned collaboration with the National Science Foundation (NSF) on energy recovery linac (ERL) research. There is a coordinated effort between DOE and NSF to facilitate x-ray detector development. There are ongoing industrial interactions through the DOE Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) programs for the development of x-ray detectors and advanced accelerator technology.

In FY 2012, continued support will be provided to develop a superconducting RF electron gun that has the potential to achieve combined peak performance and high average flux. Research will continue on timing and synchronization of RF and laser sources for seeded LUV or x-ray FELs, and on efficient generations of seeded radiation. Support will also be given to the investigation of the dynamics of beam and FEL physics in the attosecond regime and the inherent challenges of creating, manipulating, transporting, and diagnosing ultra-high brightness electron beams to drive advanced light sources. A major aspect of the program support will be the need to develop light sources with new capabilities that are less costly and more compact.

▪ **General Plant Projects (GPP)**	**8,892**	**0**

GPP funding is provided in FY 2010 for the ORNL Guest House. The Guest House is designed to meet the needs of the guest users coming to perform research at ORNL's world class DOE scientific user facilities (SNS, CNMS, HFIR, SHaRE, etc.). No funds are requested in FY 2012.

Major Items of Equipment	**25,000**	**97,000**
▪ **Spallation Neutron Source Instrumentation I (SING I)**	**5,000**	**0**

Funding for the Spallation Neutron Source Instrumentation I (SING I) is completed. The Total Project Cost is $68,500,000.

▪ **Spallation Neutron Source Instrumentation II (SING II)**	**18,000**	**11,500**

Funds are provided to continue a Major Item of Equipment with an approved CD-2 Performance Baseline Total Project Cost of $60,000,000 to fabricate four instruments to be installed at the SNS. The instrument concepts for the project have been competitively selected using a peer review

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

process. The project is managed by Oak Ridge National Laboratory.. The SING II instruments are in addition to the five instruments to be provided by the SING I project. The FY 2012 request supports the continued fabrication and installation of these instruments.

▪ **SNS Power Upgrade Project (PUP)**	**2,000**	**5,500**

Funds are provided for a Major Item of Equipment with a preliminary Total Project Cost range of $89,600,000–$96,100,000 for activities to design, build, install, and test the equipment necessary to increase the Spallation Neutron Source (SNS) proton beam energy. CD-1 was approved on January 16, 2009. In addition to the improvements in performance of instruments at the existing high power target station, this power upgrade will enable the eventual construction of a second target station. The existing facility layout and much of the existing SNS equipment was designed and built to meet the requirements of this upgrade.

The power upgrade project increases the linac beam energy from 1 GeV to 1.3 GeV. This will be accomplished by adding nine additional high beta cryomodules into the remaining nine open slots in the east end of the superconducting section of the linac. These additional cryomodule units will increase the number of high beta units from twelve to twenty one, allowing the energy to increase. The accelerator tunnel structure and cryogenic system were constructed to allow this upgrade.

FY 2012 Request supports continued engineering design of the accelerator sub-systems and project management.

▪ **Advanced Photon Source Upgrade (APS-U) 0 20,000**

The FY 2012 Request provides funds for a Major Item of Equipment with a preliminary Total Project Cost range of $300,000,000-$400,000,000 for activities to design, build, install, and test the equipment necessary to upgrade an existing third-generation synchrotron light source facility, the Advanced Photon Source (APS). Mission Need (CD-0) was approved on April 22, 2010. The APS is one of the Nation's most productive x-ray light source facilities, serving over 3500 users annually and providing key capabilities to enable forefront scientific research in a broad range of fields of physical and biological sciences. The APS is the only 7 GeV source in the U.S. and is only one of three in the world. There are only two international light sources in the class of the APS; these are the ESRF in France and SPring-8 in Japan. Both facilities, commissioned at about the same time as the APS, are well into campaigns of major upgrades due to aging of beamlines as well as technological advancements in accelerator science. With the ever increasing demand for higher penetration powers for probing real-world materials and applications, the higher energy "hard" x-rays ($E \geq 20$ keV) produced at APS provides unique capabilities in the arsenal needed for tackling the grand science and energy challenges of the 21st century—fulfilling a vision that humankind will develop materials and machines to satisfy our need for sustainable energy, healthy lives, and a thriving economy. The APS-U Project will provide an unprecedented combination of high-energy, high-average-brilliance, high flux, and short-pulse hard x-rays together with state-of-the-art x-ray beamline instrumentation. The APS-U's high-energy penetrating x-rays will provide a unique scientific capability directly relevant to problems in energy, the environment, new or improved materials, and biological studies. High-energy x-rays can penetrate into a wide range of realistic and/or extreme environments and allow us to image structures and processes in unprecedented detail.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

An upgraded APS would overcome the limitations at existing high-energy x-ray sources that prevent the simultaneous realization of nanometer spatial resolution and picosecond temporal resolution that is essential for probing and controlling a number of fundamental physical processes. The upgraded APS will complement the capabilities of the 4^{th} generation light sources, which occupy different spectral, flux, and temporal range of technical specifications. The project is managed by Argonne National Laboratory.

The FY 2012 Request supports conceptual and preliminary engineering design and project management activities.

- **Linac Coherent Light Source II (LCLS-II)** **0 30,000**

The FY 2012 Request provides funds for a Major Item of Equipment with a preliminary Total Project Cost range of $300,000,000-$400,000,000 for activities to design, build, install, and test the equipment that builds on the basic capabilities provided by LCLS, the world's first x-ray free electron laser (FEL), and exploit advances in technology and scientific understanding for significant improvements in capabilities and capacity. The LCLS was designed to support rapid extension of its capabilities and capacity, so as to remain the world's preeminent x-ray FEL facility even as new facilities around the world are constructed. The upgraded project (LCLS-II) will build upon the known characteristics of LCLS yet enable technologies for reaching into spectral regions not addressed by LCLS. It also provides unprecedented x-ray properties for combined control of spatial, temporal, and energy resolution that will enable groundbreaking research in a wide range of scientific disciplines, from advanced materials to energy and life sciences. Mission Need (CD-0) was approved on April 22, 2010. LCLS-II will provide extended spectral range for new applications in all scientific disciplines. The extension of the lower limit of the spectral range, and achievement of the ability to fine tune the x-ray energy, will create significant new scientific opportunities. For example, these upgrades will allow LCLS-II to reach energies that will reveal the chemistry of carbon, nitrogen, and oxygen underlies some of the most important processes in our world, such as photosynthesis involving catalytic reactivity between molecules containing carbon and oxygen.

U.S. leadership in FEL x-ray science will be challenged as competing foreign facilities are upgraded and come on-line in Germany and Japan in the 2011-2015 time frame. Upgrading the LCLS is an important next step for the U.S. to maintain world leadership in photon science by providing a suite of complementary facilities/tools covering the x-ray energy spectrum with diverse timing capabilities.

The FY 2012 request supports conceptual and preliminary engineering design and project management.

- **NSLS-II Experimental Tools (NEXT)** **0** **12,000**

The FY 2012 Request provides funds for a Major Item of Equipment with a preliminary Total Project Cost range of $50,000,000-$90,000,000 for activities to design, build, install, and test the equipment necessary to add beamlines to the National Synchrotron Light Source II (NSLS-II) Project. Mission Need (CD-0) was approved on May 27, 2010. 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

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

instrumentation will significantly increase the scientific quality and productivity of NSLS-II. In addition, the NEXT project will enable and enhance more efficient operations of NSLS-II.

The FY 2012 Request supports conceptual and preliminary engineering design of the beamlines and project management.

▪ **Transmission Electron Aberration-Corrected Microscope II (TEAM II)**	**0**	**18,000**

Funds are provided for a Major Item of Equipment (MIE) with a preliminary Total Project Cost of $18,000,000 for the development, design, acquisition, installation, and testing of an advanced transmission electron microscope with novel environmental, dynamic, spectroscopic, and/or other capabilities. The original TEAM I instrument, completed and made available to users in FY 2009, was designed with an emphasis on extending spatial resolution to new limits by fully integrating the correction of lens aberrations, and set new records in that regard. It was intended as the first of a new generation of world-leading instruments, serving as a platform for developing additional microscopes tailored to other characterization needs. The development of such electron optical beamlines is analogous to the development of beamlines with varying functionalities at x-ray and neutron sources.

This TEAM II MIE will produce a new microscope that incorporates many of the component innovations in the initial instrument, but will be optimized differently to provide complementary functionality. The completed instrument would be incorporated in a BES user facility. Several approaches are being evaluated that would address the recommendations of a BES workshop on the topic, *Future Science Needs and Opportunities for Electron Scattering: Next-Generation Instrumentation and Beyond.* To address the scientific challenges identified there, high-priority directions include dramatic expansion of the range of in-situ conditions (temperatures, pressures, electromagnetic fields, fluid environments) under which materials can be studied, challenges of examining soft (such as polymeric and biological or biomimetic) materials and hard/soft interfaces, and improved temporal resolution for observation of dynamic processes. These capabilities will be especially critical for exploring the unit processes and phenomena involved in clean energy technologies.

The FY 2012 Request supports the design and fabrication of the TEAM II MIE.

Facilities Operations	**734,994**	**825,416**

This activity supports the operation of the BES scientific user facilities, which consist of light sources, neutron sources, nanoscience centers, and the Linac Coherent Light Source free electron laser at SLAC. These forefront research facilities require resource commitments well beyond the scope of any non-government institution and open up otherwise inaccessible facets of Nature to scientific inquiry. The BES user facilities provide open access to specialized instrumentation and expertise that enable scientific users from universities, national laboratories, and industry to carry out experiments and develop theories that could not be done at their home institutions. For approved, peer-reviewed projects, operating time is available without charge to researchers who intend to publish their results in the open literature. These large-scale user facilities—many of which were justified and built to serve a specific discipline of the physical sciences—have made significant contributions to many other fields of

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

importance, including biology and medicine. The number of users for the synchrotron radiation sources and neutron scattering facilities are shown at the end of this subprogram description.

The FY 2012 budget request provides continued support for the operations of the BES scientific user facilities at an optimal level. The FY 2012 request includes additional funds for procurement of accelerator, beamline, and/or other capital equipment instrumentation to advance research capabilities for clean energy technologies. The expansion of capabilities to examine and characterize materials "at scale" and under a wide range of operating conditions across the suite of BES facilities supports key priority research directions of the BESAC Science for Energy Technology report.

The facility operations budget request includes operating funds, capital equipment, and accelerator and reactor improvement project (AIP) funding under $5,000,000. AIP funding will support additions and modifications to accelerator and reactor facilities. General plant project (GPP) funding is also required for minor new construction; for other capital alterations and additions; and for improvements to land, buildings, and utility systems. The total estimated cost of each GPP project will not exceed $10,000,000. Capital equipment is needed to maintain optimal operation at the facilities. Items include beam monitors, interlock systems, vacuum systems, beamline front end components, optical components, and new equipment at the NSRCs. A summary of the funding for the facilities is provided below.

	FY 2010	FY 2012
All Facilities		
Achieved Operating Hours	32,562	N/A
Planned Operating Hours	32,200	38,800
Optimal Hours	34,100	39,400
Percent of Optimal Hours	95%	98%
Unscheduled Downtime	6%	<10%
Number of Users	12,725	13,240

▪ **Synchrotron Radiation Light Sources**	**371,977**	**426,910**
Advanced Light Source, LBNL	60,119	71,000
Advanced Photon Source, ANL	128,275	145,050
National Synchrotron Light Source, BNL	39,000	40,725
Stanford Synchrotron Radiation Light Source, SLAC	33,950	42,235
Linac Coherent Light Source (LCLS), SLAC	16,633	127,900
Linac for LCLS, SLAC	94,000	0

The unique properties of synchrotron radiation include its continuous spectrum, high flux and brightness, and in the case of the Linac Coherent Light Source, high coherence, which makes it an indispensable tool in the exploration of matter. 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.

Researchers use a variety of experimental techniques when applying synchrotron radiation to their own problems. The fundamental parameters that we use to perceive the physical world (energy, momentum, position, and time) correspond to three broad categories of synchrotron experimental measurement techniques: spectroscopy, scattering, and imaging. By exploiting the short pulse lengths of synchrotron radiation, each technique can also be performed in a timing fashion.

In FY 2012, funds are provided to continue operations of the synchrotron radiation light sources. The budget also reflects an increase in the beamline and accelerator operations hours as well as user support at the LCLS as it ramps up its user program in its second full year of operations with four of the six instruments in full user service mode. Funding is also provided for capital equipment at the facilities for items such as beam monitors, interlock systems, vacuum transport systems, beamline front ends, optical components, and detectors. Additional funding will support beamline upgrades and instrumentation at BES light sources. The new and upgraded resources will enhance research opportunities for clean energy technologies.

	FY 2010	FY 2012
Advanced Light Source		
Achieved Operating Hours	5,843	N/A
Planned Operating Hours	5,500	5,600
Optimal Hours	5,600	5,600
Percent of Optimal Hours	104%	100%
Unscheduled Downtime	4.6%	<10%
Number of Users	2,032	2,300
Advanced Photon Source		
Achieved Operating Hours	4,925	N/A
Planned Operating Hours	5,000	5,000
Optimal Hours	5,000	5,000
Percent of Optimal Hours	98%	100%
Unscheduled Downtime	1.5%	<10%
Number of Users	3,796	3,800
National Synchrotron Light Source		
Achieved Operating Hours	5,735	N/A
Planned Operating Hours	5,300	5,400

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

	FY 2010	FY 2012
Optimal Hours	5,400	5,400
Percent of Optimal Hours	106%	100%
Unscheduled Downtime	4%	<10%
Number of Users	2,229	2,200
Stanford Synchrotron Radiation Light Source		
Achieved Operating Hours	4,870	N/A
Planned Operating Hours	5,300	5,400
Optimal Hours	5,400	5,400
Percent of Optimal Hours	90%	100%
Unscheduled Downtime	4.5%	<10%
Number of Users	1,436	1,400
Linac Coherent Light Source		
Achieved Operating Hours	0	N/A
Planned Operating Hours	0	5,000
Optimal Hours	0	5,000
Percent of Optimal Hours	0	100%
Unscheduled Downtime	0	<10%
Number of Users	359	450

	FY 2010 Current Appropriation	FY 2012 Request
▪ **High-Flux Neutron Sources**	**257,850**	**276,881**
High Flux Isotope Reactor, ORNL	60,000	68,291
Intense Pulsed Neutron Source, ANL	4,000	2,000
Manuel Lujan, Jr., Neutron Scattering Center, LANL	11,350	11,730
Spallation Neutron Source, ORNL	182,500	194,860

Neutrons are a unique and effective tool for probing the structure of matter. Beams of neutrons are particularly well-suited for measurement of the positions as well as the fluctuations in the positions of atomis (phonons), and the structure (position and direction) of atomic magnetic moments in solids and the excitations in their magnetic structure (spin waves). Such studies allow physicists to take measurements leading to an understanding of phenomena such as melting, magnetic order, and superconductivity in a variety of materials.

(dollars in thousands)

FY 2010 Current Appropriation	FY 2012 Request

In FY 2012, funds are provided to continue optimal operations of the neutron sources, which are routinely available to users during normal operating hours. The funding will support the operations of additional beamlines that are coming online at the Spallation Neutron Source at ORNL. The Intense Pulsed Neutron Source is closed and funds are provided to complete decommissioning of the target assembly. Additional funding will support beamline upgrades and instrumentation at BES neutron sources. The new and upgraded resources will enhance research opportunities for clean energy technologies. Additional funding will also enhance SNS and HFIR operations for clean energy.

	FY 2010	FY 2012
High Flux Isotope Reactor		
Achieved Operating Hours	4,034	N/A
Planned Operating Hours	3,500	4,500
Optimal Hours	4,500	4,500
Percent of Optimal Hours	78%	100%
Unscheduled Downtime	0%	<10%
Number of Users	375	450
Manuel Lujan, Jr. Neutron Scattering Center		
Achieved Operating Hours	2,905	N /A
Planned Operating Hours	3,000	3,000
Optimal Hours	3,600	3,600
Percent of Optimal Hours	81%	83%
Unscheduled Downtime	15%	<10%
Number of Users	325	350
Spallation Neutron Source		
Achieved Operating Hours	4,250	N/A
Planned Operating Hours	4,600	4,900
Optimal Hours	4,600	4,900
Percent of Optimal Hours	92%	100%
Unscheduled Downtime	14%	<10%
Number of Users	430	750

	FY 2010 Current Appropriation	FY 2012 Request
▪ **Nanoscale Science Research Centers (NSRCs)**	**105,167**	**121,625**
Center for Nanophase Materials Sciences, ORNL	20,641	24,360
Center for Integrated Nanotechnologies, SNL/LANL	21,290	23,565
Molecular Foundry, LBNL	20,833	24,280
Center for Nanoscale Materials, ANL	21,570	24,810
Center for Functional Nanomaterials, BNL	20,833	24,610

(dollars in thousands)

The NSRCs are DOE's premier user centers for interdisciplinary research at the nanoscale, serving as the basis for a national program that encompasses new science, new tools, and new computing capabilities. Each center has particular expertise and capabilities in selected theme areas, such as synthesis and characterization of nanomaterials; catalysis; theory, modeling and simulation; electronic materials; nanoscale photonics; soft and biological materials; imaging and spectroscopy; and nanoscale integration. The centers are housed in recently-constructed and 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. These facilities are routinely made available to the research community during normal working hours.

In FY 2012 funds are provided to continue operations for the five NSRCs, which are routinely available to users during normal operating hours. Funding is also provided for capital equipment at the facilities for nanofabrication and characterization, and computer modeling. Additional funding will support instrumentation at the BES Nanoscale Science Research Centers. The new and upgraded resources will enhance research opportunities for clean energy technologies.

	FY 2010	FY 2012
Number of Users[a]		
Center for Nanophase Materials Sciences	360	380
Center for Integrated Nanotechnologies	358	380
Molecular Foundry	274	350
Center for Nanoscale Materials	470	380
Center for Functional Nanomaterials	281	350

Other Project Costs	**7,842**	**7,700**
National Synchrotron Light Source-II, BNL	2,000	7,700
Linac Coherent Light Source (LCLS), SLAC	5,842	0

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

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

Other Project Costs (OPC) are associated with line-item construction or major item of equipment projects and include all project costs that are not identified in the Total Estimated Cost. Total Estimated Cost includes project costs incurred after Critical Decision-1 such as costs associated with the acquisition of land and land rights; engineering, design, and inspection; direct and indirect construction/fabrication; and the initial equipment necessary to place the plant or installation in operation. Generally, OPC are costs 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. Other Project Costs are always operating funds.

Funds are requested in FY 2012 for other project costs associated with the National Synchrotron Light Source-II, BNL.

SBIR/STTR	**0**	**21,718**

In FY 2010, $17,891,000 and $2,147,000 were transferred to the SBIR and STTR programs, respectively. The FY 2012 amount shown is the estimated requirement for the continuation of the congressionally mandated SBIR and STTR programs.

Subtotal, Scientific User Facilities	**803,825**	**978,931**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **General Plant Projects**	
No GPP is requested in FY 2012. Funding for the ORNL Guest House project was completed in FY 2010.	-8,892
Major Items of Equipment	
▪ **Spallation Neutron Source Instrumentation I (SING I)**	
Funding for the Major Item of Equipment for the Spallation Neutron Source Instrumentation I is completed by FY 2012.	-5,000
▪ **Spallation Neutron Source Instrumentation II (SING II)**	
Scheduled decrease for the Major Item of Equipment for the Spallation Neutron Source Instrumentation II.	-6,500
▪ **SNS Power Upgrade Project (PUP)**	
Scheduled increase for the Major Item of Equipment for the SNS Power Upgrade Project	+3,500

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Advanced Photon Source Upgrade (APS-U)**	
Initiate the Major Item of Equipment for the Advanced Photon Source Upgrade Project.	+20,000
▪ **Linac Coherent Light Source II (LCLS II)**	
Initiate the Major Item of Equipment for the Linac Coherent Light Source II Project.	+30,000
▪ **NSLS-II Experimental Tools (NEXT)**	
Initiate the Major Item of Equipment for the NSLS-II Experimental Tools Project.	+12,000
▪ **Transmission Electron Aberration-Corrected Microscope II (TEAM II)**	
Initiate the Major Item of Equipment for the Transmission Electron Aberration-Corrected Microscope II Project.	+18,000
Total, Major Items of Equipment	**+72,000**
Facilities Operations	
▪ **Synchrotron Radiation Light Sources**	
• Increase for the Advanced Light Source to support accelerator operations and users (+$2,881). Increase also requested to support beamline upgrades and instrumentation (+$8,000).	+10,881
• Increase for Advance Photon Source to support accelerator operations and users (+$7,775). Increase also requested to support beamline upgrades and instrumentation (+$9,000).	+16,775
• Increase for National Synchrotron Light Source to support accelerator operations and users.	+1,725
• Increase for the Stanford Synchrotron Radiation Light Source to support accelerator operations and users (+$1,285). Increase also requested to support beamline upgrades and instrumentation (+$7,000).	+8,285
• Increase for the Linac Coherent Light Source to support accelerator operations and users.	+17,267
Total, Synchrotron Radiation Light Sources	**+54,933**
▪ **High-Flux Neutron Source**	
• Increase for High Flux Isotope Reactor to support reactor operations (+$2,291). Increase also requested to support beamline upgrades (+$4,000) and enhance HFIR operations for clean energy (+$2,000).	+8,291

	FY 2012 vs. FY 2010 Current Approp. ($000)
• Planned decrease for the Intense Pulsed Neutron Source to finish decommissioning of the target assembly.	-2,000
• Increase for Manuel Lujan, Jr. Neutron Scattering Center to support target operations and users.	+380
• Increase for Spallation Neutron Source for new operating beamlines and to support operations and users (+$5,360). Increase also requested to support beamline upgrades (+4,000) and enhance SNS operations for clean energy (+$3,000).	+12,360
Total, High-Flux Neutron Sources	**+19,031**
▪ **Nanoscale Science Research Centers**	
• Increase for the Center for Nanophase Materials Sciences to support operations and users (+$719). Increase also requested to support instrumentation (+$3,000).	+3,719
• Increase also requested to support instrumentation (+$3,000). Decrease for the Center for Integrated Nanotechnologies due to one-time capital equipment funds provided in FY 2010 (-$725).	+2,275
• Increase for the Molecular Foundry to support operations and users (+$447). Increase also requested to support instrumentation (+$3,000).	+3,447
• Increase for the Center to Nanoscale Materials to support operations and users (+$240). Increase also requested to support instrumentation (+3,000).	+3,240
• Increase for the Center for Functional Nanomaterials to support operations and users (+$777). Increase also requested to support instrumentation (+$3,000).	+3,777
Total, Nanoscale Science Research Centers	**+16,458**
Total, Facilities Operations	**+90,422**
Other Project Costs	
▪ Increase for National Synchrotron Light Source-II per the project schedule.	+5,700
▪ Decrease for the Linac Coherent Light Source due to completion of project.	-5,842
Total, Other Project Costs	**-142**
SBIR/STTR	
Funding for SBIR/STTR increases relative to FY 2010 because of two issues: 1) the mandated SBIR/STTR set-asides that were transferred out of the program in FY 2010 are included in the FY 2012 request, and 2) an increase in total operating expenses from FY 2010 to FY 2012 increases the amount of the set-aside..	+21,718
Total Funding Change, Scientific User Facilities	**+175,106**

Construction

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Construction		
National Synchrotron Light Source-II, BNL	139,000	151,400
Linac Coherent Light Source, SLAC	15,240	0
Total, Construction	154,240	151,400

Description

Experiments in support of basic research require construction of state-of-the-art facilities and/or that existing facilities be modified to meet unique research requirements. Reactors, x-ray light sources, and pulsed neutron sources are among the expensive, but necessary, facilities used. The budget for the BES program includes funding for the construction and modification of these facilities.

The new facility that is under construction—the National Synchrotron Light Source-II—continues the tradition of BES and SC providing the most advanced scientific user facilities for the nation's research community in the most cost effective way. The Linac Coherent Light Source completed Critical Decision 4, Approve Start of Operations in FY 2010. All of the BES construction projects are conceived and planned with the broad user community and, during construction, are maintained on schedule and within cost. Furthermore, the construction projects all adhere to the highest standards of safety. These facilities will provide the research community with the tools to fabricate, characterize, and develop new materials and chemical processes to advance basic and applied research across the full range of scientific and technological endeavor, including chemistry, physics, earth science, materials science, environmental science, biology, and biomedical science.

Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
National Synchrotron Light Source-II (NSLS-II), BNL	**139,000**	**151,400**

The National Synchrotron Light Source-II (NSLS-II) will be a new synchrotron light source highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It will also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these will enable the study of material properties and functions with a spatial resolution of about 1 nm, an energy resolution of about 0.1 meV, and the ultra-high sensitivity required to perform spectroscopy on a single molecule. The NSLS-II project will design, build, and install the accelerator hardware, experimental apparatus, civil construction, and central facilities, including offices and laboratories required to produce a new synchrotron light source.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

It includes a third generation storage ring, full energy injector, experimental areas, an initial suite of scientific instruments, and appropriate support equipment, all housed in a new building.

In FY 2012 construction funding will be used to continue civil construction activities and advance experimental and accelerator systems.

Additional information is provided in the construction project data sheet 07-SC-06.

Beyond the scope of the NSLS-II construction project, an instrument development program will be initiated in FY 2012 (the NSLS-II Experimental Tools [NEXT] project) to address new advanced experimental techniques that will go beyond the six initial instruments funded by the project.

Linac Coherent Light Source, SLAC	**15,240**	**0**

The Linac Coherent Light Source (LCLS) Project provides laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak brightness than any existing coherent x-ray light source. The LCLS Project provides the first demonstration of an x-ray free electron laser (FEL) in the 1.5-15 Angstrom range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems described below. This is the world's first such facility. The LCLS has properties vastly exceeding those of earlier x-ray sources (both synchrotron radiation light sources and so-called table-top x-ray lasers) in three key areas: peak brightness, coherence (i.e., laser-like properties), and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons, providing 1011 x-ray photons in a pulse with duration of less than 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific application in the chemical, material, and biological sciences.

In FY 2010, funds completed construction and commissioning of the final elements of the project. No FY 2012 funding is requested.

Total, Construction	**154,240**	**151,400**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
National Synchrotron Light Source-II (NSLS II), BNL	
Increase in funding to continue construction of the NSLS II project, as scheduled.	+12,400
Linac Coherent Light Source, SLAC	
Decrease in funding for the Linac Coherent Light Source, project complete.	-15,240
Total Funding Change, Construction	**-2,840**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Operating Expenses	1,321,471	1,590,408
Capital Equipment	81,324	195,227
General Plant Projects	19,363	4,065
Accelerator Improvement Projects	22,570	43,900
Construction	154,240	151,400
Total, Basic Energy Sciences	1,598,968	1,985,000

Funding Summary

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	663,428	858,137
Scientific User Facilities Operations	734,994	825,416
Major Items of Equipment	25,000	97,000
Construction Projects (includes OPC)	162,082	159,100
Other	13,464	45,347
Total, Basic Energy Sciences	1,598,968	1,985,000

Scientific User Facility Operations

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Light Source User Facilities		
Advanced Light Source, LBNL	60,119	71,000
Advanced Photon Source, ANL	128,275	145,050
National Synchrotron Light Source, BNL	39,000	40,725
Stanford Synchrotron Radiation Light Source, SLAC	33,950	42,235
Linac Coherent Light Source (LCLS), SLAC	16,633	127,900
Linac for LCLS, SLAC	94,000	0
Total, Light Sources User Facilities	371,977	426,910

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Neutron Source User Facilities		
High Flux Isotope Reactor, ORNL	60,000	68,291
Intense Pulsed Neutron Source, ANL	4,000	2,000
Manuel Lujan, Jr. Neutron Scattering Center, LANL	11,350	11,730
Spallation Neutron Source, ORNL	182,500	194,860
Total, Neutron Source User Facilities	257,850	276,881
Nanoscale Science Research Center User Facilities		
Center for Nanophase Materials Sciences, ORNL	20,641	24,360
Center for Integrated Nanotechnologies, SNL/LANL	21,290	23,565
Molecular Foundry, LBNL	20,833	24,280
Center for Nanoscale Materials, ANL	21,570	24,810
Center for Functional Nanomaterials, BNL	20,833	24,610
Total, Nanoscale Science Research Center User Facilities	105,167	121,625
Total, Scientific User Facility Operations	734,994	825,416

Facilities Users and Hours

	FY 2010 Current Appropriation	FY 2012 Request
Advanced Light Source		
Achieved Operating Hours	5,843	N/A
Planned Operating Hours	5,500	5,600
Optimal Hours	5,600	5,600
Percent of Optimal Hours	104%	100%
Unscheduled Downtime	4.6%	<10%
Number of Users	2,032	2,300
Advanced Photon Source		
Achieved Operating Hours	4,925	N/A
Planned Operating Hours	5,000	5,000
Optimal Hours	5,000	5,000
Percent of Optimal Hours	98%	100%
Unscheduled Downtime	1.5%	<10%
Number of Users	3,796	3,800

	FY 2010 Current Appropriation	FY 2012 Request
National Synchrotron Light Source		
Achieved Operating Hours	5,735	N/A
Planned Operating Hours	5,300	5,400
Optimal Hours	5,400	5,400
Percent of Optimal Hours	106%	100%
Unscheduled Downtime	4%	<10%
Number of Users	2,229	2,200
Stanford Synchrotron Radiation Light Source		
Achieved Operating Hours	4,870	N/A
Planned Operating Hours	5,300	5,400
Optimal Hours	5,400	5,400
Percent of Optimal Hours	90%	100%
Unscheduled Downtime	4.5%	<10%
Number of Users	1,436	1,400
Linac Coherent Light Source		
Achieved Operating Hours	0	N/A
Planned Operating Hours	0	5,000
Optimal Hours	0	5,000
Percent of Optimal Hours	0	100%
Unscheduled Downtime	0	<10%
Number of Users	359	450
High Flux Isotope Reactor		
Achieved Operating Hours	4,034	N/A
Planned Operating Hours	3,500	4,500
Optimal Hours	4,500	4,500
Percent of Optimal Hours	90%	100%
Unscheduled Downtime	0%	<10%
Number of Users	375	450

	FY 2010 Current Appropriation	FY 2012 Request
Manuel Lujan, Jr. Neutron Scattering Center		
Achieved Operating Hours	2,905	N/A
Planned Operating Hours	3,000	3,000
Optimal Hours	3,600	3,600
Percent of Optimal Hours	81%	83%
Unscheduled Downtime	15%	<10%
Number of Users	325	350
Spallation Neutron Source		
Achieved Operating Hours	4,250	N/A
Planned Operating Hours	4,600	4,900
Optimal Hours	4,600	4,900
Percent of Optimal Hours	92%	100%
Unscheduled Downtime	14%	<10%
Number of Users	430	750
Center for Nanophase Materials Sciences[a]		
Number of Users	360	380
Center for Integrated Nanotechnologies[a]		
Number of Users	358	380
Molecular Foundry[a]		
Number of Users	274	350
Center for Nanoscale Materials[a]		
Number of Users	470	380
Center for Functional Nanomaterials[a]		
Number of Users	281	350
Total, All Facilities		
Achieved Operating Hours	32,562	N/A
Planned Operating Hours	32,200	38,800

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

	FY 2010 Current Appropriation	FY 2012 Request
Optimal Hours	34,100	39,400
Percent of Optimal Hours	95%	98%
Unscheduled Downtime	6%	<10%
Number of Users	12,725	13,240

Major Items of Equipment

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Spallation Neutron Source Instrumentation I, ORNL						
TEC/TPC	63,100	5,000	400	0	0	68,500
Spallation Neutron Source Instrumentation II, ORNL						
TEC/TPC	13,500	18,000	17,000	11,500	0	60,000
SNS Power Upgrade Project , ORNL						
TEC/TPC	0	2,000	5,000	5,500	83,600	TBD
Advanced Photon Source Upgrade (APS-U), ANL						
TEC/TPC	0	0	0	20,000	TBD	TBD
Linac Coherent Light Source II (LCLS-II), SLAC						
TEC/TPC	0	0	0	30,000	TBD	TBD
NSLS-II Experimental Tools (NEXT)						
TEC/TPC, BNL	0	0	0	12,000	TBD	TBD
Transmission Electron Aberration-corrected Microscope II (TEAM II)						
TEC/TPC, TBD	0	0	0	18,000	0	18,000
Total, Major Items of Equipment						
TEC/TPC		25,000	22,400	97,000		

Construction Projects

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
07-SC-06, National Synchrotron Light Source-II, BNL						
TEC	276,000	139,000	151,600	151,400	73,200	791,200
OPC	57,800	2,000	1,500	7,700	51,800	120,800
TPC	333,800	141,000	153,100	159,100	125,000	912,000
05-R-320 Linac Coherent Light Source, SLAC						
TEC	336,760	15,240	0	0	0	352,000[a]
OPC	56,500	5,842	0	0	0	62,342[b]
TPC	393,260	21,082	0	0	0	414,342[b]
Total, Construction						
TEC		154,240	151,600	151,400		
OPC		7,842	1,500	7,700		
TPC		162,082	153,100	159,100		

Scientific Employment

	FY 2010 Actual	FY 2012 Estimate
# of University Grants	1,210	1,480
Average Size per year	175,000	200,000
# Permanent Ph.D's (FTEs)	4,670	5,700
# Postdoctoral Associates (FTEs)	1,300	1,650
# Graduate Students (FTEs)	2,050	2,600

[a] Includes $35,974,000 of PED included in the 03-SC-002 PED, SLAC, Linac Coherent Light Source data sheet.
[b] The TPC has been reduced due to favorable performance, especially in commissioning, which allowed the project to finish one month ahead of schedule, and under the budgeted TPC of $420,000,000 for project. Remaining OPC funds were transferred to LCLS Operations.

07-SC-06, National Synchrotron Light Source II (NSLS-II)
Brookhaven National Laboratory, Upton, New York
Project Data Sheet is for PED/Construction

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-3, Start of Construction, which was approved on January 9, 2009, with a Total Project Cost (TPC) of $912,000,000. The project is approximately two years past CD-3 approval. The overall project is approximately 44% complete with cumulative project Cost Performance Index (CPI) and Schedule Performance Index (SPI) at the end of November 2010 at 1.02 and 1.00 respectively.

The Federal Project Director was certified at level 4 in September of 2010.

The project experienced some minor delays with the PED effort that necessitated delaying completion. The value of the delayed work is $286,000.

This PDS is an update of the FY 2011 PDS.

2. Design, Construction, and D&D Schedule

	CD-0	CD-1	(Design/PED Complete)	CD-2	CD-3	CD-4
FY 2007	08/25/2005	1Q FY 2007	4Q FY 2008	TBD	TBD	TBD
FY 2008	08/25/2005	2Q FY 2007	2Q FY 2009	TBD	TBD	TBD
FY 2009	08/25/2005	07/12/2007	2Q FY 2009	2Q FY 2008	2Q FY 2009	3Q FY 2015
FY 2010	08/25/2005	07/12/2007	2Q FY 2009	01/18/2008	01/09/2009	3Q FY 2015
FY 2011	08/25/2005	07/12/2007	4Q FY 2010	01/18/2008	01/09/2009	3Q FY 2015
FY 2012	08/25/2005	07/12/2007	4Q FY 2011	01/18/2008	01/09/2009	3Q FY 2015

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approved Start of Construction
CD-4 – Approve Project Completion

	D&D Start	D&D Complete	Performance Baseline Validation
FY 2007	N/A	N/A	N/A
FY 2008	N/A	N/A	N/A
FY 2009	N/A	N/A	12/11/2007
FY 2010	N/A	N/A	12/11/2007
FY 2011	N/A	N/A	12/11/2007
FY 2012	N/A	N/A	12/11/2007

D&D Start – Not Applicable to this project
D&D Complete – Not Applicable to this project

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	TEC, Construction	TEC, Total	OPC Except D&D	OPC D&D	OPC, Total	TPC
FY 2007	75,000	TBD	TBD	TBD	TBD	TBD	TBD
FY 2008	75,000	TBD	TBD	TBD	TBD	TBD	TBD
FY 2009	60,000	731,200	791,200	120,800	0	120,800	912,000
FY 2010	60,000	731,200	791,200	120,800	0	120,800	912,000
FY 2011	60,000	731,200	791,200	120,800	0	120,800	912,000
FY 2012	60,000	731,200	791,200	120,800	0	120,800	912,000

4. Project Description, Justification, and Scope

The National Synchrotron Light Source II (NSLS-II) will be a new synchrotron light source, highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It will also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these will enable the study of material properties and functions with an unprecedented combination of state-of-the-art technical specifications: spatial resolution of about 1 nm, an energy resolution of about 0.1 meV, and the ultra-high sensitivity required to perform spectroscopy on a single molecule.

The NSLS-II project will design, build, and install the accelerator hardware, experimental apparatus, civil construction, and central facilities including offices and laboratories required to produce a new synchrotron light source. It includes a third generation storage ring, full energy injector, experimental areas, an initial suite of scientific instruments, and appropriate support equipment, all housed in a new building.

Major advances in energy technologies will require scientific breakthroughs in developing new materials with advanced properties. A broad discussion is given in several recent reports, including the Basic Energy Sciences (BES) Advisory Committee reports entitled *Opportunities for Catalysis in the 21st Century*, *Basic Research Needs to Assure a Secure Energy Future*, *Basic Research Needs for the Hydrogen Economy*, and *Basic Research Needs for Solar Energy Utilization*, in addition to the report of the Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Committee entitled *Nanoscience Research for Energy Needs*.

Collectively, these reports underscore the need to develop new tools that will allow the characterization of the atomic and electronic structure, the chemical composition, and the magnetic properties of materials with nanoscale resolution. Needed are non-destructive tools to image and characterize structures and interfaces below the surface, and these tools must operate in a wide range of temperature and harsh environments. The absence of any tool possessing these combined capabilities was identified as a key barrier to progress in the 1999 BES report *Nanoscale Science, Engineering and Technology Research Directions*.

In order to fill this capability gap, the Office of Science has determined that its mission requires a synchrotron light source that will enable the study of material properties and functions, particularly materials at the nanoscale, at a level of detail and precision never before possible. NSLS-II will provide these capabilities. Only x-ray methods have the potential of satisfying all of these requirements, but advances both in x-ray optics and in x-ray brightness and flux are required to achieve a spatial resolution of 1 nm and an energy resolution of 0.1 meV.

There are no alternative tools with a spatial resolution of 1 nm and energy resolution of 0.1 meV that also have the required capabilities of being non-destructive and able to image and characterize buried structures and interfaces in a wide range of temperatures and harsh environments. In the case of NSLS-I, it was found that it would be impossible to upgrade this light source due to numerous technical difficulties, including accelerator physics and infrastructure constraints, such as its small circumference, which limit the feasible in-place upgrade options.

The key performance parameters are defined in the project execution plan. The NSLS-II project is expected to deliver an electron energy of 3.0 giga-electron volts with a stored current of 25 milliamps; build a third generation storage ring of approximately one half mile in circumference and experimental and operations facilities with a total conventional construction of approximately 400 thousand gross square feet, and include an initial suite of six beamlines ready for commissioning.

Research and development activities funded under Other Project Costs will address technical risk in several key areas including energy resolution, spatial resolution, and storage ring magnets.

Beyond the scope of the NSLS-II construction project, an instrument development program has been implemented. The NSLS II Experimental Tools (NEXT) Project MIE, received CD-0 approval in May 2010 and will provide five to six state-of-the-art scientific instruments at NSLS II with a preliminary cost range of $50M to $90M.

Project Engineering and Design funds were used to complete the detailed design, including detailed estimates of construction based on the approved design, final working drawings and specifications, and schedules for construction and procurements.

The construction of the Ring Building is progressing well and as of December 2010 is 70% complete. Steel erection is completed and the roofing, siding, interior mechanical and electrical systems are well advanced. System start-up is in progress for the Ring Building, Pentant 1 where beneficial occupancy is scheduled for February 2011. The construction contract for the Laboratory Office Buildings (LOB) has been awarded and construction of foundations is underway. All other major civil construction sub-contracts, including the Electrical Substation and Central Chilled Water Facility expansion, are at or near 100% complete. Contracts to fabricate the storage ring magnets have been awarded, with first article and production magnets being delivered and tested. The Linac and the Booster contracts were also awarded. The final design review of the Linac has been completed, with the supplier working towards the building and delivery of the Linac front end. The Booster final design review will be completely shortly. Beamline technical specifications are being finalized and statements of work for long-lead procurements are being developed.

FY 2012 funds will be used to continue civil construction and advance experimental and accelerator systems.

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

5. Financial Schedule

App	(dollars in thousands) ropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Cost (TEC)				
PED				
FY 2007	3,000	3,000	0	2,292
FY 2008	29,727	29,727	0	28,205
FY 2009	27,273	27,273	0	23,044
FY 2010	0	0	0	6,173
FY 2011[a] 0		0	0	286
Total, PED	60,000	60,000	0	60,000
Construction				
FY 2009	66,000	66,000	0	24,092
FY 2009 Recovery Act	150,000	150,000	14,751	0
FY 2010	139,000	139,000	67,424	84,826
FY 2011[a]	151,600 1	51,600	59,624	205,982
FY 2012	151,400	151,400	8,201	110,611
FY 2013	46,900	46,900	0	105,995
FY 2014	26,300	26,300	0	41,230
FY 2015	0	0	0	8,464
Total, Construction	731,200	731,200	150,000	581,200
TEC				
FY 2007	3,000	3,000	0	2,292
FY 2008	29,727	29,727	0	28,205
FY 2009	93,273	93,273	0	47,136
FY 2009 Recovery Act	150,000	150,000	14,751	0
FY 2010	139,000	139,000	67,424	90,999
FY 2011[a]	151,600 1	51,600	59,624	206,268
FY 2012	151,400	151,400	8,201	110,611
FY 2013	46,900	46,900	0	105,995
FY 2014	26,300	26,300	0	41,230
FY 2015	0	0	0	8,464
Total, TEC	791,200	791,200	150,000	641,200

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

(dollars in thousands)

App	ropriations	Obligations	Recovery Act Costs	Costs
Other Project Cost (OPC)				
OPC except D&D				
FY 2005	1,000	1,000	0	0
FY 2006	4,800	4,800	0	4,958
FY 2007	22,000	22,000	0	20,461
FY 2008	20,000	20,000	0	15,508
FY 2009	10,000	10,000	0	7,101
FY 2010	2,000	2,000	0	5,852
FY 2011[a] 1	,500	1,500	0	4,638
FY 2012	7,700	7,700	0	9,458
FY 2013	24,400	24,400	0	24,000
FY 2014	22,400	22,400	0	22,400
FY 2015	5,000	5,000	0	6,424
Total, OPC except D&D	120,800	120,800	0	120,800
Total Project Cost (TPC)				
FY 2005	1,000	1,000	0	0
FY 2006	4,800	4,800	0	4,958
FY 2007	25,000	25,000	0	22,753
FY 2008	49,727	49,727	0	43,713
FY 2009	103,273	103,273	0	54,237
FY 2009 Recovery Act	150,000	150,000	14,751	0
FY 2010	141,000	141,000	67,424	96,851
FY 2011[a]	153,100 1	53,100	59,624 2	10,906
FY 2012	159,100 1	59,100	8,201 1	20,069
FY 2013	71,300	71,300	0	129,995
FY 2014	48,700 4	8,700	0 6	3,630
FY 2015	5,000	5,000	0	14,888
Total, TPC	912,000	912,000	150,000	762,000

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design 6	0,000	60,000	49,000
Contingency 0		0	11,000
Total, PED	60,000	60,000	60,000
Construction			
Site Preparation	9,243	9,243	9,243
Equipment 3	1,579	32,078	31,579
Other Construction	567,885	545,379	518,381
Contingency 12	2,493	144,500	171,997
Total, Construction	731,200	731,200	731,200
Total, TEC	791,200	791,200	791,200
Contingency, TEC	122,493	144,500	182,997
Other Project Cost (OPC)			
Conceptual Planning	24,800	24,800	24,800
Research and Development	35,800	35,800	35,800
Start-Up 5	0,200	50,200	50,200
Contingency 1	0,000	10,000	10,000
Total, OPC	120,800	120,800	120,800
Contingency, OPC	10,000	10,000	10,000
Total, TPC	912,000	912,000	912,000
Total, Contingency	132,493	154,500	192,997

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2007[a]	TEC	75,000	0	0	0	0	0	0	0	0	75,000
	OPC	46,000	0	0	0	0	0	0	0	0	46,000
	TPC	121,000	0	0	0	0	0	0	0	0	121,000

[a] The FY 2007 and FY 2008 requests were for PED funding only.

(dollars in thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2008[a]	TEC	65,000	10,000 0		0 0		0 0		0 0		75,000
	OPC	50,800 0		0 0		0 0		0 0		0	50,800
	TPC	115,800	10,000 0		0 0		0 0		0 0		125,800
FY 2009[a]	TEC	32,727	93,273	0 1	62,500	252,900 1	66,100	57,400	26,300	0 7	91,200
	OPC	47,800	10,000	0 2	,000	1,500 7	,700	24,400	22,400	5,000	120,800
	TPC	80,527 1	03,273	0 1	64,500	254,400 1	73,800	81,800	48,700	5,000 9	12,000
FY 2010	TEC	32,727	93,273	150,000 1	39,000	151,600 1	51,400	46,900	26,300	0 7	91,200
	OPC	47,800	10,000	0 2	,000	1,500 7	,700	24,400	22,400	5,000	120,800
	TPC	80,527 1	03,273	150,000 1	41,000	153,100 1	59,100	71,300	48,700	5,000 9	12,000
FY 2011	TEC	32,727	93,273	150,000 1	39,000	151,600 1	51,400	46,900	26,300	0 7	91,200
	OPC	47,800	10,000	0 2	,000	1,500 7	,700	24,400	22,400	5,000	120,800
	TPC	80,527 1	03,273	150,000 1	41,000	153,100 1	59,100	71,300	48,700	5,000 9	12,000
FY 2012	TEC	32,727	93,273 1	50,000	139,000 1	51,600[b]	151,400 4	6,900	26,300	0	791,200
	OPC	47,800	10,000	0 2	,000 1	,500[b]	7,700 2	4,400	22,400	5,000	120,800
	TPC	80,527 1	03,273	150,000 1	41,000 1	53,100[b]	159,100 7	1,300	48,700	5,000	912,000

8. Related Operations and Maintenance Funding Requirements

Beneficial Occupancy of the Experimental Floor	4Q FY 2012
Expected Useful Life (number of years)	25
Expected Future start of D&D of this capital asset (fiscal quarter)	N/A

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life cycle costs	
	Current Estimate	Prior Estimate	Current Estimate	Prior Estimate
Operations 11	9,400	119,400	4,470,000	4,470,000
Maintenance 2	1,100	21,100	789,000	789,000
Total Operations and Maintenance	140,500	140,500	5,259,000	5,259,000

[a] FY 2009 reflects the original validated funding baseline.
[b] The FY 2011amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

9. Required D&D Information

	Square Feet
Area of new construction	Approximately 400,000
Area of existing facilities being replaced	N/A
Area of any additional space that will require D&D to meet the "one-for-one" requirement	NA (see below)

The existing facility (NSLS) will be converted to another use. The one-for-one replacement has been met through completed and planned elimination of space at Brookhaven National Laboratory (BNL) along with "banked" space at the Massachusetts Institute of Technology (MIT) in Middleton, MA, and at the East Tennessee Technology Park (ETTP) in Oak Ridge, TN. A waiver from the one-for-one requirement to eliminate excess space at Brookhaven to offset the NSLS-II project was approved by Secretary Bodman on April 20, 2007. The waiver identified approximately 460,000 square feet of banked excess facilities space that were eliminated in FY 2006 at MIT and ETTP.

10. Acquisition Approach

The acquisition strategy selected relies on the BNL management and operating (M&O) contractor to directly manage the NSLS-II acquisition. The acquisition of large research facilities is within the scope of the DOE contract for the management and operation of BNL and consistent with the general expectation of the responsibilities of DOE M&O contractors.

The design, fabrication, assembly, installation, testing, and commissioning of the NSLS-II project will largely be performed by the BNL NSLS-II scientific and technical staff. Much of the subcontracted work to be performed for NSLS-II consists of hardware fabrication and conventional facilities construction. Each system or component will be procured using fixed price contracts, unless there is a compelling reason to employ another contract type. Best-value competitive procurements will be employed to the maximum extent possible.

Many major procurements are either build-to-print, following BNL/NSLS-II drawings and specifications, or readily available off-the-shelf. Source selection will be carried out in accordance with DOE-approved policies and procedures. Acquisition strategies have been chosen to obtain the best value based on the assessment of technical and cost risks on a case-by-case basis. For standard, build-to-print fabrications and the purchase of off-the-shelf equipment for routine applications, available purchasing techniques include price competition among technically qualified suppliers and use of competitively awarded blanket purchase agreements are used.

The architect-engineer (A-E) contract was placed on a firm-fixed-price basis for the Final (Title II) Design and (Title III) construction support services. The general construction contract was also placed on a firm-fixed-price basis. The design specifications are detailed and allow prospective constructors to formulate firm-fixed-price offers without excessive contingency and allowances.

NSLS-II project management has identified major procurements that represent significant complexity or cost and schedule risk. Advance procurement plans (APPs) are prepared for each major procurement. The APPs include discussion of contract type, special contracting methods, special clauses or deviations required, and lease or purchase decisions. These final APPs will identify critical procurement activities and help to mitigate or avoid schedule conflicts and other procurement-related problems. At appropriate dollar levels, the APPs are approved by the responsible Division Director, the NSLS-II Procurement Manager, the NSLS-II Deputy Director, the NSLS-II Project Director and the DOE Site Office.

Biological and Environmental Research

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Appropriation FY	2012 Request
Biological and Environmental Research		
Biological Systems Science	309,766	376,262
Climate and Environmental Sciences	278,265	341,638
Total, Biological and Environmental Research	588,031[a] 71	7,900

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

The Biological and Environment Research (BER) program mission is to understand complex biological, climatic, and environmental systems across spatial and temporal scales ranging from sub-micron to global, from individual molecules to ecosystems, and from nanoseconds to millennia. This is accomplished by exploring the frontiers of genome-enabled biology; discovering the physical, chemical, and biological drivers of climate change; and seeking the geochemical, hydrological, and biological determinants of environmental sustainability and stewardship.

Background

We live in a world shaped and dominated by forms of life that we cannot even see—the world of microbes. Over the millennia, microbes formed an atmosphere that supports life on Earth as we know it today and the fertile soils on which we grow our food. They are Earth's ultimate recyclers, whether contributing to the global carbon cycle, a key component of climate change, or processing toxic environmental contaminants including those from energy production and DOE's Cold War activities. Understanding the remarkable diversity and capabilities of these minute forms of life is a key element of the BER program. By unlocking the secrets held in the DNA of these remarkable creatures, creatures found in every conceivable spot on Earth from boiling deep sea vents to frozen tundra, we can devise biologically inspired solutions to many challenges facing us today—clean energy, global warming, and environmental contamination.

Plants also hold potential solutions for many of the energy and environmental challenges facing our Nation and are a central element of the BER program. Although critical sources of nutrition for all of us, plants are also significant recyclers of carbon dioxide and hold the promise as feedstocks for clean, renewable sources of energy. But just as with microbes, this potential is locked in the fundamental biology that has given rise to the diversity of plants we know today. Only by unlocking the mysteries of

[a] Total is reduced by $16,151,000, $14,421,000 of which was transferred to the Small Business Innovation Research (SBIR) program, and $1,730,000 of which was transferred to the Small Business Technology Transfer (STTR) program. Additionally, $153,000 of prior year balances was transferred as follows: $137,000 for SBIR and $16,000 for STTR.

plant biology can we develop new strategies that will revolutionize the future of renewable energy use and development.

The BER science portfolio includes research programs and scientific user facilities addressing some of today's most important and mission-critical problems in biological, climatic, and environmental research. Two areas vital to the Nation's energy security and environmental future lie at the core of the BER research agenda: developing cost-effective cellulosic biofuels and improving our ability to understand, predict, and mitigate the impacts of energy production and use on climate change. Over the decades, BER's impact on the scientific world has been transformative, and this commitment to scientific leadership continues today. In 1986, BER initiated the Human Genome Project, which eventually gave birth to the modern biotechnology revolution and virtually created the new field of genomics-based systems biology. Today, with its Genomic Sciences Program and the DOE Joint Genome Institute (JGI) now sequencing over four trillion genome base pairs per year, BER-supported researchers are using the powerful tools of contemporary systems biology to pursue the scientific breakthroughs needed for the development of cost-effective cellulosic biofuels. They are probing the role that microbes can play in environmental remediation and gaining critical insight into the terrestrial carbon cycle. Indeed, BER-sponsored researchers lead the world in the sequencing, study, and reengineering of microorganisms and plants with direct relevance to energy, climate, and environment. From the characterization of biological molecules and the probing and modeling of cellular metabolism, to the genomic redesign of microbes and plants, to the capture of powerful new enzymes through the metagenomic sequencing of microbial communities, BER-supported researchers are penetrating some of the deepest mysteries of living systems and uncovering powerful new biological tools to help meet the Nation's major challenges in energy and climate. As part of the Genomic Sciences program, our three DOE Bioenergy Research Centers lead the world in fundamental biofuels research. This research is laying the foundation for a revolution in the technologies of biofuels production and contributing to unprecedented deepening of our fundamental knowledge of microbial and plant systems.

BER has similarly had a longstanding leadership role in climate science. The first studies of atmospheric circulation—forerunners of today's climate models—were initiated by SC's predecessor agency, the Atomic Energy Commission's Division of Research, in the 1950s; it was the AEC that led the way in applying computation to the study of climate in the early decades, motivated initially by an interest in radioactive fallout. Today, building on this legacy, BER is a major supporter of the Community Climate System Model, a leading U.S. climate model. Improvement of today's climate models will depend heavily on gaining a more accurate understanding of climate processes, and BER's program addresses two of the most critical and challenging areas of uncertainty in contemporary climate science: the impact of clouds and aerosols. BER supports the world's leading facility for the study of clouds and aerosols, the Atmospheric Radiation Measurement Climate Research Facility, used by hundreds of scientists worldwide. Funds from the American Recovery and Reinvestment Act (Recovery Act) have enabled a major upgrade of ARM instrumentation, which will provide data and insights needed to model these key climate processes more accurately. At the same time, through its research program, BER is spearheading greater and more rapid integration of climate data into climate models. The Program for Climate Model Diagnosis and Intercomparison project at Lawrence Livermore National Laboratory, supported by BER, remains the gold standard in climate model evaluation and validation. In addition, BER is supporting cutting-edge research into the terrestrial carbon cycle, another major piece of the climate puzzle where there are many unknowns.

Through close partnership with the Advanced Scientific Computing Research (ASCR) program, BER is leveraging DOE's high-end computational modeling, simulation, and data capabilities. DOE's world-leading computational facilities—including a new generation of petaflop computers—are enabling BER-supported researchers to increase the complexity and resolution of models and to tackle new problems that were too computationally intense for an earlier generation of machines. Among these projects was the first-ever high-resolution modeling of abrupt climate change using the Cray Jaguar XT5 at Oak Ridge National Laboratory, one of the fastest computers in the world.

Simultaneously, BER actively encourages its community of biology researchers to begin to take greater advantage of DOE's computational resources for computational biology and bioinformatics. Seed money from the Recovery Act has enabled BER to launch an initiative for a Systems Biology Knowledgebase—an effort to harness computational resources to address one of the greatest challenges of contemporary systems biology: mining knowledge from the mountain of data that is accumulating from genomic sequencing and other high-throughput "omics" technologies.

Confronted with the Cold War legacy of subsurface toxins at DOE sites, BER pioneered the new frontier of subsurface science, with BER-supported researchers discovering novel microorganisms and understanding important geochemical and hydrological processes, including the fate of environmental contaminants. The BER-supported Environmental Molecular Science Laboratory (EMSL) at Pacific Northwest National Laboratory (PNNL) provides one of the world's most powerful suites of instruments for the characterization of biological organisms and molecules, combined with enormous computational resources, enabling researchers to attack problems from multiple angles. EMSL's instrumentation was recently upgraded with a major infusion of Recovery Act funds. With EMSL's unique capabilities, PNNL leads the world in the field of proteomics.

A common theme across BER's research portfolio is the challenge and excitement of studying complex systems. Biology, climate, and subsurface environments alike confront researchers with systems not easily understood though simple reductive methods, and which pose major challenges of scale at both ends of the continuum, from the infinitesimal to the global. A major part of the intellectual excitement shared by BER-supported researchers lies in the challenges to scientific ingenuity and creativity posed by these complex systems for those who would seek useable knowledge and practical solutions from their investigation. BER's search for mission-relevant solutions to the Nation's major challenges in energy, climate, and environment is inextricably bound up with the search for foundational and fundamental insights into nature and requires the tools, the perspective, and the intellectual curiosity and integrity that are the hallmark of basic science.

Major scientific goals for BER include:

- **Genomic Science:** conducting explorations of microbes and plants at the molecular, cellular, and community levels with the goal of gaining insight about fundamental biological processes, ultimately leading to a predictive understanding of how living systems operate. This challenge is articulated in a 2009 National Research Council report on "A New Biology for the 21st Century,"[a] which advocates the systems-level study of biological systems using the latest interdisciplinary tools and approaches.
- **Radiological Sciences:** supporting research in radiochemistry and radiotracer development with the goal of developing new methodologies for real-time, high-resolution imaging of dynamic biological systems. This goal is supported by a 2008 community-based workshop, "New Frontiers of Science in Radiochemistry and Instrumentation for Radionuclide Imaging."[b] Radiobiology provides systems level research to understand radiation-induced perturbations of physiological processes.

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[a] http://www.nap.edu/openbook.php?record_id=12764
[b] http://www.sc.doe.gov/ober/radiochem_2008workshop_report.pdf

- **Climate Research:** supporting research in atmospheric and environmental systems, and predictive climate and Earth system models. This research is guided by a 2008 report by the BER Advisory Committee entitled, "Identifying Outstanding Grand Challenges in Climate Change Research: Guiding DOE's Strategic Planning."[a] The report recommended that BER research seek to understand Earth's climate system by characterizing current climate and its evolution over the last century to its present state, predicting regional climate change for the next several decades, and simulating Earth System changes and their consequences over centuries. Additional scientific insights were determined from a May 2010 community based workshop, "Climate Research Roadmap Workshop." Topics discussed included improving model simulations and quantifying uncertainty, enhancing the representation of biogeochemical process in models, and a focus on understanding and quantifying the mechanisms responsible for cloud feedbacks and aerosol effects on clouds and climate in order to improve the reliability of predictions of climate change in the future with particular attention to the impact on the radiative balance and precipitation.
- **Subsurface Biogeochemistry:** seeking to understand the role that subsurface biogeochemical processes play in determining the fate and transport of contaminants including heavy metals and radionuclides. Computational models of coupled biological, geochemical, and hydrological processes are needed to predict the rates and kinetics of transformation and sequestration of these critical DOE contaminants. This research is guided by the March 2010 community-based workshop report, "Complex Systems Science for Subsurface Fate and Transport."[b]

Subprograms

To accomplish its mission and address the scientific challenges described above, the BER program is organized into two subprograms, Biological Systems Science and Climate and Environmental Sciences.

- The *Biological Systems Science* subprogram explores the fundamental principles that drive the function and structure of living systems. The target systems range from microbes and microbial communities to plants and other whole organisms. Using the genome as a blueprint, Genomic Science provides the foundational biological understanding of microbial and plant systems in a range of natural and managed ecosystems. Three DOE Bioenergy Research Centers (BRCs)—led by Lawrence Berkeley National Laboratory, Oak Ridge National Laboratory, and the University of Wisconsin at Madison in partnership with Michigan State University—support multidisciplinary teams of leading scientists whose goal is to accelerate transformational breakthroughs needed to understand the conversion of cellulose (plant fibers) to biofuels and clean energy. The BRCs have accelerated progress in using systems biology tools to reengineer organisms and adapt them to address energy solutions. The potential for systems biology to address our energy challenges is enormous and only realized through standardization and centralization of knowledge and tools. A mature synthetic systems biology approach would have well-characterized, standardized functional biological components along with well-articulated design principles. In time, the goal would be to achieve computer-aided design of new biological systems for clean energy solutions and a range of other applications. As part of the President's commitment to clean energy R&D, BER is supporting foundational research toward this end. New Genomic Science research will identify and articulate general biological design principles, enabling functional characterizations of biological systems and synthetic redesign, paving the way for new clean energy sources. The impact of such an effort—not only on the search for energy solutions, but on U.S. competitiveness in a global bio-based economy—could be comparable to the sweeping impact of the genomics revolution, launched when

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[a] http://www.sc.doe.gov/ober/berac/Grand_Challenges_Report.pdf
[b] http://www.sc.doe.gov/ober/subsurfacecomplexity_03-05-10.pdf

DOE initiated the Human Genome Project in 1986. The DOE Joint Genome Institute (JGI), a high-throughput DNA sequencing user facility, provides the basis for systems biology and unmatched capabilities to understand and predict the function of environmental and energy-related microbes and plants. Current sequencing capacity at the JGI is over 4 trillion base pairs per year (compared to about 3 billion base pairs for the entire human genome) and growing rapidly. To understand the proteins encoded by DNA, the Structural Biology activity supports access to DOE's world-class synchrotron and neutron sources. The interface between biology and the physical sciences is explored in the Radiological Sciences with new methods for real-time high resolution imaging of dynamic biological processes and with molecular and genomic biology to underpin radiation risk policy.

- The *Climate and Environmental Sciences* subprogram advances science to understand, predict, and mitigate the impacts of energy production and use on the Earth system. Atmospheric System Research supports research to help resolve two the greatest uncertainties in climate change—the role of clouds and aerosols in Earth's radiation balance. The Atmospheric Radiation Measurement Climate Research Facility provides key observational data to the climate research community on clouds and properties of the atmosphere, especially their impact on the radiative balance. The facility includes highly instrumented ground stations, two mobile facilities, and an aerial vehicles program; it served 1,200 users from around the world in FY 2010. Climate and Earth System Modeling develops and evaluates powerful and sophisticated climate models that contribute to reports by the Intergovernmental Panel on Climate Change. Environmental Systems Science supports research to understand the impact on and role of diverse ecosystems on climate change, as well as subsurface biogeochemical research to understand and predict subsurface contaminant fate and transport. The Environmental Molecular Sciences Laboratory (EMSL) houses a supercomputer and over 60 major instruments, providing integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences, and in systems biology by providing leading edge capabilities in proteomics. EMSL serves over 700 users annually.

Benefits

BER science continues to have broad benefits for society and for science. BER's long history of biological discovery has advanced scientific discovery, improved human health, and revolutionized the field of biology. Today, some of the most daunting scientific challenges for DOE require understanding and ultimately predicting the behaviors of plant and microbial systems.

BER research on a range of biological challenges has led to the development of a number of biology-based solutions: microbes that chemically alter environmental contaminants; fungi and bacteria that degrade plant cell walls or produce next-generation biofuels; and trees, grasses, algae, and microbes that cycle carbon or serve as sources for biofuels production.

Early DOE studies to understand the fate of radioactive fallout on land and in the oceans had broad impacts, leading to the development of modern ecology and oceanography, tools to understand the intricacies of Earth's climate system, and modeling capabilities for predicting future climate. Today, our growing understanding of the climate system and our ability to more accurately predict the Earth's future climate are essential to plan for future energy needs, water resources, and land use. BER research also provides new understanding of the biological, physical, and chemical mechanisms responsible for the natural sequestration of carbon dioxide in terrestrial ecosystems; essential knowledge for understanding the impacts of land use and land management decisions on carbon release or storage from various ecosystems.

Fundamental, hypothesis-driven research in both laboratories and the field has revealed new biogeochemical processes that influence the fate and transport of contaminants from a legacy of weapons production. Today, this knowledge has been translated into new strategies for cleaning up legacy contaminants based on understanding of the broad capabilities of naturally occurring subsurface microbes.

BER researchers have pushed the technological frontiers by not only demanding but also achieving increasingly sophisticated characterization of the chemical and biological constituents of living systems. Their expanding toolkit includes the high-throughput sequencing capabilities underpinning all modern genomics; mass spectrometry to predict and identify proteins, metabolites, and lipids; and a wide-ranging array of imaging and spectroscopic techniques (many located at the DOE light sources) to enable the functional determinants of protein structures. The advances resulting from such multi-disciplinary approaches provide an unprecedented opportunity to achieve a deeper understanding of the natural world at all levels.

Program Planning and Management

BER uses broad input from scientific workshops and external reviews, including those performed by the National Academies, to identify current and future scientific and technical needs and challenges in current national and international research efforts. The resulting National Academies' reports e.g., "Research at the Intersection of the Physical and Life Sciences"[a] and BER scientific workshop reports are available online.[b] BER also receives advice from the Biological and Environmental Research Advisory Committee (BERAC) on the management of its research programs (through Committee of Visitor [COV] reviews), on the direction and focus of its research programs, and on strategies for long-term planning and development of its research activities.

In FY 2010, BERAC was charged to develop an overall strategy for drafting a long-term vision for BER. A key focus of this visioning activity was to identify the greatest scientific challenges in biological, climate, and environmental systems science that BER should address in the long-term (20-year horizon) and how BER should be positioned to address those challenges; the continued or new fields of BER-relevant science that DOE will need to pursue to achieve its future mission challenges; and the future scientific and technical advances needed to underpin BER's complex systems science. BERAC's report, "Grand Challenges for Biological and Environmental Research: A Long-Term Vision identified grand challenges in complex systems and synthetic biology, climate modeling and climate-related ecosystem science, energy sustainability, computing, and education and workforce development".[c]

BERAC conducts reviews of BER subprograms by COVs every three years. Results of these reviews and BER responses are posted online.[d] A COV was assembled in 2010 to review the Climate and Environmental Sciences Division of the BER program, and one is planned for 2011 to review the Biological Systems Science Division. Every three years, BER also conducts consolidated onsite merit, operational, management, and safety reviews of each of its user facilities: the Atmospheric Radiation Measurement Climate Research Facilities, the Joint Genome Institute, and the Environmental Molecular Sciences Laboratory. Results of these reviews are used to address management, scientific, operational, and safety deficiencies.

The BER program is coordinated with activities of other federal organizations supporting or conducting complementary research, e.g., the National Science Foundation, National Aeronautics and Space

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[a] http://www.nap.edu/catalog.php?record_id=12809
[b] http://www.sc.doe.gov/ober/BER_workshops.html
[c] http://www.science.doe.gov/ober/berac/BER_LTVreport.pdf
[d] http://www.science.doe.gov/SC-2/Committee_of_Visitors.htm

Administration, Department of Commerce/National Oceanic and Atmospheric Administration, Environmental Protection Agency, Nuclear Regulatory Commission, Department of Agriculture (USDA), National Institutes of Health, Department of State, and Department of Defense. BER Climate Change Research is coordinated with the U.S. Global Change Research Program, an interagency program codified by Public Law 101–606 and involving thirteen federal agencies and departments, and the U.S. Climate Change Technology Program. BER supports research at universities, research institutes, private companies, and DOE national laboratories. All BER-supported research undergoes regular peer review and merit evaluation based on procedures established in 10 CFR 605 for the external grant program and using a similar process for research at the national laboratories.

Basic and Applied R&D Coordination

BER research underpins the needs of DOE's energy and environmental missions. Fundamental research on microbes and plants to understand their biochemical pathways and the genetic mechanisms that control their interactions and behavior provides knowledge needed by DOE's Office of Energy Efficiency and Renewable Energy (EERE) and the USDA about new bioenergy crops and bioenergy production facilities that are cost effective and sustainable. For EERE, much of the research being carried out at the three BER-funded Bioenergy Research Centers is providing foundational knowledge for application by EERE to development of systems for conversion of biomass to biofuels that can be commercialized. BER's "Plant Feedstock Genomics for Bioenergy" program is jointly managed with and funded by USDA's National Institute of Food and Agriculture to provide fundamental knowledge about potential biomass crops.

BER research on the behavior and interactions of contaminants in the subsurface environment provides knowledge needed by DOE's Office of Environmental Management (EM) to develop new strategies for the remediation of weapons-related contaminants at DOE sites and by DOE's Office of Legacy Management (LM) to develop tools for monitoring the long-term status of contaminants at cleanup sites. BER continues to build on breakthrough advances in microbial genome science to measure expressed genes for a variety of metabolic processes in the environment and couple these results with advanced *in silico* computational approaches to develop a more predictive understanding of microbial impacts on metal and radionuclide mobility in the environment. In FY 2010, EM initiated a new modeling initiative called Advanced Simulation Capability for Environmental Management, which heavily leverages BER science investments and advances. Knowledge of the subsurface environment as a complete system will also be useful to the DOE Office of Fossil Energy (FE) in their efforts to predict the long-term behavior of carbon dioxide injected underground for long-term storage. The current focus on the understanding of processes impacting the mobility of contaminant metals and radionuclides found in the subsurface at DOE legacy waste sites is directly applicable to LM.

Finally, BER research to understand Earth's climate system and to predict future climate and climate change is needed by DOE's Office of Policy and International Affairs (PI) as it develops strategies for our Nation's future energy needs and control of greenhouse gas emissions. The BER Integrated Assessment model continues to be an important tool for PI in evaluating the impact of new energy policy on greenhouse gas emissions. In general, BER coordinates with DOE's applied technology programs through regular joint program manager meetings, participating in their internal program reviews, participating in joint contractor meetings, and conducting joint technical workshops.

Budget Overview

BER's budget strategy is based on three science drivers: exploring the frontiers of genome-enabled biology; discovering the physical, chemical, and biological drivers and environmental impacts of climate change; and seeking the geochemical, hydrological, and biological determinants of environmental sustainability and stewardship. The targeted research investments in FY 2012 and the BER scientific user facilities are key to supporting these mission priorities. In FY 2012, the BER budget request will support approximately 2,400 researchers and graduate students at over 200 U.S. academic, federal, and private sector institutions.

Genomic science research supported in FY 2012, including the DOE Bioenergy Research Centers (BRCs), will continue to advance our understanding of how plant and microbial system functions are specified by genome organization, expression, and regulation. This includes developing genomic, analytical, and computational approaches to study the structure, interdependence, and function of microbial communities and the identification of plant traits for improved bioenergy production or carbon sequestration. Research is expanded to study microbial environmental interactions, with respect to chemical and metabolic signal perception and integration. In an effort to take fuller advantage of the powerful capabilities of systems biology to produce bio-based solutions to our energy challenges, a new undertaking will be initiated to identify and articulate general biological design principles that will enable functional characterizations of biological systems and synthetic biology redesign. The goal is to achieve greater standardization and centralization of knowledge and tools, using well-characterized, standardized functional biological components and design principles, with the ultimate aim of developing computer-aided design of biological solutions. This effort leverages other activities in computational biosciences to predict, design, construct, and test new, multi-scale natural and hybrid biological systems that will lead to new clean energy solutions. The JGI will continue to support sequencing needs of the Genomic Science program, especially the BRCs. JGI activities will reflect the rapid increase in production DNA sequencing as well as the resulting need for high-throughput, complex genome annotation and analysis. New efforts in FY 2012 will include JGI grand challenge activities that encompass large scale genome comparisons across different soil environments or plant-microbe associations.

Climate sciences research supported in FY 2012 will continue to improve understanding and quantification of the role of aerosols and clouds on climate change. The ARM fixed sites and mobile facility deployments will support research in locations with different types of clouds, atmospheric conditions, and aerosol loadings to better address major outstanding questions in climate change research (clouds and aerosols). The arctic is a globally important and climatically sensitive region. Recent changes in cloud cover, warming, and ice sheet melting have been faster than predicted by current climate models. Since the upper three meters of tundra contain more carbon than Earth's atmosphere today, there is a potential for dramatic feedback, where the vast amounts of stored carbon, primarily methane, released from thawing tundra. Additionally, the changes in land and sea ice may have dramatic impact on cloud properties and extent in the region. In FY 2012, BER will enhance our Arctic Climate activity that develops new observations for cloud, aerosols, and the terrestrial carbon cycle designed to support existing BER process studies and modeling activities for improving climate simulations for this rapidly changing climatic regime. As part of this activity, a new ARM mobile facility will be deployed at Oliktok Point on the North Slope of Alaska to provide cloud and aerosol properties over land, sea, and ice sheets. Regular deployments of small unmanned aerial vehicles (UAVs) for in situ measurements will complement and extend the observational coverage to the North Pole. A new ARM fixed site will be developed in the Azores to provide critical long-term observations for marine clouds and aerosols. These measurements in the arctic and Azores are needed to improve understanding of cloud and aerosol lifecycles in these regions and their impact on the planet. The data will be used to evaluate and improve Earth System Model simulations both globally and for these climate sensitive regions.

In FY 2012, research will be expanded to improve understanding of the role of terrestrial ecosystems as sources and sinks of greenhouse gases focusing on the role of natural processes that control terrestrial carbon sequestration and how those processes might be managed to enhance carbon sequestration in terrestrial ecosystems. As part of the Arctic Climate activities, a new effort will focus on developing experimental infrastructure needed for the initiation of the next-generation ecosystem-climate change experiment, with a focus on arctic tundra—an ecosystem that is experiencing rapid climate changes and that contains vast amounts of frozen carbon susceptible to release into the atmosphere as either CO_2 or methane. In FY 2012, BER will support research on carbon cycle multi-scale dynamics in order to describe the nature of the presently observed system noise. This research will underpin measurement, reporting, and verification (MRV) of atmospheric greenhouse gases. The carbon cycle data will directly support ongoing projects for improving representation of processes into Earth System Models. BER Climate Modeling will continue research towards increasing model resolution and accuracy to better simulate climate on a regional scale.

Subsurface Biogeochemical Research will support basic research on the fate and transport of contaminants in the subsurface. This research addresses unique physical, chemical, and biological processes controlling the flux of contaminants across and within the root zone of soils and the flux of contaminants to surface water bodies. Processes in these critical zones influence fluxes of carbon and key nutrients between the atmosphere and terrestrial biosphere. The EMSL equipment refresh will continue to keep EMSL at the state of the art, including enhancement of leading capabilities in proteomics and advanced magnetic resonance.

Significant Program Shifts

In FY 2012, in an effort to take fuller advantage of the powerful capabilities of systems biology and synthetic biology, BER will initiate an effort to identify and articulate general biological design principles, enabling functional characterizations of biological systems and synthetic redesign. This new effort combines development of new molecular toolkits for understanding natural systems with testbeds for the design and construction of improved biological components or new biohybrid systems and processes. Computer-aided design and testing of directed and self-assembled natural and hybrid biological systems will provide key insights to the reorganization and remodeling of cellular processes and accelerate exploiting these insights for *in vivo* adaptation and optimization. This effort will leverage activities in computational biosciences to predict, design, construct, and test new, multi-scale natural and hybrid biological systems and will accelerate engineering plant and microbial community performance for a changing environment.

In FY 2012, BER will increase transformational science efforts towards improved understanding and predictive capabilities for the Arctic, an ecosystem that is experiencing rapid climate changes with the potential to release significant amounts of carbon into the atmosphere. Such dramatic changes in the Arctic may have powerful long-term effects on a global scale. The new research scope ranges from microbes to terrestrial ecosystems and water droplets to sea ice and cloud fields. The goal is to understand the individual components of biological carbon cycling and physical systems, and integrate them into a comprehensive Arctic environmental system model. This activity will leverage other significant investments in the program related to Arctic research, including Earth System modeling and cloud and aerosol process study research, and build upon pilot genomic activities to interrogate the microbial communities within the Arctic permafrost. A new ARM fixed site will also be developed in the Azores to provide new observations for marine clouds and aerosols.

In FY 2012, no funding is provided for Ethical, Legal and Societal Issues (ELSI), reflecting the completion of the DOE research. The societal benefits and implications of DOE mission areas are best addressed within specific programmatic activities; thus the standalone ELSI activity at DOE is complete.

BER research on the development of the components of an artificial retina was completed in FY 2010. By FY 2012, research will enable the final testing and refinement of the assembled 240+ electrode device for clinical trial readiness. No FY 2012 funding for the artificial retina is requested.

Annual Performance Targets and Results

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget.

Biological Systems Science

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation FY	2012 Request
Biological Systems Science		
Genomic Science	165,565	241,509
Radiological Sciences	46,675	34,322
Ethical, Legal, and Societal Issues	5,000	0
Medical Applications	8,226	0
Biological Systems Facilities and Infrastructure	84,300	90,173
SBIR/STTR 0		10,258
Total, Biological Systems Science	309,766	376,262

Description

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 understanding the functional principles that drive living systems, from microbes and microbial communities to plants and other whole organisms. Questions include: What information is in the genome sequence? How is information coordinated between different subcellular constituents? What molecular interactions regulate the response of living systems and how can those interactions be understood dynamically and predictively? The approaches employed include genome sequencing, proteomics, metabolomics, structural biology, high-resolution imaging and characterization, and integration of information into predictive computational models of biological systems that can be tested and validated.

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

Selected FY 2010 Accomplishments

- The DOE Bioenergy Research Centers (BRCs) developed high-risk, high-return biological solutions to critical biofuel bottlenecks using basic research. The Great Lakes Bioenergy Research Center (GLBRC) discovered controls in plants to protect energy-rich lipids in leaves and is working to develop plants with higher energy content from overproduction of leaf oils. Information from field trials on the sustainability impacts of energy crops and cultivation options is linked to results from microbial populations in the soil at small scales to national-scale economic and greenhouse gas flux models at larger scales.
- The BioEnergy Science Center (BESC) identified changes in a microbial biomass hydrolysis machine, the cellulosome, during growth on different constituents of plant biomass that may lead to new bioengineering approaches to construct enzyme complexes with "plug in" components for specific biomass feedstock. A BESC industrial partner developed a yeast strain that produces

degradation enzymes and ferments most sugars, a necessary step towards consolidated bioprocessing.

- The Joint BioEnergy Institute (JBEI) discovered novel degradation genes in microbes grown on compost and adapted to growth on switchgrass and then used synthetic biology to tailor a higher-efficiency cellulase enzyme. JBEI researchers and a biotech firm used synthetic biology to modify an industrial bacterium to produce biodiesel and other important chemicals.
- Primary productivity on Earth depends on plants and microbes converting atmospheric CO_2 and N_2 into biologically useful forms. New research showed how oxidation and reduction processes are balanced during growth of the metabolically versatile microbe *Rhodopseudomonas palustris* using a combination of photosynthesis and consumption of organic acids produced by other microbes. This advanced understanding of central metabolic processes in microbes that are relevant to bioenergy applications and play a critical role in the global carbon cycle.
- JGI significantly expanded its role in large-scale genome sequencing and analysis in support of DOE missions. New sequencing technologies were used to sequence 4 trillion base pairs of DNA annually, more than 130 times the capacity of 5 years ago. This new capacity enabled the deduction of increasingly complex genomes, including soybean (important for biodiesel production, soil sustainability and nutrition) and a fungus that provides the source of industrial cellulase enzymes to break down biomass. JGI also completed the first installment of the Genomic Encyclopedia of Bacteria and Archaea to explore Earth's microbial "dark matter" by sequencing little-studied microbes that will give insights into other microbes and microbial communities facilitating searches for novel functions and our understanding of the biosphere.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Genomic Science	**165,565**	**241,509**
▪ **Foundational Genomics Research**	**33,671**	**102,914**

Foundational Genomics Research supports fundamental research on microbes and plants to understand biological systems across multiple scales from subcellular molecular interactions to microbial community structures. Research focuses on the spatial organization of cellular components and microbial and plant regulatory and metabolic networks. It investigates how cells balance dynamic needs for synthesis, assembly, and turnover of cellular machinery in response to changing environmental signals. Research will increasingly focus on understanding how different organisms interact within a biological or environmental system to provide unique functions through mechanisms such as nutrient exchange or horizontal gene transfer. These systems-level capabilities enable a diversity of functions, from microbial respiration and speciation of soil minerals to rhizosphere nutrient uptake and cell-cell communication, as well as a testable framework for developing genome-based models for systems biology. New approaches will be developed including methods to measure metabolites, proteins, and expressed genes for microbial communities. Novel technologies will be developed enabling multi-modal chemical and biological measurements across broad spatial and temporal ranges, providing insight into environmental processes. Research employing advanced molecular and computational biology approaches enabled by genome sequencing is emphasized, with priority to multidisciplinary efforts across microbiology, plant biology, chemistry, biophysics, bioinformatics, metabolic engineering, and other fields.

In FY 2012, new research will be initiated to provide the scientific foundation for a bio-economy in which carbon-neutral and renewable processes can be safely designed and optimized. This new research will identify and articulate general biological design principles, enabling functional characterizations of biological systems and synthetic redesign. This includes the development of new synthetic molecular toolkits for understanding natural systems and computer-aided design testbeds for the design and construction of improved biological components or new, multi-scale natural and hybrid biological processes and systems. These toolkits will include the development of new genetic transformation approaches for natural and re-engineered plant and microbial systems, as well as technology to facilitate design engineering of multi-component biological functional modules and to manipulate genetic control systems. The testbeds will allow for prototyping and functional validation of natural and engineered biological modules, especially to understand cross-talk and spatial and topological constraints within cellular systems. Computer-aided design and testing of directed and self-assembled natural and hybrid biological systems will provide key insights to the reorganization and remodeling of cellular processes and accelerate exploiting these insights for *in vivo* adaptation and optimization.

This effort will leverage knowledgebase activities in computational biosciences and capabilities at the Joint Genome Institute in genome sequencing and analysis. Multi-scale measurement and characterization technologies will be developed that validate biological function, facilitate interoperability of biological modules and processes, and standardize engineering plant and microbial community performance for changing environmental conditions. The new knowledge and tools developed from this research will advance applications of biotechnology for bio-based solutions to current and emerging energy and environmental challenges.

Research is also increased to advance the understanding of how complex biological system function is specified by genome organization, expression, and regulation, through the development of genomic and analytical technologies for multi-modal, dynamic measurements in actively-occurring environmental processes and during cellular communication.

▪ **Genomics Analysis and Validation**	**10,000**	**12,000**

Genomics Analysis and Validation develops tools and resources to fully exploit information in complete DNA sequences from microbes and plants for bioenergy, carbon sequestration, and bioremediation applications. This activity supports development of new high-throughput approaches for analyzing gene regulation and function, automated tools for predicting genes and protein function from DNA sequence, and tools for identifying dynamic genome interactions within a biological or environmental system to uncover emergent properties of interacting genes. The ability to predict the function of an individual gene and sets of genes is essential for design and validation of strategies for bioenergy production, enhanced carbon sequestration, or environmental remediation.

In FY 2012, research supports innovative new approaches to validate and improve genome-scale annotation and gene models in microbes and plants. Increased funding will also support genome-scale validation of annotation in metagenomic datasets, a challenge due to the vast and fragmentary information contained within these datasets.

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
▪ **Metabolic Synthesis and Conversion**	**38,637**	**37,200**

This activity focuses on understanding the composition and regulation of biological pathways for converting carbon into advanced biomolecules. Research focuses on understanding carbon uptake, fixation, and storage in plants and soil microbes, leveraging new information from whole organism and community genomes. Research will focus on the role of microbial communities or plant-microbe associations in the transfer of carbon between roots and the soil to identify strategies that would lead to increased carbon storage in the rhizosphere and surrounding soil. Genomic knowledge of metabolic functions and regulatory networks in microbes, plants, and plant-microbe associations can enable strategies to increase biomass formation for conversion into advanced biofuels or to increase the sequestration of carbon in terrestrial ecosystems.

This activity draws on Foundational Genomics Research and technology development to address challenges unique to biofuels through understanding the conversion of simple sugars to ethanol and hydrogen. This will improve understanding of variables governing partitioning of energy precursors into different biomass, respiration, or energy producing pathways, or fixation into recalcitrant soil or marine carbon forms. Systems biology approaches enable understanding of how plant genomes can specify increased carbon fixation and biomass yield, improve feedstock characteristics, and increase sustainability.

In FY 2012, funds will continue to support research on carbon storage in plant biomass for conversion into advanced biofuels or for carbon sequestration. Funds will support research to characterize the regulation of carbon and nutrient cycling in plant and microbial systems, from subcellular or root-stem-leaf partitioning to flux within pathways or between networks of interacting organisms. FY 2012 funds will support new integrated, interdisciplinary research in biological carbon cycling by plants and microbes in the Arctic to accelerate progress in climate change research and modeling. Funding decreases with the completion of projects on fermentative microbial biohydrogen production.

▪ **Computational Biosciences**	**8,257**	**14,395**

Computational models and algorithmic and computational tools that describe the biochemical capabilities of microbial communities or plants are essential to the success of the Genomic Science activity. New models are needed to integrate diverse data types and data sets into single models that accurately describe and predict the behavior of metabolic pathways and genetic regulatory networks. A systems biology knowledgebase is an integrated modeling and experimental framework to access, compare, analyze, and test systems biology data. The extension of capabilities beyond data generation and storage to data retrieval, data access, and cross-database comparative computational modeling forms the basic requirements of a systems biology knowledgebase. This will enable and provide support for progressively more precise and comprehensive predictive modeling of various catalytic and cellular processes, and organisms and communities. The systems biology knowledgebase dimensions and requirements were recently outlined in a community workshop.[a]

[a] http://genomicscience.energy.gov/compbio/

	FY 2010 Current Appropriation	FY 2012 Request

This activity includes support for ongoing Scientific Discovery through Advanced Computing (SciDAC) research that develops multi-scale and multi-component mathematical and computational tools for modeling and analysis of complex data sets, such as mass spectrometry or metabolomics, and to develop predictive metagenomic models of complex microbial communities. SciDAC research is closely coordinated with the Advanced Scientific Computing Research program.

In FY 2012, funding will support ongoing SciDAC research to model whole cell processes that incorporate genomic information with protein production and subcellular localization, metabolic and regulatory processes, cellular signaling, and microbial sensing. Increased funding includes support to extend the systems biology knowledgebase to include research in simulating biological and ecological processes that affect microbial community physiology and the integration of three-dimensional imaging data. The developing knowledgebase will enable broad, distributed access to a virtual computational environment, enabling integrated genome-scale modeling and reconstruction using diverse microbial experimental datasets from genome sequencing, biological networks metabolic pathways, and transcriptional regulation and phenotypic data. The knowledgebase will enable interoperability among datasets and databases and new methods in data information analysis and curation. The primary experimental datasets for integration will be drawn from research conducted at the BRCs, the JGI, and from within the Genomic Science activity.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **Bioenergy Research Centers**	**75,000**	**75,000**

In 2007, BER established three Bioenergy Research Centers to accelerate transformational breakthroughs in basic science needed to develop cost-effective technologies to make production of cellulosic (plant-fiber based) biofuels commercially viable on a national scale.

The centers are multidisciplinary, multi-institutional partnerships between universities, national laboratories, and the private sector. The centers take scientific approaches that are complementary and synergistic. Areas of fundamental research include the identification, characterization, and systems-level regulation of genetic traits for cell wall composition of model plants such as Arabidopsis and rice, for which detailed genome sequence and phenotypic information are available, as well as second-generation bioenergy crops such as poplar and switchgrass for which there are more limited genomic resources. Other studies focus on understanding the metabolic pathways in individual microbes or microbial consortia that carry out efficient degradation of cell wall material and conversion into ethanol, hydrocarbons, diesel, and even jet fuel. The centers also focus on modeling structure-function relationships in enzymes and proteins important in the synthesis, turnover, and remodeling of plant cell wall biomass, as well as subsequent metabolic and enzymatic conversion.

Each center is evaluated annually by an on-site review of science and management, progress against stated milestones and planned science programs. The external review teams include scientists from universities, DOE national laboratories, and industry, with broad scientific expertise.

The Centers are using the advanced genomics-based techniques of modern systems biology to re-engineer both plants and microbes for more efficient biologically-based conversion of plant fiber into carbon-neutral biofuels. This capability addresses critical DOE mission needs in the area of secure and sustainable bioenergy production.

(dollars in thousands)		
	FY 2010 Current Appropriation	FY 2012 Request

In FY 2012, funds will support the continued fundamental research to improve breakdown of plant biomass, discover and bioengineer new microbes and enzymes capable of degrading lignocellulose, and convert cellulose-derived sugars to carbon-neutral biofuels.

Radiological Sciences	**46,675**	**34,322**
▪ **Radiochemistry and Imaging Instrumentation**	**20,772**	**20,000**

This activity supports fundamental research in radiochemistry and radiotracer development including development of new methodologies for real-time, high-resolution imaging of dynamic energy- and environment-relevant biological processes. 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.

Radiotracer imaging methods provide new opportunities for quantitative measurement of in situ chemical reactions in living systems. The activity primarily benefits DOE mission needs, while also providing fundamental research and tool development that may translate to nuclear medicine diagnostic and therapeutic research.

In FY 2012, funds will support the development and use of innovative radiotracer chemistry and complementary radionuclide imaging instrumentation technologies for quantitative in vivo measurement of radiotracer concentration and site-specific chemical reactions. Funding will continue to support integrative training opportunities in radiochemistry to build and maintain the radiochemistry scientific workforce. Funding is decreased for the development of methodologies for high activity level synthesis of immunoPET radiotracers.

▪ **Radiobiology 25,903**		**14,322**

The Radiobiology activity supports research to help determine health risks from exposures to low levels of ionizing radiation, information critical to adequately and appropriately protect radiation workers and the general public. Research includes critical biological phenomena induced by low dose exposure and support to understand the role of genetic susceptibility and epigenetics in integrated gene function and response of biological systems to environmental conditions.

Radiobiology research will provide a scientific basis for informed decisions regarding remediation of contaminated DOE sites and for determining acceptable levels of human health protection, both for cleanup workers and the public in the most cost-effective manner.

In FY 2012, funds will support systems genetic studies of integrated gene function and response to the environment, drawing on prior studies of specific gene targets and individual cellular response and focusing at the tissue or whole organism level. These studies will contribute towards development of models that are reconciled with available epidemiological data. Funding is reduced for studies on bystander effects and adaptive immune function and is completed for research on genome instability and DNA damage in single cells.

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
Ethical, Legal, and Societal Issues	**5,000**	**0**

In FY 2012, no funding is provided for ELSI, reflecting the completion of the DOE involvement with the Human Genome Project and the alignment of the BER program with DOE mission priorities in energy and the environment. With the evolution of ELSI to address broader mission-relevant science topics, such as bioenergy, synthetic genomics, and nanoscience, the societal benefits and implications of DOE mission areas will be addressed within relevant programmatic activities.

Medical Applications	**8,226**	**0**

Research is completed by FY 2012 on the 240+ electrode artificial retina device integration and preparation for pre-clinical testing. The activity is ready to transition out of DOE for development and application.

Biological Systems Facilities and Infrastructure	**84,300**	**90,173**
▪ **Structural Biology Infrastructure**	**15,300**	**19,417**

The Structural Biology Infrastructure activity continues to develop and support access to beamlines and instrumentation at DOE's national user facilities for the Nation's structural biologists. BER coordinates, with the NIH and NSF, the management and maintenance of 22 experimental stations at DOE synchrotrons (Advanced Photon Source, Advanced Light Source, National Synchrotron Light Source, and Stanford Synchrotron Radiation Light source) and neutron sources (High Flux Isotope Reactor and Los Alamos Neutron Science Center). User statistics for BER structural biology user stations are included in the Basic Energy Sciences facility user reports. BER continually assesses the quality of the instrumentation at its experimental stations, supports development of new state-of the-art stations, and upgrades existing stations to install the most effective instrumentation for taking full advantage of the facility capabilities.

The Structural Biology infrastructure enables a broad user community to conduct the high-resolution study of biological molecules involved in cellular architecture, biocatalysis, environmental sensing, and carbon capture. It advances and promotes scientific and technological innovation in support of the DOE mission.

In FY 2012, funds will enable initial development of life science experimental stations at the National Synchrotron Light Source II (early beam availability currently scheduled for February 2014) and at the Linac Coherent Light Source and the Spallation Neutron Source, two facilities that have commenced operations and demonstrated pilot activities with considerable potential benefits for the structural biology user community. The increased funding includes support for new end stations and access to proposed new x-ray fluorescence and absorption nanotomography undulator beamlines, optimized for lower energies (2–15 keV) and spatial resolution (less than 50nm) to allow multi-modal imaging of biological cellular substructures with co-localization of trace elements. These capabilities will allow visualization of in situ processes critical to DOE mission needs, ranging from carbon cycling in microbial communities to nutrient exchange at microbe-plant interfaces during bioenergy crop growth.

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
▪ **Joint Genome Institute**	**69,000**	**70,756**

The 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. JGI contributes valuable information through the large-scale genome sequencing of bioenergy crops such as sorghum, maize, poplar, and soybean, as well as targeted sequencing of gene expression sets for switchgrass, cotton, wheat, and conifers. The JGI provides the genomic blueprint which is the basis for systems biology of plants and environmental microbes. Through the development of genome assembly algorithms, tools for comparative gene and pathway analysis, and systems-level integration of data from multiple sequencing technology and functional genomics platforms, JGI has enabled researchers and plant breeders to identify key traits and genes for specific bioenergy applications or environmental conditions. In addition to a broad reference set of laboratory cultured microbes, JGI has pioneered approaches for sequencing uncultured environmental microbial isolates and microbial communities. These metagenomic capabilities will eventually enable elucidation of the functional potential of all the biological organisms that comprise a specific environmental system.

JGI provides DOE mission-relevant genome sequencing, genome data acquisition, and genome analysis to the broad scientific user community, DOE national laboratories, and the DOE Bioenergy Research Centers. JGI's suite of high-throughput tools, technologies, and comparative analytical capabilities serve as a discovery platform for understanding the organization and function of complex genomes. This genomic-level understanding is vital to the predictive design and engineering of microbial and plant systems for mission capabilities in bioenergy, carbon cycling and biosequestration, and environmental remediation and stewardship.

In FY 2012, JGI funding will continue to support access by the scientific user community and the DOE Bioenergy Research Centers to large-scale genome data acquisition and analysis. Funding will also support a greater emphasis on metagenome expression and sequencing of environmental microbial communities or the plant-microbe rhizosphere, improved genome annotation, and functional analysis and verification of genome-scale models. Funding is increased to support JGI grand challenge activities that encompass large scale genome comparisons across different soil environments or plant-microbe associations. These activities will require development of significant new capabilities for acquisition, analysis, and integration of huge genome datasets.

	FY 2010	FY 2012
Achieved Operating Hours	8,400	N/A
Planned Operating Hours	8,400	8,400
Optimal hours	8,400	8,400
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	0	N/A
Number of Users[a] 9	40	940

[a] All JGI users are remote. Primary users are individuals associated with approved projects being conducted at the JGI in a reporting period. Each user is counted once per year regardless of how many proposals their name may be associated with. Different users may utilize vastly differing levels of JGI resources.

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
SBIR/STTR	**0**	**10,258**

In FY 2010, $7,777,000 and $933,000 were transferred to the SBIR and STTR programs, respectively. Additionally, $15,000 of prior year balances was transferred as follows: $14,000 for SBIR and $1,000 for STTR.

FY 2012 amount shown for the SBIR and STTR programs is the estimated requirement for continuation of these congressionally mandated programs.

Total, Biological Systems Science	**309,766**	**376,262**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Genomic Science	
▪ **Foundational Genomics Research**	
Funding is increased to support foundational science aimed at advancing applications of biotechnology for bio-based solutions to current and emerging energy and environmental challenges. Funding will support the development of new synthetic molecular toolkits for understanding natural systems combined with computer-aided design testbeds for the design and construction of improved biological components or new, multi-scale natural and hybrid biological processes and systems. These toolkits will include the development of new genetic transformation approaches for natural and re-engineered plant and microbial systems, as well as technology to facilitate design engineering of multi-component biological functional modules and to manipulate genetic control systems. The testbeds will allow for prototyping and functional validation of natural and engineered biological modules, especially to understand cross-talk and spatial and topological constraints within cellular systems. Funding is also increased to support the development of genomic and analytical technologies for multi-modal, dynamic measurements in actively-occurring environmental processes and during cellular communication.	+69,243
▪ **Genomics Analysis and Validation**	
Funding is increased to support genome-scale validation of annotation in metagenomic datasets.	+2,000
▪ **Metabolic Synthesis and Conversion**	
Funding is decreased with the completion of projects focused on fermentative microbial biohydrogen production.	-1,437

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Computational Bioscience**	
Funding is increased to further develop a systems biology knowledgebase to integrate microbial community genomic, proteomic, and transcriptomic experimental data sets from research conducted at the DOE Bioenergy Research Centers, the Joint Genome Institute, and the Genomic Science supported activities. The increase will also support development of new methods for simulation of microbial metabolism and cellular regulation.	+6,138
Total, Genomic Science	**+75,944**
Radiological Sciences	
▪ **Radiochemistry and Imaging Instrumentation**	
Funding is decreased for the development of methodologies for high activity level synthesis of immunoPET radiotracers.	-772
▪ **Radiobiology**	
Funding is reduced for studies on bystander effects and adaptive immune function, and completed for research on genome instability and DNA damage in single cells in response to low dose radiation exposure.	-11,581
Total, Radiological Sciences	**-12,353**
Ethic, Legal, and Societal Issues	
ELSI research is completed in FY 2012. The societal benefits and implications of DOE mission areas will be addressed within relevant programmatic activities, completing the standalone ELSI activity in BER.	-5,000
Medical Applications	
BER funding for the Artificial Retina effort is completed with integration and pre-clinical testing of a 240 electrode retinal device as a basis for fabrication of a 1,000 electrode device. The activity is ready to transition out of DOE for development and application.	-8,226
Biological Systems Facilities and Infrastructure	
▪ **Structural Biology Infrastructure**	
Increased funding will enable initial development of life science experimental stations and instrumentation at major new DOE national user facilities such as SNS and LCLS, providing access to proposed new x-ray fluorescence and absorption nanotomography undulator beamlines. Their optimization for lower energies (2–15 keV) and spatial resolution (less than 50nm) will allow multi-modal imaging of biological cellular substructures with co-localization of trace elements. +4,1	17

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Joint Genome Institute**	
Increased funding will support JGI grand challenge activities that encompass large scale genome comparisons across different soil environments or plant-microbe associations.	+1,756
Total, Biological Systems Facilities and Infrastructure	**+5,873**
SBIR/STTR	
Amount shown is the estimated requirement for FY 2012; FY 2010 amounts were previously transferred to the SBIR and STTR programs.	+10,258
Total Funding Change, Biological Systems Science	**+66,496**

Climate and Environmental Sciences

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation FY	2012 Request
Climate and Environmental Sciences		
Atmospheric System Research	26,385	26,392
Environmental System Science	83,048	101,177
Climate and Earth System Modeling	69,081	77,294
Climate and Environmental Facilities and Infrastructure	99,751	128,171
SBIR/STTR 0		8,604
Total, Climate and Environmental Sciences	278,265	341,638

Description

The Climate and Environmental Sciences subprogram focuses on a predictive, systems-level understanding of the fundamental science associated with climate change and DOE's environmental challenges—both key to supporting the DOE mission. The subprogram supports an integrated portfolio of research from molecular-level to field-scale studies with emphasis on multidisciplinary experimentation and use of advanced computer models. The science and research capabilities enable DOE leadership in climate-relevant atmospheric-process research and modeling, including clouds, aerosols, and the terrestrial carbon cycle; large-scale climate change modeling; experimental research on the effects of climate change on ecosystems; integrated analysis of climate change impacts; and advancing fundamental understanding of coupled physical, chemical, and biological processes controlling contaminant mobility in the environment.

The subprogram supports three primary research activities and two national scientific user facilities.

- Atmospheric System Research seeks to resolve the two major areas of uncertainty in climate change model projections: the role of clouds and the effects of aerosols on the atmospheric radiation balance.
- Environmental System Science supports research that provides scientific understanding of the effects of climate change on terrestrial ecosystems, the role of terrestrial ecosystems in global carbon cycling, and the role of subsurface biogeochemical processes on the fate and transport of DOE-relevant contaminants.
- Climate and Earth System Modeling focuses on development, evaluation, and use of large scale climate change models to determine the impacts of climate change and mitigation options.
- Two 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 the BER mission and of importance to DOE.

Selected FY 2010 Accomplishments

- ARM researchers completed peer reviewed experiments using fixed, mobile, and aerial ARM facilities in several climatically important regions including the mid-continental U.S., Tropical Western Pacific, the North Slope of Alaska, the Azores, and a mountainous region in Colorado to address critical science questions regarding marine clouds, cirrus clouds, and climatic effects of aerosols. Two ARM aerial facility experiments included a five-month campaign to determine the impact of cirrus cloud microphysical properties on radiative effects in the atmosphere and a field campaign to increase scientific knowledge about evolution of black carbon and secondary organic aerosols from both urban/manmade and biogenic sources. Strong collaborations with other agencies and countries were developed to conduct these experiments. In FY 2010, the ARM facility hosted approximately 1,200 users, resulting in over 185 publications in the scientific literature.
- Through a novel combination of field site comparisons and laboratory experiments, scientists showed that photodegradation plays a significant role in the carbon release through direct breakdown of organic matter by solar irradiance in some ecosystems. The study showed that photodegradation may account for 20-90% of carbon releases from ecosystems in which organic matter is exposed to solar irradiation. This result identifies a previously unquantified source of terrestrial ecosystem carbon flux that is not accounted for in major land models.
- Researchers characterized the genomes of the dominant microbial populations and the proteins they expressed during in situ tests of uranium bioremediation. Changes in microbial metabolism, energy generation and microbial strain composition over time reflected the changing geochemical conditions stimulated during the field test. The results yielded important insights into the functioning of subsurface microbial communities, providing mechanistic information that can be used to inform models of uranium bioremediation. This approach enables scientists to study the mechanistic basis for the growth and functioning of active microbes in the environment and is applicable not only to bioremediation but carbon sequestration, nutrient cycling, and other DOE mission areas.
- The Community Climate System Model (CCSM), the leading U.S. open-source, community-driven climate model, is supported predominantly by DOE and NSF. The most recent release, version 5 (CCSM5), included several climate system components exclusively developed by DOE supported scientists. BER provided a new sea ice sub-model, a new land ice sheet sub-model, physical formulation improvements to the global ocean sub-model, and a new option to make the CCSM5 ready for petascale computing platforms. BER provided a new radiation package, a new aerosol sub-model, and two new cloud schemes: more accurate representations of near-surface cloud formations leading to precipitation and a description of the lifecycle of cirrus clouds.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Atmospheric System Research	**26,385**	**26,392**

The emphasis for Atmospheric System Research is to understand and model the radiation balance from the surface of the Earth to the top of the atmosphere and how this balance is affected by clouds, aerosols, and increased concentrations of greenhouse gases in the atmosphere. In the presence of clouds

	FY 2010 Current Appropriation	FY 2012 Request

and aerosols, current transfer models are inaccurate, limiting our ability to predict future climates with a high degree of confidence.

The Intergovernmental Panel on Climate Change (IPCC) fourth assessment report establishes that cloud simulation is poor in all climate models. With regard to aerosols we are unsure of the magnitude (or even sign) of its forcing on the climate. BER research seeks to increase the fidelity of process representations and interactions that are needed to develop the next-generation of climate models, both in the U.S. and internationally.

In FY 2012, research will continue to focus on improving understanding of the relationship of clouds and radiative transfer processes in the atmosphere, characterization of aerosol physical, chemical, and optical properties and their effects on the Earth's energy balance, and incorporation of this understanding into improved physical process representations. Specific focus areas include the life cycle of marine boundary layer clouds and their impacts on radiation, aerosol-cloud-precipitation interactions, arctic clouds and their interactions with aerosols, high altitude (cirrus) clouds and their life cycles and impacts on radiation budget, and processes and atmospheric transformations involving biogenic aerosols. Analyses will continue on data from recent ARM campaigns in the continental U.S., India, the Azores, and China. Research will be coordinated with BER's Earth System Modeling activity to quickly and effectively incorporate process representations into climate models. Research on clear sky conditions has been completed.

Environmental System Science	**83,048**	**101,177**
▪ **Terrestrial Ecosystem Science**	**28,693**	**49,994**

The Terrestrial Ecosystem Science activity advances fundamental science on the effects of climate change on terrestrial ecosystems and the role of terrestrial ecosystems in global carbon cycling. Research focuses on determining the effects of climate change on the structure and functioning of terrestrial ecosystems, including the processes that control exchanges of carbon dioxide and energy between the atmosphere and the terrestrial biosphere. Results are used to improve the reliability of global carbon cycle models for predicting future atmospheric concentrations of carbon dioxide (CO_2) and to quantify ecological effects of climate change.

Climate change is expected to cause changes in many terrestrial ecosystems, but present correlations between climate and ecosystems do not provide the cause-and-effect understanding needed to forecast effects of future climate changes on terrestrial ecosystems and their interactions with the atmosphere. Experiments involving controlled manipulations of climate factors, and atmospheric CO_2 concentration are needed to establish cause-and-effect relationships between ecosystems and climate changes. While a significant fraction of the CO_2 released to the atmosphere during fossil fuel combustion is apparently being taken up by terrestrial ecosystems, future impacts of the timing and magnitude of climate change, particularly warming, on the uptake of CO_2 by the terrestrial biosphere remains a mystery. The significant sensitivity of climate models to a terrestrial carbon cycle feedback, and the uncertain sign of that feedback, makes resolving the role of the terrestrial biosphere in the global carbon cycle a high priority.

In FY 2012, research will focus on potential effects of warming, changes in rainfall, and elevated atmospheric CO_2 on terrestrial ecosystems and the terrestrial carbon cycle. Continuing research will

(dollars in thousands)	
FY 2010 Current Appropriation	FY 2012 Request

support AmeriFlux, the network of ecosystem CO_2 and energy flux measurement sites, for directly estimating net ecosystem production and carbon storage by terrestrial ecosystems. Ecosystem model development and testing will support the activity goals.

In FY 2012, new activities will include prototyping of experimental infrastructure needed to initiate the next-generation ecosystem-climate change experiment, with a focus on arctic tundra. The urgency of understanding the Arctic ecosystem and its fundamental responses to climate change is based on the fact that the upper three meters of tundra contain more carbon, primarily methane, than Earth's atmosphere. Release of this carbon from thawing permafrost could dramatically amplify the warming of the planet. In FY 2012, increased funding will support critical model development needs, initial data collection, prototype-scale observational efforts, and field experiments. Model development will include length scales from watershed to global, focus on extending existing models from one to three dimensions, and address spatial heterogeneities that will likely be important in understanding not only compartment interdependencies but also the impact of landscape change on carbon cycling. The research will refine the experimental approach, technology development, and field site requirements for subsequent, long-term field-intensive studies.

In FY 2012 enhanced carbon cycle research will describe and predict the emissions and dynamics governing total atmospheric greenhouse content and trace changes in atmospheric carbon content back to specific natural and anthropogenic emitters and/or natural carbon exchanges. This activity (+$9,720,000), to underpin measurement, reporting, and verification (MRV), will focus on the science and technical capability required to understand the carbon cycle and multi-scale dynamics involved in natural and anthropogenic emissions in order to describe the stochastic nature of the presently observed system noise in geographically dispersed ecosystems. While emissions rely in large part on technologies to measure or infer surface fluxes, the greatest challenge is to adequately describe and model the exchange of carbon involving and within geographically dispersed ecosystems and to reliably utilize inverse modeling to distinguish between natural and anthropogenic emissions. This activity also provides fundamental knowledge and capabilities important to future applications including, for example, the upscaling of carbon cycle dynamic modeling associated with next generation ecological experimental sites to regional scales as well as MRV related to possible future climate treaties.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **Terrestrial Carbon Sequestration Research**	**4,603**	**1,000**

Terrestrial Carbon Sequestration research supports efforts to identify, understand, and predict the fundamental physical, chemical, biological, and genetic mechanisms controlling carbon sequestration in terrestrial ecosystems including soils. The activity develops models of these systems to predict future scenarios and to inform larger-scale coupled earth systems models and seeks ways to exploit these processes to enhance carbon sequestration in terrestrial ecosystems. Current research focuses on switchgrass (*Panicum virgatum*) ecosystems associated with DOE's cellulosic biofuels research. Results indicate that the switchgrass rooting system could be managed for enhanced soil carbon sequestration.

In FY 2012, the program will focus on completing the current field research and on the synthesis of data and knowledge collected over the history of the program. Funding is reduced with the completion of research on the cycling of carbon associated with agriculture and forestry.

(dollars in thousands)		
	FY 2010 Current Appropriation	FY 2012 Request
▪ **Subsurface Biogeochemical Research**	**49,752**	**50,183**

The Subsurface Biogeochemical Research activity addresses fundamental science questions at the intersection of biology, geochemistry, and physics that, together with computational modeling, advances a predictive understanding of processes controlling the mobility of radionuclides in the environment. This activity supports research at many scales and includes field research sites at Oak Ridge, Tennessee; Hanford, Washington; and Rifle, Colorado (a uranium mill tailings site). Field sites provide researchers opportunities to obtain samples of environmental media for laboratory analysis and to test laboratory-derived hypotheses at the field scale. Field sites are also used to test and evaluate computer models describing contaminant mobility in the environment. Strong ties have been developed between the Environmental Molecular Sciences Laboratory and subsurface biogeochemical researchers. This activity includes SciDAC support for research on advanced models to predict the mobility of subsurface contaminants.

This research provides the scientific foundation for the solution of key environmental challenges within DOE and other agencies, including nuclear waste cleanup, carbon sequestration, and monitoring of contaminants in groundwater around existing and future waste disposal and storage sites. These efforts will assist DOE research on using deep geological formations to store carbon dioxide taken from the atmosphere.

In FY 2012, the activity will incorporate a complex, integrated, multi-disciplinary, multi-scale systems approach that builds on the findings of the 2009 workshop, *Complex Systems Science for Subsurface Fate and Transport*, and frames the current scope of environmental research across scales as a continuum of complex interdependent processes.

Climate and Earth System Modeling	**69,081**	**77,294**

Climate and Earth System Modeling seeks to develop and test an application-focused comprehensive Earth system modeling capability and analysis environment that includes natural and human Earth systems, information on climate change at decade-to-century time scales and global-to-local spatial scales, and descriptions and quantifications of uncertainties.

▪ **Regional and Global Climate Modeling**	**27,470**	**29,061**

Regional and Global Climate Modeling focuses on the development, evaluation, and use of regional and global climate models to project future climate with quantified uncertainty over decades to centuries. Core research includes development of general circulation models and associated components; development of regional models; regional and global model diagnosis through the use of appropriate metrics; analysis of multi-model climate change simulations and projections; and the development and use of new techniques for uncertainty quantification. The activity also provides support for national and international climate modeling research and assessments. Currently there is also a pressing need to evaluate the best methods to obtain regional and local scale information for climate adaptation.

In FY 2012, the focus will be on improving and evaluating the reliability of climate predictions at higher resolution. The results of the coordinated experiments from about 20 modeling groups world-wide, available as part of the Climate Model Intercomparison Project (CMIP5) archive, will continue to facilitate the development and improvement of the diagnostic tools and metrics used to evaluate the reliability of climate change projections and the multiscale natural modes of variability. Studies on understanding climate extremes; reducing the uncertainty in model predictions, detection and attribution; and using the newly developed models will continue, as well as efforts to understand feedback processes, such as high latitude ocean-ice interaction and carbon cycle feedbacks that are important for understanding climate change. Current models have an unacceptably large range of uncertainty, due to differences in the simulation of feedbacks and insufficient information to properly constrain model parameters. Research will continue to reduce these uncertainties using leadership computing resources and integrated observational data sets.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **Earth System Modeling**	**30,353**	**36,569**

Earth System Modeling develops and integrates components of climatic processes into Earth System Models (ESMs) using high computational throughput to provide simulations of climate variability and change over decades to centuries. Research includes incorporation of improved physical representations, e.g., atmospheric, biogeochemical, terrestrial, land-surface-ice, aerosol, and cloud, in the specific modules of the coupled model; development of algorithms and computational methods for coupling of ESM components; coupling and testing of ESM components; abrupt climate change; and visualization and analysis.

The high computational throughput effort is closely coordinated with BER's SciDAC Climate Change Research activities in partnership with the Advanced Scientific Computing Research program. This partnership specifically addresses scaling and other computational issues, so that needed high throughput is achieved.

Improvement of the representation of the physical, chemical, and biogeochemical processes crucial for climate change prediction, such as cloud-aerosol and carbon cycle-climate, are an important part of this activity. Development and testing of these processes and their incorporation into high resolution models will continue. The activity also continues development of software tools that enhance the ability to analyze high resolution model output and observational data in a single framework. This modeling program will also continue support of data visualization initiated in FY 2010.

In FY 2012, funding will expand research that focuses on converting observational datasets into specialized, multi-variable datasets for model testing and improvement; establishment of model development testbeds in which model components can be rapidly prototyped and evaluated using integrated observational datasets; and development of numerical methods to enable climate models to effectively use future computer architectures. The goal of these activities is to develop the next generation comprehensive coupled, high resolution earth system model.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **Integrated Assessment**	**11,258**	**11,664**

Integrated Assessment research provides scientific insights into options for mitigation of adaptation to climate change through multi-scale models of the entire climate system, including human processes responsible for greenhouse gas emissions, land use, and combined impacts on and feedbacks from changing human and natural systems, including the energy system. Research focuses on improving the fundamental knowledge and methodologies for analysis of climate change impacts and adaptations; innovative general approaches to modeling impacts and adaptation; developing different measures of impacts; and developing approaches to address probabilities and uncertainties. Integrated Assessment develops advanced quantitative tools for exploring the implications of science and technology decisions and innovations on our energy, environmental, and economic futures leading to improved understanding of potential emissions trajectories and the environmental costs and benefits of stabilization options.

In FY 2012, BER will continue research on several key research challenges identified in the November 2008 *Integrated Assessment Research* Workshop. In particular, Integrated Assessment research will continue to provide the scientifically rigorous, quantitative basis from which policy makers and researchers may assess the impacts of the Nation's scientific and engineering enterprise, improve their understanding of its dynamics, and assess likely outcomes for decision-making on our climate, energy, economic futures. The Integrated Assessment activity will continue to support open source, community-based approaches to modeling; improve capacity to conduct inter-model comparisons and multi-model studies; improve capacity to enhance convergence of models and collaborations across the Integrated Assessment, Earth System Modeling, and Impacts, Adaptation, and Vulnerability research communities, especially for regional-scale and multi-scale questions; and enhance transparency and accessibility for both data and models by the Integrated Assessment research community, their collaborators, and other user communities.

Climate and Environmental Facilities and Infrastructure	**99,751**	**128,171**
▪ **Atmospheric Radiation Measurement Climate Research Facility**	**42,208**	**67,977**

The Atmospheric Radiation Measurement Climate Research Facility (ARM) is a multi-platform national scientific user facility, with stationary and mobile platforms and instruments around the globe. ARM provides continuous field measurements of climate data to promote the advancement of atmospheric process understanding and climate models through precise observations of atmospheric phenomena. Stationary sites provide scientific testbeds in three different climate regions (mid-latitude, arctic, and tropical). The operating paradigm of continuous measurement of atmospheric and surface properties at long-term sites is well suited to climate studies. The two mobile facilities provide a capability to address high priority scientific questions in other regions. The ARM aerial capability provides in situ cloud and radiation measurements that complement the ground-based measurements. ARM provides continuous, long-term observations needed to develop and test understanding of the central role of clouds in the Earth's climate and to determine the effects of aerosol emissions on the atmospheric radiation balance, the two largest uncertainties in climate change research.

In FY 2012, ARM will continue its long-term observations from the fixed sites and will provide data from new instruments acquired with Recovery Act funding. These new instruments provide data on 3-D cloud evolution and properties, a broader geographic coverage of aerosol measurements, and enhanced surface characterization measurements. ARM will conduct field experiments to study questions on aerosols and various cloud types—cirrus, marine, and mixed-phase (ice and water)—to improve process understanding as well improving regional and Earth System Models that simulate climate change. A mobile facility and accompanying aerial measurements will support an experiment in India to examine the impact of aerosols on the Indian monsoon. The experiment using the other mobile facility will continue to examine liquid and mixed-phase clouds in Colorado. Experiments proposed for use of the mobile facilities after completion of these two deployments are currently under peer review.

Increased funding in FY 2012 will support the development of a new mobile facility to be initially located at Oliktok Point, Alaska for three dimensional measurements of cloud and aerosol properties over land, sea, and ice, as part of the program's expanded arctic research efforts. Regular flights of small UAVs will provide in situ measurements that complement the mobile facility measurements as well as extend the observational coverage from Oliktok to the North Pole. This includes full funding for a major item of equipment, the Dual-Frequency Scanning Cloud Radar at Oliktok, with a total estimated cost of $3,070,000.

Additionally, in FY 2012, a new ARM fixed site will be developed in the Azores to provide new long-term observations for marine clouds and aerosols. This includes full funding for the major item of equipment, the Dual-Frequency Scanning Cloud Radar at the Azores site, with a total estimated cost of $3,070,000.

	FY 2010	FY 2012
Achieved Operating Hours	8,185	N/A
Planned Operating Hours	7,884	7,884
Optimal hours	7,884	7,884
Percent of Optimal Hours	104%	100%
Unscheduled Downtime	0	N/A
Number of Users[a] 1,	185	1,200

- **Environmental Molecular Sciences Laboratory** **52,510 55,721**

  The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), a scientific user facility located at the Pacific Northwest National Laboratory, provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences for DOE and the Nation. With more than fifty leading-edge instruments and a supercomputer, EMSL enables users to undertake molecular-scale experimental and theoretical research on aerosol chemistry, biological systems, biogeochemistry, and interfacial and surface science.

  EMSL encourages the use of multiple experimental systems to provide fundamental understanding of the physical, chemical, and biological processes that underlie DOE's energy and environmental mission areas, including alternative energy sources, improved catalysts and materials for industrial applications, insights into the factors influencing climate change and carbon sequestration processes, and an understanding of subsurface biogeochemistry at contaminated sites. For example, EMSL's nuclear magnetic resonance spectrometers; high resolution mass spectrometers; ultra-high vacuum

[a] ARM users are both onsite and remote. A user is an individual who accesses ARM databases or uses equipment at an ARM site. Individuals are only counted once per year at an individual site but may be counted at different ARM sites if they are a user at more than one site.

(dollars in thousands)	
FY 2010 Current Appropriation	FY 2012 Request

scanning, tunneling, cryogenic and atomic force microscopy capabilities; and 160 teraflop supercomputer are all used to study microbial and plant species important for bioenergy and other energy sources. The EMSL capability for proteomics is unique and essential for advances in the field of systems biology.

In FY 2012, EMSL operations funding is increased to provide users with enhanced access to new EMSL capabilities obtained with Recovery Act funding. Capital equipment support for EMSL enables instrument upgrades and modifications as well as the development and procurement of unique state-of-the-art capabilities. A multi-year effort to acquire a High Magnetic Field Mass Spectrometer, a major item of equipment with a total estimated cost of $17,500,000, was initiated in FY 2010 and will continue in FY 2012. This transformational instrument will enable users to undertake world-leading proteomics, metabolomics and lipidomics of plant, animal and microbial cells, communities, and other complex systems with application to biofuels, systems biology, bioremediation, aerosol particle characterization, catalysis, and fossil fuel analysis. A suite of integrated imaging capabilities (advanced data processing, image correlation, and remote operational capabilities) will be developed to better understand biological transformations and energy and materials transport in complex environments and to support systems biology research, particularly proteomics.

	FY 2010	FY 2012
Achieved Operating Hours	4,329	N/A
Planned Operating Hours	4,352	4,365
Optimal hours	4,365	4,365
Percent of Optimal Hours	99.7%	100%
Unscheduled Downtime	<1%	N/A
Number of Users[a] 7	32	750

- **Data Management and Education** **4,258** **2,773**

The role of climate data management is to facilitate full and open access to quality-assured carbon cycle data for climate change research. Data holdings include records of the concentrations of atmospheric CO_2 and other greenhouse gases; the role of the terrestrial biosphere and the oceans in biogeochemical cycles of greenhouse gases; emissions of CO_2 into the atmosphere; long-term climate trends; the effects of elevated CO_2 on vegetation; and the vulnerability of coastal areas to rising sea levels. Data management support for major projects, such as the AmeriFlux network, measurements of CO_2 taken aboard ocean research vessels, and DOE-supported Free-Air CO_2 Enrichment (FACE) experiments, are also included.

In FY 2012, the data management activity will continue to support data users with tools for identifying and accessing those data needed to address important climate change research questions. The activity will also implement information technology advances to meet evolving data sharing

[a] EMSL users are both onsite and remote. Individual users are counted once per year.

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
needs of researchers. These include user interfaces, visualization capabilities, and customized data extractions from large, complex, data files. Education activities were completed in FY 2010.		
▪ **General Purpose Equipment (GPE)**	**75**	**1,000**
GPE funding provides equipment for the Oak Ridge Institute for Science and Education (ORISE), such as information system computers and networks and instrumentation that support multi-purpose research. In FY 2012 GPE funding is increased to enable ORISE to replace and upgrade obsolete networking and data storage systems with more efficient and less energy intensive systems in support of programmatic activities.		
▪ **General Plant Projects (GPP)**	**700**	**700**
GPP funding supports minor construction, capital alterations, and additions, such as replacing utility systems in 30 to 40 year old buildings. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and meeting the requirements for safe and reliable facilities operation. This activity includes stewardship GPP funding for ORISE. The total estimated cost of each GPP project will not exceed $10,000,000 in FY 2012.		
SBIR/STTR	**0**	**8,604**
In FY 2010, $6,644,000 and $797,000 were transferred to the SBIR and STTR programs, respectively. Additionally, $138,000 of prior year balances were transferred as follows: $123,000 for SBIR and $15,000 for STTR.		
FY 2012 amount shown for the SBIR and STTR programs is the estimated requirement for continuation of these congressionally mandated programs.		
Total, Climate and Environmental Sciences	**278,265**	**341,638**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Appropriation ($000)
Atmospheric System Research	
Atmospheric System Research is held at the FY 2010 appropriated level.	+7
Environmental System Science	
▪ **Terrestrial Ecosystem Science**	
The increased funding will support prototyping of experimental infrastructure needed for the initiation of the next-generation ecosystem-climate change experiment, with a focus on arctic tundra. Additionally, BER will support research on carbon cycle multi-scale dynamics in order to describe the nature of	

	FY 2012 vs. FY 2010 Current Appropriation ($000)
the presently observed system noise. This research will underpin MRV of atmospheric greenhouse gases.	+21,301
▪ **Terrestrial Carbon Sequestration Research**	
Funding is reduced with the completion of a series of research projects focused on the cycling of carbon sequestration associated with long-studied field sites.	-3,603
▪ **Subsurface Biogeochemical Research**	
Funding is held near the FY 2010 appropriated level.	+431
Total, Environmental System Science	**+18,129**
Climate and Earth System Modeling	
▪ **Regional and Global Climate Modeling**	
Funding is increased to continue efforts to improve the accuracy of climate predictions at higher resolution.	+1,591
▪ **Earth System Modeling**	
The increased funding will support enhanced research on the development of numerical methods and model testing and validation for a comprehensive coupled, high resolution earth system model.	+6,216
▪ **Integrated Assessment**	
In FY 2012, Integrated Assessment is held near the FY 2010 appropriated level.	+406
Total, Climate and Earth System Modeling	**+8,213**
Climate and Environmental Facilities and Infrastructure	
▪ **Atmospheric Radiation Measurement Climate Research Facility (ARM)**	
The increase will support new remote sensing and in situ measurements of clouds and aerosols over arctic land, ice, and ocean surfaces; a new fixed site in the Azores for remotely sensed measurements of marine clouds and aerosols; and continuing operations of the current ARM infrastructure.	+25,769
▪ **Environmental Molecular Sciences Laboratory**	
Funding is increased to support acquisition of new facility instrumentation.	+3,211
▪ **Data Management and Education**	
Funding is reduced to reflect the completion of the education program.	-1,485

	FY 2012 vs. FY 2010 Current Appropriation ($000)
▪ **General Purpose Equipment**	
GPE Funding is increased to enable ORISE to replace and upgrade obsolete networking and data storage systems with more efficient and less energy intensive systems in support of programmatic activities.	+925
Total, Climate and Environmental Facilities and Infrastructure	**+28,420**
SBIR/STTR	
Amount shown is the estimated requirement for FY 2012; FY 2010 amounts were previously transferred to the SBIR and STTR programs.	+8,604
Total Funding Change, Climate and Environmental Sciences	**+63,373**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

FY	2010 Current Appropriation FY	2012 Request
Operating Expenses	564,523	673,636
Capital Equipment	19,640	43,564
General Plant Projects (GPP)	3,868	700
Total, Biological and Environmental Research	588,031	717,900

Funding Summary

(dollars in thousands)

FY	2010 Current Appropriation FY	2012 Request
Research 39	4,370	470,077
Scientific User Facilities Operations and Research	179,018	213,871
Major Items of Equipment	10,700	13,390
Facility related GPP	3,168	0
Other[a]	775	20,562
Total, Biological and Environmental Research	588,031	717,900

Scientific User Facilities Operations and Research

(dollars in thousands)

FY	2010 Current Appropriation FY	2012 Request
Biological Systems Science		
Structural Biology Infrastructure	15,300	19,417
Joint Genomics Institute	69,000	70,756
Total, Biological Systems Science	84,300	90,173
Climate and Environmental Sciences		
Atmospheric Radiation Measurement Climate Research Facility	42,208	67,977
Environmental Molecular Sciences Laboratory	52,510	55,721
Total, Climate and Environmental Science	94,718	123,698
Total Science User Facilities Operations and Research	179,018	213,871

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

Facilities Users and Hours

FY	2010 Current Appropriation FY	2012 Request
Joint Genome Institute		
Achi eved Operating Hours	8,400	N/A
Planned Operating Hours	8,400	8,400
Opt imal hours	8,400	8,400
Percent of Optimal Hours	100%	100%
Unscheduled Downtime	0	N/A
Num ber of Users[a] 9	40	940
Atmospheric Radiation Measurement Climate Research Facility (ARM)		
Achieved Operating Hours	8,185	N/A
Planned Operating Hours	7,884	7,884
Optimal hours	7,884	7,884
Percent of Optimal Hours	104%	100%
Unscheduled Downtime	0	N/A
Number of Users[b] 1,	185	1,200
Environmental Molecular Sciences Laboratory		
Achieved Operating Hours	4,329	N/A
Planned Operating Hours	4,352	4,365
Optimal hours	4,365	4,365
Percent of Optimal Hours	99.7%	100%
Unscheduled Downtime	<1%	N/A
Number of Users[c] 7	50	750

[a] All JGI users are remote. Primary users are individuals associated with approved projects being conducted at the JGI in a reporting period. Each user is counted once per year regardless of how many proposals their name may be associated with. Additionally, different users reflect vastly differing levels of JGI resources.

[b] ARM users are both onsite and remote. A user is an individual who accesses ARM databases or uses equipment at an ARM site. Individuals are only counted once per reporting period at an individual site but may be counted at different ARM sites if they are a user at more than one site.

[c] EMSL users are both onsite and remote. Individual users are counted once per year.

FY	2010 Current Appropriation FY	2012 Request
Total Facilities		
Achieved Operating Hours	20,914	N/A
Planned Operating Hours	20,636	20,649
Optimal hours	20,649	20,649
Percent of Optimal Hours	101.3%	100%
Unscheduled Downtime	<1%	N/A
Number of Users	2,875	2,890

Structural Biology Infrastructure activities are at Basic Energy Sciences user facilities and the user statistics are included in the BES user statistics.

Major Items of Equipment

(dollars in thousands)

Prior	Years	FY 2010 Current Appropriation	FY 2011 CR	FY 2012 Request	Total
Atmospheric Radiation Measurement Climate Research Facility (ARM)					
Dual-Frequency Scanning Cloud Radar for Oliktok, Alaska ARM Site					
TEC/TPC	0	0	0 3	,070 3	,070
Dual-Frequency Scanning Cloud Radar for ARM Azores Climate Activity					
TEC/TPC	0	0	0 3	,070 3	,070
Total ARM TEC/TPC	0	0	0 6	,140 6	,140
Environmental Molecular Sciences Laboratory (EMSL)					
Advanced Oxygen Plasma Assisted Molecular Beam Epitaxy system					
TEC/TPC	0	3,200 0 0			3,200
Secondary Ion Mass Spectrometer					
TEC/TPC	0	4,500 0 0			4,500
Next Generation, High Magnetic Field Mass Spectrometer					
TEC/TPC	0	3,000 7	,250 7	,250	17,500
Total EMSL TEC/TPC	0 1	0,700	7,250	7,250	25,200
Total BER TEC/TPC	0	10,700	7,250 1	3,390 3	1,340

Atmospheric Radiation Measurement Climate Research Facility

Dual-frequency scanning cloud radar for the ARM Arctic Climate activity. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties at Oliktok, Alaska: essential data for developing high-resolution climate models.

Dual-frequency scanning cloud radar for the ARM Azores Climate activity. This instrument will provide the capability to measure cloud properties in a volume and will provide three-dimensional cloud properties in the Azores, essential data for developing high-resolution climate models.

Environmental Molecular Sciences Laboratory

Advanced Oxygen Plasma Assisted Molecular Beam Epitaxy system is designed for the growth of a wide variety of oxide materials and is funded at $3,200,000 in FY 2010. This instrument will enable synthesis and characterization of oxide films and surfaces important for catalysis, electronic and spintronic materials, and geochemistry.

Secondary Ion Mass Spectrometer will be used for high spatial resolution as well as trace element and isotopic analysis of ultra-fine features and is funded at $4,500,000 in FY 2010. This instrument will provide extremely high resolution of organic and inorganic samples applicable to geochemistry, aerosol particles, and materials.

Next Generation, High Magnetic Field Mass Spectrometer system will be a world-leading system to measure and characterize complex mixtures of intact proteins and other biomolecules, aerosol particles, petroleum, and constituents from other types of fluids and is funded at $3,000,000 in FY 2010 and $7,250,000 in FY 2012. Mission Need (CD-0) was approved on October 14, 2009; the Alternative Selection and Cost was reviewed and approved September 28, 2010, with an estimated cost range of $16,000,000 to $17,500,000. CD-2, Approved Performance Baseline is planned for spring 2011. The system will enable world-leading proteomics, metabolomics, and lipidomics with application to bioenergy, as well as provide insights relevant to climate science, fossil fuel processing, and catalysis.

Scientific Employment

	FY 2010 Estimate	FY 2012 Estimate
# University Grants	492	530
Average Size per year	$352,000	$350,000
# Laboratory Projects	234a	190
# Permanent Ph.D.s[b] 1,	460	1,600
# Postdoctoral Associates[c] 3	35	375
# Graduate Students[c] 4	80	535
# Ph.D.s awarded[d] 11	0	110

[a] In FY 2010, BER began consolidating funding for laboratories resulting in fewer individual projects in the outyears.
[b] The number of permanent Ph.D.s is estimated. Information is not readily available on the total number of permanent Ph.D. scientists associated with each research project. In addition to the principal investigator for each research project funded by BER, individual projects typically have between 1 and 20 additional Ph.D.-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.
[c] The number of Postdoctoral Associates and graduate students is estimated for national laboratory projects.
[d] The number of Ph.D.s awarded is estimated. Information is not available on the number of Ph.D.s awarded as a result of BER funded research at universities or national laboratories.

Fusion Energy Sciences

Funding Profile by Subprogram

(dollars in thousands)

	FY 2010 Current Appropriation FY	2012 Request
Fusion Energy Sciences		
Sci ence	169,045	177,816
Facility Operations	223,002	195,882
En abling R&D	25,603	26,002
Total, Fusion Energy Sciences	417,650[a] 39	9,700

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act," 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

The Fusion Energy Sciences (FES) mission is to expand the fundamental understanding of matter at very high temperature and density and to build the scientific foundation needed to develop a fusion energy source. This is accomplished by studying plasma and its interactions with its surroundings across wide ranges of temperature and density, developing advanced diagnostics to make detailed measurements of its properties and dynamics, and creating theoretical and computational models to resolve the essential physics principles.

Background

The pursuit of fusion energy embraces the challenge of bringing the energy-producing power of a star to earth for the benefit of humankind. The promise is enormous—an energy system whose fuel is obtained from seawater and from plentiful supplies of lithium in the earth, whose resulting radioactivity is modest, and which yields zero carbon emissions to the atmosphere. The pursuit is one of the most challenging programs of scientific research and development that has ever been undertaken. With the support of FES, a devoted, expert, and innovative scientific and engineering workforce has been responsible for the impressive progress in harnessing fusion energy since the earliest fusion experiments over sixty years ago. As a result, we are on the verge of a new age in fusion science during which researchers will undertake fundamental tests of fusion energy's viability. Establishing a deep scientific understanding of the requirements for harnessing and optimizing this process on earth is critical, and the progress has been dramatic.

The science underpinning much of fusion energy research is plasma physics. Plasmas—the fourth state of matter—are hot gases, hot enough that electrons have been knocked free of atomic nuclei, forming an ensemble of ions and electrons that can conduct electrical currents and can respond to electric and magnetic fields. The science of plasmas is elegant, far-reaching, and impactful. Comprising over 99% of

[a] Total reduced by $8,350,000; $7,455,000 of which was transferred to the Small Business Innovation Research (SBIR) program and $895,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

the visible universe, plasmas are also pervasive. It is the state of matter of the sun's center, corona, and solar flares. Plasma dynamics are at the heart of the extraordinary formation of galactic jets and accretion of stellar material around black holes. On earth it is the stuff of lightning and flames. Plasma physics describes the processes giving rise to the aurora that gently illuminates the far northern and southern nighttime skies. Practical applications of plasmas are found in various forms of lighting and semiconductor manufacturing, and of course plasma televisions.

On earth, fusion is in fact routinely created and controlled in our research laboratories; leading experiments have generated millions of watts of fusion power for seconds at a time. In the vision of a working reactor, some of the energy will be captured by the plasma itself, and the plasma will self-heat, enabling more fusion to take place. The energy of the energetic ions and neutrons escaping the plasma will be captured and converted into heat. This heat will drive conventional power plant equipment to boil water, generate steam, and turn turbines to put electric power on the grid.

The foremost challenge for fusion is controllable, stable confinement of the hot plasma. The leading approach to fusion energy being pursued in the world is confining the hot fusion fuel with magnetic-field. Presently, this "magnetic fusion energy" approach is the primary focus of the FES program. A second approach is to compress the fuel and then raise its temperature rapidly so as to reach fusion conditions and rely on the inertia of the fuel itself to keep it confined long enough for fusion to happen. This "inertial fusion energy" approach is being studied by the National Nuclear Security Administration (NNSA) and FES together in a joint sponsored program researching high energy density states of matter relevant to inertial fusion.

In the last two decades, progress in our understanding of plasma systems and their control requirements has enabled the fusion community to move to the edge of a new era, the age of self-sustaining "burning" plasmas. For both magnetic and inertial fusion, new experimental plans are being developed to make historic first studies of fusion systems where the energy produced in the fusion process is substantially greater than the energy applied externally to heat and control the plasma. In a burning plasma, energy confinement, heating, and stability affect each other in ways we need to predict, and the scientific issues associated with creating and sustaining power-producing plasma can be explored directly. The flagship program of this new era is the ITER project, an international fusion research project being constructed in Cadarache, France, that will realize magnetically confined burning plasmas for the first time.

A second great challenge for fusion is developing materials that can tolerate the extreme conditions of a fusion reactor. A plasma at a high enough temperature and density to undergo nuclear fusion in a reactor, while generating close to a billion watts of fusion power, will present a uniquely hostile environment to the materials comprising the reactor. The extreme heat fluxes inflicted on a reactor vessel's walls—at rates of tens of millions of watts per square meter—present significant materials science challenges. Furthermore, in a fusion reactor, material near the burning plasma is bathed in a harsh shower of neutrons that will displace its constituent atoms, alter its volume and shape, and thus qualitatively change its strength and other characteristics in unknown ways. The advances in material science required for reactor components that can withstand exposure to the enormous heat and neutron fluxes emanating from prolonged fusion burns are likely to benefit other technologies, including fission power.

Experimental research reveals to us how to scale the results from present fusion experiments to those required for energy production. Increasingly, this research is grounded in a deep, experimentally validated theoretical understanding that is growing in parallel with the empirical accomplishments. High-end computation is playing an integral role in this effort. Theory-based computational modeling and simulation are improving our ability to predict the performance of experimental systems. In many areas once regarded as too complex to allow anything except an empirical approach, modeling and simulation are being used as tools for discovery and are guiding experimental choices, a sign of increasing maturity of the scientific field and increasing readiness for the engineering challenges of fusion energy development. It is this progress that has laid the foundation for the Fusion Simulation Program, a computational initiative aimed at the development of a world-leading, experimentally validated, predictive simulation capability for fusion plasmas in the regimes and geometries relevant for practical fusion energy. The Fusion Simulation Program is led by FES with cross-office support from Advanced Scientific Computing Research.

Advances in fusion science are also fostering discoveries outside the realm of fusion. An example is our increasing understanding of the anomalous heating of the solar corona, where studies in plasma physics are helping to unravel this mystery. Fusion's theory-based computational tools have also been used recently to explain the unexpectedly low brightness of the accretion plasma in the extraordinary environment surrounding super massive black holes in the center of our galaxy. In the past 20 years, similar computational tools have helped to increase dramatically our understanding of the nonlinearly saturated state of plasma turbulence and the resulting energy transport.

FES has four strategic goals:

- Advance the fundamental science of magnetically confined plasmas to develop the predictive capability needed for a sustainable fusion energy source;
- Pursue scientific opportunities and grand challenges in high energy density plasma science to explore the feasibility of the inertial confinement approach as a fusion energy source, to better understand our universe, and to enhance national security and economic competitiveness;
- Support the development of the scientific understanding required to design and deploy the materials needed to support a burning plasma environment; and
- Increase the fundamental understanding of basic plasma science, including both burning plasma and low temperature plasma science and engineering, to enhance economic competiveness and to create opportunities for a broader range of science-based applications.

These distinct but scientifically linked goals synthesize the input from the National Academies, the Fusion Energy Sciences Advisory Committee (FESAC), and the U.S. fusion community.

FES research activities have led to significant advances in fusion related sciences, such as increasing the fusion power output in laboratory experiments by 12 orders of magnitude over the past three decades, developing advanced computation and simulation capability in the areas of energy transport and plasma stability needed to design a device capable of achieving a burning plasma with significant fusion energy output, and demonstrating control of plasma states that scale favorably to burning plasmas and future fusion reactors. The U.S. leads the world in developing the tools and the operating scenarios that impact the plans for ITER operations and design, and in developing the foundations for a validated predictive capability that will enable ITER scenario development and interpretation of the results obtained from this device. Importantly, FES is also establishing the basis for a strong move into the frontier fields of materials science needed for managing the fusion environment and for harnessing its power.

Subprograms

To accomplish its mission and address the strategic goals described above, the FES program is organized into three subprograms—Science, Facility Operations, and Enabling R&D.

- The *Science* subprogram is developing a predictive understanding of plasma properties, dynamics, and interactions with surrounding materials. The greatest emphasis is presently weighted towards understanding the plasma state relevant to stable magnetically confined fusion systems, but increasing emphasis is expected in the areas of plasma-material interaction physics and the materials science associated with the high heat and neutron fluxes that will be encountered in a burning plasma environment. This subprogram also addresses fundamental scientific questions on high-energy-density laboratory plasmas (HEDLP), non-neutral and single-component plasmas, ultra cold plasmas, dusty plasmas, low-temperature plasmas, space and astrophysical plasma physics, plasma control and dynamics, plasma-related atomic and molecular physics, plasma diagnostic techniques, plasma sources, magnetic-field-line reconnection and self-organization, and plasma waves, turbulence, structures, and flows. Since these efforts are typically carried out in university environments, they also serve a critical function in educating and training scientific and technical personnel.

- The *Facility Operations* subprogram includes efforts to build, operate, maintain, and upgrade the large facilities needed to carry out research on fusion energy science. It also includes funding for the U.S. share of the ITER project. The three major experimental facilities in the FES program—the DIII-D tokamak at General Atomics in San Diego, California; the Alcator C-Mod tokamak at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts; and the National Spherical Torus Experiment (NSTX) at Princeton Plasma Physics Laboratory (PPPL) in Princeton, New Jersey—provide the essential tools for the U.S. research community to explore and solve fundamental issues of fusion plasma physics and to address a subset of the materials science issues required to manage the intense heat and particle fluxes of a fusion reactor. All three are operated as national collaborative user facilities and involve users from many laboratories, industries, and universities. The funding for facility operations includes expenses for running the facility; providing the required plasma diagnostics; and for facility maintenance, refurbishment, and minor upgrades.
- The *Enabling R&D* subprogram supports research to optimize and control plasma states in the laboratory, increasing the scientific output of present experiments and the likelihood of success of future fusion facilities. Research is aimed at improving the components and systems that are used to build present and future fusion facilities, thereby enabling them to achieve improved performance and scientific output and bring us closer to the goal of achieving practical fusion energy.

Benefits

The development of plasma science has been motivated by a diverse set of applications such as astrophysics, space science, plasma processing, national defense, and fusion energy. Advances in plasma science have led to significant applications, such as plasma processing of semiconductors and computer chips, material hardening for industrial and biological uses, waste management techniques, lighting and plasma displays, space propulsion, and non-contact infection-free surgical scalpels. Particle accelerators and free electron lasers also rely on plasma science concepts. Related areas of science addressed in these research programs include turbulence and complex systems, multiphase interactions and plasma-material interactions, self-organization of complex systems, astrophysics, geodynamics, and fluids.

Understanding the plasma science and the materials science associated with magnetic fusion energy environments are essential to the development of practical fusion energy. Fusion has the potential to provide an energy source that is virtually inexhaustible and environmentally benign, producing no combustion products or greenhouse gases. While fusion is a nuclear process, the products of the fusion reaction (helium and neutrons) are not intrinsically radioactive. Short-lived radioactivity may result from interactions of the fusion products with the reactor walls, but with proper design a fusion power plant would be passively safe and would produce no long-lived radioactive waste. Fusion reactor design studies suggest that electricity from fusion could cost about the same as electricity from other sources.

Studies of the extreme states of matter in HEDLP are scientifically relevant to inertial fusion energy, a potential alternate path to a fusion energy source. This research is also related to the NNSA stockpile stewardship program and, hence, indirectly supports DOE's national security mission.

Program Planning and Management

FES uses a variety of external entities to gather input for making informed decisions on programmatic priorities and allocation of resources. As part of this effort, FES has developed a system of planning and priority setting that draws on advice from groups of outside experts. FES has also instituted a number of peer review and oversight measures designed to assess productivity and maintain effective communication and coordination among participants in FES activities.

During 2008 and 2009, FES sponsored a series of workshops focused on providing input for a new FES strategic plan.[a] The first workshop covered the field of low temperature plasma physics and produced the report entitled *Low Temperature Plasma Science: Not only the Fourth State of Matter but All of Them* in September 2008. FES organized a community-wide effort that, in June 2009, culminated in a Magnetic Fusion Energy Sciences (MFES) Research Needs Workshop (ReNeW) to describe the scientific research required during the ITER era to develop the knowledge needed for a practical fusion power source. The report *Research Needs for Magnetic Fusion Energy Sciences* was published in September 2009. The planning activities will also describe increased FES stewardship of general plasma science as recommended by the National Research Council (NRC) report entitled *Plasma Science: Advancing Knowledge in the National Interest*.[b]

A Research Needs Workshop for HEDLP was held in November 2009 to evaluate research opportunities in fundamental high-energy-density plasma science and in inertial-fusion-energy-related high-energy-density plasma science. The report was published in October 2010. A FESAC report on scientific issues and opportunities in both fundamental and mission-driven HEDLP, entitled *Advancing the Science of High Energy Density Laboratory Plasmas*, was used as the technical basis for the workshop. SC and NNSA have jointly appointed FESAC as the Federal Advisory Committee for the FES-NNSA joint program in HEDLP. To assist in the management and coordination of U.S. scientific and technical activities in support of ITER, and to prepare for the eventual participation by U.S. scientists in ITER operations and research, FES established the U.S. Burning Plasma Organization (USBPO). The USBPO Director is also the chief scientist for the U.S. ITER Project Office (USIPO), thus providing close coupling between the ITER Project and these scientific activities. The U.S. is also a very active member of the International Tokamak Physics Activity (ITPA) which facilitates international coordination of tokamak research in support of ITER.

FES requires the three major experimental facilities supported by the program to have Program Advisory Committees (PACs). The PACs, composed primarily of researchers from outside the host facility, serve an important role in providing guidance to the facility directors in the form of program review and advice regarding allocation of facility run-time.

FES charges FESAC to convene a Committee of Visitors (COV) panel every three years to assess the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document application, proposal, and award actions and the quality of the resulting portfolio. A COV charge was given to FESAC in November 2008 asking FESAC to review the entire FES research program and report its findings. The COV has conducted its review, meeting with the FES program staff in August 2009. The COV presented its findings to the full committee at the FESAC meeting on March 9-10, 2010. The final FESAC report on this COV activity entitled: "*Fusion Energy Sciences Advisory*

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[a] The 2008/2009 reports are located at http://www.science.doe.gov/ofes/programdocuments.shtml.
[b] Available at http://www.nap.edu/catalog.php?record_id=11960.

Committee: Report on A Committee of Visitors-Review of Procedures and Processes Used to Solicit and Fund Research at Universities, National Laboratories and Industrial Firms", April 2010, has been published.

Basic and Applied R&D Coordination

FES and NNSA have a joint program in HEDLP to provide stewardship of high-energy-density laboratory plasma physics. High energy density plasmas are defined as having pressures exceeding one million atmospheres (1 megabar). The FES high energy density physics program includes discovery-driven fundamental research as well as inertial fusion related science. At the present time this research includes the science of fast ignition, laser-plasma interaction, magnetized high energy density plasmas, high-density high Mach-number plasma jets, heavy-ion-beam driven warm dense matter, compressible and radiative hydrodynamics, laser-plasma interactions, material properties under extreme conditions, and laboratory astrophysics. The joint SC and NNSA program in HEDLP coordinates solicitations, peer reviews, scientific workshops, and Federal Advisory Committee input between the two offices.

Budget Overview

FES is the primary supporter of research in the field of plasma physics in the United States. The FY 2012 budget request is designed to optimize the scientific productivity of the program. FES funds activities involving over 1,240 researchers and students in 31 states at approximately 63 universities, 9 industrial firms, 10 DOE national laboratories, and 2 other Federal laboratories. Some of the key activities of the FES program and their status in the FY 2012 budget request follow:

- The United States will continue to meet our obligations during construction of the U.S. Contributions to the ITER Project including research and development of key components, long-lead procurements, and contributions of personnel and funds to the ITER Organization (IO). In addition, the U.S., working in conjunction with the other partners, will continue to emphasize the importance of formal, coherent, and disciplined project management practices by the IO as a means to control schedule and cost.

  Research at the major experimental facilities in the FES program—DIII-D, Alcator C-Mod, and NSTX—will continue to focus on building the predictive science needed for ITER operations and providing solutions to high-priority ITER technical issues. These facilities will conduct experiments to improve active control of various plasma parameters, measure the effects and mitigation of disruptions in the plasma, develop a better understanding of the physics of the plasma edge in the presence of large heat flows, control the current density profile for better stability, and develop a scientific basis of advanced operating scenarios for ITER. Maintaining a high level of facility usage and upgrades so as to best exploit these investments is a priority. Attention will increase on these facilities regarding research important to materials science and solutions for managing the intense energy fluxes of future fusion devices.

- The planning phase of the Fusion Simulation Program (FSP), a computational initiative aimed at the development of an experimentally validated, predictive simulation capability for magnetically confined fusion plasmas in the regimes and geometries relevant for practical fusion energy, is expected to be completed by FY 2012. While no specific FSP activities are planned in FY 2012, the planning report will help FES prepare future solicitations for the eventual launching of this program.

- Plasma Science Centers (PSCs) support multi-institutional teams to work on some of the most integrated and challenging plasma science problems of our time. The three PSCs are intended to foster scientific collaborations and contribute significantly to the education and training of plasma scientists.

- FES investments in emerging scientific opportunities in HEDLP have strengthened U.S. leadership in this growing field of plasma science and will continue basic research on the science of fast ignition, laser-plasma interaction, magnetized high energy density plasmas, and warm dense matter. FES and NNSA continue the joint research program that was initiated in FY 2009. The Materials in Extreme Conditions (MEC) end station at the recently commissioned Linac Coherent Light Source at Stanford Linear Accelerator Center (SLAC) will permit studies of high energy states of matter with unprecedented precision after project completion in 2013. The Neutralized Drift Compression Experiment-II (NDCX-II) will enable enhanced warm dense matter experiments relevant to the interiors of giant planets and to the high energy density science underpinning the concept of heavy ion fusion.
- A modest increase in fusion-related materials science research is requested in this budget. One of the clearest recommendations that comes from the magnetic fusion community from the ReNeW process and underscored by the FESAC *Priorities, Gaps, and Opportunities report,* described above, is the need to develop the materials science essential to practical fusion energy. Indeed, pursuit of this research by the United States provides an opportunity to assert leadership worldwide in this important area. Full maturation of this endeavor in the coming years will require collaboration with other research programs in the Department, including those stewarded by Basic Energy Sciences.
- A modest increase in magnetic fusion research conducted at overseas facilities is requested. This research positions the U.S. to leverage international investments in unique facilities focused on long pulse, steady-state research through the use of superconducting magnet technology. Potential future international engagement includes development of research on the world's largest tokamak, the Joint European Torus (JET) in the United Kingdom, as a prototype for ITER scenarios and tools, and joint research on assessing the physics requirements for operating tokamaks of compact geometry such as NSTX as a potential volume source of neutrons for future materials and component testing. A mature research approach on international facilities will also need to be developed to gain maximal scientific benefit from ITER.

Annual Performance Results and Targets

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget.

Science

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation FY	2012 Request
Science		
Tokamak Experimental Research	52,381	60,900
Alternative Concept Experimental Research	65,942	59,290
Theory	25,105 2	4,348
Advanced Fusion Simulations	11,182	8,312
General Plasma Science	14,435	16,780
SBIR/STTR	0 8	,186
Total, Science	169,045	177,816

Description

Plasmas are ionized gases composed of a mixture of ions and electrons that are influenced by magnetic and electric fields either externally applied or generated by the plasma itself. The Science subprogram seeks to understand the fundamental nature of plasmas, especially fusion-relevant plasmas, through an integrated program of experiments, theory, and simulation.

The Science subprogram focuses on the physical processes that govern the behavior of a plasma, and the creation, confinement, heating, and control of a burning plasma to make fusion power a reality.

The Science subprogram supports preparation for the exploration of burning plasmas by developing a range of advanced computational simulation tools, taking advantage of petascale computing resources, to understand the behavior of burning plasma. This effort will yield the integrated computational tools needed to fully utilize ITER and keep the U.S. science community in the lead in using high performance computers to advance understanding of the plasma state. Ultimately, research on ITER is expected to provide sufficient information on burning plasmas to make a definitive assessment of the scientific feasibility of magnetic confinement fusion power.

Selected FY 2010 Accomplishments

- *Improved understanding of intrinsic rotation in tokamak plasmas*: The phenomenon of spontaneous rotation—where the plasma spins in the toroidal direction without any apparent external momentum input—has been observed experimentally in almost all tokamaks and has significant performance implications for ITER and burning plasmas, since plasma rotation can reduce the loss of heat from the plasma and can help stabilize macroscopic instabilities. Recent simulations by researchers at the Scientific Discovery through Advanced Computing (SciDAC) Center for Gyrokinetic Particle Simulation of Turbulent Transport in Burning Plasmas (GPS-TTBP) significantly advanced our understanding of the physical mechanisms responsible for this rotation in tokamak plasmas. The GPS-TTBP simulations—enabled by the SC High Performance Computing resources at Oak Ridge National Laboratory and National Energy Research Scientific Computing Center—confirmed the role of hypothesized symmetry breaking mechanisms such as electric field shear and identified new rotation-inducing mechanisms such as variations in the turbulent fluctuation amplitude.

- *Exploration of the new "I"-mode advanced operating scenario on Alcator C-Mod:* Good confinement involves large values of temperature and density, stationary conditions, and small heat and particle loss. New operational parameter regimes were found that combine a stronger barrier to thermal loss and the elimination of edge-localized loss perturbations over a duration that is larger by ten additional intervals of pertinent confinement-time units. In scaled terms, the achievement exceeds certain requirements of ITER, reinforcing confidence in the ITER design. In actual numbers, the achievement nearly matches plasma pressure and fusion reactivity records under any operating scenario mode ever documented in the Alcator C-Mod.
- *Innovative diagnostic developments for turbulence and transport measurement and visualization:* High resolution in time and space is crucial for validating experimental observations with theoretical and numerical predictions. The advanced, dual array Electron Cyclotron Emission Imaging system, which began collecting data on the DIII-D tokamak on March 1, 2010, has demonstrated the ability to resolve coherent fluctuations in electron temperature of less than 0.1% on millisecond time scales. The spatially resolved imaging and this degree of temporal resolution is a vast improvement over previously used methods that average over the plasma volume and need time to gather information from the overwhelming majority of velocity components in the electron population. The new information makes possible comparisons to computer models that need this resolution to discriminate between what, when, and where for validation purposes.
- *Advanced divertor configurations yield improved performance in NSTX:* Handling the very high heat flux expected in future fusion devices and controlling the amount of impurities that enter the plasma will be a significant problem. Operation with a "snowflake" divertor configuration in NSTX resulted in a significant reduction in heat flux to the divertor and improved impurity screening. Peak heat flux was reduced about a factor of two and carbon impurity concentrations were also reduced by about a factor of two. Another option for handling the high divertor heat flux is to operate with a liquid lithium coating on the divertor plates. The use of liquid lithium coatings in NSTX produced improved confinement and higher electron and ion temperatures in the plasma along with a reduction of impurities.

Detailed Justification

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
Tokamak Experimental Research	**52,381**	**60,900**

The tokamak magnetic confinement concept is presently the most effective approach for magnetically confining high-temperature plasmas in a laboratory environment. Many of the important issues in fusion science are being studied in tokamaks, including the two major U.S. tokamak facilities: DIII-D and Alcator C-Mod. Through participation in the International Tokamak Physics Activity (ITPA), U.S. tokamaks continue to give high priority to joint experiments with tokamak facilities in Europe and Japan to resolve ITER-relevant physics issues.

Tokamak experimental research is advancing rapidly through improvements to plasma control, new plasma measurements of unprecedented detail and accuracy, and ever-stronger connections to theory and simulation efforts. Both DIII-D and Alcator C-Mod use flexible plasma shaping and dynamic control capabilities to attain good confinement and stability. The distribution of current in the plasma, vital to reaching the optimal equilibrium state, is controlled with electromagnetic wave heating and current drive. The interface between the plasma edge and the material walls of the confinement vessel, vital to maintaining the desired boundary conditions for minimizing outflow of energy and particles, is managed by means of a magnetic divertor and magnet coils for fine control. Through tokamak research, the science of plasma confinement, plasma control, plasma responses to heating and fueling sources, and plasma-wall interactions has matured sufficiently to establish the physics basis for ITER and continues to advance rapidly.

Both DIII-D and Alcator C-Mod are operated as national collaborative scientific user facilities with research programs established through public research forums, program advisory committee recommendations, and peer review. Both programs are also closely coordinated with international tokamak research through collaborations with major foreign tokamaks in the European Union, Japan, China, and Korea. As JET and ASDEX-UG in Europe resume research operations in 2011 after recent hardware modifications and as the new superconducting tokamak programs in China (Experimental Advanced Superconducting Tokamak, or EAST) and Korea (Korean Superconducting Tokamak Advanced Research, or KSTAR) advance their research operations, increases in international collaborations are planned. These planned collaborations are intended to address ITER physics, steady-state physics, and technology issues, and three-dimensional magnetic field configurations that are not currently being addressed in U.S. facilities.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **DIII-D Research**	**27,255**	**28,888**

The DIII-D tokamak at General Atomics in San Diego, California, is the largest magnetic fusion facility in the United States. DIII-D provides for considerable experimental flexibility and has extensive diagnostic instrumentation to measure the properties of high temperature plasmas. It also has unique capabilities to shape the plasma and provide feedback control of error fields that, in turn, affect particle transport and plasma stability. DIII-D has been a major contributor to the world fusion program over the past two decades.

The DIII-D program is operated as a national research effort, with extensive participation from many U.S. laboratories and universities who receive direct funding from FES. The DIII-D program also plays a central role in U.S. international collaborations with the European Union, Japan, Korea, China, India, and the Russian Federation, hosting many foreign scientists, as well as sending DIII-D scientists overseas to participate in foreign experiments. The primary goal of the DIII-D program is to establish the scientific basis for the optimization of the tokamak approach to fusion energy. This is being accomplished by advancing basic scientific understanding across ITER-relevant fusion plasma topical areas including transport, stability, plasma-wave physics, and boundary layer physics.

In the first part of FY 2012, hardware and diagnostics improvements will take place and the 7^{th} gyrotron will begin operations in support of experiments, substantially increasing the DIII-D research capabilities for support of burning plasma physics and ITER. The DIII-D program will strengthen collaborations with the international community by accommodating joint experiments, thereby improving the potential for the U.S. leverage of foreign facilities.

	FY 2010 Current Appropriation	FY 2012 Request
▪ **Alcator C-Mod Research**	**9,035**	**10,454**

Alcator C-Mod is a unique compact tokamak facility that uses intense magnetic fields to confine high-temperature, high-density plasmas in a small volume. It is the only tokamak in the world operating at and above the ITER design magnetic field and plasma densities, and it produces the highest pressure tokamak plasma in the world, approaching pressures expected in ITER. It is also unique in the use of all-metal walls to accommodate high power densities. By virtue of these characteristics, Alcator C-Mod is particularly well suited to operate in plasma regimes that are relevant to ITER. The facility has made significant contributions to the world's fusion program in the areas of plasma heating, stability, confinement, non-inductive current drive, and rotational flows in high field tokamaks, all of which are important integrating issues for burning plasmas.

In FY 2012, Alcator C-Mod will continue its research program, while providing support of ITER. Experiments will continue to address issues with the undesirable consequences of plasma-sheath generation in the proximity of radio frequency (RF) antennae during RF heating of the plasma discharge. A new RF antenna, designed for the ion cyclotron frequency range that better matches the geometry of the C-Mod magnetic field lines will be installed and utilized for experiments this year. Current drive experiments using a second advanced microwave launcher for the lower hybrid frequency range will also be possible at high power in FY 2012 with the completion of the auxiliary heating upgrades in FY 2011 with Recovery Act funding.

Other ITER- and power plant-relevant topics that the Alcator C-Mod team will focus on in FY 2012 include impurity seeding and power handling studies with a high heat flux divertor, fuel retention and surface studies with new diagnostic capabilities, study of the combined effects of lower hybrid RF power and ion cyclotron RF power, steady-state scenario studies, lower hybrid RF-power efficiency experiments, and exploration of unique improved confinement regimes. A primary effort in understanding particle and energy transport will be to provide data to universities and DOE laboratories to validate theoretical models. C-Mod will also continue its participation in joint international experiments.

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▪ **International Research**	**5,075**	**7,435**

In addition to work on domestic experiments, FES-funded researchers will participate in scientific experiments at fusion facilities in Europe, Japan, China, South Korea, Russia, and India to conduct comparative studies of underlying physics of fusion plasmas. FES, in return, hosts visiting scientists from the international community, who participate in experiments on U.S. facilities. This international collaboration provides U.S. scientists access to the unique capabilities of several foreign fusion facilities, including the world's highest performance tokamak, the Joint European Torus (JET) in England; a stellarator, the Large Helical Device in Japan; a superconducting tokamak, Tore Supra in France; the Axisymmetric Divertor Experiment Upgrade (ASDEX-U) and Tokamak Experiment for Technology Oriented Research (TEXTOR) in Germany; and several smaller devices. In addition, the U.S. is collaborating on two new superconducting tokamaks, one in China (EAST) and one in South Korea (KSTAR). These collaborations provide a valuable link with the 80% of the world's ITER-related fusion research that is conducted outside the U.S.

The JET and ASDEX-U tokamaks will be restarting in 2011 after shutdowns for major modifications involving ITER-like walls and internal control coils. The KSTAR and EAST tokamaks will be adding increased auxiliary heating power and diagnostics during the next few years. Increased funding in FY 2012 will provide an opportunity to expand collaborations and joint experiments on these unique and powerful foreign facilities.

In FY 2012, the U.S. will also continue to be a major participant in the ITPA, which identifies experimental and computational studies needed to resolve high priority ITER physics design needs

	FY 2010 Current Appropriation	FY 2012 Request

and implements the studies through collaborative work among the world's leading experimental and theoretical research teams. Planned studies include experiments in the areas of plasma wall interactions, plasma instabilities, and first wall design considerations for ITER.

▪ **Diagnostics**	**3,911**	**3,519**

Support for the development of unique measurement capabilities (diagnostic instruments) will continue. Diagnostic instruments serve two important functions: to provide a link between theory/computation and experiments, thereby increasing the understanding of the complex behavior of the plasma in fusion research devices; and to provide sensory tools for feedback control of plasma properties in order to enhance device operation.

In FY 2012, research will include the development of diagnostics for fundamental plasma parameter measurements, state-of-the-art measurement techniques, and R&D for ITER-relevant diagnostic systems to provide data and analyses to validate theoretical models and fusion simulation codes in support of the FES goal to develop an experimentally validated predictive capability for magnetically confined fusion plasmas.

▪ **Other**	**7,105**	**10,604**

Funding in this category supports educational activities such as research at historically black colleges and universities, postgraduate fellowships in fusion science and technology, and summer internships for undergraduates. In addition, funding in this category supports outreach efforts related to fusion science and enabling R&D, and the activities of the U.S. Burning Plasma Organization and the Fusion Energy Sciences Advisory Committee (FESAC). New fellowships will be funded through the Office of Science Graduate Fellowship (SCGF) program, which is funded by the Workforce Development for Teachers and Scientists program. This program was initiated in FY 2010 and supports graduate students pursing advanced degrees in areas of basic research supported by the Office of Science, including fusion science.

Alternative Concept Experimental Research	**65,942**	**59,290**

The FES Alternative Concepts Research program has the long-term performance measure of demonstrating enhanced fundamental understanding of magnetic confinement and improving the basis for future burning plasma experiments through research on magnetic confinement configuration optimization, including knowledge arising from research on the spherical torus and the stellarator. In FY 2012, the spectrum of this program element is sharpened by addressing three changes to the focus. The magnetic-fusion-relevant component will become more concentrated on projects that solve problems that hinder the tokamak approach to controlling plasma dynamics and improving plasma parameters. This component deepens the scientific foundations of understanding the tokamak concept, provides experimental data in regimes of relevance to the FES mainline magnetic confinement and materials science efforts, and validates theoretical models and simulation codes in support of the FES goal to develop an experimentally-validated predictive capability for magnetically-confined fusion plasmas. The warm-dense-matter-relevant component will see a modest increase for the purpose of starting research activity on new Recovery Act-funded facilities. The magnetized high-energy-density plasma component will become more concentrated on discovery-oriented fundamental science.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **NSTX Research**	**16,868**	**17,549**

The National Spherical Torus Experiment (NSTX) is one of two large research facilities in the world designed to explore the physics of plasmas magnetically confined in a spherical torus (ST) configuration; the other is the Mega Amp Spherical Tokamak (MAST) in the United Kingdom. The ST configuration is characterized by a more spherical doughnut shape with a narrow hole through the center. The ST is an innovative confinement configuration that can achieve a higher plasma pressure relative to the applied magnetic field than a conventional tokamak. The unique operating regimes of NSTX allow it to address several important physics issues relevant to burning plasmas and thereby contribute to optimizing the performance of ITER. The NSTX program investigates the attractiveness of the ST configuration as a cost-effective facility for carrying out the nuclear engineering science research needed to design the power extraction and tritium breeding systems for a fusion power plant.

NSTX is operated as a national collaborative scientific user facility, with extensive involvement of researchers from other national laboratories, universities, and industry who receive their funding from FES via a competitive peer review process.

In FY 2012, NSTX will continue to make significant progress in understanding the unique physics properties of STs, exploit these unique properties to contribute to the physics basis for ITER, and advance the fundamental understanding of ST plasmas to establish attractive scenarios for future fusion facilities. Using a liquid lithium divertor to confront the harsh plasma environment and new diagnostic capabilities developed with Recovery Act funding, NSTX researchers will perform critical experiments to understand and increase non-inductive current drive at reduced collisionality, understand and improve H-mode confinement at low collisionality, and demonstrate non-inductive start-up and ramp-up of the plasma current. In addition, they will investigate means to handle the large heat and particle fluxes that will fall on the surface of the divertor and seek to understand the relationship between electron energy confinement and fluctuations in the plasma density and electron temperature. NSTX researchers will continue studying macroscopic instabilities and will focus on sustaining the plasma pressure at or above the magnetohydrodynamic limit for a plasma without a nearby conducting wall. The basic principles of error field correction and resistive wall mode control have been demonstrated, so future work will focus on developing reliable active control techniques to stabilize these modes. Plasma-wave interaction studies will concentrate on developing a predictive understanding of the redistribution/loss of fast-ions due to energetic particle modes. Research on energetic particle modes will focus on how the plasma current density is modified by energetic ion driven instabilities and how this will affect the ability to sustain the plasma with currents driven by injected high energy particle beams. Finally, experiments on solenoid-free start-up and current ramp-up will focus on reducing impurity influx during co-axial helicity injection start-up and using radio frequency waves to ramp-up the plasma current to 400–500 kiloamperes.

	(dollars in thousands)	
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▪ **Experimental Plasma Research**	**17,494**	**11,000**

Experimental Plasma Research provides experimental data in regimes of relevance to the FES mainline magnetic confinement and materials science efforts and helps validate theoretical models and simulation codes in support of the FES goal to develop an experimentally validated predictive capability for magnetically confined fusion plasmas.

A peer review of all projects in the program took place in FY 2010. The goal of the program is to generate sufficient experimental data to elucidate the underlying physics principles upon which concepts of toroidal confinement are based and, as needed, to develop computational models to a sufficient degree of scientific fidelity to allow an assessment of the relevance of those concepts to future fusion energy systems. New emphasis will be placed on the ability of some elements in this portfolio to contribute to the science needed in order to deepen our understanding of burning plasmas such as ITER.

In FY 2012, experimental plasma research will continue to examine stellarator and spherical torus configurations that address potential deficiencies in the tokamak and support development of instability mitigation techniques for ITER.

▪ **High Energy Density Laboratory Plasmas**	**24,538**	**24,741**

High-energy-density laboratory plasma (HEDLP) physics is the study of ionized matter at extremely high density and temperature, specifically when matter is heated and compressed to a point that the stored energy in the matter reaches approximately 10 billion Joules per cubic meter. This corresponds to a pressure of approximately 1 million atmospheres. Such conditions exist in the interior of the Sun, in supernovae, in accretion disks around black holes, near pulsars, and astrophysical jets. On Earth, such conditions can only be created transiently in the laboratory by using intense pulses of lasers, particle beams (electrons or ions), or pulsed magnetic field pressure.

Through the Joint NNSA-SC Program in HEDLP Science, FES-funded research by universities, private industry, and DOE laboratories takes place on small-scale-size and medium-scale-size facilities at universities and at DOE laboratories. There are two key elements in the FES HEDLP program. The first element focuses on the basic science of high energy density plasmas without regards to specific applications. This will include facilitating user access to the several, geographically distributed, supporting and complementary facilities, as well as NIF; developing diagnostics and experimental platforms for general high energy density science; funding university and laboratory researchers to develop and field experiments in HEDLP science; and supporting theory and modeling. The second element focuses on inertial fusion energy science (IFES). On-going research in IFES explores science related to fast ignition, shock ignition, heavy-ion fusion, and magnetized high-energy-density plasmas.

In FY 2012, FES and NNSA will jointly hold a solicitation. One of the three areas presently receiving funding in HEDLP, magnetized high-energy-density plasmas, will be significantly redirected and re-sized toward basic science. Also, FES is building a Matter in Extreme Conditions (MEC) Instrument project at the SLAC National Accelerator Laboratory Linac Coherent Light Source (LCLS) with Recovery Act funding, which will initiate research activities in FY 2012, for which partial first-year funds are newly included. LCLS is the world's first coherent hard x-ray laser; the MEC instrument will provide researchers with the ability to utilize LCLS's capabilities to probe

	(dollars in thousands)	
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and control high energy density matter with unprecedented spatial and temporal resolution. Recovery Act funding is also being spent on constructing the Neutralized Drift Compression Experiment-II (NDCX-II) at Lawrence Berkeley National Laboratory which will facilitate studies of heavy-ion driven warm dense matter and the high energy density physics intrinsic to the science of heavy ion fusion.

▪ **Madison Symmetrical Torus**	**7,042**	**6,000**

The goals of the Madison Symmetrical Torus (MST), at the University of Wisconsin-Madison, are to obtain a fundamental understanding of the physics of reversed field pinches (RFPs), particularly magnetic fluctuations and their macroscopic consequences, and to use this understanding to develop the validation of models by experimental investigation. The RFP is geometrically similar to a tokamak, but with a much weaker externally applied magnetic field that reverses direction near the edge of the plasma. Research in the RFP's self-organization properties has astrophysical applications and may lead to a more cost-effective fusion system. The plasma dynamics that limit the energy confinement and plasma pressure, as well as novel means to the sustainment of the plasma current, are being investigated in this experiment. MST is one of the four leading RFP experiments in the world and is unique in that it pioneered the reduction of magnetic fluctuations by current density profile control.

In FY 2012, the major plans for the MST program are plasma current enhancement by oscillating field current drive with twice the pulse length, investigation of neutral beam (NB) injection, and pellet and supersonic gas injection. The transformation of MST from a fusion-oriented program to a validation-oriented program will be accompanied by reductions to support higher priority activities. Staffing will be reduced and the number of run weeks will decrease from 7 to 5.

Theory	**25,105**	**24,348**

The Theory program is a broad-based program with researchers located at six national laboratories, over thirty universities, and several private companies. Theorists in larger groups, located mainly at national laboratories and in private industry, generally support major experiments, work on large problems requiring a team effort, or tackle complex issues requiring multidisciplinary teams. Those at universities tend to support innovative validation being carried out on smaller experiments, experimental platforms, or work on more fundamental problems in plasma physics while training the next generation of fusion plasma scientists.

The Theory program provides the conceptual scientific underpinning of the magnetic fusion energy sciences program by supporting three thrust areas: burning plasmas, fundamental understanding, and configuration improvement. Theory efforts describe the complex multiphysics, multiscale, non-linear plasma systems at the most fundamental level and, in doing so, generate world-class science. These descriptions—ranging from analytic theory to highly sophisticated computer simulation codes—are used to interpret results from current experiments, plan new experiments on existing facilities, design future experimental facilities, and assess projections of facility performance. The program focuses on both tokamaks and alternate concepts. Work on tokamaks is aimed at developing a predictive understanding of advanced tokamak operating modes and burning plasmas—both of which are important to ITER—while the emphasis on alternate concepts is on understanding the associated fundamental processes that determine equilibrium, stability, and confinement for each concept. The theory program also provides

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the input needed in the FES large-scale simulation efforts that are part of the SciDAC portfolio and, together with SciDAC, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and controlled.

In FY 2012, the Theory program will focus particular attention on many important scientific issues, including:

- turbulent transport of toroidal and poloidal momentum in tokamak plasmas and the understanding of spontaneous toroidal rotation;
- progress toward a predictive understanding of particle and electron transport;
- the physics of the edge pedestal and the transition from low to high confinement modes in tokamaks;
- the formation of edge and internal transport barriers;
- a first-principles formulation of moment closures in extended magnetohydrodynamics models;
- studies of how to improve the stellarator concept and find configurations that are less prone to the formation of islands;
- understanding fast magnetic reconnection in high temperature fusion plasmas; and
- development of predictive integrated computational models for tokamak plasmas.

Advanced Fusion Simulations	**11,182**	**8,312**

The FES Advanced Fusion Simulations program includes projects funded under the auspices of the Scientific Discovery through Advanced Computing (SciDAC) program as well as the Fusion Simulation Program (FSP) which, after an initial planning phase, will focus on the development of an experimentally validated simulation capability for magnetically confined plasmas.

- **SciDAC 7,182** **8,312**

  The SciDAC program is a set of coordinated research efforts across all SC programs overseen by the Advanced Scientific Computing Research (ASCR) program with the goal of achieving breakthrough scientific advances by exploiting the emerging capabilities of high performance "ultrascale" computing. The SciDAC program encourages and enables a new model of interdisciplinary multi-institutional collaboration among physical scientists, applied mathematicians, computer scientists, and computational scientists where distributed resources and expertise are combined to address complex questions that no single institution or investigator can manage alone.

  The FES SciDAC portfolio is aimed at advancing scientific discovery in fusion plasma science by exploiting the emerging capabilities of petascale computing and associated progress in software and algorithm development and contributes to the FES goal of developing a validated predictive capability for magnetically confined plasmas. The current portfolio includes eight projects focused on burning plasmas and ITER. Of these, five are focused on topical "single physics" science areas (macroscopic stability, plasma turbulence, interaction of radiofrequency waves with plasmas, and energetic particles) while the remaining three, also known as Fusion Simulation Prototype Centers or proto-FSPs, are focused on code integration and computational framework development in the areas of edge plasma transport, interaction of radiofrequency waves with magnetohydrodynamic instabilities, and the coupling of the edge and core regions of tokamak plasmas.

(dollars in thousands)	
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The FES SciDAC Centers have been very successful in taking advantage of the SC leadership computing facilities to develop high-performance computational tools that have provided new and significant insights into questions of fundamental importance in fusion plasma science.

The five "single physics" projects in the FES SciDAC portfolio were recompeted in 2010. Five multi-institutional Centers—comprising 10 universities, 3 national laboratories, and 5 private companies—were selected for funding (one new and four renewals) with a funding distribution of 39% to universities, 40% to national laboratories, and 21% to private industry. These projects will continue to focus their efforts on grand challenge scientific questions of importance to burning plasmas and ITER. More specifically, in FY 2012, the projects in the FES SciDAC portfolio will focus on:

- the development of high fidelity models for core interactions of radio-frequency waves with energetic ions and electrons for a better understanding of how these energetic species affect power flow in the confined plasma;
- the performance of realistic simulations with extended magnetohydrodynamic codes to understand and control performance-limiting macroscopic instabilities and related effects such as edge localized modes, resonant magnetic perturbations, resistive wall modes, neoclassical tearing modes, and sawteeth, as well as the development of computational capabilities for assessing, mitigating, and avoiding damaging disruptions;
- the further understanding of the role of plasma turbulence in driving particle, momentum and heat transport from the core and the edge of magnetically confined plasmas with emphasis on experimental validation; and
- the prediction of energetic particle transport in burning plasmas in the presence of energetic-particle driven modes as well as the coupling of energetic particle driven meso-scale turbulence with the background thermal plasma micro-scale turbulence.

The three proto-FSP projects expire in FY 2011 and this part of the FES SciDAC portfolio will be recompeted as part of the SC-wide SciDAC review scheduled for mid-2011. In addition, the increase in funding in FY 2012 will allow FES to add a new computational materials project in its SciDAC portfolio, reflecting the importance of materials science for the FES mission.

- **Fusion Simulation Program** **4,000 0**

The Fusion Simulation Program (FSP) is a computational initiative aimed at the development of a world-leading, experimentally validated, predictive simulation capability for magnetically confined fusion plasmas in the regimes and geometries relevant for practical fusion energy. Once launched, a successful FSP will advance the fundamental science of magnetically confined plasmas by enabling scientific discovery of important new plasma phenomena with associated understanding that emerges only upon integration, will maximize the return of the U.S. investment in ITER, and reduce risk in the design of future devices.

	(dollars in thousands)	
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The FSP planning activity, a two-year effort initiated in mid-2009 to carry out a detailed design study for the FSP, will submit a report once planning activities are completed. While no FSP activities are planned in FY 2012, the FSP planning report will help FES prepare a set of future solicitations for the competitive selection of interdisciplinary multi-institutional teams to develop, verify, and validate integrated science applications targeting the highest priority science drivers identified in the planning report.

General Plasma Science	**14,435**	**16,780**

The General Plasma Science program is directed toward basic plasma science and engineering research. This research strengthens the fundamental underpinnings of the discipline of plasma physics that complements burning plasma science and reaches beyond into many basic and applied physics areas. Principal investigators at universities, laboratories, and private industry carry out the research. A critically important element is the education of plasma physicists.

Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Plasma Science Centers (PSCs), the General Plasma Science program at the DOE laboratories, and basic plasma physics user facilities at laboratories and universities (sharing costs with NSF where appropriate). The PSCs perform plasma science research in areas of such wide scope and complexity that significant benefit to progress is derived by the multi-expertise, 5-year funding model of a center.

In FY 2012, FES will continue to share the cost with NSF of the multi-institutional plasma physics Frontier Center started in FY 2003 and renewed by NSF for five years in FY 2008. In FY 2009, the PSCs program was renewed following an intensive merit review process. Of the applications received for PSC funding in FY 2009, one new center (in low-temperature plasma science) was selected for funding with regular appropriations and two additional centers were selected (one fully funded for five years and the second funded at the 50% level) using Recovery Act funding. In FY 2012, regular appropriations funding is provided for the third PSC continuation. Also in FY 2012, the U.S. component of a Joint Center for Plasma Research, between Princeton Plasma Physics Laboratory and Germany's Max-Planck-Institute for Plasma Physics, will have funds available to support several postdoctoral researchers who will work on cross-disciplinary (astrophysics and fusion) research projects. The Atomic and Molecular Physics program is being reduced by approximately 50%. This is being accomplished by by closing out the atomic physics program at ORNL while retaining the atomic physics work at NIST. The Atomic and Molecular Physics program at ORNL is being closed out because it has lost its cross-SC-office support and outlived its relevance to the FES program.

SBIR/STTR	**0**	**8,186**

In FY 2010, $7,455,000 and $895,000 were transferred to the congressionally mandated Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. The FY 2012 amount is the estimated requirements for the continuation of these programs.

Total, Science	**169,045**	**177,816**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Tokamak Experimental Research	
▪ **DIII-D Research**	
The increased funding will support the research staff at General Atomics and researchers from collaborating institutions to plan, conduct, and analyze the data from experiments on the DIII-D tokamak for the planned 13 weeks of operation using the upgrades provided by Recovery Act funding.	+1,633
▪ **Alcator C-Mod Research**	
The increase in funding will support the research staff at the Massachusetts Institute of Technology and the national program collaborators to plan, conduct, and analyze experiments on the Alcator C-Mod tokamak for the planned 17 weeks of research operation.	+1,419
▪ **International Research**	
The increase in funding will allow for continued support of burning plasma research, ITER physics, and stellarator research through collaboration with foreign programs. The increase will be used to enhance collaborations with JET in the areas of ELM mitigation and ITER-like wall programs and will enhance support for KSTAR and other international collaboration through remote participation. +2,360	
▪ **Diagnostics**	
The decrease will cause a small reduction in the number of activities supported.	-392
▪ **Other**	
The increase in funding will allow for additional support of a number of activities including educational activities such as research at historically black colleges and universities, postgraduate fellowships in fusion science and technology, summer internships for undergraduates, U.S. Burning Plasma Organization, and FESAC.	+3,499
Total, Tokamak Experimental Research	**+8,519**
Alternative Concept Experimental Research	
▪ **NSTX Research**	
The increased funding will support the research staff needed to plan, conduct, and analyze experiments on NSTX during the planned 10 weeks of operation and prepare for the shutdown to carry out planned upgrades.	+681
▪ **Experimental Plasma Research**	
The decrease will narrow the portfolio of university and DOE laboratory projects as this program shifts to funding projects that meet the expectations	

	FY 2012 vs. FY 2010 Current Approp. ($000)
of the newly re-directed program. The new emphasis is on tokamak-related confinement-relevant physics, on the physics at the interface of plasma and plasma-facing components, and on the linkage between prediction and measurement for scientific leverage in testing the theories and scaling the phenomena that are relevant to future burning plasma systems. Key program issues include initiation and increase of plasma current; dissipation of plasma exhaust power; symmetric-torus confinement prediction; stability, continuity, and profile control of symmetric tori; quasi-symmetric and three-dimensional shaping benefits to toroidal confinement performance; divertor design for three-dimensional magnetic confinement configurations.	-6,494
▪ **High Energy Density Laboratory Plasmas (HEDLP)**	
There is an increase of funds in the warm-dense-matter area for cultivating the development of a user population on the Recovery Act-funded facilities at SLAC and at LBNL in the partial first year of their research activities after project completion in mid-FY 2012.	+203
▪ **Madison Symmetrical Torus**	
The decrease will result in suspending the lower-hybrid RF heating development, the electron Bernstein wave project development, the multi-phase Thomson scattering, the new boundary diagnostics project, and the new ion Doppler spectrometer. The number of weeks with all diagnostics operating will decrease from 7 to 5 and the staff will be reduced.	-1,042
Total, Alternative Concept Experimental Research	**-6,652**
Theory	
The decrease will reduce support in non-tokamak-related theory.	-757
Advanced Fusion Simulations	
▪ **SciDAC**	
The increase in funding will support a new computational materials project that will address the interactions of different materials that will be located in and around the fusion chamber with the plasma.	+1,130
▪ **Fusion Simulation Program**	
The decrease in funding reflects the decision by FES to first evaluate the results of the two-year planning phase of the FSP, which will be completed before proceeding with the initiation of the full program.	-4,000
Total, Advanced Fusion Simulations	**-2,870**

	FY 2012 vs. FY 2010 Current Approp. ($000)
General Plasma Science	
The increase will allow the U.S. to initiate a new Joint Center for Plasma Research between PPPL and MPI (Germany) and to fund fully a Plasma Science Center which was started with Recovery Act funding.	+2,345
SBIR/STTR	
The support for SBIR/STTR is funded at the mandated level.	+8,186
Total Funding Change, Science	**+8,771**

Facility Operations

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation FY	2012 Request
Facility Operations		
DIII-D 3	7,830	39,731
Alcator C-Mod	17,424	18,042
NSTX 2	1,320	17,504
NSTX Upgrade (MIE)	8,950	14,630
Other, GPE and GPP	2,478	975
U.S. Contributions to ITER (MIE TPC)	135,000	105,000
Total, Facility Operations	223,002	195,882

Description

The mission of the Facility Operations subprogram is to provide for the operation, maintenance, and minor modifications of the major fusion research user facilities (Alcator C-Mod, DIII-D, and NSTX), to carry out major upgrades to existing facilities, and to construct new facilities such as ITER. Periodic facility reviews are used to ensure that the facilities are operated efficiently and in a safe and environmentally sound manner. Operations, maintenance, and upgrades are balanced to ensure safe operation of each facility; provide modern experimental tools such as heating, fueling, and exhaust systems; and provide the operating time to meet the needs of scientific collaborators.

The major FES user facilities enable U.S. scientists from universities, laboratories, and industry, as well as visiting foreign scientists, to conduct world-class research funded through the Science and Enabling R&D subprograms. Upgrades of the major fusion facilities, such as installation of new diagnostics, and execution of new projects, such as ITER, help to keep U.S. scientists at the forefront of plasma and fusion research.

The *DIII-D* tokamak at General Atomics in San Diego, California is the largest magnetic fusion facility in the United States. DIII-D provides for considerable experimental flexibility and has extensive diagnostic instrumentation to measure the properties of high temperature plasmas. It also has unique capabilities to shape the plasma and provide feedback control of error fields that, in turn, affect particle transport and the stability of the plasma. The extensive tokamak database from DIII-D has provided the major physics input to the ITER design.

Alcator C-Mod at MIT is the only tokamak in the world operating at and above the ITER design magnetic field and plasma densities, and it produces the highest pressure tokamak plasma in the world, approaching pressures expected in ITER. It is also unique in the use of all-metal walls to accommodate high power densities. Because of these characteristics, C-Mod is particularly well suited to examine plasma regimes that are highly relevant to ITER.

The *National Spherical Torus Experiment* (NSTX) is an innovative magnetic fusion device at PPPL using the spherical torus confinement configuration. A major advantage of this configuration is the ability to confine a higher plasma pressure for a given magnetic field strength, which could enable the development of smaller and more economical fusion research facilities in the future.

ITER will be the first magnetic fusion facility to achieve self-sustaining "burning" plasmas, and will thus open a new era in fusion energy science. The study of burning plasmas is essential to demonstrate the scientific feasibility of fusion energy and study its underlying physics, making ITER an important step between today's facilities and a demonstration fusion power plant. An international collaboration of scientists and engineers led the design of this burning plasma physics experiment. ITER is presently under construction in Cadarache, France by the seven project partners: China, the European Union (EU), India, Japan, Russia, South Korea, and the United States.

Selected FY 2010 Accomplishments

- *DIII-D:* Long-term trapping of tritium in the vessel walls is a critical issue in minimizing the tritium inventory on site of a fusion burning plasma device such as ITER. Recent experiments on DIII-D have demonstrated the ability to remove a significant fraction of hydrogen isotopes that are trapped in hard films on the vessel surfaces using a technique known as thermal oxidation (or oxygen bake). In this technique, the vessel walls are heated to 350° C and then oxygen gas (mixed with helium for safety) is introduced to a moderate pressure. Consistent with lab tests of this technique, these DIII-D experiments show virtually all of deuterium trapped in hardened carbon-deuterium films to be removed. Subsequent experiments showed that even though the vessel walls were exposed to large quantities of oxygen, good confinement plasmas could be re-established within a few plasma shots, indicating that this technique can be used on ITER without risk to subsequent plasma operations. DIII-D is now in a maintenance period to conduct major facility modifications, such as the tilting of one neutral beam line to provide off-axis heating and current drive, which is needed for improved plasma control.
- *Alcator C-Mod:* The new advanced lower hybrid heating (LH) and current drive antenna was installed, and initial experiments were conducted to investigate the coupling of the LH waves to the plasma. Lower hybrid heating and current drive will give Alcator C-Mod the capability to achieve significant non-inductive current drive, a capability that will be needed in a fusion power plant. Also, a new infrared camera diagnostic viewing the divertor region provided important data in the examination of heat flow to the divertor.
- *NSTX:* In early FY 2010, NSTX technicians installed a new liquid lithium divertor, consisting of four heated plates with a porous molybdenum surface. A thin film of lithium can be deposited on the plates using lithium evaporators. The heaters in the plates maintain the temperature above the melting point of lithium, thereby creating a thin film of liquid lithium on the plates that absorbs impinging deuterium. Early indications with the liquid lithium coated divertor plates are that the edge density and the plasma collisionality are reduced, implying and resulting in higher edge temperatures, improved confinement, increased central temperatures, and the elimination of edge localized modes that induce losses of hot ions and electrons.
- *ITER:* Throughout the life of the ITER Project, the U.S. has insisted that it be properly managed to improve the chances of an on-schedule, on-cost completion. To this end, the U.S. has advocated that the project be baselined and managed according to international best practices and that the management team be staffed and structured to take on a construction project of this scope and complexity. In July 2010, the ITER Council approved the project baseline and appointed a new Director General with significant experience in fusion facility construction and gave him the authority to implement sweeping management changes and pursue cost savings throughout the ITER project.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
DIII-D	**37,830**	**39,731**

To carry out the research funded in the Science subprogram, support is provided for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. The DIII-D program will complete 13 weeks (40 hours per week) of experimental operations beginning in April 2012 after a shutdown at the beginning of the fiscal year for facility modifications. The Recovery Act funding for the DIII-D Upgrades provided for additional electron cyclotron heating (a 7th gyrotron), which will become fully operational in FY 2012. Operations will continue to support experiments addressing ITER design and operations issues and developing the advanced tokamak concept for fusion energy. Experiments in FY 2012 will take advantage of the off-axis neutral beam and the additional electron cyclotron heating.

	FY 2010	FY 2012
Achieved Operating Hours	608	N/A
Planned Operating Hours	560[a] 5	20
Optimal Hours	1,000	1,000
Percent of Optimal Hours	61%	52%
Unscheduled Downtime	9.8%	N/A
Number of Users	235	230

Alcator C-Mod	**17,424**	**18,042**

Support is provided for operation, maintenance, minor upgrades, and improvement of the Alcator C-Mod facility. The upgrades include installation of a second advanced 4-strap ion cyclotron radio frequency antenna to explore higher heating power, addition of a second advanced lower hybrid launcher for increased current drive capability and plasma control, and the installation of a high temperature tungsten divertor for plasma material interaction studies relevant to ITER. In FY 2012, Alcator C-Mod will be operated for 17 weeks, focusing on ITER design and operations issues and addressing high field and density issues.

[a] Planned hours do not include Recovery Act supported operations in FY 2010. Utilizing Recovery Act funding, DIII-D had an additional 120 hours of planned operations in FY 2010. All of these additional operating hours were achieved.

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

	FY 2010	FY 2012
Achieved Operating Hours	512	N/A
Planned Operating Hours	416[a] 5	44
Optimal Hours	800	800
Percent of Optimal Hours	64%	68%
Unscheduled Downtime	4.7%	N/A
Number of Users	195	194

NSTX **21,320 17,504**

Support is provided for operation and maintenance of NSTX. In FY 2012, there is funding for 10 weeks of operation to explore issues of sustained spherical torus (ST) operation and study ST confinement at high fields relevant to evaluating the science base for high-heat flux and plasma nuclear science initiatives. In FY 2012, NSTX will complete experiments with the present configuration and shut down for approximately two years to install a new "center stack" and a second neutral beam (see NSTX Upgrade MIE below). The new center stack will allow operation at nearly twice the toroidal field (1 Tesla versus 0.6 Tesla) and twice the plasma current (2 MA versus 1 MA) and the second neutral beam will greatly increase the current that can be driven in NSTX. The upgrade will enable higher performance and longer pulses, which will provide the physics data needed to evaluate the viability of the ST for high-heat flux and plasma nuclear science applications.

	FY 2010	FY 2012
Achieved Operating Hours	576	N/A
Planned Operating Hours	560[b]	400
Optimal Hours	1 ,000	1 ,000
Percent of Optimal Hours	58%	40%
Unscheduled Downtime	9.8%	N/A
Number of Users	1 45	1 45

NSTX Upgrade (MIE) **8,950 14,630**

Support is provided to complete design work and begin fabrication of a major upgrade of NSTX to keep its world-leading status. After the design work is completed in mid-FY 2012, NSTX will be shut down for approximately two years to carry out the upgrade work. The NSTX Upgrade project comprises two major improvements to the device: a new center stack magnet assembly, which will double the magnetic field and plasma current and increase the pulse length from one second to a maximum of five seconds,

[a] Planned hours do not include Recovery Act supported operations in FY 2010. Utilizing Recovery Act funding, C-Mod had an additional 160 hours of planned operations in FY 2010. All of these additional operating hours were achieved.
[b] Planned hours do not include Recovery Act supported operations in FY 2010. Utilizing Recovery Act funding, NSTX had an additional 40 hours of planned operations in FY 2010. All of these additional operating hours were achieved.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

and installation of a second neutral beam line, which will double the neutral beam heating power. Critical Decision 2 (CD-2), approval of the performance baseline was achieved in December 2010.

Other, GPE, and GPP	**2,478**	**975**

Funding for general plant projects (GPP) and general purpose equipment (GPE) provides support for general infrastructure repairs and upgrades for the PPPL site based upon quantitative analysis of safety requirements, equipment reliability, and research needs. Due to the receipt of Recovery Act funding that was used to improve PPPL's infrastructure, the need for GPP funding is reduced in FY 2012.

U.S. Contributions to ITER Project (MIE)	**135,000**	**105,000**

Background: The U.S. ITER Project represents the U.S. share of a seven-member international collaboration to design and build a first-of-a-kind international research facility in Cadarache, France to demonstrate the scientific feasibility of fusion energy. The U.S. ITER Project scope consists of delivering hardware components, personnel, and funds to the ITER Organization (IO). The legal framework for construction, operation, deactivation, and decommissioning is contained in the *Agreement on the Establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project* (or the JIA), which entered into force in October 2007 for a period of 35 years.

While significant technical progress has been made with large fusion experiments around the world, most of which were constructed in the 1980s, it has long been obvious that a larger and more powerful magnetic confinement device would be needed to create the physical conditions expected in a fusion power plant (i.e., a sustained "burning plasma" comprised of hot ionized deuterium and tritium gas) and to demonstrate its feasibility. The idea to cooperatively design and build such a device originated from the Geneva Summit between the United States and the former Soviet Union held in November 1985; the U.S. participated in the initial design activity and, after a hiatus, the U.S. joined the ITER negotiations in early 2003.

International ITER Project Status: The IO, located at Cadarache, has been established as an independent international legal entity comprised of personnel from all of the Members. The IO is led by a Director General who is appointed by the ITER Council. The ITER Council serves as ITER's executive governing board and includes representatives from all of the Members. Like all non-host Members, the U.S. share for ITER's construction is 1/11 (9.09%) of the total value estimate—roughly 80% will be in-kind components manufactured by U.S. industry. Beyond that, the United States has agreed to fund 13% of the cost for subsequent operation, deactivation, and decommissioning of the ITER device. As the Host, the EU is obligated to provide 5/11 (45.45%) of ITER's construction value. An Annex to the JIA identifies the hardware procurement allocations among the seven Members based on this cost sharing arrangement. Starting from a green field site in 2006, the ITER enterprise at Cadarache is currently at 400 professional staff.

An international design review in 2007 recommended several ITER design improvements and identified some missing items of scope, such as certain test facilities and a number of spare parts. Although the JIA included a goal for construction completion and first plasma to be achieved in 2016, this has proven to be unrealistic. Together with other factors, these developments have increased the estimate for ITER's construction cost.

The IO's efforts to complete work on the overall ITER design and systems engineering are almost done and the IO has made recent strides to work from these approved technical, schedule, and cost baselines as agreed by the ITER Council in July 2010. Concurrently, the Administration gained agreement from the ITER Council and IO for a range of U.S. initiatives to implement management reforms at the IO and to accelerate ITER construction with the goal of minimizing the overall cost of the Construction Phase for the U.S. and the other ITER Members.

U.S. ITER Project Status: The main cost risk to the U.S. ITER Project is the slow rate of progress by the IO and some Members' Domestic Agencies who are responsible for critical path hardware components, which has delayed the construction schedule. Next, there remains some ambiguity over the effect of EU/French nuclear regulatory requirements on U.S. hardware designs. The Council formally agreed upon a revised ITER technical, schedule, and cost baseline in July 2010; now the U.S. ITER Project Office will be able to develop schedule and cost baselines for the U.S. ITER Project scope in preparation for CD-2, Approve Performance Baseline. CD-2 is currently projected to occur in mid-FY 2012.

Estimated ITER TPC Range: In late 2007, the TPC range approved at CD-1 accounts for the magnitude of cost risks that were identified. The identified sources of potential cost growth within the CD-1 range have been and continue to be: actions taken by the ITER Council and the IO to address technical, cost, and schedule issues; external factors outside of the ITER project; and industry input/design maturity for several very complicated systems/components. As the project has proceeded, these risks are better understood and are being retired by the IO. As part of this effort, the IO has committed to pursuing significant cost savings on the ITER project without reducing essential scope. These cost savings will be assessed by the ITER Council and the Members to ensure that they do not adversely affect the ITER research mission. The U.S. has requested an assessment of cost savings ranging up to 20%. The information derived from the IO efforts will feed into U.S. formulation of our CD-2 cost, schedule, and technical baseline.

As a Member of the ITER Council, the U.S. can exercise a veto over annual budgets and project cost increases, both of which can be used to control project cost growth.

Among the aspects under the IO's purview which drive the cost are the overall project schedule, design changes and other actions affecting hardware scope and manufacturing costs, and French and EU licensing/regulatory requirements. However, in July 2010, the ITER Council approved the IO's integrated technical, cost, and schedule baseline for the construction phase that includes detailed inputs from the seven Members, and placed the entire project under a formal change control project management regime, consistent with U.S. DOE project management practices.

External project cost risk factors include changes in Dollar/Euro exchange rates, escalation rates, commodity prices, changes agreed under formal change control, and market conditions for hardware procurement. The JIA requires funding contributions from the Members to be made in euros, which introduces the possibility of increased U.S. ITER Project costs due to less favorable dollar-euro exchange rates. Prices for raw materials used in manufacturing U.S.-supplied hardware have also been a significant concern. A Test Blanket Module (TBM) program has been established to demonstrate a key element of fusion technology, namely the breeding of tritium for a closed fuel cycle in a fusion power plant. While not part of the construction scope of ITER, it will have near-term financial implications

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

since certain modifications to the currently designed ITER civil infrastructure must be made to accommodate TBMs. The U.S. share of these modifications is expected to be under $10 million and will be funded through the U.S. ITER Project.

All of these risks were previously evaluated to develop a TPC range for CD-1. It was determined that the bottom of the range should be set at $1.45 billion, which included a contingency amount equal to 27% of the hardware cost at the time. The difference between $1.45 billion and the top end of the TPC range, $2.2 billion, provides additional contingency for known risks in the above categories as well as an amount for unidentified risks. SC has assessed the costs associated with the schedule delays to date and believes they are manageable within the existing CD-1 cost range.

ITER Financial Schedule Total Project Cost (TPC)[a]

(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Costs	Total Project Costs
2006	15,866	3,449	19,315
2007	42,000	18,000	60,000
2008	22,500	3,570	26,070
2009	109,000	15,000	124,000
2010	115,000	20,000	135,000
2011	TBD	TBD	TBD
2012	90,000	15,000	105,000
Outyears	TBD	TBD	TBD

The $105 million requested for the U.S. ITER Project in FY 2012 is a reflection of the accelerated pace of ITER construction as of mid-2010. As discussed above, the Administration, working with the USIPO, successfully pursued a range of initiatives to implement management reforms at the IO and to accelerate ITER construction with the goal of minimizing the overall cost of the Construction Phase for the U.S. and the other ITER Members.

The FY 2012 funding request will be used to make progress on all of the design, R&D, and long-lead procurement activities for the U.S. hardware contribution. Emphasis will continue to be given to industrial involvement in completing design work in preparation for subsequent large-scale fabrication activities. In particular, designs will be completed with industry input for the majority of U.S. hardware needed for first plasma, including the largest U.S. hardware subsystems: Central Solenoid Magnets and Tokamak Cooling Water. Long-lead items for magnet materials and Ion/Electron Cyclotron heating systems will be initiated and R&D will continue to support finalization of design efforts for diagnostics and other systems. Purchase of hardware for the U.S share of the Steady State Electrical system will also be initiated.Toroidal field magnet conductor production will be largely completed. The U.S. effort on the in-vessel coils will be handed over to the IO, which will be responsible for completing preliminary

[a]A complete baseline funding profile, including the outyears, will be established at CD-2, which is anticipated to be in mid FY 2012.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

design, prototyping, final design, as well as fabrication. The balance of funds will be used to support the USIPO, provide a small number of U.S. secondees to work on the IO staff, and furnish prescribed funding contributions to the IO.

ITER Related Annual Funding Requirements: The current estimate in the table below incorporates the terms of the JIA on cost sharing during operations, deactivation and decommissioning. Specifically, it considers the procedure for converting currencies into Euros and the 20-year period of annual contributions to the decommissioning fund in conjunction with ITER operations.

(dollars in thousands)

	Current Estimate	Previous Estimate
FY 2015–FY 2034		
U.S. share of annual facility operating costs including commissioning, maintenance, repair, utilities, power, fuel, improvements, and annual contribution to decommissioning fund for the period 2015 to 2034. Estimate is in 2015 dollars.	80,000	80,000
FY 2035–FY 2039		
U.S. share of the annual cost of deactivation of ITER facility for the period 2035–2039. Estimate is in 2037 dollars.	25,000	25,000

Total, Facility Operations	**223,002**	**195,882**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
DIII-D	
The increased funding is needed to support increased personnel and electrical power costs.	+1,901
Alcator C-Mod	
The increased funding will support an additional two weeks of operation.	+618
NSTX	
The decrease in funding for the NSTX Facility is applied to the increase for the NSTX Upgrade MIE project. This budget will support 10 weeks of plasma operation during the first half of the fiscal year prior to the shutdown for the upgrade.	-3,816

	FY 2012 vs. FY 2010 Current Approp. ($000)
NSTX Upgrade (MIE)	
The increase in funding will provide for continued work on the two enhancements to the NSTX Facility. An upgrade to the magnet system, including the central solenoid, is designed to permit higher plasma currents and magnetic fields. The additional neutral beam heating power is designed to enable control of the plasma stability by modifying the plasma current profile. The two upgrades will enable higher plasma pressures to be obtained.	+5,680
Other, GPE, and GPP	
This funding decrease reflects the receipt of Recovery Act funding which was used to improve PPPL's infrastructure that, in turn, reduced the burden on GPP funding needed in FY 2012.	-1,503
U.S. Contributions to ITER Project (MIE)	
The decrease in funding reflects the Administration's assessment of the level of effort required to sustain U.S. commitments to ITER in FY 2012 and to fully transition from the design, engineering, and planning phase to the construction phase.	-30,000
Total Funding Change, Facility Operations	**-27,120**

Enabling R&D

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation FY	2012 Request
Enabling R&D		
Engineering Research	19,136	18,273
Materials Research	6,467	7,729
Total, Enabling R&D	25,603	26,002

Description

The Enabling R&D subprogram helps the Science subprogram address its scientific challenges by developing and continually improving the hardware, materials, and technology that are incorporated into existing fusion research facilities, thereby enabling these facilities to achieve higher levels of performance. Enabling R&D also supports the development of new hardware, materials, and technology that are incorporated into the design of next generation facilities, thereby increasing confidence that the predicted performance of these new facilities will be achieved.

Selected FY 2010 Accomplishments

- *Understanding materials under fusion conditions:* A unique aspect of the fusion environment is substantial production of helium in the materials that confine the plasma. The microstructure properties of fusion materials can be degraded by the presence of helium. Oak Ridge National Laboratory (ORNL), working with others in the fusion materials community has made progress toward solving this very difficult problem by using novel experimental techniques and advanced computer simulations to better understand and mitigate the degradation caused by large amounts of helium. From an experimental standpoint, ORNL has been able to simulate helium in the microstructure by covering the surface of a sample with a coating of a nickel-bearing alloy before placing the sample in the High Flux Isotope Reactor at ORNL. Under neutron irradiation energetic helium atoms are produced in the coating and injected into the sample. These experiments show that a new class of materials, nanocomposited ferritic alloys, appears to offer an effective way to manage helium and mitigate radiation damage. While these early experimental results are promising, there is still a significant amount of research required to demonstrate that these alloys can survive in a fusion environment.
- *Plasma Edge Disturbance Mitigation Technique Demonstrated on DIII-D:* The plasma edge in a magnetic fusion device can have a periodic disturbance known as an edge localized mode (ELM) that can potentially damage the plasma chamber from pulsed high thermal loads. ORNL has developed a technique to mitigate these effects by injecting small solid hydrogen pellets into the edge of the plasma frequently. The pellets are fired by a pneumatic gun using the same technology developed by ORNL for fueling fusion plasmas. The pellets are able to trigger very small ELMs that have a much lower pulsed thermal load than the naturally occurring high thermal loads but lower frequency ELMs. This technique has been used on the DIII-D tokamak at General Atomics to demonstrate the reduction of ELM energy onto the plasma chamber by a factor of four. This technique can potentially be employed on ITER to prevent large ELMs from occurring that can reduce the lifetime of the plasma facing components in the chamber and thus increase the machine availability for burning plasma research.

- *Addressing ITER operational issues:* The chemical erosion of carbon surfaces, in an area called the divertor region, is expected to be the dominant mechanism responsible for tritium accumulation in ITER, which can be a safety concern. Previous experiments performed in a small linear plasma device at the University of California at San Diego revealed the mitigation of carbon chemical erosion by the presence of beryllium impurities contained within a plasma. The beneficial mitigation effect is expected to occur naturally in the ITER device due the transport of beryllium into the divertor region. However, operation of the divertor requires that there be carbon radiation in this region to achieve an effective plasma. Without carbon radiation, an additional radiating species, such as argon, must be intentionally added. It was feared that that addition of argon to the plasma might cause increased erosion and remove the protective beryllium carbide surface layer that is responsible for the mitigation. Fortunately, it has recently been experimentally verified that the beneficial mitigation effect survives.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Engineering Research	**19,136**	**18,273**

The Engineering Research element addresses the breadth and diversity of domestic interests in enabling R&D for magnetic fusion systems as well as international collaborations with emphasis on heating, fueling, plasma chamber, safety research, and surface protection technologies. While much of the effort is focused on current devices, an increasing amount of the research is oriented toward the technology needs or issues that will be faced in future experiments, including ITER. An example is to understand scientifically what is occurring in a burning plasma with material erosion and redeposition within the fusion chamber caused by this harsh environment and what effect it can have on the plasma and ITER operation. In addition to providing the tools that help accomplish the experimental research, a part of this element also conducts system studies of the most scientifically challenging concepts for fusion research facilities that may be needed in the future as well as identifying critical scientific issues and missions for the next stage in the FES program. Finally, analysis and studies of critical scientific and technological issues are supported, the results of which will provide guidance for optimizing future experimental approaches and for understanding the implications of fusion research on applications of fusion.

▪ **Plasma Technology**	**15,772**	**13,906**

Plasma Technology efforts will focus resources on developing enabling technologies for current and future machines, both domestically and internationally, and on addressing potential ITER operational issues. In addition, the Tritium Irradiation Thermofluid American-Japanese Network (TITAN), a collaborative program on plasma facing and blanket materials for use in future facilities, will be continued.

In FY 2012, the following specific activities will be supported:

- Continue the experimental studies and modeling activities of tungsten-carbon-beryllium mixed materials layer formation and redeposition in the University of California at San Diego experimental facility and in the Tritium Plasma Experiment at Idaho National Laboratory (INL). Results will be applied to evaluate tritium accumulation in plasma facing components that will occur during ITER operation.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

- Continue a series of material science experiments under the TITAN cost-sharing collaboration with Japan in the Safety and Tritium Applied Research Facility at INL to resolve key issues of tritium behavior in materials proposed for use in fusion systems.

Research will also be conducted on plasma facing components, heating and fueling technologies, and blanket concepts that could be tested in ITER. In addition, this category funds research in safety and plasma-surface interaction and modeling to address potential issues that could be encountered during operation of ITER or future devices.

▪ **Advanced Design**	**3,364**	**4,367**

FES supports a system studies design team that carries out conceptual fusion power plant studies for various fusion confinement concepts, such as the tokamak, stellarator, reverse field pinch, spherical torus, and tandem mirror. Fusion researchers use these studies to compare technical requirements of an attractive fusion system with present achievements to identify remaining technical challenges that must be addressed to develop a commercial fusion power plant. FES uses this knowledge to guide the research program. The systems studies team is composed of a multi-institutional core group of individuals that have a wealth of experience in fusion science and technology. The core team is augmented by experts in whatever fusion concept is being studied at a given time. The team is known in the community for its objective approach and its ability to develop innovative solutions to a wide range of scientific and technological problems. The team has also participated in pre-conceptual design efforts of nearer-term test facilities and experimental devices.

In FY 2010, the systems design team initiated a 3-year integrated study to determine the advances needed in the plasma materials interface (PMI) science area to achieve practical fusion energy. This effort is built on the results of a broad study the results of which are contained in the June 2009 report Research Needs for Magnetic Fusion Energy Sciences. In FY 2012, the team will be nearing completion of this study. In FY 2010, FES directed the team to participate in the Fusion Nuclear Science planning activity to assist in identifying approaches for moving the U.S. fusion nuclear sciences research program forward in parallel with the ITER program. This may result in a six to nine month delay in the completion of the PMI study.

Materials Research	**6,467**	**7,729**

Fusion reactor materials will be required to function in an extraordinarily demanding environment that includes various combinations of high temperatures, chemical interactions, time-dependent thermal and mechanical loads, and intense neutron fluxes. In addition, radiation damage degrades materials properties through processes that include hardening, embrittlement, phase instabilities, segregation, precipitation, irradiation creep, volumetric swelling, and radiation-induced conductivity. Developing materials for use in a fusion environment is a long-standing feasibility issue. The challenge for the Materials Research element is to focus its efforts to address all of these issues with a strong science-based program that will eventually lead to materials that can be used in future facilities. This element leverages the substantial work on nanosystems and computational materials science being funded by other programs such as Basic Energy Sciences. The long-term goal of this element is to develop experimentally validated predictive and analytical tools that can lead the way to nanoscale design of advanced fusion materials with superior performance and lifetimes.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

The FY 2012 request will maintain and grow a Materials Research program that addresses significant challenges involved with operating in this extraordinarily demanding environment. The funding will be used for both modeling and experimental activities aimed at the science of materials behavior in fusion environments, including research on candidate materials for the structural and plasma facing elements of fusion chambers. Through a variety of cost-shared international collaborations, this element supports irradiation testing of candidate fusion materials in the simulated fusion environments of fission reactors to provide data for validating and guiding the development of models for the combined effects of helium, which is produced by transmutation reactions, and neutron bombardment on the microstructural evolution, damage accumulation, and property changes of fusion materials in this environment. This research will be coordinated among the Office of Science, Office of Nuclear Energy, and the National Nuclear Security Administration.

Total, Enabling R&D	**25,603**	**26,002**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Engineering Research	
▪ **Plasma Technology**	
The decrease will cause an overall reduction in support for planned upgrades to a plasma material testing facility located at Sandia National Laboratories.	-1,866
▪ **Advanced Design**	
The increase will result in a higher level of effort in the advanced concepts studies that are examining possible pre-conceptual designs for a new facility in the U.S.	+1,003
Total, Engineering Research	**-863**
Materials Research	
The increase will support both modeling and experimental research on nano-composited high strength structural materials such as oxide-dispersion strengthened steels; tungsten, the leading candidate for a plasma facing material; and other fusion chamber materials.	+1,262
Total Funding Change, Enabling R&D	**+399**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Operating Expenses	290,651	292,288
Capital Equipment	125,506	106,947
General Plant Projects	1,493	465
Total, Fusion Energy Sciences	417,650	399,700

Funding Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Research 19	4,648	203,818
Scientific User Facilities Operations	76,574	75,277
Major Items of Equipment	143,950	119,630
Other (GPP, GPE and Infrastructure)	2,478	975
Total, Fusion Energy Sciences	417,650	399,700

Scientific User Facilities Operations and Research

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
DIII-D		
Operations 3	7,830	39,731
Facility Research	27,255	28,888
Total DIII-D	65,085	68,619
Alcator C-Mod		
Operations 1	7,424	18,042
Facility Research	9,035	10,454
Total Alcator C-Mod	26,459	28,496
NSTX		
Operations 2	1,320	17,504
Facility Research	16,868	17,549
Total NSTX	38,188	35,053

	(dollars in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
Scientific User Facilities Operations and Research		
Operations 7	6,574	75,277
Facility Research	53,158	56,891
Total, Scientific User Facilities Operations and Research	129,732	132,168

Facility Hours and Users

	FY 2010 Current Approp.	FY 2012 Request
DIII-D National Fusion Facility		
Achieved Operating Hours	608	N/A
Planned Operating Hours	560[a] 5	20
Optimal Hours	1,000	1,000
Percent of Optimal Hours	61%	52%
Unscheduled Downtime	9.8%	N/A
Number of Users	235	230
Alcator C-Mod		
Achieved Operating Hours	512	N/A
Planned Operating Hours	416[a] 5	44
Optimal Hours	800	800
Percent of Optimal Hours	64%	68%
Unscheduled Downtime	4.7%	N/A
Number of Users	195	194
National Spherical Torus Experiment		
Achieved Operating Hours	576	N/A
Planned Operating Hours	560[a] 4	00
Optimal Hours	1,000	1,000
Percent of Optimal Hours	58%	40%
Unscheduled Downtime	9.8%	N/A
Number of Users	145	145

[a] Planned hours do not include Recovery Act supported operations in FY 2010. Utilizing Recovery Act funding, DIII-D had an additional 120 hours of planned operations, C-Mod had an additional 160 hours of planned operations and NSTX had an additional 40 hours of planned operations in FY 2010. All of these additional operating hours were achieved.

	FY 2010 Current Approp.	FY 2012 Request
Total, Facilities Hours and Users		
Achieved Operating Hours	1,696	N/A
Planned Operating Hours	1,536[a] 1,	464
Optimal Hours	2,800	2,800
Percent of Optimal Hours	61%	53%
Unscheduled Downtime	N/A	N/A
Number of Users	575	569

Major Items of Equipment (MIE)

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request Ou	tyears	Total
MIEs						
NST X Upgrade						
TEC	0	3,550	9,000	14,630	56,485	83,665
O PC	5,235	5,400	0	0	0	10,635
TPC	5,235	8,950	9,000	14,630	56,485	94,300
ITER						
TEC	189,366	115,000	113,000	90,000	TBD	TBD
O PC	40,019	20,000	13,000	15,000	TBD	TBD
TPC	229,385	135,000	126,000	105,000	TBD	TBD
Total MIEs						
TEC		118,550	122,000	104,630		
O PC		25,400	13,000	15,000		
TPC		143,950	135,000	119,630		

Facility Operations MIEs:

- ***National Spherical Torus Experiment Upgrade Major Item of Equipment Project***

  The NSTX Upgrade Project supports major upgrades at NSTX to keep its world-leading status. As presently envisioned, this project will add a new centerstack magnet assembly that will double the magnetic field, and a second neutral beam (NB) line that will double the NB power available to heat the plasma. CD-0 (Approve Mission Need) was completed on February 23, 2009. The CD-1

[a] Planned hours do not include Recovery Act supported operations in FY 2010. Utilizing Recovery Act funding, DIII-D had an additional 120 hours of planned operations, C-Mod had an additional 160 hours of planned operations and NSTX had an additional 40 hours of planned operations in FY 2010. All of these additional operating hours were achieved.

Independent Project Review was completed in December 2009. The Departmental review and approval of CD-1 was completed on April 15, 2010. CD-2 was achieved on December 20, 2010.The performance baseline for the MIE project is $94.3M with completion in September 2015. In FY 2012, PPPL will focus on completing design and R&D required for both the magnet and neutral beam upgrades and initiate some small advanced procurements.

- ***U.S. Contributions to ITER***

  The objective of the U.S. ITER Project is to deliver the U.S. share of the hardware components, personnel, and funding contributions to the ITER Organization (IO) for the ITER construction phase per the terms of the ITER Joint Implementation Agreement. The U.S. ITER Project is being managed by the U.S. ITER Project Office (USIPO), located at Oak Ridge National Laboratory (ORNL). ORNL serves as the prime contractor to DOE, working with its partners Princeton Plasma Physics Laboratory and Savannah River National Laboratory. Each laboratory has been assigned a well-defined portion of the project's scope that takes advantage of their respective technical strengths. DOE serves as the U.S. Domestic Agency for ITER, and under its direction, the USIPO has responsibility for planning, managing, and delivering the entire scope of the U.S. ITER Project. All U.S. ITER Project activities are being overseen by a DOE Federal Project Director at the DOE Oak Ridge Office. As the design agent and eventual operator/owner of the ITER facility, the IO is responsible for specifying top level hardware design requirements and delivery schedules.

  The U.S. ITER Project was formally initiated in July 2005 when Critical Decision-0 (CD-0), Mission Need, was approved by the DOE Senior Acquisition Executive, and the first year of project funding was FY 2006. CD-1, Alternative Selection and Cost Range (including authorization for long-lead procurements), was subsequently approved in January 2008. This set the Total Project Cost (TPC) range at $1.45 to $2.2 billion (as spent). A schedule range for U.S. ITER Project completion (CD-4) was set at FY 2014–2017. Current efforts are focused on completing U.S. hardware component designs and supporting R&D, the majority of which should be completed in FY 2012, and assisting the IO with establishing a functionally mature project management organization.

  The $105,000,000 requested for the U.S. ITER Project in FY 2012 is a reflection of the accelerated pace of ITER construction as of mid-2010. The Administration has successfully engaged in a range of initiatives to implement management reforms at the IO and accelerate ITER construction with the goal of minimizing the overall cost of the construction phase for the U.S. and the other ITER Members.

Scientific Employment

FY	2010 estimate	FY 2012 estimate
# University Grants	307	310
# Laboratory Projects	171	175
# Permanent Ph.D's (FTEs)	760	774
# Postdoctoral Associates (FTEs)	116	124
# Graduate Students (FTEs)	342	347
# Ph.D.'s awarded	42	44

High Energy Physics

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
High Energy Physics		
Proton Accelerator-Based Physics	438,369	411,207
Electron Accelerator-Based Physics	30,212	22,319
Non-Accelerator Physics	97,469	81,852
Theoretical Physics	68,414	68,914
Advanced Technology R&D	156,347	171,908
Subtotal, High Energy Physics	790,811	756,200
Construction	0	41,000
Total, High Energy Physics	790,811[a]	797,200

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

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

Background

Research in high energy physics, also called particle physics, has led to a profound understanding of the physical laws that govern matter, energy, space, and time. The Standard Model of particle physics, first established in the 1970s, well describes the behavior of elementary particles and forces, often to very high precision. Nevertheless, the Standard Model is understood to be incomplete since the model fails at high energies—energies now being created in particle accelerators—and describes only a small fraction of the matter and energy filling the universe. Data have revealed that only about 5% of the universe is made of the normal, visible matter described by the Standard Model. The remaining 95% of the universe consists of matter and energy whose fundamental nature remains a mystery.

A world-wide program of particle physics research is underway to explore what lies beyond the Standard Model. To this end, HEP supports a program focused on three scientific frontiers:

- *The Energy Frontier,* where powerful accelerators are used to create new particles, reveal their interactions, and investigate fundamental forces;

[a] Total reduced by $19,672,000: $17,564,000 of which was transferred to the Small Business Innovation Research (SBIR) program and $2,108,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

- *The Intensity Frontier,* where intense particle beams and highly sensitive detectors are used to pursue alternate pathways to investigate fundamental forces and particle interactions by studying events that occur rarely in nature; and
- *The Cosmic Frontier,* where ground and space-based experiments and telescopes are used to make measurements that will offer new insight and information about the nature of dark matter and dark energy to understand fundamental particle properties and discover new phenomena.

Together, these three interrelated and complementary discovery frontiers offer the opportunity to answer some of the most basic questions about the world around us, such as:

- *Are there undiscovered principles of nature, such as new symmetries or new physical laws?*

  The laws of quantum physics that describe elementary particles and forces are based on underlying symmetries of nature. Some of these symmetries prevail only at very high energies. A possible new symmetry, called supersymmetry, relates particles and forces. If this symmetry exists, it would solve the failure of the standard model at high energies. It predicts a superpartner for every particle currently known. The search for such superparticles will be carried out with accelerators that operate at the Energy Frontier or by observing rare decays or new phenomena at the Intensity or Cosmic Frontiers.

- *How can we solve the mystery of dark energy?*

  The structure of the universe today is a result of two opposing forces: gravitational attraction and cosmic expansion. For approximately the last six billion years, the universe has been expanding at an accelerating rate due to a mysterious dark energy that overcomes gravitational attraction. This energy, which permeates empty space, must have a quantum explanation. The existence of dark energy was first discovered in 1998 by HEP-supported researchers (among others); more and other types of data, gathered from the Cosmic Frontier, along with new theoretical ideas, are necessary to make progress in understanding its fundamental nature.

- *Are there extra dimensions of space?*

  String theory is an attempt to unify physics by explaining particles and forces as the vibrations of sub-microscopic strings. String theory predicts that space has more than three dimensions, although the extra ones are too small to be observed directly, and many versions of string theory also predict that supersymmetry is real. Accelerators at the Energy Frontier may find evidence for extra dimensions, requiring a completely new paradigm for thinking about the structure of space and time.

- *Do all the forces become one?*

  All the basic forces in the universe could be various manifestations of a single unified force. Unification was Einstein's great, unrealized dream, and advances in string theory give hope of achieving it. The discovery of superpartners or extra dimensions at Energy Frontier accelerators, or hints of them at the Intensity or Cosmic Frontiers, would lend strong support to current ideas about unification.

- *Why are there so many kinds of particles?*

  Three different pairings or "families" of quarks and leptons have been discovered—most of these at DOE national laboratories. Does nature somehow require that there are only three, or are there more? Moreover, the various quarks and leptons have widely different masses and force couplings. These differences suggest there may be an undiscovered explanation that unifies quarks and leptons, just as the discovery of quarks simplified the zoo of composite particle states discovered in the

1960s. Detailed studies that employ Energy Frontier accelerators, as well as precision measurements made at Intensity Frontier facilities, may provide the dramatic insights into this complex puzzle.

- *What is dark matter? How can we make it in the laboratory?*

  Most of the matter in the universe is invisible. We can detect its existence only through its gravitational interactions with normal matter. This dark matter is thought to consist of exotic particles (relics) that have survived since the Big Bang. Experiments are being mounted to try to directly detect these exotic particles, via observations of relic dark matter at the Cosmic Frontier or by producing them at Energy Frontier accelerators that briefly recreate the conditions of the Big Bang.

- *What are neutrinos telling us?*

  Of all the 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. Many trillions of neutrinos can pass through an area the size of a postage stamp every second with little or no interaction. Their detection requires intense neutrino sources and large detectors. HEP supports research into fundamental neutrino properties because they can reveal important clues to the unification of forces and the very early history of the universe. Naturally occurring neutrinos are produced by cosmic ray interactions with the Earth's atmosphere, by supernovae, and in the interior of stars. These can be studied at the Cosmic Frontier. Man-made neutrinos can be studied at the Intensity Frontier using intense neutrino sources such as nuclear reactors and advanced accelerators.

- *How did the present universe come to be?*

  The universe began with a massive explosion known as the Big Bang, followed by a burst of expansion of space itself. The universe then expanded more slowly and cooled, which allowed the formation of stars, galaxies, and ultimately life. Understanding the very early evolution of the universe will require a breakthrough in physics: the theoretical reconciliation of quantum mechanics with gravity.

- *What happened to the antimatter?*

  The universe appears to contain very little antimatter. Antimatter is continually produced by naturally occurring nuclear reactions only to undergo near immediate annihilation. The Big Bang, however, should have produced equal amounts of both matter and antimatter. This has, to date, been borne out by the study of high-energy collisions in the laboratory. Precise Energy and Intensity Frontier accelerator-based measurements of the subtle asymmetries present in the weak nuclear interaction may shed light on how the present day matter-antimatter asymmetry arose.

Because of the strong connections between the key questions in each area, successfully addressing these questions requires coordinated initiatives at each of the frontiers. The HEP program invents new technologies to answer these questions and to meet the challenges of research at the frontiers. HEP supports theoretical and experimental studies by individual investigators and large collaborative teams—some who gather and analyze data from accelerator facilities in the U.S. and around the world, and others who develop and deploy ultra-sensitive instruments to detect particles from space and observe astrophysical phenomena that advance our understanding of fundamental particle properties.

Subprograms

HEP is divided into five subprograms that are organized around the tools and facilities they employ (such as an electron accelerator or cosmic ray detector) and the knowledge and technology they develop (such as superconducting radio frequency cavities or computational capabilities):

- The *Proton Accelerator-Based Physics subprogram* exploits two major applications of proton accelerators. The protons can be used directly in collisions such as the Large Hadron Collider (LHC) or proton accelerators can also produce other particles (such as antiprotons, K mesons, muons, and neutrinos) by colliding intense proton beams into targets. These particles can then be formed into secondary beams for experiments. The proposed Intensity Frontier program utilizes the high-power proton beam at Fermi National Accelerator Laboratory (Fermilab) to produce intense secondary beams of muons and neutrinos for world-leading experiments.
- The *Electron Accelerator-Based Physics subprogram* utilizes accelerators with high-intensity and ultra-precise electron beams to create and investigate matter at its most basic level. Unlike protons, electrons are low mass, point-like particles that are well-suited for precision measurements of particle properties and exacting beam control. The next-generation Energy Frontier accelerator after the LHC is likely to be a high-energy lepton (electron or perhaps muon) facility that can probe LHC discoveries in detail. In addition, new developments in beam luminosity and interaction region control have yielded designs of Super B Factories which could produce luminosities one hundred times higher than previously available.
- The *Non-Accelerator Physics subprogram* supports particle physics studies that cannot be investigated with accelerators, or are best studied by other means. These activities have provided experimental data, new ideas, and techniques complementary to those provided by accelerator-based research. Scientists in this subprogram investigate topics such as dark matter, dark energy, neutrino properties, proton decay, the highest energy cosmic rays and gamma rays, and primordial antimatter. Some of the non-accelerator particle sources used in this research are cosmic rays, gamma rays, and photons and neutrinos from both astrophysical sources and nuclear power reactors.
- The *Theoretical Physics subprogram* provides the vision and mathematical framework for understanding and extending the knowledge of particles, forces, space-time, and the universe. This subprogram supports activities that range from detailed calculations of the predictions of the Standard Model to advanced computation and simulations to solve otherwise intractable problems. Theoretical physicists play key roles in determining which experiments to perform and explaining experimental results in terms of underlying theories that describe the interactions of matter, energy, and space-time.
- The *Advanced Technology R&D subprogram* develops the next generation of particle accelerator and detector technologies for the future advancement of high energy physics and other sciences, supporting world-leading research in the physics of particle beams, fundamental advances in particle detection, and R&D on new technologies and research methods appropriate for a broad range of scientific disciplines.

Benefits

Seeking answers to big questions drives basic research. It appeals to our deepest human nature. However, the new technologies created to answer the questions that high energy physicists seek to answer, and the knowledge acquired in their pursuit, also yield substantial benefits of a more tangible nature for society as a whole. The discovery of x-rays was driven not by surgeons in search of a better way to diagnose bone fractures but by scientists engaged in basic research. Today, those x-rays, along with all the improvements over the years in delivery and imaging systems, are vital tools in service of humanity.

The continuous improvement of accelerator and detector technology necessary to pursue high energy physics as well as the scale of the science itself, have had transformative impacts on the Nation's economy, security, and society. HEP, as the primary steward of accelerator science and advanced accelerator technology R&D in the Office of Science, has developed the knowledge and technologies that are the basis of Office of Science major accelerator user facilities. HEP's contributions to the underlying technologies now used in medicine, science, industry, and national security, as well as for workforce training, are also well known. HEP coordinates acceleratory research investments with the Basic Energy Sciences (BES) and Nuclear Physics (NP) programs.[a]

Looking to the future, HEP's ongoing and future development of accelerator, detector, electronics, and magnet technologies is anticipated to have significant impact in a number of areas:

- homeland and national security—where particle accelerators and detectors developed for high energy physics research have the potential for hazardous material detection and non-proliferation verification;
- industry—where, for example, superconducting cables being developed for next generation magnets for high energy physics research could be used to transmit, with minimal power losses, far more electricity than conventional cables;
- internet grid development—where the developments of the international grid capability for data analysis of the large detectors at the LHC may result in a paradigm change in the handling of huge data sets;
- medical treatment and diagnosis—where new, more cost-efficient particle accelerators, detectors, and magnets for cancer treatment and diagnosis should emerge; and
- other scientific fields—where HEP's development of the science and technologies needed for next-generation particle accelerator and detector applications will be transferred and exploited.

Program Planning and Management

Advisory and Consultative Activities

To ensure that resources are allocated to the most scientifically promising experiments, DOE actively seeks external input using a variety of advisory bodies. The High Energy Physics Advisory Panel (HEPAP), jointly chartered by DOE and the National Science Foundation (NSF), provides advice regarding the scientific opportunities and priorities of the national high energy physics research program. HEPAP and its subpanels undertake special studies and planning exercises in response to specific charges from the funding agencies.

In 2007, HEPAP was charged to examine the options for mounting a world-class U.S. particle physics program at various funding levels. A subpanel called the Particle Physics Project Prioritization Panel (P5) was formed to review progress and future plans of the various research areas of the HEP program and to assess and prioritize the scientific opportunities and proposed projects identified. The HEPAP P5 report[b] submitted in June 2008 has provided important input for setting programmatic priorities for the HEP program. This guidance was further refined in the HEPAP report generated in response to a charge by the agencies to identify and prioritize the scientific opportunities and options that can be pursued at

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[a] For more information, visit http://www.science.doe.gov/hep/benefits.
[b] The full HEPAP report is available at http://www.science.doe.gov/hep/files/pdfs/P5_Report%2006022008.pdf.

different funding levels to achieve an optimum program in particle astrophysics. This Particle Astrophysics Science Assessment Group (PASAG) Report[a] was submitted to the agencies in October 2009. Many of the recommendations contained in these reports have been implemented, and this budget request supports recommendations of the P5 roadmap.

The National Academies Decadal Survey of Astronomy and Astrophysics (Astro2010) report[b] was released in August 2010 recommending priorities for the next decade for the U.S. program in astronomy and astrophysics under various funding scenarios. This study is particularly relevant to the National Aeronautics and Space Administration (NASA) and NSF, the federal stewards of astronomy and astrophysics, on opportunities and priorities in these scientific areas. However, it also provides advice on the opportunities for DOE HEP participation and also provides guidance on scientific/technical aspects of the proposed program. HEP has participated in discussions with NSF (Astronomical Sciences and Physics Divisions), NASA (Astrophysics Division), and the Office of Science and Technology Policy (OSTP) to develop a coordinated agency response to the guidance provided by the Astro2010 Report. HEP's Budget Request and planning for FY 2012 are consistent with guidance obtained from the scientific community and the implementation of a coordinated interagency national program that will deliver the best science with the available resources in this scientific area.

The Astronomy and Astrophysics Advisory Committee (AAAC) reports on a continuing basis to DOE, NSF, and NASA with advice on the direction and management of the national astronomy and astrophysics research programs. The AAAC operates similarly to HEPAP, and the two advisory bodies have been charged to form joint task forces or subpanels to address research issues at the intersection of high energy physics, astrophysics, and astronomy, such as dark energy and dark matter and the study of high energy cosmic and gamma rays.

Triennially, HEP convenes a Committee of Visitors (COV) to perform an independent review of HEP's solicitation, proposal, and research management processes, as well as an evaluation of the quality, performance, and relevance of the research portfolio, including an assessment of its breadth and balance. The second HEP COV review took place in summer 2007. The 2007 COV report[c] had 18 specific recommendations relating primarily to staffing, grants review and processing, and project management, which HEP has addressed or put processes in place to address all of them. The third COV review was held on October 2010. The report has been made public, as has the HEP response[d].

Review and Oversight

The HEP program office reviews and provides ongoing oversight of its research portfolio. All university research proposals are subject to an external peer review process to ensure high quality research and relevance to achieving the goals of the national program. Proposals to HEP for grant support are peer-reviewed by external technical experts, as they are for all Office of Science research programs, following the guidelines established by 10 CFR Part 605.

Following recommendations of the 2007 COV, HEP implemented a new review process for high energy physics research and basic technology R&D efforts at DOE laboratories. Laboratory high energy physics research or technology R&D groups are peer-reviewed triennially on a rotating basis, using the same criteria established for the university reviews. In FY 2012, the Proton Accelerator Based Physics and Detector R&D subprograms will be reviewed. Laboratory proposals involving significant new research scope are also subject to peer-review by external experts on an ad hoc basis.

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[a] http://www.science.doe.gov/hep/files/pdfs/HEPAP_2009_10_Ritz_PASAG.pdf
[b] http://www.nap.edu/catalog.php?record_id=12951
[c] The 2007 COV report and HEP's response are available at http://www.science.doe.gov/SC-2/COV-HEP/HEP_Reviews.htm.
[d] The 2010 COV report and HEP's response are available at http://www.science.doe.gov/SC-2/COV-HEP/HEP_Reviews.htm

Basic and Applied R&D Coordination

Many of the broader applications of technology originally developed for HEP research have been serendipitous. In order to obtain guidance on how to better bridge the gap between accelerator research and technology deployment, HEP organized a symposium entitled "Accelerators for America's Future," held in October 2009[a]. The symposium was followed by a two-day workshop in which more than 100 experts familiar with accelerator needs and requirements met to identify technological and policy issues that if overcome could have transformative impacts in the areas of national security, medicine, energy and environment, industry, and discovery science (including accelerator science).

The report from this workshop identifies possible future applications of accelerators, as well as key technical areas where focused additional R&D efforts as well as dedicated user and demonstration facilities would advance the broad beneficial uses of accelerators in society. HEP will use the workshop report to develop a strategic plan for accelerator technology R&D in collaboration with BES and NP that recognizes its broader societal impacts.

Budget Overview

The HEP program addresses fundamental questions about the nature of the universe by balancing the scientific priorities of the research community with the constraints of the facilities, tools, and resources available. Research facilities for high energy physics generally require significant investments over many years and the coordinated efforts of international teams of scientists and engineers to realize accelerators and detectors that push the frontiers of Energy, Intensity, and Cosmic exploration.

HEP, with input from the scientific community, has developed a long-range plan which maintains a leadership role for the U.S. within this global context. In this plan there is a continuing shift of focus from the operation of the facilities built at the end of the 1990s to the design and construction of new research facilities and instruments, while maintaining a world-leading scientific program and supporting advanced technology R&D for the future. This strategic plan positions the Nation to play a role at all three frontiers of particle physics. In the FY 2012 Budget Request, investments are prioritized to develop future accelerator-based experimental research facilities.

The Energy Frontier: The Tevatron Collider at Fermilab completes its planned program in FY 2011. Its record-breaking performance in delivering data over the last few years will result in a dataset that can continue to be mined for significant discoveries during the first few years of Large Hadron Collider (LHC) operations at CERN. In FY 2012, HEP will support the analysis needs of researchers to exploit the data obtained. HEP's primary scientific goals over the next five years are to enable such discoveries—for example, the Higgs boson and supersymmetric particles—either from Tevatron data or the LHC data now being acquired.

First beam collisions at the LHC occurred in November 2009. The beam energies were raised to 3.5 TeV per beam (7 TeV center of mass energy) in March 2010, a new record for man-made particle collisions. The first run of the LHC is currently planned to end in late 2011. After a year-long consolidation and maintenance period, it is planned to resume running at its design energy (14 TeV center of mass). In FY 2012, HEP will provide support for LHC detector operations, maintenance, computing, and R&D necessary to maintain a significant U.S. role in the LHC program. However, CERN is considering delaying the shutdown and extending the run into 2012 for the discovery or exclusion of a Standard Model Higgs. A formal announcement on this is expected in February 2011.

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[a] http://www.acceleratorsamerica.org

The Intensity Frontier: The Neutrinos at the Main Injector (NuMI) beamline at Fermilab will operate in its current configuration through mid-FY 2012 for ongoing neutrino experiments and then will shut down for a year-long upgrade that will enhance the beam power from approximately 400 kW to 700 kW for the NuMI Off-Axis Neutrino Appearance (NOvA) experiment. The NOvA project, currently under fabrication, will be in full operation in 2014 to enable key measurements of neutrino properties. In FY 2012, project engineering and design funding is provided for the Long Baseline Neutrino Experiment (LBNE) and the Muon to Electron Conversion Experiment (Mu2e), which will use the NuMI beam and other auxiliary beamlines before the end of the decade. The HEP program has been developing the LBNE project in coordination with NSF, because the Deep Underground Science and Engineering Laboratory (DUSEL) in the Homestake mine in South Dakota proposed to be built by the National Science Foundation was a possible site for the LBNE far detector. However, based on a National Science Board decision, NSF will not pursue DUSEL as previously proposed. The Project Engineering and Design (PED) request for LBNE has been reduced due to the anticipated delay in achieving Critical Decision 1. High Energy Physics will support activities for minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.

The Cosmic Frontier: HEP is partnering with NASA and NSF in world class space-based, and ground-based particle astrophysics observatories for exploration of the Cosmic Frontier. In FY 2012, funding supports existing and ongoing endeavors with NSF (such as VERITAS, Auger, DES, BOSS, and CDMS) and NASA (Fermi and AMS). Looking to the future, HEP has utilized the guidance of HEPAP and the recent National Academies Astro2010 reports on scientific priorities and worked with NASA and NSF to mount a U.S. program that will advance our understanding of dark matter and dark energy. HEP plans to collaborate with NSF on a staged program of research and technology development designed to directly detect dark matter particles using ultra-sensitive detectors located underground. HEP also plans to work with NSF on implementing the Large Synoptic Survey Telescope for studies of dark energy using a ground-based telescope, and plans to support researchers working with NASA on design of a space-based mission. HEP's FY 2012 request supports R&D and conceptual design efforts for these initiatives.

Significant Program Shifts

To position the U.S. to remain among the leaders in particle physics it is critical that investments are made in new U.S. research capabilities that can make significant discoveries and advance our understanding of fundamental properties of matter. In the FY 2012 Budget Request, funds are shifted from facility operations, particle physics research, advanced technology R&D, and Major Items of Equipment to support the increase in the planned funding profiles for two construction projects (LBNE and Mu2e). In this Request, funding for Facility Operations, Particle Physics Research, Advanced Technology R&D, and Major Item of Equipment projects are all significantly reduced, while selected other activities are supported to address key site infrastructure investments at Fermilab. The FY 2012 Budget Request supports a strong, productive program that is making the needed investments for future sustained leadership; however, there will be a downsized research program in the short term that will result in diminished leadership role in a number of endeavors.

The reduction in Facility Operations comes primarily from savings from the completion of Tevatron operations at Fermilab in 2011. FY 2012 funding supports operations of NuMI and smaller neutrino experiments for half a year followed by a half-year shutdown for the accelerator upgrade for the NOvA experiment. Decontamination and decommissioning (D&D) activities for the Tevatron ring and detectors begins in FY 2012. LHC detector operations and support is held at approximately the FY 2010 level of effort to fulfill U.S. responsibilities in this high priority effort. SLAC B-Factory D&D activities start to decrease as detector disassembly is completed. Funding is provided within the Proton Accelerator-based subprogram under Other Facilities to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.

The reduction in Particle Physics Research is taken across the HEP subprograms, with reductions in most areas of a few percent to accommodate the overall budget constraints noted above, with two notable exceptions: the reduction in Electron Accelerator-Based Physics continues the resizing of U.S. participation in this area since the completion of SLAC B-Factory operations in 2008, and the reduction in funding between FY 2010 and FY 2012 for Non-Accelerator Physics is dominated by the roll-off of funding of the Daya Bay and Dark Energy Survey projects, according to the approved profiles.

The reduction in Advanced Technology R&D reflects the completion of some activities, offset by support for ongoing and planned initiatives. Directed accelerator R&D efforts (ILC R&D and Superconducting RF R&D) ramp down as they near completion of planned activities. Funding for Accelerator Science ramps up to support the research programs of the wakefield plasma demonstration experiments (BELLA/FACET) and for consolidation of muon accelerator R&D activities into a five year muon directed R&D effort to better understand the feasibility of this technology as a possible future energy frontier accelerator. Detector R&D is reduced to approximately the FY 2010 funding level.

The reduction in Major Items of Equipment (MIE) projects reflects the completion or ramp down of ongoing projects in Proton Accelerator-Based and Non-Accelerator Physics and the start of a small Cosmic Frontier MIE (High Altitude Water Cherenkov detector).

Annual Performance Results and Targets

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget.

Proton Accelerator-Based Physics

Funding Schedule by Activity

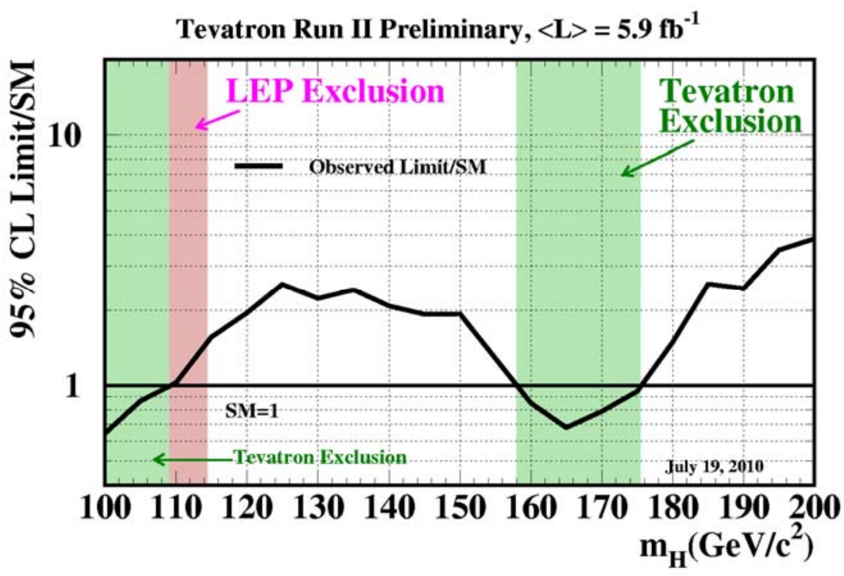
	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Proton Accelerator-Based Physics		
Research	125,743	127,696
Facilities	312,626	283,511
Total, Proton Accelerator-Based Physics	438,369	411,207

Description

The Proton Accelerator-Based Physics subprogram exploits the application of proton accelerators at two of the scientific frontiers. At the Energy Frontier, experiments at the LHC will be used to determine whether the Standard Model correctly predicts the mechanism that generates mass for all fundamental particles and will search for the first clear evidence of new physics beyond the Standard Model. At the Intensity Frontier, experiments using the beams from NuMI will make precise, controlled measurements of basic neutrino properties and will provide important clues and constraints on the new world of matter and energy beyond the Standard Model, which is a primary goal of HEP-supported neutrino research.

Selected FY 2010 Accomplishments

- Researchers continue treading on unexplored Higgs territory with the Tevatron Collider experiments at Fermilab. Combined results from the Tevatron Collider experiments now exclude a region of Higgs mass between 158 and 175 times the mass of the proton (see below). As more data is collected



Recent Tevatron Standard Model Higgs exclusion limits. The vertical scale corresponds to the limit in units of the Standard Model (SM) prediction (i.e., 1=experimental limit at the predicted SM level); the horizontal scale corresponds to Higgs mass. The solid jagged line represents the observed experimental result. The Tevatron excludes the Higgs at 95% probability when the observed result curve is below the horizontal SM=1 line for a particular Higgs mass (shaded areas).

and analyzed at the Tevatron, either this exclusion region will expand or the first possible hints of the Higgs boson will appear.

- The Tevatron Collider experiments, CDF and D-Zero, continue to observe rare Standard Model processes such as double Z boson production, simultaneous W and Z boson production, and single top quark production. As more data is collected and better techniques are developed, Tevatron researchers continue to refine their measurements of top quark and W boson parameters, which are used to further constrain new physics theories. The innovative analysis methods employed by CDF and D-Zero scientists and their thorough understanding of detector performance and backgrounds are opening new opportunities for discoveries. For example, the D-Zero collaboration announced in the spring of 2010 indications of a possible anomalous CP violation in the mixing of neutral B mesons.
- Operations of the LHC began in late 2009 after a year-long shutdown to repair electrical problems discovered in its initial start-up. The energy of the machine was ramped up to a center-of-mass energy of 7 TeV in March 2010, surpassing the Tevatron Collider as the world's highest energy accelerator, although initial luminosity was very low as the machine is being carefully commissioned. Both the ATLAS and CMS large detectors are collecting data with full functionality. Results from first data have already been published, and the LHC experiments presented their first Standard Model "re-discovery" results showing observation of expected W and Z boson and top quark events during summer 2010. The LHC has increased its luminosity dramatically over the course of 2010 and is expected to accumulate much more data in 2011 during its first physics run.
- Two Fermilab neutrino experiments, MINOS and MiniBooNE, have collected data with an anti-neutrino beam and reported first results. Although statistically limited, an initial analysis of the data offers tantalizing hints regarding the fundamental properties of neutrinos, which may be an indication of new physics in the neutrino sector.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	**125,743**	**127,696**

The major research activities under the Proton Accelerator-Based Physics subprogram are the research programs using the CDF and D-Zero detectors at the Tevatron at Fermilab, the neutrino research program using the MINOS detectors located at Fermilab and at the Soudan Mine site in Minnesota, and the research programs of ATLAS and CMS at the LHC at CERN.

The research program using the Tevatron Collider at Fermilab is being carried out by a collaboration composed of approximately 1,200 scientists from Fermilab, Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), 50 U.S. universities, and institutions in over 20 foreign countries. The major effort in FY 2012 is the analysis of data from the CDF and D-Zero detectors. The physics issues to be addressed include searches for the Higgs boson, supersymmetry, or other new phenomena; B meson studies including charge-parity (CP) violation; and precision measurements of the top quark and the W boson properties. In particular, the direct experimental searches for a Standard Model Higgs boson with a mass in the range expected (based on other indirect experimental data) will require the entire Tevatron data set. With the data

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

collected through FY 2011, the Tevatron Collider experiments will continue their data analysis in FY 2012 of the entire region of the expected Higgs mass range.

The research program using the MINOS facilities at Fermilab and the Soudan Mine is being carried out by a collaboration that includes approximately 250 scientists from Fermilab, ANL, BNL, 16 U.S. universities, and institutions in five foreign countries. The major effort through mid-FY 2012 will be data collection and analysis, along with optimizing accelerator performance to improve beam intensity for higher statistics measurements. The experiment is planned to complete its data taking in FY 2012 to achieve its ultimate sensitivity, approximately a factor of two improvement over its current result, and will search for the as-yet unseen oscillation of muon neutrinos to electron neutrinos.

In FY 2012, U.S. researchers will play a leadership role in the physics discoveries at the high energies enabled by the LHC. Achieving this goal requires effective integration of U.S. researchers in the LHC detector calibration and data analysis efforts, and implementation and optimization of the U.S. data handling and computing capabilities needed for full participation in the LHC research program. Maintenance of U.S.-supplied detector elements for LHC experiments at CERN will continue.

▪ **Grants Research**	**60,090**	**61,815**

The grant-based HEP experimental research program consists of groups at more than 60 universities performing experiments at proton accelerator facilities. Grant-supported scientists typically constitute about 50–75% of the personnel needed to create, run, and analyze an experiment, and they usually work in collaboration with other university and laboratory groups.

Grant-based research efforts are selected based on peer review and funded at levels commensurate with the effort needed to carry out the approved research scope. The detailed funding allocations will take into account the quality and scientific priority of the research proposed.

In the FY 2012 request, grant research funding is held at approximately the FY 2010 level-of-effort, in order to accommodate overall budget constraints. High priority activities within this program will be support of LHC research activities, and growth of a strong neutrino physics programs. High-priority data analysis efforts in the Tevatron Collider program will be maintained but there will be reductions in the broader Tevatron research effort. There will be healthy scientific competition between completion of Run II of the Tevatron Collider program and the LHC experiments. At the same time, university groups are expected to take important roles in developing the design, physics optimization, and analysis techniques for the planned neutrino initiatives, such as NOνA and LBNE, and support the operation and data analysis of the Main Injector Experiment ν-A (MINERνA). U.S. university groups also have leadership roles in the Tokai-to-Kamioka (T2K) neutrino oscillation experiment that complements and extends the physics reach of NOνA.

▪ **National Laboratory Research**	**64,069**	**64,990**

Proton accelerator research activities concentrate on experiments at the Tevatron complex (collider and neutrino physics programs) at Fermilab and the LHC at CERN. The HEP program conducted a comparative peer review of laboratory research groups in this subprogram in 2009, and findings from this review have been used to inform the funding decisions in the FY 2012 request. In the FY 2012 request, national laboratory research funding is held slightly below the FY 2010 level-of-

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

effort, in order to accommodate the programmatic priority for construction of new research facilities within the context of overall budget constraints. Within this activity, the priority research efforts will be support of LHC research activities and growth of a strong neutrino physics programs. High-priority data analysis efforts in the Tevatron Collider program will be maintained, but since Tevatron experiments will no longer be taking data, the overall size of the effort is somewhat reduced.

The Fermilab research program includes analysis of the CDF, D-Zero, and MINOS experiments; the CMS research and computing program; and research related to the NOνA, MINERνA, MicroBooNE, and LBNE experiments. Research at LBNL consists of a large and active group in the ATLAS research program. The BNL research group will focus on the ATLAS research and computing program, and an enhanced effort related to future neutrino initiatives, in particular detector design for LBNE. The research group at ANL will be working primarily on the ATLAS research and computing program, analysis of the MINOS data, and research on NOνA. The research group from SLAC on the ATLAS experiment has taken on important roles in data analysis and physics studies for possible detector upgrades.

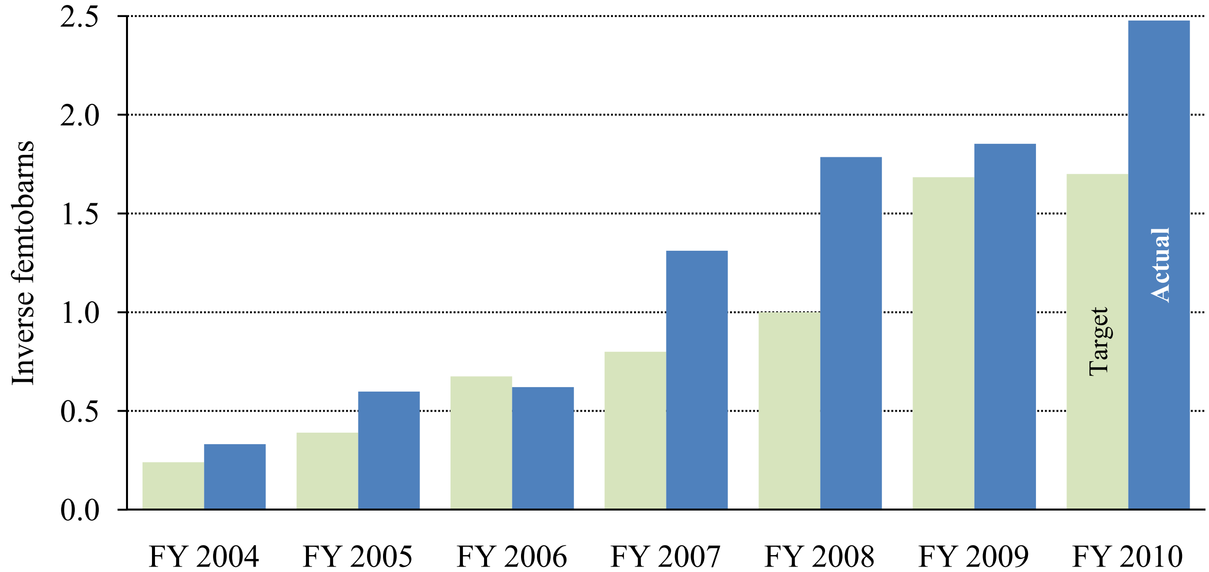
▪ **University Service Accounts**	**1,584**	**891**

University Service Accounts facilitate the support of university groups working at accelerator facilities. This activity provides funding for these groups to purchase needed equipment and services from the laboratories with a minimum of time and cost overhead. Currently, 45 university groups maintain service accounts at Fermilab and at BNL. Funding for these university service accounts reflects the anticipated need.

Facilities	**312,626**	**283,511**
▪ **Proton Accelerator Complex Operations**	**125,945**	**103,374**

Fermilab operations include running the Tevatron accelerator complex for both collider and neutrino physics programs comprising two collider detectors and several neutrino experiments, respectively. The performance of the Tevatron collider has continued to improve as the laboratory staff has learned to effectively exploit the upgrades that were completed in FY 2006. Tevatron performance improved significantly in FY 2007 and FY 2008 and reached a steady state of high performance in FY 2009. The plot below shows the annual integrated luminosity delivered to the experiments.

Tevatron Yearly Luminosity, Actual vs. Target



Some of the increase in luminosity in FY 2008 was due to additional running time that was scheduled to maximize the integrated luminosity before the first beam collisions at the LHC. Performance in FY 2009 improved and the yearly total was slightly higher than FY 2008 with a normal length run. Performance in FY 2010 was approximately 2.5 fb^{-1} and should plateau at that level.

In FY 2012, the reduced funding in this category reflects the fact that Tevatron Collider operations will have been completed and the accelerator complex will shut down for a large part of the year to install proton beam intensity upgrades for NOνA and other neutrino experiments. Funding is provided for initiating stand down and decommissioning activities of the Tevatron ring and two detectors. Portions of the collider complex including the recycler, debuncher, and accumulator rings will be reused to raise the intensity of the proton source and create new beams as part of the NOνA and Mu2e projects. The collider ring and detectors will be put into a safe state in preparation for decommissioning.

Operations of the accelerator complex will provide increased intensity beams to the neutrino program, since there will no longer be a need to share protons with the collider program. The NuMI beam will support the MINOS experiment and the small MINERνA experiment which is located in the MINOS near detector hall at Fermilab and is measuring the rates of neutrino interactions with ordinary matter. Its results are important for interpreting the data from MINOS and other neutrino experiments, including NOνA. A lower energy neutrino beam produced with protons from the Booster accelerator will support operations of the MiniBooNE experiment. Both MINOS and MiniBooNE are studying differences in the behavior of neutrinos versus antineutrinos.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

	FY 2010	FY 2012
Proton Accelerator Complex[a]		
Achieved Operating Hours	7,631[b]	N/A
Planned Operating Hours	5,400	2,650
Optimal hours (estimated)	5,400	2,650
Percent of Optimal Hours	141%	100%
Unscheduled Downtime	11%	N/A
Total Number of Users	2,000	1,400

- **Proton Accelerator Complex Support** **13,001** **12,462**

This category includes funding for accelerator improvements, experimental computing expansion, and other detector support, as well as funds for general plant projects (GPP) and other infrastructure improvements at Fermilab. A backlog of GPP projects was addressed with Recovery Act funding in 2009-10 resulting in reduced need for GPP funds in recent years. Planned GPP funding in FY 2012 is restored to historical levels in order to adequately maintain site infrastructure over the long term, offset by a declining need for accelerator complex infrastructure after completion of the Tevatron program. Improvements to the cooling, shielding, and power supplies in the booster, main injector, and NuMI beam-line will be performed to support the higher beam intensities that become available after the NuMI power upgrade that is being done as part of the NOνA project.

- **Proton Accelerator Facility Projects** **86,591** **75,240**
  - **Current Facility Projects** **79,998** **60,240**

After the completion of Tevatron Collider Run II, it will be possible to adapt portions of the existing collider complex to support operations of the NuMI beam-line at even higher intensity. Reconfiguration of the recycler, which currently serves as a storage ring for antiprotons, can raise the beam power to the NuMI target from 400 kW to 700 kW and is being done as part of the NOνA project.

The NOνA detector is optimized to identify electron-type neutrinos and, using the NuMI beam from Fermilab, it will observe for the first time the transformation of muon-type neutrinos into electron-type neutrinos. It will also make important indirect measurements from which we may be able to determine the mass hierarchy of the three known neutrino types (e.g., whether there are two light and one heavier type neutrinos or vice versa). This will be a key piece of information that will help determine the currently unknown masses of neutrinos. The project includes the very large far detector (approximately five stories high with a football-field size

[a] Only NuMI runs FY 2012 and beyond.
[b] Additional operating hours were added during the year to maximize the amount of data taken at the Tevatron before the LHC turned on.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

footprint), the far detector enclosure, its associated electronics and data acquisition system, and a small near detector on the Fermilab site. The project baseline was approved in September 2008. In FY 2012, the Fermilab accelerator complex will be modified in order to increase the beam power to 700 kW and work will continue on the far detector. Planned funding in FY 2012 for NOνA is $41,240,000. Fabrication will be completed in FY 2014, but the experiment can start taking data with a partially completed detector in FY 2013.

Funding in FY 2012 includes $6,000,000 to continue fabrication of the MicroBooNE experiment. This is a Major Item of Equipment (MIE) project that will fabricate a liquid argon neutrino detector to be used in the Booster neutrino beam at Fermilab for the measurement of low energy neutrino cross-sections. These cross sections will be measured at lower neutrino energy than the work planned for MINERνA and will be important for interpreting data from T2K and the proposed LBNE.

Support for conceptual design and planning of two construction projects is included for LBNE ($7,000,000) and Mu2e ($6,000,000). The planned profiles reflect CD-1 approval in FY 2012 and proceed with Project Engineering and Design work as described in the Construction section.

- **Future Facility R&D** **6,593 15,000**

  Pre-conceptual R&D for possible future projects that utilize the Fermilab facility is funded in this category. Specifically, pre-conceptual R&D is supported in FY 2012 for: detector concepts tied to future facilities, possible new experiments using the existing Tevatron complex, and for a superconducting GeV linac. This linac would provide the beam power needed to continue Intensity Frontier experiments using the Fermilab accelerator complex. It would replace the current linac and booster accelerators at Fermilab, which are over 35 years old, and upgrade the beam power approximately 2–3 times beyond the upgrades planned for NOνA.

▪ **Large Hadron Collider Support** **79,511** **72,761**

U.S. involvement in the LHC has been regularly endorsed by HEPAP and by a National Academies report (EPP 2010[a]). The overall U.S. LHC effort is jointly supported by DOE and NSF and is one of HEP's highest priorities. HEP resources will be used for LHC software and computing, as well as operations and maintenance of the U.S.-built systems that are part of the LHC detectors. The U.S. also participates in accelerator commissioning and accelerator physics studies that use the LHC, along with R&D for potential future upgrades to both the accelerator and its detectors.

- **LHC Accelerator Research** **12,390 12,390**

  The U.S. LHC Accelerator Research Program (LARP) is supported solely by DOE. It will continue to focus its R&D effort on the production of full-scale, accelerator-quality magnets that sustain the highest possible magnetic fields. This R&D effort will provide important technical data to CERN for management decisions on possible future accelerator upgrades to increase the LHC energy and/or luminosity. In late 2009, full-size prototype upgraded high-field LHC interaction region magnets composed of niobium-tin (Nb_3Sn) superconductor material, were

[a] "Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics" is available at http://www.nap.edu/catalog.php?record_id=11641.

(dollars in thousands)

FY 2010 Current Appropriation	FY 2012 Request

demonstrated by the U.S. groups developing this technology. Further development and implementation of these magnets is one avenue for possible U.S. participation in upgrades to the LHC. Special instrumentation such as LHC beam collimation and monitoring systems is also being developed under the LARP program. These instruments will play an important role in improving and achieving reliable LHC accelerator operations.

- **LHC Detector Support** **58,121 60,371**

  Funding is provided for operations and maintenance of the U.S.-built detector subsystems. These detectors were commissioned with cosmic ray data until the first LHC beam collisions occurred late in 2009. This effort will support the continuing development, deployment, and improvement of tools and procedures required to collect the detector data at high efficiency and develop the calibration and alignment procedures required in order to understand the detector performance at the level necessary for physics analysis. Support is also provided for technical coordination and program management.

  To date, U.S. detector support efforts have focused on hardware commissioning and on the infrastructure needed for full analysis of data using professional-quality software. Grid computing solutions are integrated into the experiment computing models, building on the tools provided by the Scientific Discovery through Advanced Computing (SciDAC) Open Science Grid project. The grid provides U.S. researchers the access and computing power needed to analyze the large and complex data sets. For FY 2012, well-connected computing hardware facilities running grid computing interfaces are essential to enable a rapid analysis of the data from the first full LHC physics run.

  Support is also provided for detector R&D, with specific focus on detector technologies needed to accommodate the proposed LHC upgrade in luminosity.

- **LHC Upgrades** **9,000 0**

  Fabrication of the Accelerator Project for the Upgrade of the LHC (APUL) was planned to be initiated in FY 2010. The Mission Need (CD-0) was approved October 2008 and conceptual design has been completed, but subsequent changes in the LHC operations schedule announced in the spring of 2010, including a significant delay in the timeframe for LHC upgrades, forced a reconsideration of these plans. Options for a revised U.S. scope of work, with reduced participation in near-term upgrades, were coordinated with CERN management. The analysis of alternatives and conceptual design for the revised project have been completed, and CD-1 was approved in September 2010. No funds will be needed in FY 2012.

▪ **Other Facilities** **7,578** **19,674**

This category includes funding for long-term D&D of the Alternating Gradient Synchrotron (AGS) facility at BNL, where operations as a HEP user facility were terminated at the end of FY 2002. Funding for private institutions, government laboratories, and foundations that participate in high energy physics research is also included, as well as recurring contributions to general program operations activities, such as the federal laboratory consortium, financial auditing, support for internal and external program and project reviews, personnel support under the Intergovernmental Personnel Act, and technical consultation on programmatic issues. This category also includes

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
funding to respond to new opportunities and unexpected changes in facilities operations and support. This will be particularly important during FY 2012, considering the inherent uncertainties in estimating the resources needed for a smooth transition at the end of Tevatron operations.		
Funding is also provided within this category to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.		
Total, Proton Accelerator-Based Physics	**438,369**	**411,207**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **Grants Research**	
Funding for the core grants research program will fully support LHC collider research while growing a strong neutrino physics program to exploit future facilities. To enable this growth in a roughly constant level-of-effort budget, some reductions will be taken in Tevatron research support.	+1,725
▪ **National Laboratory Research**	
Funding is somewhat below the FY 2010 level-of-effort, but will fully support LHC collider research and enhance efforts in the neutrino physics program. Reductions will be taken in Tevatron research support.	+921
▪ **University Accounts**	
Funding reflects anticipated need, including reduced support for Tevatron activities.	-693
Total, Research	**+1,953**
Facilities	
▪ **Proton Accelerator Complex Operations**	
Funding for Proton Accelerator Complex Operations decreases in FY 2012 with the termination of Tevatron Collider operations.	-22,571
▪ **Proton Accelerator Complex Support**	
Proton Accelerator Complex Support operating funds decrease as support needed for the Tevatron Collider program is reduced, but this is mostly offset by increases in planned GPP funding needed to maintain Fermilab site and accelerator infrastructure over the long term.	-539

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Proton Accelerator Facility Projects**	
• **Current Facility Projects**	
Net funding for Current Facility Projects decreases according to the planned project profiles. Reductions are driven by ramp-down in the NOvA profile, partially offset by funding increases for MicroBooNE and Mu2e. Funding in this category for LBNE decreases as conceptual R&D activities will be shifted to Project Engineering and Design funding, as reflected in the Construction section.	-19,758
• **Future Facility R&D**	
Funding increases reflect expanded activities on pre-conceptual R&D for a superconducting GeV linac in support of the future Intensity Frontier program.	+8,407
Total, Proton Accelerator Facility Projects	**-11,351**
▪ **Large Hadron Collider Support**	
• **LHC Detector Support**	
Support for U.S. activities on LHC experiments, including responsibilities for maintenance and operations of the detectors, and support for data analysis, are maintained at the FY 2010 level-of-effort in order to enable increased pre-conceptual R&D for possible LHC upgrades.	+2,250
• **LHC Upgrades**	
Funding for the LHC upgrade project (APUL) is completed in FY 2011.	-9,000
Total, Large Hadron Collider Support	**-6,750**
▪ **Other Facilities**	
Funding provides for various service and support activities in FY 2012 at a level significantly above FY 2010, mostly to support minimal, sustaining operations for one year at the Homestake mine in South Dakota.	+12,096
Total, Facilities	**-29,115**
Total Funding Change, Proton Accelerator-Based Physics	**-27,162**

Electron Accelerator-Based Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Electron Accelerator-Based Physics		
Research	15,263	13,069
Facilities	14,949	9,250
Total, Electron Accelerator-Based Physics	30,212	22,319

Description

The Electron Accelerator-Based Physics subprogram utilizes accelerators with high-intensity and ultra-precise beams to create and investigate matter at its most basic level. Over the last decade, the electron B-factory at SLAC led investigations at the Intensity Frontier, providing precision measurements of different behavior of matter and antimatter observed in the decay products of B-mesons. Physicists consider this asymmetric behavior, called charge-parity (CP) violation, to be vital to understanding the apparent predominance of matter over antimatter, one of the greatest puzzles in comprehending the structure of the universe. In FY 2012, HEP will support U.S. researchers to participate in the Japanese B-factory at KEK and will begin R&D towards an upgrade of the BELLE detector at KEK.

Selected FY 2010 Accomplishment

- Over the past several years, the B-factories in the U.S. and Japan discovered several unexpected new particles which contain a charm quark and a charm antiquark. However, the masses and decay patterns of these new states do not fit within the theoretical expectations from quantum chromodynamics (QCD) for standard strongly bound quark-antiquark states, and the evidence for some of these new states is controversial and in need of independent confirmation. These recently discovered exotic particles may be hybrid quark-antiquark-gluon states, loosely bound "molecules" of conventional charmed mesons, or four quark states. The exploration of this unforeseen new spectroscopy is an essential step towards fully understanding QCD. Studies of these exotic hadrons with the full B-factory datasets are ongoing.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	**15,263**	**13,069**

The research program at the B-factory/BaBar Facility at SLAC will continue winding down analysis of the 557 fb^{-1} data set that has been accumulated over the nine-year operational life of the facility. Physicists from approximately 17 universities, three national laboratories (LLNL, LBNL, and SLAC), and seven foreign countries have been actively involved in the data analysis. The physics issues to be addressed include expanding our understanding of CP violation in many particle decay modes and the investigation of the many heavy quark states predicted by QCD.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

The research programs at other electron accelerator facilities complement the B-factory/BaBar efforts and consist of a group of experimental research activities using the KEK-B electron accelerator facilities in Japan and recently upgraded electron accelerator facilities in China. A total of three DOE-funded U.S. university groups currently work on the BELLE detector at KEK-B and two groups work at the Beijing Electron-Positron Collider (BEPC). There are also R&D efforts aimed at designing detectors for next-generation off-shore "Super-B factories" in Japan and Italy and possible future high-energy lepton colliders. Two collaborative proposals for participation in off-shore Super-B factory upgrades were reviewed by HEP in 2010, and based on the outcome of that review, HEP plans to support modest participation in the future Japanese Super-B factory upgrades and research program.

▪ **Grants Research**	**5,959**	**5,192**

Grant-supported scientists typically constitute about 50–75% of the personnel needed to create, run, and analyze an experiment, and they usually work in collaboration with other university and laboratory groups. Grant-based research efforts are funded based on peer review and at levels commensurate with the effort needed to carry out the experiments.

In the FY 2012 request, funding continues at a reduced level of effort, since the U.S. will have a reduced role in future B-factory facilities. Support is provided to complete the final analysis of physics data from BELLE and BaBar. Smaller efforts devoted to operations and data analysis at the Beijing Spectrometer at BEPC will also be supported.

▪ **National Laboratory Research**	**9,278**	**7,877**

The national laboratory research program consists of groups at four laboratories participating in experiments at electron accelerator facilities with a physics program similar to the grant program described above. Electron accelerator research activities concentrate on experiments at the SLAC B-factory. HEP conducted a comparative peer review of laboratory research groups in this subprogram in FY 2010 and funding allocations reflect the findings of that review.

In FY 2012, laboratory-based research in this subprogram continues at a reduced level of effort and will be focused on completing the highest-priority data analysis from BaBar. The research groups at SLAC, as well as the other laboratories, will be in transition in FY 2012 as they ramp down activities, complete analyses, and phase into new research activities.

▪ **University Service Accounts**	**26**	**0**

University Service Accounts facilitate the support of university groups working at accelerator facilities by providing funds for these groups to purchase needed supplies and services from the laboratories with minimum time and cost overhead. Currently 12 university groups maintain service accounts at SLAC. It is anticipated that there will be no need for this support in FY 2012.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Facilities	**14,949**	**9,250**
▪ **Electron Accelerator Complex Operations**	**12,019**	**8,350**

B-factory operations ended in FY 2008. Funding in this category supports the transition of the B-factory accelerator complex to a safe and stable maintenance mode and decommissioning and decontamination (D&D) activities. Funding follows the established profile for the D&D activity and is re-evaluated annually.

▪ **Electron Accelerator Complex Support**	**2,930**	**900**

Funding is provided for the necessary maintenance and operation of computing capabilities in order to complete the analysis of the B-factory data.

Total, Electron Accelerator-Based Physics	**30,212**	**22,319**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **Grants Research**	
Funding for electron accelerator-based experimental research is reduced. Only analysis of the highest priority final archival results from BELLE and BaBar data will be completed. Reductions will be taken in BaBar research support.	-767
▪ **National Laboratory Research**	
Funding for electron accelerator-based experimental research is reduced. Only analysis of the highest priority final archival results from BaBar data will be completed. Reductions will be taken in BaBar research support.	-1,401
▪ **University Service Accounts**	
Decreased funding as a result of no planned support in FY 2012.	-26
Total, Research	**-2,194**
Facilities	
▪ **Electron Accelerator Complex Operations**	
Funding for B-factory Operations is reduced according to the planned profile for safe dismantling and decommissioning of the BaBar detector and putting the accelerator into a minimum maintenance configuration.	-3,669

	FY 2012 vs. FY 2010 Current Approp. ($000)
• **Electron Accelerator Complex Support**	
Funding is significantly reduced from the FY 2010 level as BaBar data analysis is completed.	-2,030
Total, Facilities	**-5,699**
Total Funding Change, Electron Accelerator-Based Physics	**-7,893**

Non-Accelerator Physics

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Non-Accelerator Physics		
Grants Research	21,708	21,417
National Laboratory Research	44,933	46,435
Projects	30,828	14,000
Total, Non-Accelerator Physics	97,469	81,852

Description

The Non-Accelerator Physics subprogram provides U.S. leadership in the study of those topics in particle physics that cannot be investigated with accelerators or are best studied by other means. For example, some of the earliest discoveries in particle physics were due to the production of previously unobserved particles in high-energy cosmic rays. Non-Accelerator Physics studies play an important role in the HEP program, using ever more sophisticated techniques to probe fundamental physics questions with naturally occurring particles and phenomena. Scientists in this subprogram investigate topics central to both the Intensity and Cosmic Frontiers, such as understanding the nature of dark matter and dark energy; precision measurements of neutrino properties; and searches for new phenomena such as proton decay and primordial antimatter. These areas of research probe well beyond the Standard Model of particle physics and offer possibilities for discovery of significant new physics phenomena.

Selected FY 2010 Accomplishments

- In FY 2010, the Large Area Telescope (LAT), the primary instrument on NASA's Fermi Gamma-ray Space Telescope (FGST) mission, continued to perform outstandingly. In March 2010, the LAT collaboration showed that less than a third of gamma-ray emission arise from black-hole powered jets from active galaxies, previously suspected as the primary source. Instead it could come from particle acceleration in star-forming galaxies or clusters of galaxies that are merging. Another possibility, which would need much more work to determine, is that it comes from gamma ray production from dark matter particle interactions.
- The FGST identified stringent limits on Lorentz invariance violations (LIV) predicted by some quantum gravity and string models. Lorentz invariance—the idea that the laws of physics are the same to observers everywhere in the universe—is one of the bedrock principles of physics. On May 9, 2009, the FGST observed a gamma-ray burst (GRB) about 10 billion light-years away with a 30 GeV gamma-ray arriving 0.8 seconds after the initial X-ray burst. Since linear LIV models predict a measurable variation of light speed with photon energy, the short delay time between the beginning of the GRB and the gamma-ray arrival severely constrains these models.
- The Cryogenic Dark Matter Search (CDMS) collaboration announced in late 2009, the final results of the first phase of their experiment. The results are based on several years of data taking with a few kilograms of ultra-sensitive silicon and germanium detectors that can detect extremely rare dark matter interactions. They found two events in their signal region, but this could be a statistical fluctuation of the expected background due to naturally-occurring radioactivity. An upgraded 15 kg

detector with improved background rejection is in fabrication (SuperCDMS) and will be installed in the Soudan Mine in Minnesota and operated to confirm or deny the tantalizing initial results. Other experiments using different techniques are also actively exploring this region.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Grants Research	**21,708**	**21,417**

The grant-based program supports research groups at more than 35 universities that perform experiments at non-accelerator-based physics facilities. This program also funds private institutions, government laboratories, and foundations that participate in non-accelerator-based physics research. This subprogram is carried out in collaboration with physicists supported by other government agencies and institutes; among them NSF, NASA, and the Smithsonian Astrophysical Observatory. The selection of research efforts supported is based on peer review.

In FY 2012, the Non-Accelerator Physics grants program will support research on experiments that are now engaged in data collection, as well as preparations for future experiments. Funding is held slightly below the FY 2010 level. The operating experiments include the Very Energetic Radiation Imaging Telescope Array System, a ground-based gamma ray experiment at the Whipple Observatory in Arizona; the Pierre Auger Observatory in Argentina, which studies cosmic rays; and the LAT gamma-ray survey on NASA's FGST space-based mission. Studies of dark energy use data from the Baryon Oscillation Spectroscopic Survey (BOSS) experiment on the Sloan Digital Sky Survey telescope in New Mexico, and data from other telescope facilities detecting and studying supernovae.

Other active research efforts that expect to be taking data in 2012 include searches for direct detection of dark matter using the upgraded "Super" Cryogenic Dark Matter Search (SuperCDMS) at the Soudan Mine in Minnesota and the Large Underground Xenon experiment at the Sanford Lab in South Dakota as well as other dark matter searches using different techniques.

Research on neutrinos continues with Super-Kamiokande, a proton decay and neutrino detector located in the Kamioka Underground Laboratory in Japan; and the Enriched Xenon Observatory (EXO-200), an ultra-low-background detector with 200 kg of isotopically enriched Xenon, which is searching for neutrino-less double beta decay at the DOE Waste Isolation Pilot Plant facility in New Mexico.

New experiments that will be in operation by 2012 are Reactor Neutrino Detector at Daya Bay in China, Dark Energy Survey experiment at the Cerro Tololo Interamerican Observatory in Chile, and the Alpha Magnetic Spectrometer (AMS) experiment which is on the Space Shuttle manifest for launch in 2011 and will begin taking data shortly thereafter.

National Laboratory Research	**44,933**	**46,435**

Groups at several national laboratories (ANL, BNL, Fermilab, LBNL, LLNL, LANL, and SLAC) currently participate in non-accelerator-based physics experiments. With strong laboratory technical resources, the laboratory groups provide invaluable and unique service to the research program in terms of experiment management, design, construction, and operations. Laboratory scientists are also involved in the research. HEP conducted a comparative peer-review of the laboratory research efforts in this subprogram in 2010, and funding allocations reflect the findings of that review.

(dollars in thousands)

FY 2010 Current Appropriation	FY 2012 Request

In FY 2012, the laboratory research program in non-accelerator physics will continue to support research and operations for ongoing experiments such as the Pierre Auger Observatory, the LAT gamma-ray survey on NASA's FGST, and dark matter search experiments such as SuperCDMS and the Chicagoland Observatory for Underground Particle Physics 60 kg (COUPP-60) experiment. SLAC operates the instrument science operations center for the LAT. Laboratory groups also lead the commissioning, installation, operations and research efforts for various dark energy experiments such as Baryon Oscillation Spectroscopic Survey (BOSS) and Dark Energy Survey (DES).

Laboratory groups also participate in planning and implementation of future experiments that are completing their fabrication phase or initiating, such as the reactor neutrino detector for the Daya Bay experiment and High Altitude Water Cherenkov. The funding for FY 2012 in this category includes new support for the pre-operations and commissioning of DES ($980,000) and initial operations of the Daya Bay experiment ($3,920,000). Therefore, the core research component of this activity is reduced relative to previous years as some scientists move their effort primarily to commissioning and operations.

Projects 30,828		**14,000**
▪ **Current Projects**	**21,110**	**2,000**

FY 2012 is the last year of funding for the fabrication of the Reactor Neutrino Detector MIE for Daya Bay. DOE and the Chinese Institute for High Energy Physics are partners in this experiment, which will be located at a site near several commercial nuclear reactors in Daya Bay, China. This experiment will measure and compare the number of neutrinos observed by a detector close to a reactor (the near detector) with the number observed in a far detector about 10 km away. From this data, a crucial neutrino oscillation parameter can be extracted. The U.S. collaboration is led by groups from BNL and LBNL. The project is expected to be completed in FY 2012.

The DES project is expected to be completed in FY 2012. During FY 2012, installation, commissioning and pre-operations activities will take place. DOE supported the fabrication of a new camera to be installed and operated on the existing Blanco four-meter telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile. The DES collaboration is led by Fermilab and also, is a partnership between DOE, NSF, which operates the telescope, and international participants. The data management system and upgrades to the telescope facility are supported by NSF.

In FY 2012, one new major item of equipment (MIE) project is started. The High Altitude Water Cherenkov (HAWC) detector is a new experiment in Mexico (preliminary estimated DOE TPC $2,500,000–$3,500,000) that will survey the sky for sources of TeV gamma-rays in the 10–100 TeV range. This effort was identified in the HEPAP Particle Astrophysics (PASAG) Report as a scientific opportunity that should be pursued even in the case of constrained HEP budgets. This project is being done in collaboration with NSF and Mexican research institutes.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **Future Projects R&D**	**9,718**	**12,000**

This category provides support for R&D and pre-conceptual design activities for promising proposed future experiments and includes R&D on technical issues and concepts for dark matter, dark energy, and other particle astrophysics experiments. In previous years these have been focused primarily on possible dark matter and dark energy approaches and experiments.

In the FY 2012 Request, funding for future project R&D is increased relative to FY 2010 to position selected projects for the design phase, particularly in the areas of dark matter and dark energy. The available funding will be focused on R&D and pre-conceptual design for the proposed Large Synoptic Survey Telescope (LSST), and will be coordinated with NSF efforts. Consistent with the National Academies' Astro2010 recommendations, HEP will make LSST its highest priority dark energy initiative. DOE will continue to work with NASA in the development of a space-based dark energy observatory that is consistent with a national strategy and available resources.

Total, Non-Accelerator Physics	**97,469**	**81,852**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Grants Research	
Funding for grant-based research decreases somewhat below the FY 2010 level-of-effort, but will fully support research on currently operating experiments or those that will soon reach completion. Reductions will be taken in research support for future cosmic frontier experiments that are not priority efforts, as recommended by scientific community reports.	-291
National Laboratory Research	
Support for pre-operations, operations, and commissioning for projects that have reached or will soon reach completion (SuperCDMS, DES, Reactor Neutrino Detector) is increased, but this is partially offset by a reduction in funding for core research to meet overall budget constraints. Reductions will be taken in research support for future cosmic frontier experiments that are not priority efforts.	+1,502
Projects	
▪ **Current Projects**	
Project funding decreases for the Reactor Neutrino Detector, DES, and SuperCDMS following their planned profiles, partially offset by funds provided in FY 2012 for final design and beginning of fabrication for a new MIE, HAWC.	-19,110

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **Future Projects R&D**	
R&D funding is provided for proposed next-generation experiments in dark energy, dark matter, and other particle astrophysics topics. This funding is increased relative to FY 2010 to ready selected future projects for the design phase.	+2,282
Total, Projects	**-16,828**
Total Funding Change, Non-Accelerator Physics	**-15,617**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Theoretical Physics		
Grants Research	27,415	27,415
National Laboratory Research	25,838	26,074
Computational HEP	11,476	11,076
Other	3,685	4,349
Total, Theoretical Physics	68,414	68,914

Description

The Theoretical Physics subprogram provides the vision and mathematical framework for understanding and extending the knowledge of particles, forces, space-time, and the universe. This program supports activities that range from detailed calculations of the predictions of the Standard Model to the extrapolation of current knowledge to a new level of understanding and the identification of the means to experimentally search for them. Symmetries play a major role in the current understanding of the subatomic world: discovering how particle symmetries are realized (or broken) in nature has provided many fundamental breakthroughs in the development of the Standard Model. This subprogram supports and advances research at all three high energy physics Frontiers.

Selected FY 2010 Accomplishments

- Theorists continue to improve simulation tools for LHC experiments. In particular, calculations of next-leading-order Standard Model processes using BlackHat (software primarily developed at SLAC and University of California, Los Angeles) and those using other calculation tools primarily developed at Fermilab show excellent agreement with each other.
- In collaboration with their experimental colleagues, theorists at Rutgers University developed a technique for detecting a particle whose decay chain produced only hadronic final states. The search algorithm was tested successfully with top quark data from the Tevatron. This method may prove useful for new particle searches at the LHC.
- Harvard theorists identified a variable called “jet pull” which may be used to distinguish the color flow in jets. If successful, this will make it possible to distinguish b-jets produced in Higgs (color singlet) decay from the b-jets produced in gluon (color octet) decay, thus making it easier to identify a Higgs signal from the vast background.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Grants Research	**27,415**	**27,415**

This program consists of research groups at approximately 70 colleges and universities. It includes funding for private institutions, universities, and foundations that participate in theoretical physics. As part of their research efforts, the university groups train graduate students and postdoctoral researchers. Physicists in this theoretical research area often work in collaboration with other university and laboratory groups. Research efforts are selected based on a peer review process.

The grants program addresses topics across the full range of theoretical physics research. The main thrust is to search for a more complete theory that encompasses the Standard Model, in particular, a theory that can explain the underlying mechanism of electroweak symmetry breaking, the origin of particle mass, and the origin of quark and lepton flavors. A particularly interesting topic is the possibility of additional space-time dimensions that are normally hidden. This is motivated by the effort to unify Einstein's theory of gravity with quantum mechanics in a consistent way. Some of these extra dimensions and their consequences may be accessible to experimental investigation and may manifest themselves at the LHC as so-called Kaluza-Klein excitations, named after the physicists who first suggested in the 1920s that we might live in a 5-dimensional universe. Another topic of current research interest is the nature of dark matter and dark energy in the context of high energy physics. University research groups play leading roles in addressing these research areas.

In the FY 2012 Request, grant research funding is held constant with the FY 2010 level, in order to accommodate the programmatic priority for construction and fabrication of new research facilities within the context of overall budget constraints. Reductions in the number of research groups supported are anticipated.

National Laboratory Research	**25,838**	**26,074**

The national laboratory theoretical research program currently consists of groups at seven DOE laboratories (Fermilab, SLAC, BNL, ANL, LBNL, LLNL, and LANL). The laboratory theory groups are a resource for the national research program, with a particular emphasis on collaborations with experimental scientists and data interpretation to provide a clear understanding of the significance of measurements from ongoing experiments and to help shape and develop the laboratories' experimental programs. Because of the significant computing capabilities available at national laboratories, the laboratory theory groups make major contributions to the U.S. and worldwide lattice QCD efforts. HEP conducted a comparative peer-review of the laboratory research efforts in this subfield in 2008 whose findings have been used to inform the funding decisions in this budget request; in particular there have been targeted increases in 2010 to support laboratory research programs that reviewed well. HEP plans to review these programs again in 2011.

The laboratory theoretical research groups address topics across the full range of theoretical physics, including the analysis and interpretation of the new data expected from the Tevatron Collider detectors and forthcoming data from the LHC. There are also efforts to understand properties of neutrinos through reactor, accelerator, and non-accelerator neutrino experiments. As data from the LHC becomes available, an increased effort will be made to identify the most promising and sensitive methods for finding signs of new phenomena in these data.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

In the FY 2012 Request, laboratory research funding is maintained at approximately the FY 2010 level, in order to accommodate the programmatic priority for construction and fabrication of new research facilities within the context of overall budget constraints. Accordingly, no new or expanded research efforts are started in FY 2012.

Computational HEP	**11,476**	**11,076**

This budget category provides for high energy physics research activities that require extensive or customized computational resources including R&D, design, fabrication, procurement, maintenance, and operation of computational software and hardware that is not associated with specific high energy physics experiments or research facilities. Current activities in this category include the Scientific Discovery through Advanced Computing (SciDAC) program, the Lattice QCD (LQCD) computing initiative, support for dedicated transatlantic networking, and U.S. contributions to experiment-independent computer codes required for HEP's program.

- **SciDAC 6,000** **5,600**

  All current HEP-supported SciDAC projects had mid-term continuation reviews in FY 2009 and are planned to be re-competed in FY 2012. The focus of the SciDAC competition will be in targeted areas where computational advances can make a significant contribution to HEP research and technology. The SciDAC program is managed and cooperatively funded by the Advanced Scientific Computing Research program and other SC programs. There are currently four principal HEP-supported SciDAC efforts: Type Ia supernova simulations, a joint effort with Nuclear Physics (NP) and the National Nuclear Security Administration; platform-independent software to facilitate large-scale QCD calculations (see also the Computational QCD computing initiative below), a joint effort with NP; very large scale, fault-tolerant data handling and distributed grid computing which will allow physicists in the U.S. to analyze petabytes of data produced in Europe at the LHC, a joint effort with NP and NSF; and large-scale computational infrastructure for accelerator modeling and optimization, to support design and operations of complex accelerator systems throughout the SC complex, a joint effort with NP and the Basic Energy Sciences program.

- **Computational QCD and Network Support** **5,476** **5,476**

  The interpretation of many HEP experimental results has been limited by a lack of precision in QCD calculations, which describe the underlying physics; these calculations are in turn limited by a lack of computational power. This activity includes funding for the LQCD computing initiative that is a coordinated effort with the NP program aimed toward the development, procurement, and operation of a multi-teraflop computer capability for dedicated LQCD simulations. After successfully completing a dedicated ~10 teraflop "virtual facility" in 2009, researchers are now engaged in a follow-on effort to deploy and implement approximately 100 teraflops of dedicated capacity for QCD computing.

  This category also includes funding for the HEP-related transatlantic network requirements between the U.S., CERN, and HEP-related computing facilities in Europe. These requirements are dictated by the unprecedented size of the LHC data set. The dedicated network paths are known as the U.S. LHC Net. In FY 2010, the U.S. LHC Net provided 60 gigabits per second of connectivity between CERN and points of presence in Chicago and New York. U.S. LHC Net is closely integrated with the DOE

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

Energy Science Network, which connects the U.S. LHC Net transatlantic bridge to the main U.S. research network backbone.

In the FY 2012 Request, funding is maintained at the FY 2010 level, in order to accommodate overall budget constraints.

Other	**3,685**	**4,349**

This activity includes funding for education and outreach activities, compilations of high energy physics data, reviews of data by the Particle Data Group (PDG) at LBNL, conferences, studies, workshops, funding for theoretical physics research activities to be determined by peer review, and for responding to new and unexpected physics opportunities. In the FY 2012 request, this effort is maintained slightly above the FY 2010 funding level to follow the planned increase in support for the PDG effort, including planned computing and software upgrades.

This category also includes funding for the QuarkNet education project which began in FY 1999. This project takes place in QuarkNet centers which are set up at universities and laboratories around the country. The purpose of each center is to engage high school physics teachers in the analysis of real data from an active high energy physics experiment (such as at the Tevatron Collider or LHC). The experience these teachers garner is taken back to their classrooms in order to expose high school students to the world of high energy physics.

Total, Theoretical Physics	**68,414**	**68,914**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
National Laboratory Research	
The National Laboratory theoretical physics research program is maintained at approximately the FY 2010 funding level due to overall budget constraints, pending a comparative review of the laboratory research groups in 2011.	+236
Computational HEP	
▪ **SciDAC**	
Funding for HEP-related SciDAC projects, to be re-competed in FY 2012, is reduced to meet overall budget constraints. The number and scope of new proposals supported will be reduced.	-400

	FY 2012 vs. FY 2010 Current Approp. ($000)
Other	
Other Theoretical Research is maintained somewhat above the FY 2010 level, in order to support planned computing and software upgrades for the data compilations and summaries provided by the Particle Data Group at LBNL.	+664
Total Funding Change, Theoretical Physics	**+500**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Advanced Technology R&D		
Accelerator Science	42,427	54,117
Accelerator Development	88,712	73,146
Other Technology R&D	25,208	25,481
SBIR/STTR	0	19,164
Total, Advanced Technology R&D	156,347	171,908

Description

The Advanced Technology R&D subprogram fosters world-leading research in the physics of particle beams, accelerator research and development, and particle detection—all necessary for continued progress in high energy physics. High energy physics research relies on the use of high energy and high intensity particle beams generated with charged particle accelerators, storage rings, and their associated tracking and identification detectors. New developments are stimulated and supported through proposal driven, peer reviewed research. Ultimately, these new technological developments are incorporated into construction projects sponsored by HEP. This subprogram supports and advances research at all three particle physics Frontiers. Advanced Technology R&D also provides new technologies and research methods appropriate for a broad range of scientific disciplines, thereby enhancing DOE's broader strategic goals for science.

Selected FY 2010 Accomplishments

- An example of a novel technology developed in 2010 with DOE support is the water based liquid scintillator. By sulfonating linear alkyl benzene, a common chemical used to make detergent, to linear alkylbenzene sulfonate, a water-soluble biodegradable surfactant detergent, a water based scintillator can be created. The characteristics of this scintillator are now being studied at BNL for possible future applications for large scintillator detectors in high energy physics.
- As part of the ILC R&D effort, a consortium of DOE laboratories successfully increased the quality of superconducting radiofrequency (SRF) accelerator cavities, with production accelerator gradients now commonly approaching the benchmark level of 35 MeV per meter. This program also successfully initiated lab-industry partnerships to develop the production of cavities in U.S. industry and improve processing of the cavities at DOE laboratories. SRF is the technology of choice for a number of future accelerator projects and the increasingly higher yields will improve performance and reduce cost for these next generation accelerators.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Accelerator Science	**42,427**	**54,117**

This activity 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 that enable breakthroughs in particle accelerator size, cost, beam intensity and control. Funding in this category includes costs for operating university and laboratory-based accelerator R&D test facilities.

▪ **Grants Research**	**8,770**	**10,520**

The FY 2012 budget will continue support for a broad research program in advanced accelerator physics and related technologies. Funding is included for private institutions, universities, industry, and federal research centers that participate in fundamental accelerator physics. As part of their research efforts, these groups train graduate students and postdoctoral researchers. Physicists in this research area often work in collaboration with other university and laboratory groups. For example, university groups are leading the development and execution of the proposals for the experimental program at FACET. Research efforts are selected based on a peer review process.

The grant-based research program will continue to investigate novel acceleration concepts, such as the use of plasmas and lasers to accelerate charged particles; theoretical studies in advanced beam dynamics, including the study of non-linear optics and space-charge dominated beams; studies of accelerating gradient limits in normal conducting accelerators; development of advanced particle beam sources and instrumentation; and accelerator R&D into the fundamental issues associated with the ionization cooling of muon beams.

Funding is slightly over a constant level-of-effort to support university participation in developing proposals and conducting experiments at new accelerator R&D facilities (BELLA and FACET, see below).

▪ **National Laboratory Research**	**33,657**	**43,597**

This activity supports accelerator R&D efforts and operations of test facilities at ANL, BNL, Fermilab, LBNL and SLAC, and theoretical studies of space-charge dominated beams at the Princeton Plasma Physics Laboratory. HEP conducted a comparative peer-review of the laboratory research efforts in this subfield in 2008, whose findings have been used to inform the funding decisions in this budget request; in particular there are targeted increases to support laboratory research programs which reviewed well. HEP plans to review these programs again in 2011.

The national laboratory accelerator science program explores advanced methods to accelerate charged particles with the goal of more efficient, compact, and inexpensive particle accelerators. In FY 2012, funding is increased to support additional participation of national laboratory scientists in fully exploiting the research potential of the new accelerator R&D facilities, BELLA and FACET.

Efforts in FY 2012 will focus on the development of new accelerating structures and techniques needed to achieve accelerating gradients in excess of 100 MeV/m. This work currently occurs primarily at the Argonne Wakefield Accelerator, the Laser Optical Accelerator Systems Integrated

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

Studies (LOASIS) test facility at LBNL, and the new Facility for Accelerator Science and Experimental Test Beams (FACET) at SLAC. In FY 2011, the first round of experiments will begin at the new FACET facility where an electron bunch (the beam is not a continuous stream of electrons but structured in discrete bunches) is accelerated by plasma wakefields. The goal of this effort will be a demonstration of efficient, full-length accelerating structures with gradients well above 1 GeV per meter. The new BErkeley Lab Laser Accelerator (BELLA) project will be in fabrication in FY 2011 with completion planned for FY 2012. Funding for FACET operations ($6,000,000) and BELLA pre-operations and commissioning ($2,000,000) is included in this category.

The national laboratory groups are also involved in a significant long-range R&D effort to demonstrate the advanced technologies needed to realize muon-based accelerators; this is a global R&D program with major U.S. participation coordinated by Fermilab. A five-year R&D plan for muon-based accelerators, with milestones and deliverables, has been submitted by U.S. research institutions and was reviewed by HEP in 2010. Part of the increased funding in this category is directed towards ramping-up this effort to execute the five-year R&D plan.

BNL is the home of the very successful Accelerator Test Facility. The facility supports HEP-funded research at universities as well as through the Small Business Innovation Research (SBIR) program, based on proposal-driven, peer-reviewed research in accelerator concepts and beam physics. In FY 2012, the facility will continue a program to test advanced accelerator concepts, develop new instrumentation, and further next-generation, high-brightness electron sources that are based on laser-driven photocathodes.

Accelerator Development	**88,712**	**73,146**

The task of this activity is to demonstrate the feasibility of concepts and technical approaches on an engineering scale. This includes R&D and prototyping to bring new concepts to a stage of engineering readiness where they can be incorporated into existing facilities, upgrade existing facilities, or applied to the design of new facilities. Carrying out development of advanced high-technology components at this level often requires significant investments in research infrastructure. Major thrusts in this activity are superconducting radio frequency (RF) infrastructure development, studies of very high intensity proton sources for potential application in neutrino physics research, and R&D relevant to the proposed International Linear Collider.

▪ **General Accelerator Development**	**31,721**	**33,146**

This activity focuses on R&D that can be widely applied to a range of accelerator facilities. The work is primarily done at Fermilab, LBNL, and SLAC. Funding is maintained at approximately the FY 2010 level-of-effort to maintain a robust technology development program as more directed R&D efforts ramp down. The major areas of R&D are superconducting magnet and related materials technology; high-powered RF acceleration systems; instrumentation; beam dynamics, both linear and nonlinear; and development of large simulation programs. The latter effort is coordinated with the SciDAC accelerator simulation project.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

The R&D program on high-power RF systems is led by SLAC, including simulation codes for modeling RF system components and high-powered microwave tubes. This program also builds custom high-power RF sources for HEP and other scientific applications.

Fermilab leads the R&D for a future high-intensity neutrino beam facility, in particular developing very high intensity proton sources for neutrino physics research.

The R&D program on superconducting magnets and materials includes efforts at BNL, Fermilab, and LBNL, focusing on demonstrating very high field superconducting magnets using advanced superconducting materials, and an industrially-based program to develop these materials, particularly niobium-tin.

▪ **Superconducting RF R&D**	**22,000**	**17,500**

Superconducting Radio Frequency (SRF) technology is applicable to a variety of future accelerator projects central to the HEP scientific strategy. Centered at Fermilab, the program supports development of the infrastructure necessary for SRF development and includes equipment and facilities for accelerator cavity processing, assembly, and testing and for cryomodule assembly and testing. The infrastructure will be utilized to improve cavity and cryomodule performance and prototype cryomodules for future projects. Information on processing and construction will be of use to a broad spectrum of projects throughout the Office of Science. Completion of this essential technology infrastructure was accelerated in FY 2009 using Recovery Act funding.

In FY 2012, this effort is ramping down as major infrastructure procurements are completed, but will continue to provide funds for procurement of components and equipment support necessary to develop prototype multi-cavity cryomodules. It also enables continued development of U.S. capabilities for testing individual bare cavities, dressed cavities with all power components attached, and cryomodules. Fermilab is the lead U.S. laboratory and coordinates the national R&D program in this area.

▪ **International Linear Collider R&D**	**34,991 22,500**	

This R&D effort is driven by the performance requirements of a TeV-scale linear electron-positron collider, but these R&D efforts have wider applicability to other projects supported by the Office of Science, particularly in the production and control of extremely small particle beams.

A TeV-scale linear electron-positron collider is widely considered by the international high energy physics community to be the most desirable successor to the LHC, though the data from the LHC may indicate that an even higher energy accelerator (such as a muon collider) will be needed to understand the new physics that emerges at this energy scale. In 2007, the International Linear Collider (ILC) collaboration under the auspices of the ILC Steering Group and the direction of the Global Design Effort (GDE) completed a detailed review of the R&D to be accomplished worldwide with milestones and priorities for that work. In 2008, the GDE initiated a five-year program to develop a Technical Design Report (TDR) that addresses outstanding R&D issues, complete a baseline design, and provide possible project implementation and governance plans. Throughout FY 2010 the ILC baseline configuration, to be finalized in FY 2011, was optimized for flexibility, cost control, and cost reduction. Selection of the baseline will permit finalizing of the design. Completion of the TDR in 2012 is consistent with worldwide resources currently available for the

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

ILC R&D and coincident with first physics results from the LHC (necessary to finalize operating parameters for a TeV-scale linear collider).

In FY 2012, the ILC R&D program will continue, but with a significantly reduced U.S. role in the comprehensive and coordinated international R&D program. Efforts will focus on the final phases of R&D for systems associated with the generation and maintenance of very bright particle beams, such as particle sources, damping rings, and beam delivery systems at a level consistent with the minimum necessary to complete U.S. contributions.

Other Technology R&D	**25,208**	**25,481**

This category includes R&D on new particle detector technologies, addressing fundamental scientific problems to foster new technologies in particle detection, measurement, and data processing and providing support for prototyping and detector systems development to bring the technologies to maturity where they can be incorporated into future particle physics experiments.

▪ **Detector Development, Grants Research**	**3,679**	**3,952**

The grants-based R&D program provides support for university physicists to develop new detector technologies or advance technologies that have broad applicability to a wide range of high energy physics experiments. This support includes maintaining university infrastructure to enable state-of-the-art R&D into new detector technologies. Technologies targeted for development are selected based on anticipated applications that require further technological improvements before deployment, and specific proposals are selected based on peer-review. Current areas of investigation include liquid and high pressure noble gas detectors, radiation hard pixel detectors including single crystal diamond detectors, bonding technologies, silicon photomultipliers, large area photodetectors, water based liquid scintillators, and high speed electronics. Funding is maintained at approximately the FY 2010 level-of-effort to emphasize small-scale, university-led initiatives.

▪ **Detector Development, National Laboratory Research**	**21,529**	**21,529**

This activity supports a variety of particle detector R&D efforts and operations of test facilities at ANL, BNL, Fermilab, LBNL and SLAC. Detectors for both accelerator-based and non-accelerator applications are developed by this program. HEP conducted a comparative peer-review of the laboratory research efforts in this subfield in 2009, whose findings have been used to inform the funding decisions in this budget request.

The FY 2012 Request will maintain priority R&D efforts directed toward developing new detectors, including prototyping and in-beam studies. Some larger-scale technology demonstrations will not be renewed. A diverse program will continue, including efforts on particle flow calorimeters, very low-mass trackers, advanced charged-coupled devices, and radiation resistant, fast readout electronics. Prototype detector systems will be operated in the Fermilab test beam, providing a major test of new detector technologies and fabrication techniques. Since the Fermilab test beam is heavily-subscribed, reconfiguration and incremental operations of an old experimental beam line at SLAC as a dedicated test beam for detectors to meet this demand is supported.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
SBIR/STTR	**0**	**19,164**

In FY 2010 $17,564,000 and $2,108,000 was transferred to the congressionally mandated Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. The FY 2012 amount is estimated requirements for the continuation of these programs.

Total, Advanced Technology R&D	**156,347**	**171,908**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Accelerator Science	
▪ **Grants Research**	
Funding is increased above a constant level of effort to provide support for university groups to work on the new FACET and BELLA facilities.	+1,750
▪ **National Laboratory Research**	
Funding is significantly increased to support operations of the new FACET and BELLA facilities and additional participation of national laboratory scientists in fully exploiting the research potential of the new advanced accelerator R&D facilities and implementation of the muon accelerator R&D plan. Staffing increases will be provided to accelerator research groups based on peer review and programmatic impact.	+9,940
Total, Accelerator Science	**+11,690**
Accelerator Development	
▪ **General Accelerator Development**	
Funding for General Accelerator Development is maintained at approximately the FY 2010 level-of-effort to maintain a robust technology development program as more directed R&D efforts ramp down.	+1,425
▪ **Superconducting RF R&D**	
Funding for Superconducting RF development supports the planned implementation of capabilities at Fermilab but ramps down as major procurements begin to be completed. Reductions will be taken from technical and engineering support in this area.	-4,500

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **International Linear Collider R&D**	
Funding for ILC R&D is significantly reduced to the minimum necessary to complete U.S. contributions to the international Technical Design Report. Reductions will be taken from technical, engineering, and scientific personnel working in this area.	-12,491
Total, Accelerator Development	**-15,566**
Other Technology R&D	
▪ **Detector Development, Grants Research**	
Grant Research funding is restored to FY 2010 level-of-effort to emphasize small-scale, university-led initiatives.	+273
SBIR/STTR	
SBIR/STTR programs are funded at the mandated level.	+19,164
Total Funding Change, Advanced Technology R&D	**+15,561**

Construction

Funding Schedule by Activity

	(dollars in thousands) FY 2010 Current Appropriation	FY 2012 Request
Construction		
11-SC-40, Long Baseline Neutrino Experiment, PED	0	17,000
11-SC-41, Muon to Electron Conversion Experiment, PED	0	24,000
Total, Construction	0	41,000

Description

This subprogram provides for the Construction and Project Engineering and Design that is needed to meet overall objectives of the High Energy Physics program.

Detailed Justification

	(dollars in thousands) FY 2010 Current Appropriation	FY 2012 Request
11-SC-40, Long Baseline Neutrino Experiment, PED	**0**	**17,000**

The Long Baseline Neutrino Experiment will be composed of a neutrino beamline, small (near) detector located near to the neutrino beamline, and a large (far) neutrino detector located a long distance from the neutrino source. In order to build a neutrino beam that passes through the earth, a beam of protons must be transported through a tunnel that points into the ground. At the end of the tunnel the protons hit a target producing neutrinos that then travel through the earth. An existing neutrino beam of this type is the Neutrino at the Main Injector (NuMI) beam at Fermilab. The new LBNE beamline would provide low-energy neutrinos, a more intense beam, and point in a different direction from NuMI in order to provide the needed longer distance to the detector to extend the study of neutrino oscillations.

It is expected that the far detector will also need to be located underground to reduce the background from cosmic rays to a manageable level. The scope of work currently being developed includes a neutrino beamline, a small near detector, one or more large far neutrino detectors, the large underground cavern(s) needed to house the far detector(s), and the infrastructure needed to support the construction and operation of the large detector if housed underground.

The HEP program has been developing the LBNE project in coordination with NSF, because the Deep Underground Science and Engineering Laboratory (DUSEL) in the Homestake mine in South Dakota proposed to be built by the National Science Foundation was a possible site for the LBNE far detector. However, based on a National Science Board decision, NSF will not pursue DUSEL as previously proposed. High Energy Physics will support activities for minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
11-SC-41, Muon to Electron Conversion Experiment, PED	**0**	**24,000**

The conversion of a muon to an electron in the field of a nucleus provides a unique window on the structure of potential new physics discoveries and allows access to new physics at very high mass scales. The Particle Physics Project Prioritization Panel (P5) identified this opportunity as a top priority for the Intensity Frontier of particle physics. This project will construct a new beamline to take protons from the existing 8 GeV Booster synchrotron at Fermilab to a muon production target, a beamline to transport those muons to the detector, a low-mass magnetic spectrometer, which can measure the electron momentum with a resolution of order 0.15%, and a new experimental hall to house the muon production target, muon beamline, and the detector.

Total, Construction	**0 41,000**	

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
11-SC-40, Long Baseline Neutrino Experiment, PED	
Funding provides for PED activities.	+17,000
11-SC-41, Muon to Electron Conversion Experiment, PED	
Funding provides for PED activities.	+24,000
Total, Construction	**+41,000**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Operating Expenses	676,923	682,952
Capital Equipment	110,376	65,623
General Plant Projects	1,142	7,625
Accelerator Improvement Projects	2,370	0
Construction	0	41,000
Total, High Energy Physics	790,811	797,200

Funding Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Research	442,126	442,275
Scientific User Facilities Operations	230,999	212,847
Projects		
Major Items of Equipment	91,153	49,240
Construction	18,955	54,000
Total, Projects	110,108	103,240
Other	7,578	38,838
Total, High Energy Physics	790,811	797,200

Scientific User Facilities Operations

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Tevatron	145,539	130,836
B-factory	14,949	9,250
LHC Detector Support and Operations	70,511	72,761
Total, Scientific User Facilities Operations	230,999	212,847

Total Facility Hours and Users

	FY 2010 Current Approp.	FY 2012 Request
Proton Accelerator Complex[a]		
Achieved Operating Hours	7,631[b]	N/A
Planned Operating Hours	5,400	2,650
Optimal hours (estimated)	5,400	2,650
Percent of Optimal Hours	141%	100%
Unscheduled Downtime	11%	N/A
Total Number of Users	2,000	1,400
SLAC B-factory		
Total Number of Users	600	200
Total Facilities		
Achieved Operating Hours	7,631	N/A
Planned Operating hours	5,400	2,650
Optimal hours (estimated)	5,400	2,650
Percent of Optimal Hours	141%	100%
Unscheduled Downtime	11%	N/A
Total Number of Users	2,600	1,600

Major Items of Equipment (MIE)

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Proton Accelerator-Based Physics						
MINERνA						
Total Estimated Costs (TEC)	9,700	0[c]	0	0	0	9,700
Other Project Costs (OPC)	5,600	0	0	0	0	5,600
Total Project Costs (TPC)	15,300	0	0	0	0	15,300

[a] Only NuMI runs FY 2012 and beyond.
[b] Additional operating hours were added during the year to maximize the amount of data taken at the Tevatron before the LHC turned on.
[c] Project was completed ahead of schedule and $1,500,000 was redirected to Proton Accelerator, Detector Support activities.

	(dollars in thousands)					
	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
NOνA						
TEC	40,528	59,000	44,220	41,240	19,480	204,468
OPC	71,532	0	2,000	0	0	73,532
TPC	112,060	59,000	46,220	41,240	19,480	278,000
Accelerator Project for the Upgrade of the LHC[a]						
TEC	0	0	250	0	0	250
OPC	2,500	9,000	0	0	0	11,500
TPC	2,500	9,000	250	0	0	11,750
MicroBooNE[b]						
TEC	0	0	2,000	6,000	8,400	16,400
OPC	0	2,043	1,500	0	0	3,543
TPC	0	2,043	3,500	6,000	8,400	19,943
Non-Accelerator Physics						
Reactor Neutrino Detector						
TEC	19,460	11,000	1,740	500	0	32,700
OPC	2,480	0	320	0	0	2,800
TPC	21,940	11,000	2,060	500	0	35,500
Dark Energy Survey						
TEC	10,640	8,610	4,000	0	0	23,250
OPC	11,900	0	0	0	0	11,900
TPC	22,540	8,610	4,000	0	0	35,150

[a] This MIE is not yet baselined, and therefore the TEC and OPC have not been determined. Mission Need (CD-0) was approved November 2008. Delay at the LHC has reduced the need for some of the planned components. The CD-1 of a descoped effort was approved September 2010 with a cost range of $10,000,000-$12,000,000 in the project execution plan.

[b] This MIE is not yet baselined, and therefore the TEC and OPC have not yet been determined. The Mission Need (CD-0) was approved September 2009 and subsequent CD-1 was approved June 2010, with an estimated TPC range of $18,800,000–$20,000,000.

	(dollars in thousands)					
	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
SuperCDMS at Soudan						
TEC/TPC	1,000	1,500	0	0	0	2,500
HAWC[a]						
TEC/TPC	0	0	0	1,500	1,000	2,500
Advanced Technology R&D						
Advanced Accelerator R&D Test Facility[b]						
BELLA						
TEC	26,798	0	0	0	0	26,798
OPC	420	0	0	0	0	420
TPC	27,218	0	0	0	0	27,218
FACET						
TEC	13,670	0	0	0	0	13,670
OPC	830	0	0	0	0	830
TPC	14,500	0	0	0	0	14,500
Total MIEs						
TEC		80,110	52,210	49,240		
OPC		11,043	3,820	0		
TPC		91,153	56,030	49,240		

Proton Accelerator-Based Physics MIEs:

Main Injector Experiment ν-A (MINERνA) will make precision measurements of neutrino interaction rates in the NuMI beam, an important input to analyze data from neutrino oscillation experiments (such as MINOS and NOνA) and was successfully completed on schedule and within budget in FY 2010. CD-4 was approved June 28, 2010.

[a] This project is not yet baselined. The TPC as well as the OPC/TEC split may change. Funding was not requested in the FY 2011 budget for this project's OPC. Once Mission Need is approved, funds will be redirected from the non-accelerator research program to support conceptual design, and these funds will be included in the TPC.

[b] Two proposals, Berkeley Lab Laser Accelerator (BELLA) Project and the Facility for Accelerator Science and Experimental Test Beams (FACET) were reviewed as candidates for this facility. Both received excellent reviews and using Recovery Act funds, both are proceeding. FACET received only Recovery Act funds and BELLA received both FY 2009 funds and Recovery Act funds. Projects are displayed to capture the correct TPC for each project; $1,500,000 of Recovery Acts (Prior Years) was transferred from BELLA to FACET.

NuMI Off-axis Neutrino Appearance (NOνA) Detector will use the NuMI beam from Fermilab to directly observe and measure the transformation of muon neutrinos into electron neutrinos over a distance of 700 km. The project also includes improvements to the proton source to increase the intensity of the NuMI beam. The occurrence of these particular neutrino "flavor" changes is expected to be much rarer than the phenomenon under study with MINOS. The baseline was approved in September 2008 with a TPC of $278,000,000. A total of $55,000,000 was provided under the Recovery Act to advance the project. Funding planned for the outyears was reduced to maintain the same TPC.

Accelerator Project for the Upgrade of the LHC (APUL) is a project to design and construct selected magnets for the LHC. The Mission Need was approved November 2008 and conceptual design is underway, funded under Other Project Costs. CD-1 was approved September 2010 with a cost range of $10,000,000-$12,000,000 in the project execution plan. Brookhaven National Laboratory is expected to fabricate components and deliver them to CERN for installation in the LHC. The scope of the project has been reduced and no funding is requested in FY 2012.

MicroBooNE is a new MIE planned to begin fabrication in FY 2011. This project will build a large (several hundreds of tons) liquid argon neutrino detector to be used in the Booster neutrino beam at Fermilab for the measurement of low energy neutrino cross-sections. These cross sections will be measured at lower neutrino energy than MINERνA and will be important for future neutrino oscillation experiments such as T2K and the proposed Long Baseline Neutrino experiment for which PED funds are initially requested in FY 2012 (see LBNE project data sheet). This experiment will also be an important demonstration of efficacy of large-scale liquid argon time projection chambers as neutrino detectors.

Non-Accelerator Physics MIEs:

Reactor Neutrino Detector, located in Daya Bay, China, is being fabricated in partnership with research institutes in China. This experiment will use anti-neutrinos produced by commercial power reactors to precisely measure a fundamental parameter that will help resolve ambiguities in neutrino properties and will be input to setting future directions of neutrino research. A baseline change increasing the TPC from $34,000,000 to $35,500,000 with a planned completion date of April 2013 was approved January 2010. This baseline change was needed to accommodate delays in the civil construction being performed by our Chinese partners. CD-4A, Start of Initial Operations, was approved December 2010.

Dark Energy Survey (DES) project will provide the next step beyond the discovery of dark energy by making more detailed studies using several different observational methods. DOE is supporting the fabrication of a new camera to be installed and operated on the existing Blanco four-meter Telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile. This project is a partnership between DOE and the NSF, which operates the telescope, along with international participation.

Super Cryogenic Dark Matter Survey (SuperCDMS) at Soudan is an upgrade of an existing dark matter search experiment (CDMS) to increase sensitivity for direct detection of dark matter over current experiments by a factor of three. The ultra-cold, supersensitive superconducting germanium detectors with a novel design will be manufactured at Stanford University and tested at various U.S. institutions before being installed at the Soudan Underground Laboratory in Minnesota.

High Altitude Water Cherenkov (HAWC) detector is a new experiment in Mexico that will survey the sky for sources of TeV gamma-rays in the 10-100 TeV range. It was identified in the HEPAP PASAG report as a scientific opportunity that should be pursued even in the case of constrained HEP budgets. The project is done in collaboration with NSF and Mexican research institutes. The estimated total DOE cost is $2,500,000–$3,500,000 and the estimated completion date is in FY 2014.

Advanced Technology R&D MIEs:

Advanced Accelerator R&D Test Facility was initiated in FY 2009. Two proposals, Berkeley Lab Laser Accelerator (BELLA) Project at LBNL and the Facility for Accelerator Science and Experimental Test Beams (FACET) at SLAC were reviewed as candidates for this facility. Both received excellent reviews and using Recovery Act funds, both projects are proceeding. FACET received only Recovery Act funds and BELLA is funded with both FY 2009 funds and Recovery Act funds. FACET will fabricate equipment to be installed in the portion of the SLAC linac not utilized by Linac Coherent Light Source. It will support experiments on plasma wakefield acceleration of electrons, a technique that exploits the field created by one electron bunch moving through a plasma to accelerate a second bunch following in the wake of the first. The BELLA Project will utilize a 1 petawatt laser to produce the wakefields in the plasma, instead of a beam of electrons. The goal of the project is to produce 10 GeV electron beams in less than 1 meter of plasma. Both projects have received CD-3 and are in full fabrication.

Construction Projects

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Long Baseline Neutrino Experiment (PED)						
TEC	0	0	0	17,000	116,000	133,000
OPC	12,443	14,178	9,000	7,000	0	42,621
TPC	12,443	14,178	9,000	24,000	116,000	175,621
Muon to Electron Conversion Experiment (PED)						
TEC	0	0	0	24,000	12,500	36,500
OPC	0	4,777	8,000	6,000	0	18,777
TPC	0	4,777	8,000	30,000	12,500	55,277
Total, Construction						
TEC		0	0	41,000		
OPC		18,955	17,000	13,000		
TPC		18,955	17,000	54,000		

Scientific Employment

	FY 2010 actual	FY 2012 estimate
# University Grants	200	195
# Laboratory Groups	45	45
# Permanent Ph.D.'s (FTEs)	1,110	1,065
# Postdoctoral Associates (FTEs)	535	510
# Graduate Students (FTEs)	595	560
# Ph.D.'s awarded	110	105

11-SC-40, Long Baseline Neutrino Experiment (LBNE), Fermi National Accelerator Laboratory, Batavia, Illinois
Project Data Sheet is for PED

1. Significant Changes

The most recent DOE O 413.3A approved Critical Decision (CD) is CD-0 that was approved January 8, 2010 with a cost range of $660,000,000–$940,000,000.

A Federal Project Director (FPD) has not been assigned to this project, but an FPD will be assigned by CD-1.

This PDS is a continuation of a PED PDS. The FY 2012 request is for PED only.

The conceptual design work has begun. The work is shared between Brookhaven, Los Alamos National Laboratories and Fermi National Accelerator Laboratory, which is leading the effort.

The HEP program has been developing the LBNE project in coordination with NSF, because the Deep Underground Science and Engineering Laboratory (DUSEL) in the Homestake mine in South Dakota proposed to be built by the National Science Foundation was a possible site for the LBNE far detector. However, based on a National Science Board decision, NSF will not pursue DUSEL as previously proposed. The PED request has been reduced due to the anticipated delay in achieving CD-1. High Energy Physics will support activities for minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided by the Nuclear Physics program. High Energy Physics will assess options for a future Long Baseline Neutrino Experiment and dark matter experiments.

2. Design, Construction, and D&D Schedule[a]

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3	CD-4	D&D Start	D&D Complete
FY 2011	1/8/2010	1Q FY 2011	4Q FY 2013	TBD	TBD	TBD	TBD	TBD
FY 2012	1/8/2010	2Q FY 2012	2Q FY 2015	TBD	TBD	TBD	TBD	TBD

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
D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete – Completion of D&D work

[a] This project does not have CD-2 approval and is not requesting construction funds. The preliminary estimate for the CD-4 date in the Mission Need Statement is the 2nd quarter of FY 2020.

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC, PED	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[b]	TBD	TBD	42,621[c]	TBD	TBD	TBD

4. Project Description, Justification, and Scope

The Long Baseline Neutrino Experiment (LBNE) will be composed of a neutrino beamline, a small near detector, and a large neutrino detector located a long distance from the neutrino beam. A neutrino beam designed to pass through earth is built by constructing a downward sloping tunnel that holds the proton beamline, production target, and decay volume where the neutrinos are produced. By the end of this tunnel, the neutrinos have been produced and they then pass through the earth to the far detector. The Neutrinos at the Main Injector (NuMI) beam is an existing example of this. This new beamline would provide low-energy neutrinos, a more intense beam, and point in a different direction from NuMI in order to provide the longer distance to the detector needed for the study of neutrino oscillations.

Depending on the technology used, the detector may also need to be located underground to reduce the background from cosmic rays to a manageable level. The scope of work currently being developed includes: a neutrino beamline, a near detector close to the source of the neutrinos, one or more large neutrino detectors, the large underground cavern(s) needed to house the detector(s), and the infrastructure needed to support the construction and operation of the large detector underground.

Among the technical issues that need to be addressed in the alternatives analysis is the preferred detector technology. Two technologies are presently being considered: water Cerenkov and liquid argon time projection chamber. Water Cerenkov is a well established technology with more than 20 years of use, while liquid argon is a highly promising technology that could prove to be less expensive. Funding will be provided for R&D to answer a number of questions about liquid argon that will allow for a better comparison of the technologies. The possibility to locate the experiment at Homestake is still being considered.

The project is being conducted in accordance with the project management requirements in DOE O 413.3A, Program and Project Management for the Acquisition of Capital Assets, and all appropriate project management requirements have been met.

[a] This project is not yet baselined.
[b] This is a preliminary estimate for the planned PED over FY 2012–FY 2015.
[c] This is a preliminary estimate for Other Project Costs (OPC) including R&D, conceptual design, but not commissioning and pre-operations.

5. Financial Schedule

	(dollars in thousands)			
	Appropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Cost (TEC)				
PED				
FY 2012	17,000	17,000	0	16,000
FY 2013	36,000	36,000	0	35,000
FY 2014	38,000	38,000	0	40,000
FY 2015	42,000	42,000	0	42,000
Total, PED	133,000	133,000	0	133,000
Other Project Cost (OPC)				
OPC except D&D				
FY 2009 Recovery Act	12,443[a]	12,443	0	0
FY 2010	14,178	14,178	4,696	6,336
FY 2011[b]	9,000	9,000	7,747	7,842
FY 2012	7,000	7,000	0	11,110
FY 2013	0	0	0	4,890
Total, OPC except D&D	42,621	42,621	12,443	30,178
Total Project Cost (TPC)				
FY 2009 Recovery Act	12,443	12,443	0	0
FY 2010	14,178	14,178	4,696	6,336
FY 2011[b]	9,000	9,000	7,747	7,842
FY 2012	24,000	24,000	0	27,110
FY 2013	36,000	36,000	0	39,890
FY 2014	38,000	38,000	0	40,000
FY 2015	42,000	42,000	0	42,000
Total, TPC	175,621	175,621	12,443	163,178

[a] $13,000,000 of Recovery Act funding was originally planned for the conceptual design; the difference of $557,000 was needed prior to approve mission need (CD-0) for pre-conceptual activities.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

6. Details of Project Cost Estimate[a]

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design 1	01,000	75,000	N/A
Contingency 3	2,000	27,000	N/A
Total, PED	133,000	102,000	N/A
Total, TEC	133,000	102,000	N/A
Contingency, TEC	32,000	27,000	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D 6,	000	2,000	N/A
Conceptual Planning	13,000	7,000	N/A
Conceptual Design	15,000	9,000	N/A
Contingency 8,	621	4,180	N/A
Total, OPC except D&D	42,621	22,180	N/A
Contingency, OPC	8,621	4,180	N/A
Total, TPC	175,621	124,180	N/A
Total, Contingency	40,621	31,180	N/A

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	Outyears	Total
FY 2011	TEC	0	0	0	12,000 3	5,000 5	5,000	TBD	TBD	102,000
	OPC	0	13,000	9,180	0 0 0			TBD	TBD	22,180
	TPC	0 1	3,000	9,180 1	2,000	35,000	55,000	TBD	TBD	124,180
FY 2012[a]	TEC	0	0	0	0 1	7,000 3	6,000	38,000 4	2,000	133,000
O	PC	0	12,443	14,178	9,000[b]	7,000 0		0 0		42,621
TPC		0	12,443	14,178	9,000[b]	24,000 3	6,000	38,000 4	2,000	175,621

8. Related Operations and Maintenance Funding Requirements

Not applicable for PED.

[a] This project is not yet baselined. This is a preliminary estimate for the planned PED over FY 2012–FY 2015.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

9. Required D&D Information

Not applicable for PED.

10. Acquisition Approach

The conceptual design and study of alternatives is being led by Fermi National Accelerator Laboratory with the assistance of Brookhaven National Laboratory and Los Alamos National Laboratory. This work will be used to develop an Acquisition Strategy that will be approved as part of CD-1. It is expected that a new neutrino beamline and neutrino detector will be needed. The technical expertise needed to design and build these components is very specialized and will limit the acquisition approaches.

11-SC-41, Muon to Electron Conversion Experiment (Mu2e), Fermi National Accelerator Laboratory, Batavia, Illinois
Project Data Sheet is for PED

1. Significant Changes

The most recent DOE O 413.3A approved Critical Decision (CD) is CD-0 and was approved November 24, 2009.

A Federal Project Director has not yet been assigned to this project, but will be by CD-1.

This PDS is a continuation of a PED PDS. Conceptual Design has begun, led by Fermi National Accelerator Laboratory.

2. Design, Construction, and D&D Schedule[a]

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3	CD-4	D&D Start	D&D Complete
FY 2011	11/24/2009	4Q FY 2010	4Q FY 2012	TBD	TBD	TBD	TBD	TBD
FY 2012	11/24/2009	4Q FY 2011[b]	4Q FY 2013	TBD	TBD	TBD	TBD	TBD

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
D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete –Completion of D&D work

3. Baseline and Validation Status[c]

(dollars in thousands)

	TEC, PED	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[d]	TBD	TBD	18,777[e]	TBD	TBD	TBD

4. Project Description, Justification, and Scope

The conversion of a muon to an electron (Mu2e) in the field of a nucleus provides a unique window on the structure of potential new physics discoveries and allows access to new physics at very high mass scales. The Particle Physics Project Prioritization Panel (P5) identified this opportunity as a top priority for the Intensity Frontier of particle physics.

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[a] This project does not have CD-2 approval and is not requesting construction funds. The estimated CD-4 date is 4th quarter of FY 2016.
[b] The CD-1 date from CD-0 approval is the formal milestone, however it is clear that funding to proceed beyond CD-1 has been delayed and work will be delayed to avoid a gap in funding.
[c] This project is not yet baselined.
[d] This is a preliminary estimate for the planned PED in FY 2012 and FY 2013.
[e] This is a preliminary estimate for the OPC including R&D, conceptual design, but not commissioning, and pre-operations.

This project will construct a new beamline to take protons from the existing 8 GeV Booster synchrotron at Fermilab to a muon production target, a beamline to transport those muons to the detector, a low-mass magnetic spectrometer, which can measure the electron momentum with a resolution of order 0.15%, and a new experimental hall to house the muon production target, muon beamline, and the detector.

The project is being conducted in accordance with the project management requirements in DOE O 413.3A, Program and Project Management for the Acquisition of Capital Assets, and all appropriate project management requirements have been met.

5. Financial Schedule[a]

(dollars in thousands)

App	ropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2012	24,000	24,000	21,000
FY 2013	12,500	12,500	14,000
FY 2014	0	0	1,500
Total, PED	36,500	36,500	36,500
Other Project Cost (OPC)			
OPC except D&D			
FY 2010	4,777	4,777	3,769
FY 2011[b]	8,000 8,	000	5,877
FY 2012	6,000	6,000	9,131
Total, OPC except D&D	18,777	18,777	18,777
Total Project Cost (TPC)			
FY 2010	4,777	4,777	3,769
FY 2011[b]	8,000 8,	000	5,877
FY 2012	30,000	30,000	30,131
FY 2013	12,500	12,500	14,000
FY 2014	0	0	1,500
Total, TPC	55,277	55,277	55,277

[a] This project has not yet received CD-2 approval. Only PED and OPC excluding D&D are shown.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design 2	9,500	28,000	N/A
Contingency 7,	000	7,000	N/A
Total, PED	36,500	35,000	N/A
Total, TEC	36,500	35,000	N/A
Contingency, TEC	7,000	7,000	N/A
Other Project Cost (OPC)			
OPC except D&D			
R&D 1	50	150	N/A
Conceptual Planning	7,350	3,850	N/A
Conceptual Design	8,000	4,000	N/A
Contingency 3,	277	2,000	N/A
Total, OPC except D&D	18,777	10,000	N/A
Contingency, OPC	3,277	2,000	N/A
Total, TPC	55,277	45,000	N/A
Total, Contingency	10,277	9,000	N/A

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2010	FY 2011	FY 2012	Outyears	Total
FY 2011	TEC	0	0	5,000	30,000	TBD	35,000
O	PC	0	5,000	5,000	0	TBD	10,000
	TPC	0	5,000 1	0,000	30,000	TBD 4	5,000
FY 2012[a]	TEC	0	0	0 2	4,000 1	2,500	36,500
OPC		0	4,777	8,000[b] 6	,000	0	18,777
TPC		0	4,777	8,000[b] 3	0,000	12,500	55,277

8. Related Operations and Maintenance Funding Requirements

Not applicable for PED.

[a] This project has not yet received CD-2 approval. Only PED and OPC excluding D&D are shown.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

9. Required D&D Information

Not applicable for PED.

10. Acquisition Approach

The conceptual design is being performed by Fermilab, and it will inform the acquisition approach that will be documented in the Acquisition Strategy required for CD-1. It is already known that beamlines, detectors, and an experimental hall will be needed, and that the specialized expertise in those areas will limit the range of acquisition options.

Nuclear Physics

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Nuclear Physics		
Medium Energy Nuclear Physics	122,113	130,380
Heavy Ion Nuclear Physics	205,063	219,984
Low Energy Nuclear Physics[a]	116,216	126,536
Nuclear Theory	39,952	42,166
Isotope Development and Production for Research and Applications	19,116	20,234
Subtotal, Nuclear Physics	502,460	539,300
Construction	20,000	66,000
Total, Nuclear Physics	522,460[b]	605,300

Public Law Authorizations:

Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 101–101, "1989 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
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

The mission of the Nuclear Physics (NP) program is to discover, explore, and understand all forms of nuclear matter. The fundamental particles that compose nuclear matter—quarks and gluons—are relatively well understood, but exactly how they fit together and interact to create different types of matter in the universe is still largely not understood. To solve this mystery, NP supports experimental and theoretical research—along with the development and operation of particle accelerators and advanced technologies—to create, detect, and describe the different forms and complexities of nuclear matter that can exist, including those that are no longer commonly found in our universe.

Background

It is one of the enduring mysteries of the universe: What, really, is matter? What are the units that matter is made of, and how do they fit together to give matter the properties we observe? These are questions which philosophers have wrestled with for millennia. Over two thousand years ago, the Greek

[a] Funding for the establishment of the Facility for Rare Isotope Beams is included within the Low Energy Nuclear Physics subprogram.
[b] Total is reduced by $12,540,000: $11,197,000 of which was transferred to the Small Business Innovation Research (SBIR) program and $1,343,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

philosopher Democritus suggested that if one were to divide matter into smaller and smaller pieces, one would eventually be left with indivisible entities called atoma. It was not until the 1800s, however, that scientists had solid evidence that such atoma—or atoms—actually existed, and it was not until the early 1900s that techniques were developed that made it possible to examine their composition.

In 1909 the physicist Ernest Rutherford fired a beam of helium ions at a thin sheet of gold foil and measured how the ions scattered, showing that each atom has at its center, a small, dense, positively charged core, which Rutherford named the nucleus. Scientists later determined that the nucleus is surrounded by a cloud of tiny negatively charged electrons that account for less than 0.1% of the total mass of the atom. Upon closer inspection, researchers found that the nucleus was composed of even smaller particles: the positively charged proton and the electrically neutral neutron. Research showed that protons and neutrons—or nucleons—are bound in the nucleus by a fundamental force named the strong force because it is far stronger than either gravity or electromagnetism, although it operates on smaller distance scales. As scientists delved further into the properties of the proton and neutron, they discovered that each proton and neutron is composed of three tiny particles called quarks. Quarks are bound together by yet other particles called gluons, which are believed to be the generators of the strong force. One of the major goals of nuclear physics is to understand precisely how quarks and gluons bind together to create protons, neutrons, and other hadrons (the generic name for particles composed of quarks) and, in turn, to determine how all hadrons fit together to create nuclei and other types of matter.

The quest to understand matter takes place through theory and experiment, with both being necessary to develop a full understanding of the properties and behavior of matter. In the theoretical approach, scientists have developed a precise mathematical description of how the quarks and gluons in nuclear matter interact, referred to as Quantum Chromodynamics (QCD). On the experimental side, scientists accumulate a great deal of experimental data about the behavior of quarks and gluons as well as protons, neutrons, and nuclei in a variety of settings. Unlike Rutherford's table-top experiment, most of the experiments today require large facilities spanning acres. These particle accelerators slam bits of matter into each other, and scientists observe the results. The main differences from Rutherford's time are the ability to accelerate the bits of matter to much higher speeds, the variety of types of matter that can be used, and the sophistication of the instruments used in the observations. The careful integration and comparison of experimental measurements with theoretical calculations provides both insight into the behavior of matter and the information needed to test the validity of theoretical models.

Nuclear physics seeks to understand matter in all of its manifestations—not just the familiar forms of matter we see around us, but also such exotic forms as the matter that existed in the first moments after the creation of the universe and the matter that exists today inside neutron stars—and to understand why matter takes on the particular forms that it does. Nuclear physics has come to focus on three broad yet tightly interrelated areas of inquiry. These three areas are described in *The Frontiers of Nuclear Science*[a], a long range plan for nuclear science released in 2007 by the Nuclear Science Advisory Committee (NSAC). The plan represents a consensus within the nuclear science community about compelling scientific thrusts. The three frontiers the long range plan identified are:

- **Quantum Chromodynamics:** The focus of this frontier is to develop a complete understanding of how quarks and gluons assemble themselves into the various forms of matter and, as part of that process, to search for yet undiscovered forms of matter. While nuclear scientists want to know how quarks and gluons assemble to form matter, they also want to understand what happens when nucleons "melt." QCD predicts that nuclear matter can change its state in somewhat the same way that ordinary matter can change from solid to liquid to gas. This can happen when nucleons are

[a] http://www.sc.doe.gov/np/nsac/nsac.html

compressed well beyond the density of atomic nuclei, as in the core of a neutron star, or when they are heated to the kind of extreme temperatures found in the early universe. One of the most startling recent discoveries is the creation of a new form of matter, thought to have existed only moments after the birth of the universe under conditions of extreme temperature and density, and the fact that it behaves as an almost perfect liquid instead of a dilute gaseous plasma as originally hypothesized.

- **Nuclei and Nuclear Astrophysics:** Nuclear physicists seek to understand how protons and neutrons combine to form atomic nuclei and how these nuclei have arisen during the 13.7 billion years since the birth of the cosmos. The forces that bind protons and neutrons together into nuclei are immensely strong, with the result being that nuclear processes such as nuclear fusion and fission can release huge amounts of energy. Looking inward, nuclear scientists seek a comprehensive description of the behavioral characteristics of multi-nucleon systems and marginally stable exotic nuclei not naturally found on earth. Looking outward, nuclear scientists seek to understand the nuclear processes that have shaped the cosmos, from the origin of the elements, the evolution of stars, and the detonation of supernovae, to the structure of neutron stars and the nature of matter at extreme densities. Nuclear scientists have made great strides in nuclear astrophysics, for example by decreasing the limits of the age of the universe by about one billion years through studies of the reaction cross sections that control hydrogen burning in stars.
- **Fundamental Symmetries and Neutrinos:** Although the strong force plays the dominant role in the nucleus, it is not the only force that nuclear physicists must consider. Because protons (and quarks) are electrically charged, electromagnetism comes into play in such circumstances as proton-proton interactions, and the weak force is responsible for the transformation of protons into neutrons and vice versa. The three forces have been unified by a single theory, referred to as the Standard Model, which does an excellent job of explaining the interactions of the various fundamental particles. However, certain inadequacies of that theory have led physicists to begin developing a New Standard Model. In particular, nuclear physicists are interested in developing a better understanding of the fundamental properties of the neutron and of the neutrino, the nearly undetectable fundamental particle produced by the weak interaction that was first indirectly detected in nuclear beta decay. One of the most surprising results to come out of neutrino studies in the past decade was the discovery that electron neutrinos produced in the Sun are changing into a different type of neutrino, thus explaining the puzzling shortage of events seen in previous solar neutrino detectors. These results confirm models for solar energy production and indicate that these elusive messengers from the cosmos do indeed have mass.

In addition to the three frontiers identified in the long range plan, NP also has responsibility for **Isotope Development and Production for Research and Applications**. For over 50 years, this program and its predecessors have been at the forefront of the development and production of stable and radioactive isotope products that are now used world-wide. DOE applies its unique expertise and capabilities to address technology issues associated with the application, production, handling, and distribution of isotopes. Adequate supplies of medical and research isotopes are essential to maintain effective diagnosis, treatment, and research capabilities in the U.S. The program's products and services are sold to over 20 countries. The program produces isotopes only where there is no U.S. private sector capability or other production capacity is insufficient to meet U.S. needs.

Subprograms

To accomplish its mission and address the scientific challenges described above, NP is organized into five subprograms: Medium Energy Nuclear Physics, Heavy Ion Nuclear Physics, Low Energy Nuclear Physics, Nuclear Theory, and Isotope Development and Production for Research and Applications.

- The *Medium Energy* subprogram primarily explores the frontier of QCD with research conducted at two NP national user facilities and other facilities worldwide. The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) provides high quality beams of polarized electrons that allow scientists to extract information on the quark and gluon structure of protons and neutrons. CEBAF also uses polarized electrons to make precision measurements of parity violating processes that can provide information relevant to the development of the New Standard Model. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) provides colliding beams of spin-polarized protons to probe the spin structure of the proton, another important aspect of the QCD frontier. This subprogram supports one of the Nuclear Physics program's university Centers of Excellence at the Massachusetts Institute of Technology that has infrastructure capabilities to develop advanced instrumentation and accelerator equipment.
- The *Heavy Ion* subprogram also investigates the frontier of QCD, but with a different approach—by trying to recreate and characterize new and predicted forms of matter and other new phenomena that might occur in extremely hot, dense nuclear matter and which have not existed since the Big Bang. Measurements are carried out primarily using relativistic heavy ion collisions at RHIC. Participation in the heavy ion program at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) provides U.S. researchers the opportunity to search for new states of matter under substantially different initial conditions than those provided by RHIC, yet still provide information regarding the matter that existed during the infant universe. New results announced on the properties of the perfect liquid of quarks and gluons discovered at RHIC garnered worldwide attention in scientific and popular literature in April 2010.
- The *Low Energy* subprogram studies two nuclear science frontiers—Nuclear Structure and Astrophysics and Fundamental Symmetries and Neutrinos. Two NP national user facilities have been pivotal in making progress in these frontiers. The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) is used to study questions of nuclear structure by providing high-quality beams of all the stable elements up to uranium and selected beams of short-lived nuclei for experimental studies of nuclear properties under extreme conditions and reactions of interest to nuclear astrophysics. The Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) has provided beams of short-lived radioactive nuclei that scientists use to study exotic nuclei that do not normally exist in nature. HRIBF has also been used to explore reactions of interest to nuclear astrophysics. The future Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU) is a next-generation machine that will advance the understanding of rare nuclear isotopes and the evolution of the cosmos by providing beams of rare isotopes with neutron and proton abundances far from those of stable nuclei in order to test the limits of nuclear existence and models of stellar evolution. The subprogram also supports three university Centers of Excellence, two with unique low energy accelerator facilities and one with infrastructure capabilities for developing advanced instrumentation. These university Centers of Excellence provide outstanding hands-on science, technology, and engineering educational opportunities for students at various stages in their career. In addition, the program partners with the National Reconnaissance Office and the United States Air Force to support limited operations of the 88-Inch Cyclotron at the Lawrence Berkeley National Laboratory (LBNL) for a small in-house research program and to meet national security needs.

  Finally, within the portfolio of this subprogram there are experiments designed to develop a better understanding of the properties of neutrons and neutrinos and, in particular, of the neutrino mass. Neutrino science is typically explored with large detectors sited underground to shield them from cosmic background radiation so that they can detect rare particle signals. Measurements of symmetry properties of the neutron are carried out by nuclear physicists at the Spallation Neutron Source at ORNL.

- The *Nuclear Theory* subprogram provides the theoretical underpinning needed to support the interpretation of a wide range of data obtained from all the other nuclear science subprograms and to advance new ideas and hypotheses that stimulate experimental investigations. This subprogram supports one of the program's university Centers of Excellence, the Institute for Nuclear Theory (INT) at the University of Washington, where leading nuclear theorists are assembled from across the Nation to focus on key frontier challenges in nuclear physics. Five-year topical collaborations were established in FY 2010 to address high-priority topics in nuclear theory that require concerted effort to advance the field. The subprogram also collects, evaluates, and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies with its support of the National Nuclear Data Center (NNDC). The extensive nuclear databases produced by this effort are an international resource consisting of carefully organized scientific information gathered from over 100 years of low-energy nuclear physics research worldwide.
- The *Isotope Development and Production for Research and Applications* subprogram supports the production, distribution, and development of production techniques of radioactive and stable isotopes that are 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. A goal of the program is to make key isotopes more readily available to meet domestic U.S. needs. This subprogram is steward of the Isotope Production Facility (IPF) at Los Alamos National Laboratory (LANL), the Brookhaven Linac Isotope Producer (BLIP) facility at BNL, and hot cell facilities for processing isotopes at ORNL, BNL, and LANL. In addition, the subprogram has begun to coordinate and support isotope production at a suite of university, other national laboratory, and commercial accelerator and reactor facilities throughout the Nation to promote a reliable supply of domestic isotopes. The National Isotope Development Center (NIDC) at ORNL 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.

Benefits

NP supports a wide range of facilities, instruments, and research that create forefront scientific knowledge and state-of-the-art tools to serve the Nation. Nuclear science basic research and the advancement of knowledge of nuclear matter and its properties are inherently relevant to and intertwined with a broad range of applications including nuclear power, waste disposal, nuclear medicine, commerce, medical physics, space exploration, finance, geology, environmental sciences, and national security. NP also develops advanced instrumentation, accelerator technologies, and analytical and computational techniques that are needed for nuclear science research which have broad societal and economic benefits, including reliable, timely, and economical delivery of stable and radioactive isotopes for commercial application and research. The development and construction of facilities and advanced instrumentation and accelerator technology needed to reach the performance goals of the program not only contribute technically to other research and applied sciences, but also provide tools and research opportunities essential for workforce development, helping to ensure that a technically and scientifically capable generation of new scientists will be available to meet national challenges and help promote U.S. economic competitiveness in the future. In addition, the process of overcoming challenging technical problems to achieve the goals of the basic research program in nuclear science provide an engine for game-changing innovation which supports applications directly aligned with national needs and priorities.

Research into the nucleus has led to a number of valuable applications with practical benefits to society. The realization that the nucleus contains a tremendous amount of energy led to the development of both nuclear power and the atomic bomb. Some of the cutting-edge instrumentation being developed for nuclear physics experiments, such as high-resolution gamma ray detectors, can provide improved imaging techniques with important applications in combating terrorism. The discovery and understanding of nuclear spin made possible the development of techniques for the study of molecular structure and dynamics through nuclear magnetic resonance (NMR) and development of magnetic resonance imaging (MRI) for medical use. Medical imaging, cancer therapy, and biochemical studies all rely on isotopes produced in accelerators that were first developed for nuclear research. Particle beams are used in a broad range of materials science studies and for cancer therapy.

Valuable applications have resulted from isotope availability and nuclear radiation, which made possible the entire field of nuclear medicine used today in both the diagnosis and treatment of disease. Enhancements in isotope production and processing techniques have fueled the development of new uses of isotopes, including those for neutron detectors, special nuclear material and explosives detection, oil exploration, industrial radiography, heart and lung imaging, cancer therapy, smoke detectors, and tracers for climate change research. The various applications resulting from isotope availability have improved the ability of physicians to diagnose illnesses, improved the quality of life and longevity for innumerable patients, and strengthened national security.

Another societal benefit of the NP program is the boost to the Nation’s R&D workforce through its support of undergraduate researchers, graduate students working toward an advanced degree, and postdoctoral associates developing their research and management expertise. These researchers provide new research talent and help meet the demand for skilled personnel in a wide variety of scientific, technical, medical, security, and industrial fields that require the unique problem-solving abilities and the computational and technical skills developed through an education and experience in nuclear science. Each year several national laboratory junior scientists within the NP program have been recognized with Presidential Early Career Awards for Scientists and Engineers for their outstanding contributions to nuclear and accelerator physics research and their promise as future leaders of the field.

The potential for new high tech jobs is significant. The Office of Nuclear Physics provides support for tools, facilities, and research opportunities which challenge the imagination and the scientific and technical abilities of U.S. scientists and the international scientific community. In the process of stretching to reach the ground breaking advances made possible as a result of these strategic investments, scientists and technical experts produce new innovations and new technologies. In addition to producing new knowledge and important applications such as isotopes for medicine, business, and research, these innovations and technologies are helping to transition the character of the U.S. workforce by creating high tech jobs which are resilient to offshore outsourcing. Current examples include:

- Technical developments in super conducting radio frequency (SRF) particle acceleration technology, a collateral benefit of meeting the challenges of the basic research programs in nuclear and high energy physics, have advanced the technology for accelerator driven sub-critical (ADS) reactors, a potential innovation for nuclear power generation and waste transmutation. New companies have already formed to industrialize SRF technology.
- Using Accelerator Mass Spectroscopy (AMS) technology developed to achieve the goals of the basic research program in nuclear science, NP supported scientists are collaborating with scientists from the Office of Nuclear Energy to understand how to design fuel for future nuclear reactors that burns

more completely, is proliferation resistant, and has reduced long-lived waste products. Innovation in this area supports the goal of deploying next generation nuclear reactor technology in the U.S.

- The future Facility for Rare Isotope Beams will produce knowledge on nuclear reaction cross sections not presently measureable anywhere in the world. Scientifically, this knowledge will inform the understanding of the evolution of stars and the makeup and evolution of the inter-stellar medium. As a practical matter, this knowledge will revolutionize the field of nuclear forensics, creating new technical expertise and innovation.

These are just three examples of how stretching beyond the limits of present day science and technology to realize the groundbreaking advances made possible by strategic investments in the basic nuclear science research program is driving innovation in areas important for a secure energy future and for the national and economic security of the United States. Ultimately, about half of the workforce trained in the U.S. nuclear science program will find long term careers and positions of responsibility in business, government, industry, and medicine, extending the impacts of basic nuclear science research well beyond the traditional boundaries of the nuclear science community itself.

Program Planning and Management

To ensure that funding is allocated as effectively as possible, NP has developed a rigorous and comprehensive process for strategic planning and priority setting that relies heavily on input from groups of outside experts. All activities within the subprograms are peer reviewed and performance is assessed on a regular basis. Priority is given to those research activities which support the most compelling scientific opportunities. NP has also instituted a number of peer review and oversight measures designed to assess productivity and maintain effective communication and coordination among participants in NP activities. On an as-needed basis, the program has taken the initiative to establish interagency working groups to tackle issues of common interest and enhance communication. NP takes all of this input into account in its budget requests, making decisions to maximize scientific impact, productivity, quality, and cost-effectiveness within available resources.

NP works closely with the National Science Foundation (NSF) to jointly charter the Nuclear Science Advisory Committee (NSAC) for advice regarding compelling opportunities and productivity of the national nuclear science program. NP develops its strategic plan for the field with input from the scientific community via long range plans produced by NSAC every five to six years. These plans provide retrospective assessments of major accomplishments, assess and identify scientific opportunities, and set priorities for the next decade. NSAC provides NP with additional guidance in the form of reviews of subfields, special interest topics, and assessment of the management of the NP program itself. In 2009, NSAC completed a report that identifies *Compelling Research Opportunities Using Isotopes,*[a] and a second report that lays out a strategic plan for the Isotope Development and Production for Research and Applications subprogram, *Isotopes for the Nation's Future—A Long Range Plan.*[a] NSAC conducted a Committee of Visitors (COV) review of NP management processes in January 2010. The general finding of the COV in the report transmitted to NP was that the operations of the office and decisions made in the context of the Long Range Plan position the Nuclear Physics program to lead the world in this critical area of research. NP's response to the recommendations contained in the COV report is on the Office of Science website.[b]

NP strategic plans are also influenced by National Academies reports and Office of Science and Technology Policy (OSTP) and National Security Council (NSC) Interagency Working Group (IWG)

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[a] http://www.sc.doe.gov/np/nsac/nsac.html
[b] http://www.science.doe.gov/SC-2/COV-NP/NP_Reviews.htm

efforts, the latter two under the auspices of the White House Executive Office of the President. The 2007 National Academies study *Advancing Nuclear Medicine through Innovation*[a] motivated NP to establish a federal working group with the National Institutes of Health (NIH), along with the SC Biological and Environmental Research program, to better coordinate radioisotope production and to address other issues important to nuclear medicine. The National Academies embarked on a new decadal study of nuclear science in 2009. In order to optimize interagency activities, NP is involved in five OSTP or NSC IWG's: *Large Scale Science*, *Forensic Science*, *Molybdenum-99 Production*, *Helium-3 Shortage*, and *The Physics of the Universe*.

NP peer reviews all of its activities. Annual science and technology reviews of the national user facilities and isotope production facilities with panels of international peers assess operations, performance, and scientific productivity. These results influence budget decisions and NP's assessment of laboratory performance as documented in annual SC laboratory appraisals. The institutions are held accountable for responding to the peer review recommendations. Annual reviews of instrumentation projects focus on scientific merit, technical status and feasibility, cost and schedule, and effectiveness of management approach. NP conducted 27 reviews with panels of national and international experts in FY 2010. All NP baselined projects are currently on cost and on schedule. Performance of instrumentation projects is also assessed on a monthly and quarterly basis.

One of the most pressing priority-setting issues at the national user facilities is how to allocate available beam time, or time spent doing experiments on a facility's accelerator. Facility directors seek advice from facility Program Advisory Committees to determine the allocation of this valuable scientific resource. The facility Program Advisory Committees review research proposals requesting resources and time at the facilities and then provide advice on the scientific merit, technical feasibility, and personnel requirements of the proposals.

University grants are proposal driven. NP funds the best and most promising ideas submitted in response to grant solicitation notices. Proposals are reviewed by external scientific peers and competitively awarded according to the guidelines published in 10 CFR 605. The quality and productivity of university grants are peer reviewed on a three-year basis. Laboratory groups performing research are peer reviewed on a four-year basis to examine the quality of research and to identify needed changes, corrective actions, or redirections of effort. Funding decisions in this budget request are influenced by the results of these periodic peer reviews of the national laboratory research efforts. The laboratory research groups in the Medium Energy laboratory research groups were reviewed in 2010. A review of the Low Energy laboratory research program is planned for 2011.

Basic and Applied R&D Coordination

The knowledge, data, techniques, and methods of nuclear science are utilized in a broad portfolio of applications, including nuclear power, waste disposal, nuclear medicine, commerce, medical physics, space exploration, finance, geology, environmental sciences, national security, and others. In FY 2009, NP initiated support for targeted initiatives in Applications of Nuclear Science and Technology, the primary goal of which is to pursue forefront nuclear science research and development important to the NP mission, but inherently relevant to applications. One of the goals of this initiative was to help bridge the gap between basic research and applied science. The first 22 awards under this initiative were funded in FY 2009 using appropriated base funding and Recovery Act funds, and an additional five awards were made in FY 2010. Projects include: nuclear physics research that is relevant to the development of advanced fuel cycles for next generation nuclear power reactors; advanced and cost-effective accelerator

[a] http://dels.nas.edu/dels/rpt_briefs/advancing_nuclear_medicine.pdf

technology and particle detection techniques for medical diagnostics and treatment; and research in developing neutron, gamma and particle beam sources with applications in cargo screening and nuclear forensics. These initiatives are peer reviewed with participation from the applied sciences community. The integration of the underpinning nuclear science advances, resulting from innovative basic research with the applied sciences, optimizes cross fertilization, cost effectiveness, performance, and technology transfer.

The Isotope Development and Production for Research and Applications subprogram is an excellent example of basic and applied R&D coordination. The subprogram produces commercial and research isotopes that are important for basic research and applications. NP has taken significant steps in aligning the industrial and research stakeholders of the isotope program with each other and with the nuclear science research community, all of whom can contribute collectively in advancing the technology of this field. To ascertain current and future demands of the research community, NP continues to develop working groups with the National Nuclear Security Administration and other federal agencies, foster interactions between researchers and Isotope Program staff, obtain data from site visits, attend society exhibitions, and develop strategic plans and priorities with community input. Examples include: participating in an interagency working group for prioritizing requested allocations of helium-3 and seeking alternative supplies; participating in the joint DOE/National Institutes of Health (NIH) federal working group to develop a strategic plan and priorities for medical isotope production; participating in the OSTP Interagency and the Organization for Economic Cooperation and Development (OECD) international working group to address the supply of molybedenum-99; and working with industry to ensure continued availability of californium-252, an isotope of strategic and economic importance to the Nation. NP is also working to establish cooperative isotope supply contracts with universities to increase the Department’s ability to meet researchers’ requests by improving product availability and reliability.

The Isotope Development and Production for Research and Applications subprogram also supports research for the development of alternative production and extraction techniques of stable and radioactive isotopes, and the production of research isotopes identified by NSAC as needed for high priority research opportunities across a broad range of scientific disciplines.

Budget Overview

NP is the largest federal steward for basic research in nuclear science, operating four national user facilities through FY 2011, as well as supporting isotope production and development for the Nation. The FY 2012 budget request continues support for the two highest priorities in the 2007 Long Range Plan for Nuclear Science: an energy upgrade of the Thomas Jefferson National Accelerator Facility (TJNAF) Continuous Electron Beam Accelerator Facility (CEBAF) and the Facility for Rare Isotope Beams (FRIB). These investments in forefront facilities for new research capability, the first in the NP program in over ten years, will secure global U.S. leadership in research on the quark structure of nucleons, nuclear structure, and nuclear astrophysics. The increase of $70,300,000 relative to the FY 2010 Appropriation (including SBIR/STTR) is dominated by a $64,000,000 increase in the profiles of large construction projects: a $46,000,000 increase for the 12 GeV CEBAF Upgrade project, consistent with the baselined funding profile, and an $18,000,000 increase for FRIB, consistent with the cooperative agreement with Michigan State University. The increases required for these two high priority projects have required strategic decisions elsewhere in the program, most notably the closure of HRIBF as a national user facility in FY 2012. Also terminated in FY 2012 is the Rare Isotope Beam Science Initiatives MIE. The profile of the neutron Electric Dipole Moment Experiment MIE is slowed down relative to project plans approved at Critical Decision-1. Operations of the national user facilities are below optimal levels. At the heart of the NP program are groups of highly trained scientists who conceive, plan, execute, and interpret the numerous experiments carried out at various nuclear physics facilities. NP supports scientists at both universities and national laboratories and is involved in a variety of international collaborations. The program supports approximately two-thirds of the Nation's university researchers and graduate students who are doing fundamental nuclear physics research. More than 2,000 researchers and students at approximately 100 U.S. academic, Federal, and private-sector institutions are supported. With the FY 2012 request, research activities are conducted at approximately 90 academic institutions located in 35 states and the District of Columbia, as well as at 9 DOE laboratories in 8 states. Approximately 80 Ph.D. degrees are granted annually to students for research supported by the program. Five university Centers of Excellence, each with different capabilities and expertise, provide excellent hands-on training opportunities for junior scientists.

Research at nine national laboratories is guided by the DOE mission and priorities and is the underpinning of strategic core competencies needed to achieve the goals of the NP program. The national laboratory scientists work and collaborate with academic scientists, other national laboratory experimental researchers, and those carrying out theoretical investigations. The national laboratory scientists collect and analyze data as well as support and maintain the detectors and facilities used in these experiments. The national laboratories also provide state-of-the-art resources for detector and accelerator R&D for future upgrades and new facilities.

Investigating the frontiers of nuclear physics requires being able to accelerate various particles, such as protons, electrons, and a variety of ions, up to nearly the speed of light, smashing them into other particles, and then observing the results of the collisions. Exploring the various areas of nuclear physics demands having a variety of accelerators, each designed to examine the subatomic world in its own unique way and employing a variety of particle detectors and other equipment. Thus, NP supports facilities that complement one another and provide a variety of approaches to producing and collecting data about matter at the level of the nucleus, as well as the sub-nuclear level. The necessary facilities and equipment are large, complex, and expensive to build and operate, and thus they account for a significant portion of the program's budget—approximately 67 percent of the FY 2012 request. NP also supports collaborative work at foreign accelerator facilities, as well as joint development of instrumentation.

NP supported four national user facilities (RHIC, CEBAF, ATLAS, and HRIBF) in FY 2011, each with capabilities found nowhere else in the world, that provide research time for scientists at universities and other federal laboratories. These major scientific facilities provide research beams for a user community of approximately 3,200 scientists from all over the world, with more than 2,500 of the users utilizing RHIC and CEBAF. Approximately 38 percent of the users are from institutions outside of the U.S., and they often provide experimental equipment or instrumentation. A number of other SC programs, DOE offices (National Nuclear Security Administration and Nuclear Energy), Federal agencies (NSF, NASA, and Department of Defense), and industries use the NP user facilities to carry out their own research programs.

The FY 2012 budget request closes HRIBF, a national user facility with unique capabilities for studies of nuclear structure and astrophysics at the Oak Ridge National Laboratory, in order to support higher priorities within the program. The closure of HRIBF will impact a university and laboratory international community of 260 users The request supports operations at the three remaining NP national user facilities at levels that will allow significant progress towards achieving performance goals defined by the 2008 *Report to NSAC of the Subcommittee on Performance Measures*[a] for nuclear science. The facilities will provide an estimated 12,810 hours of beam time for research, 90% of optimal for the operating facilities, but a decrease of about 7,260 hours compared with the beam hours achieved in

[a] http://www.sc.doe.gov/np/nsac/nsac.html

FY 2010 as a result of the HRIBF closure; a planned shutdown period at CEBAF associated with the construction of the 12 GeV CEBAF Upgrade project at TJNAF; and a decrease in operations at RHIC. The scientific user facilities will be maintained and operated so that the unscheduled operational downtime will be kept to less than 20 percent, on average, of total scheduled operating time. Investments will be made in programmatic infrastructure, facility equipment, and accelerator improvement projects that will increase productivity, reliability, and cost-effectiveness, and provide new capabilities to pursue high discovery science.

Construction of the 12 GeV CEBAF Upgrade project, the highest priority in the NSAC Long Range Plan for Nuclear Science, continues in FY 2012. Because the project is of high priority, over $50,000,000 is redirected from the base CEBAF program towards the construction over the lifetime of the project.

Less than 1.5 percent of the total NP budget in FY 2012 is invested in a handful of ongoing small-scale Major Item of Equipment (MIE) projects in order to position the program strategically for the future to address compelling scientific opportunities identified by NSAC. The majority of these MIEs are collaborative in nature, with the DOE investment leveraged by contributions from other agencies and international partners. One MIE, the Rare Isotope Beam Science Initiatives, is terminated in FY 2012.

The proposed Facility for Rare Isotope Beams (FRIB), a next-generation nuclear structure and astrophysics machine that will map out the nuclear landscape, is supported with operating funds through a Cooperative Agreement with MSU. Although the FRIB property will not be a capital asset to the Federal Government and will be owned by the university, FRIB will be operated as a DOE national user facility upon completion around the start of the next decade. In FY 2012, funds are requested to support engineering and design activities for FRIB, pursue long-lead procurements, and possibly a phased construction start that will reduce project risks.

Significant Program Shifts

Strategic decisions and significant shifts are required within the Nuclear Physics FY 2012 budget as a result of the priority given to investments in major new research capability for the Nation's future nuclear science program.

Operations of the HRIBF national user facility cease in order to support higher priorities within the program.

The Rare Isotope Beam Science Initiatives MIE, for cutting edge nuclear structure and nuclear astrophysics research at international facilities during the lead-up and execution of FRIB construction, is terminated in FY 2012 to direct funds to higher priority activities. A limited number of the smaller international research efforts, among those selected following peer review in FY 2010, will be completed with funding in FY 2010 and FY 2011, while the larger projects will not be pursued.

The funding for the nEDM MIE is slowed relative to the most recent approved funding profile as support is redirected to higher priority activities and NSAC reviews priorities in the U.S. neutron science portfolio.

Funding is provided within the Low Energy subprogram under Other Operations to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided from the High Energy Physics program. Nuclear Physics will assess options for a future neutrinoless double beta decay experiment.

Finally, operation of one university accelerator Center of Excellence is terminated to direct funds to higher priority activities.

Annual Performance Targets and Results

The Department is in the process of updating its strategic plan, and has been actively engaging stakeholders including Congress. The draft strategic plan is being released for public comment concurrent with this budget submission, with the expectation of official publication this spring. The draft plan and FY 2012 budget are consistent and aligned. Updated measures will be released at a later date and available at the following link http://www.mbe.doe.gov/budget/12budget.

Medium Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Medium Energy Nuclear Physics		
Research		
University Research	19,422	20,222
National Laboratory Research	16,908	17,710
Other Research[a]	2,456	8,518
Total, Research	38,786	46,450
Operations		
TJNAF Operations	83,327	83,930
Total, Medium Energy Nuclear Physics	122,113	130,380

Description

The Medium Energy Nuclear Physics subprogram focuses primarily on questions having to do with the first scientific frontier, Quantum Chromodynamics (QCD) and the behavior of quarks inside protons and neutrons, although it touches on all three scientific frontiers. Specific questions addressed include: What is the internal landscape of the nucleons? What does QCD predict for the properties of strongly interacting matter? What governs the transition of quarks and gluons into pions and nucleons? What is the role of gluons and gluon self-interactions in nucleons and nuclei? One major goal, for example, is to achieve an experimental description of the substructure of the proton and the neutron. In pursuing that goal the Medium Energy subprogram supports different experimental approaches that seek to determine such things as the distribution of up, down, and strange quarks in the nucleons; the roles of the gluons that bind the quarks; the role of the "sea" of virtual quarks and gluons, which makes a significant contribution to the properties of protons and neutrons; the effects of the quark and gluon spins within the nucleon; and the effect of the nuclear environment on the quarks and gluons. The subprogram also measures the excited states of hadrons (composite particles made of quarks, including nucleons) in order to identify which properties of QCD determine the dynamic behavior of the quarks.

The subprogram also supports investigations into a few aspects of the second frontier, Nuclei and Nuclear Astrophysics, such as the question: What is the nature of the nuclear force that binds protons and neutrons into stable nuclei? Finally, this subprogram examines certain aspects of the third area, Fundamental Symmetries and Nuclei, including the questions: Why is there now more visible matter than antimatter in the universe? What are the unseen forces that were present at the dawn of the universe, but disappeared from view as it evolved?

Funding for this subprogram supports both research and operations of the subprogram's primary research facility, CEBAF, as well as research that is supported at RHIC. CEBAF is a facility with capabilities unique world-wide; the upgrade in energy opens up compelling new scientific opportunity

[a] In FY 2010, $4,034,000 was transferred to the SBIR program and $1,334,000 was transferred to the STTR program. This activity includes FY $4,105,000 for SBIR and $1,356,000 for STTR in FY 2012.

and secures continued world leadership in the U.S. for this physics arena. Research support at both facilities includes the laboratory and university personnel needed to implement and run experiments and to conduct the data analysis necessary to publish results. Individual experiments are supported at the High Intensity Gamma Source (HIγS) at Triangle Universities Nuclear Laboratory, at Fermi National Accelerator Laboratory (Fermilab), and at several facilities in Europe. All these facilities produce beams of sufficient energy (that is, of small enough wavelength) to see details smaller than the size of a nucleon. In addition, research is supported at the Research and Engineering Center at the Massachusetts Institute of Technology which has infrastructure capabilities to develop advanced instrumentation and accelerator equipment.

Construction of the 12 GeV CEBAF Upgrade project is a priority. CEBAF operations are reduced from 5,280 hours achieved in FY 2010 to 3,870 hours, reflecting the maximum level of operations possible in FY 2012 while accommodating installation of components for the 12 GeV CEBAF Upgrade project. Modest funding is provided to develop a group of scientists that will operate and utilize the new experimental hall being constructed for the 12 GeV CEBAF Upgrade project.

Selected FY 2010 Accomplishments

- Scientists have known for decades that the quark structure of protons in nuclei differs from that of free protons. The explanation of this effect has remained elusive, but new TJNAF precision results on light nuclei such as helium show that this difference is not dependent on the mass or density of the entire nucleus, as previously suggested, but that the quark structure of the protons changes according to the nuclear density in their immediate neighborhood within the nucleus, thus being a relatively short range effect.
- TJNAF designed and constructed a new polarized electron beam source that suppresses correlations between the beam parameters and the spin of the electrons by at least two orders of magnitude. Such high quality polarized electron beams are needed for a new generation of demanding parity-violation experiments planned for the facility to further test the limitations of the Standard Model of subatomic physics. A compact "inverted insulator" in the new design reduces field emission and thus prolongs the photocathode lifetime of the source.
- Data taken in two experiments at TJNAF using the highly polarized electron beam capability of the facility and a highly polarized target allowed the separated extraction of two functional form factors needed to describe the spin and transverse spatial distributions of the quarks in the proton. This result demonstrates the feasibility of a key part of TJNAF's plans to do proton "tomography" and map out the quark structure of the proton with the 12 GeV CEBAF Upgrade.
- A crucial part of the RHIC spin program is the study of intermediate vector (W) boson production in high-energy collisions of polarized proton beams. To produce W bosons in sufficient quantity, RHIC must operate at its maximum possible energy for proton-proton collisions (500 GeV). Collisions at this energy were provided at RHIC in the 2009 run and data was analyzed in FY 2010. Although this was a first commissioning run, both the PHENIX and STAR collaborations detected a sufficient number of W bosons to allow the first spin dependent measurements of their production.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Research 38,786		**46,450**
▪ **University Research**	**19,422**	**20,222**

This activity supports about 160 scientists and 125 graduate students at 33 universities in 21 states and the District of Columbia studying QCD and the behavior of quarks inside protons and neutrons. The university scientists conduct experiments at CEBAF and RHIC and participate in the development and fabrication of advanced instrumentation for utilization at these facilities. These state-of-the-art detectors often have relevance to applications in medicine and homeland security. Included in this activity is support for the Massachusetts Institute of Technology's Research and Engineering (R&E) Center that has specialized infrastructure for fabrication of scientific instrumentation. The Center has unique expertise in the study of high current, polarized electron sources.

The FY 2012 request holds research approximately flat, relative to FY 2010, although an increase is provided to start building the university groups that will be needed to support the new CEBAF experimental hall (Hall D) upon completion of the 12 GeV project.

▪ **National Laboratory Research**	**16,908**	**17,710**

This funding supports research groups at TJNAF, BNL, ANL, LBNL, and LANL that carry out research at CEBAF and RHIC. It also supports two experiments at Fermilab and nuclear research using laser trapping technology at ANL. Funding decisions are influenced by the results of periodic peer reviews of the national laboratory research groups and their subsequent ranking in terms of performance level. The FY 2012 request relative to FY 2010 is essentially flat, although a small increment is provided to start building the support needed for the new CEBAF experimental hall (Hall D) upon completion of the 12 GeV project.

• **TJNAF Research**	**6,200**	**6,473**

TJNAF staff research efforts include developing experiments, acquiring data, and performing data analysis in the three existing CEBAF experimental Halls. Funding is provided in FY 2012 to develop a scientific group for the new experimental Hall D that is being constructed as part of the 12 GeV CEBAF Upgrade project. Scientists also are identifying the scientific opportunities and developing the scientific goals for next generation facilities. In addition, funding supports an active visiting scientist program at the laboratory and bridge positions with regional universities, which is a cost-effective approach to augmenting scientific expertise at the laboratory and boosts educational opportunities in the southeast region of the Nation. Detectors developed for nuclear physics research supported at TJNAF have found applications in medical imaging instrumentation.

• **Other National Laboratory Research**	**10,708**	**11,237**

Argonne National Laboratory scientists continue their primary research program at TJNAF and are leading an experiment at Fermilab to distinguish the different quark contributions to the structure of the proton. These measurements are also important to interpreting the RHIC proton spin measurements. ANL scientists are also using their unique laser atom-trapping technique to

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

make a precision measurement of the atomic electric dipole moment that could shed light on the excess of matter over antimatter in the universe. This technology at ANL has found practical applications in geology and environmental fields, for example, in tracking ground water flows in Egypt.

Support is provided to the RHIC spin physics research groups at BNL, LBNL, and LANL, which have important roles and responsibilities in the RHIC program. These groups play lead roles in determining the spin structure of the proton by development and fabrication of advanced instrumentation, as well as data acquisition and analysis efforts.

At LANL, support is provided to allow scientists and collaborators to complete the Fermilab MiniBooNE anti-neutrino running and analysis. A present discrepancy between the anti-neutrino and neutrino data needs to be resolved with additional anti-neutrino running. If these results are confirmed, they could unveil new physics beyond the Standard Model. The results of these efforts will drive future research directions of this group.

The FY 2012 request holds other national laboratory research approximately flat for all these efforts, with the exception of growth of about one Full-Time-Equivalent scientist (FTE) to develop the 12 GeV experimental program and implement the ANL experiment at Fermilab.

▪ **Other Research**	**2,456**	**8,518**
• **SBIR/STTR and Other**	**1,666**	**7,818**

In FY 2010, $4,034,000 was transferred to the Small Business Innovation Research (SBIR) program and $1,334,000 was transferred to the Small Business Technology Transfer (STTR) program. This activity includes $4,105,000 for SBIR and $1,356,000 for STTR in FY 2012, as well as funds needed to meet other obligations required of the Nuclear Physics program.

• **Accelerator R&D Research**	**790 700**	

The Medium Energy Accelerator R&D research at universities and laboratories will develop the knowledge, technologies, and trained scientists to design and build the next-generation NP accelerator facilities. These programmatic activities are of relevance to machines being developed by other domestic and international programs and can lead to technological advances that are relevant to a variety of applications. Allocation of these funds is determined by peer review and competed amongst university and laboratory proposals.

Operations 83,327		**83,930**
▪ **TJNAF Operations**	**83,327**	**83,930**

CEBAF is a unique facility with unparalleled capabilities using polarized electron beams to study quark structure; there is no other facility in the world like it and its user community has a strong international component. Funding supports CEBAF operations and experimental support for 3,870 hours and a 3-Hall operations schedule. The run time is near the maximum possible considering the planned one-year shutdown beginning in the latter half of FY 2012 as part of the 12 GeV CEBAF Upgrade project installation schedule.

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
• **TJNAF Accelerator Operations**	**50,755**	**53,550**

Support is provided for the accelerator physicists that operate the facility as well as operations, power costs, capital infrastructure investments, and accelerator improvements of the CEBAF accelerator complex. While the facility is only partially operating in FY 2012 during the planned installation of components for the 12 GeV Upgrade, the funding will support opportunities for increased maintenance during this period. There is a redistribution of funds from experimental support to accelerator operations to properly reflect the efforts during the shutdown; in total, funding for TJNAF Operations is essentially flat relative to FY 2010.

Support is also provided to maintain efforts in developing advances in superconducting radiofrequency (SRF) technology. The core competency in SRF technology that is nurtured at this laboratory plays a crucial role in many DOE projects and facilities outside of nuclear physics and has broad applications in medicine and homeland security. For example, SRF research and development at TJNAF has led to techniques for detection of buried land mines using terahertz radiation and carbon nanotube and nano-structure manufacturing techniques for the manufacture of 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.

TJNAF accelerator physicists are also strongly engaged in educating the next generation of accelerator physicists, with graduate students integrated into research programs and eleven staff members with university affiliations. TJNAF started a Center for Accelerator Science at Old Dominion University (ODU) where staff members teach courses and the laboratory jointly supports the ODU Director position.

Investments in accelerator improvement projects are aimed at increasing the productivity, cost-effectiveness, and reliability of the facility. Capital equipment investment is targeted towards instrumentation needed to support the laboratory's core competencies in SRF and cryogenics.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

CEBAF Hours of Operation with Beam	FY 2010	FY 2012
Achieved Operating Hours	5,280	N/A
Planned Operating Hours	5,110	3,870
Optimal Hours	5,980	3,940[a]
Percent of Optimal Hours	88%	98%
Unscheduled Downtime	9%	N/A
Number of Users	1,260	1,300

- **TJNAF Experimental Support** **32,572 30,380**

  Experimental Support is provided for the scientific and technical staff, as well as for materials, and services for CEBAF experiments and to integrate assembly, modification, and disassembly of large and complex experiments. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment. Capital equipment investments for experimental support at TJNAF provide scientific instrumentation for the major experiments, including data acquisition computing and supporting infrastructure (e.g., targets, mechanical structures, power supplies, gas systems, and cooling equipment). In FY 2012, TJNAF expects to run experiments distributed among all three halls that address compelling physics including a precision measurement of the weak charge of the proton to help constrain new physics beyond the Standard Model, an important experiment for the laboratory's search for missing excited states of the neutron, and experiments that will help develop the laboratory's research program using the 12 GeV CEBAF Upgrade. Funds are redistributed to accelerator operations to better align with ongoing activities during the period of 12 GeV installation efforts.

  The FY 2012 funding focuses on efforts to implement high priority experiments before the completion of the current 6 GeV experimental program and prior to the 12 GeV CEBAF Upgrade project installation.

Total, Medium Energy Nuclear Physics **122,113 130,380**

[a] The approach in previous years was to reflect the maximum hours a facility could conceivably operate. As a result, while the maximum operations for CEBAF remained at 5,980 hours in FY 2011, the optimal number of hours the facility can actually operate in FY 2011 is 4,090 hours due to the planned shutdown for installation of 12 GeV components. In FY 2012, the optimal hours are adjusted to reflect the hours the facility can operate that year after taking into account planned downtime for upgrades and maintenance.

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **University Research**	
Funding for university research is held flat relative to FY 2010 with the exception of an increase to start building the university groups that will be involved in Hall D experiments upon completion of the 12 GeV CEBAF Upgrade.	+800
▪ **National Laboratory Research**	
• **TJNAF Research**	
Funding is increased modestly to complete the highest priority 6 GeV experiments at CEBAF and to start developing the scientific group for the new experimental Hall D that is being constructed as part of the 12 GeV CEBAF Upgrade project.	+273
• **Other National Laboratory Research**	
Funding is provided to complete the highest priority 6 GeV experiments at CEBAF, develop the scientific groups for the new experimental Hall D that is being constructed as part of the 12 GeV CEBAF Upgrade project, and implement the ANL-led Drell-Yan experiment at Fermilab.	+529
Total, National Laboratory Research	+802
▪ **Other Research**	
• **SBIR/STTR and Other**	
Funding increases relative to FY 2010 primarily because the mandated SBIR/STTR set-asides have been transferred out of the program in FY 2010 while those funds are included in the FY 2012 request. Increased funding is also included for other obligations and mandatory requirements of the Nuclear Physics program.	+6,152
• **Accelerator R&D Research**	
A portion of the funding reflected within Medium Energy shifts to Accelerator R&D under the Heavy Ion subprogram.	-90
Total, Other Research	**+6,062**
Total, Research	**+7,664**

	FY 2012 vs. FY 2010 Current Approp. ($000)
Operations	
▪ **TJNAF Operations**	
• **TJNAF Accelerator Operations**	
FY 2012 funding operates CEBAF at near the maximum allowable schedule, considering a planned shutdown for 12 GeV CEBAF Upgrade project component installation. FY 2012 funding of accelerator operations is increased to provide high reliability for completing the 6 GeV program in addition to maintaining existing systems at the high performance required for the 12 GeV program. Funds are redistributed from experimental support to better align with activities in FY 2012; the overall staffing levels do not increase.	+2,795
• **TJNAF Experimental Support**	
Funding is decreased as the 6 GeV experimental program completes its running in existing experimental configurations. Funds are redistributed to accelerator operations to better align with planned activities in FY 2012.	-2,192
Total, Operations	**+603**
Total Funding Change, Medium Energy Nuclear Physics	**+8,267**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Heavy Ion Nuclear Physics		
Research		
University Research	14,466	15,201
National Laboratory Research	27,222	28,131
Other Research[a]	1,270	7,042
Total, Research	42,958	50,374
Operations		
RHIC Operations	157,195	164,610
Other Operations	4,910	5,000
Total, Operations	162,105	169,610
Total, Heavy Ion Nuclear Physics	205,063	219,984

Description

The Heavy Ion Nuclear Physics subprogram focuses on studies of nuclear matter at extremely high densities and temperatures. A program of research on hot nuclear matter began at the Relativistic Heavy Ion Collider (RHIC) at BNL in 2000 when the first collisions of counter-circulating gold nuclei were observed at beam energies ten times higher than those available at any other facility in the world. At RHIC, beams of gold nuclei are accelerated to close to the speed of light and then slammed head on into one another in order to create extremely high-energy collisions between pairs of gold nuclei. In the aftermath of these collisions 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 accumulate data that offer insights into those brief moments immediately following the creation of the universe and begin to understand how the protons, neutrons, and other bits of normal matter developed from that plasma.

The RHIC facility places heavy ion research at the energy frontier of nuclear physics. RHIC serves two large-scale international experiments called PHENIX and STAR. In these experiments, scientists are now trying to determine the physical characteristics of the recently discovered perfect liquid of quarks and gluons. A 10-fold enhancement in the heavy ion beam collision rate and detector upgrades are expected to be completed within the next five years. Accelerator R&D is being conducted at RHIC in a number of advanced areas including cooling of high-energy hadron beams; 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.

The Large Hadron Collider (LHC) at CERN offers opportunities for making new discoveries in relativistic heavy ion physics. LHC will provide a 30-fold increase in center-of-mass energy over what is available now. U.S. scientists are preparing to conduct research using ALICE (A Large Ion Collider Experiment) and the Compact Muon Spectrometer (CMS). U.S. researchers are fabricating a large

[a] In FY 2010, $5,662,000 was transferred to the SBIR program. This activity includes $5,673,000 for SBIR in FY FY 2012.

Electromagnetic Calorimeter (EMCal) detector to be installed in phases in the ALICE experiment over the next few years. First heavy ion beam operations at the LHC started in late 2010.

The RHIC and LHC research programs are directed primarily at answering the overarching questions that define the first frontier identified by the nuclear science community—Quantum Chromodynamics (QCD). The fundamental questions addressed include: 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 what is their relation to the nature of gravity and space-time?

The funding for this subprogram in FY 2012 will operate RHIC to address the highest priority scientific opportunities and goals, meet commitments to the LHC heavy ion program, and implement the STAR Heavy Flavor Tracker MIE project.

Selected FY 2010 Accomplishments

- Previous RHIC results demonstrated that collisions of gold nuclei at nearly light speed produce matter in an exotic state believed to have dominated the universe a few microseconds after its birth in the Big Bang. New results show particles composed exclusively from "strange" quarks, as opposed to the much lighter "up" and "down" quarks that are the dominant constituents of normal matter, also exhibit similar fluid-flow patterns. These results indicate that the nearly perfect liquid is created very quickly, before the quarks condense into observable particles.
- New results provided hints of a predicted form of symmetry breaking in the hot liquid of quarks and gluons produced in RHIC's most energetic collisions. These results, reported in the journal Physical Review Letters, suggest that "bubbles" formed within this hot liquid may internally disobey the so-called "mirror symmetry," or parity, that normally characterizes the interactions of quarks and gluons. RHIC may have a unique opportunity to test some crucial features of symmetry-altering bubbles that are speculated to have played important roles in the evolution of the early universe. Studies of this effect are expected to be an important topic in future RHIC experiments.
- New results obtained from high-energy collisions of deuterium with gold nuclei provide the strongest experimental evidence to date that all matter, at its heart, is dominated by an ultra-strong force field arising from a dense ensemble of gluons (the ghostly particles exchanged between quarks to confine them inside protons and neutrons). This intense gluon field is predicted by Quantum Chromodynamics (QCD)—the fundamental theory describing the interactions of quarks and gluons.
- In 2008, RHIC accelerator physicists were the first to use the bunch beam stochastic cooling technique along the beam direction to compensate for the tendency of beam bunches to lengthen (heat-up) as they circulate. As the beam ions spread, the number of protons and neutrons colliding—and the amount of useful data—declines. In 2010, RHIC physicists demonstrated stochastic cooling in the transverse direction for the first time. Computer simulations show that combining the two stochastic cooling techniques should increase collision rates by a factor of five, thus avoiding much more expensive upgrade options to achieve the collision rates required in the future.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research 42,958		**50,374**
▪ **University Research**	**14,466**	**15,201**

Research support is provided for about 120 scientists and 100 graduate students at 30 universities in 19 states. Funding supports research efforts at RHIC and the continuation of a modest program at the LHC with heavy ions. The university groups provide scientific personnel and graduate students needed for running the RHIC and LHC heavy ion experiments, as well as for data analysis and publishing RHIC results, and designing and fabricating the RHIC and LHC heavy ion detector upgrades. For example, university personnel led the effort in the fabrication of the STAR Time-of-Flight detector, an MIE which was completed on cost and schedule in FY 2009.

The FY 2012 request holds research flat with the exception of fulfilling the NP commitment with the international ALICE experiment by providing for an increase of required M&O costs associated with the LHC instrumentation.

▪ **National Laboratory Research**	**27,222**	**28,131**

This funding supports research groups at BNL, LBNL, LANL, ORNL, and LLNL that carry out research primarily at RHIC and a modest program at the LHC that supports the high priority scientific goals for the field of heavy ion physics. The FY 2012 request holds the heavy ion research efforts at laboratories flat, but fulfills the NP commitment with the international ALICE experiment by providing for an increase of required M&O costs associated with the LHC instrumentation, and provides support as planned for implementation of instrumentation. These scientists provide essential personnel for designing, fabricating, and operating the RHIC detectors; analyzing RHIC data and publishing scientific results; conducting R&D of innovative detector designs; project management and fabrication of MIEs; and planning for future experiments. Also, BNL and LBNL provide substantial computing infrastructure for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development. Some of the new research topics that will be investigated at RHIC in the next several years include determining the speed of sound in the quark-gluon plasma and trying to discover the critical point in the QCD phase diagram; discovering the speed of sound and the QCD critical point could revolutionize the quantitative understanding of the QCD phase diagram. Funding decisions are influenced by the results of periodic peer reviews of the national laboratory research groups and their subsequent ranking in terms of performance level.

- **BNL RHIC Research** **10,032 12,185**

  The FY 2012 budget request holds research activities flat. BNL scientists will continue to develop and implement new instrumentation needed to effectively utilize the RHIC beam time for research, develop and implement new instrumentation for RHIC's future, train junior scientists, and develop the computing infrastructure used by the scientific community.

  The PHENIX Silicon Vertex Tracker (VTX) MIE, a joint project with Japan, received its final funding increment under the Recovery Act and was completed in 2010. It consists of a barrel of silicon pixel and strip detectors that will provide precision measurement of heavy quark production to study the thermalization process in heavy ion collisions. The PHENIX Forward Vertex Detector (FVTX) MIE also received its final funding under the Recovery Act and is on

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

track for completion in FY 2011. Important for both the heavy ion and spin programs, this detector will provide new vertex tracking capabilities to PHENIX by adding two silicon endcaps.

The STAR Heavy Flavor Tracker (HFT), an MIE initiated in FY 2010, is an ultra-thin, high-precision tracking detector that will provide direct reconstruction of short-lived particles containing heavy quarks. Support for this cutting-edge device ramps up in FY 2012; the funding profile for this MIE is the only increase in this funding category relative to FY 2010.

- **Other National Laboratory Research** **17,190** **15,946**

Researchers at LANL, LBNL, LLNL, and ORNL provide support for the RHIC and LHC experiments and develop new instrumentation. They also provide unique expertise and facilities for RHIC and LHC detector upgrades and analyses of data. For example, at LBNL, the large scale computational system, Parallel Distributed Systems Facility (PDSF), is a major resource used for the analysis of RHIC and LHC data, in alliance with the National Energy Research Scientific Computing Center (NERSC). At LLNL, computing resources are made available for the LHC data analysis. LBNL leads the fabrication of the LHC Heavy Ion MIE, a joint project with France and Italy that adds a large Electromagnetic Calorimeter (EMCal) to the CERN ALICE heavy ion experiment to provide the capability to study energy loss in the quark-gluon plasma. Funding support for the EMCal is completed in FY 2011 according to the planned profile. Funding requested in FY 2012 holds research funding and efforts at the national laboratories flat relative to FY 2010, but supports increased mandatory LHC fees.

- **Other Research** **1,270** **7,042**

  - **SBIR and Other** **0 5,742**

In FY 2010, $5,662,000 was transferred to the Small Business Innovative Research (SBIR) program. This activity includes $5,673,000 for SBIR in FY 2012, as well as other established obligations of the Nuclear Physics program.

  - **Accelerator R&D Research** **1,270 1,300**

The Heavy Ion Accelerator R&D research at universities and laboratories will develop the knowledge, technologies, and trained scientists to design and build the next-generation NP accelerator facilities. These programmatic activities are of relevance to machines being developed by other domestic and international programs and can lead to technological advances that are relevant to a variety of applications. Allocation of these funds is competed among university and laboratory proposals and is determined by peer review.

Operations 162,105 **169,610**

- **RHIC Operations** **157,195** **164,610**

RHIC operations are supported for an estimated 3,040 hour operating schedule (74 percent utilization) in FY 2012, a decrease of 540 hours from that achieved in FY 2010, which will be focused on addressing the highest priority scientific opportunities and goals of this program for this year.

The Electron Beam Ion Source (EBIS) construction project was completed in FY 2010 and its implementation, along with detector upgrades, will allow the RHIC program to make incisive

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

measurements leading to better insights into the discovery of strongly interacting quark gluon matter and to establish whether other phenomena, such as a color glass condensate or chiral symmetry restoration exist in nature. EBIS will also lead to more cost-effective operations of the facility as it replaces the aging Tandems as part of the RHIC injector. DOE and NASA partnered on the construction of EBIS, and this project will also provide new capabilities to the NASA Space Radiation Laboratory Program.

- **RHIC Accelerator Operations** **121,935** **127,797**

  Funding continues to operate RHIC and maintains the level of effort. Support is provided for the operations, power costs, capital infrastructure investments, and accelerator improvement projects of the RHIC accelerator complex. This includes the new EBIS injector, the Booster, and AGS accelerators that together serve as the injector for RHIC. Modest support is provided for R&D of electron beam cooling and other luminosity enhancement technologies. Funding is also provided to reduce the backlog of infrastructure items that most impede the cost-effective and efficient operations of the facility. Operations of RHIC also support parallel and cost-effective operations of the NASA Space Radiation Laboratory Program, for the study of space radiation effects applicable to human space flight, and the Brookhaven Linac Isotope Production Facility (BLIP), for the production of research and commercial isotopes critically needed by the Nation. BNL has nurtured important core competencies in accelerator physics techniques, which have had applications in industry, medicine, homeland security, and other scientific projects outside of NP. The RHIC accelerator physicists have been leading the effort to address technical feasibility issues of relevance to a possible next-generation collider, including beam cooling techniques and energy recovery linacs. RHIC accelerator physicists also play an important role in the education of next generation accelerator physicists, with support of graduate and post-doctoral students. The laboratory supports the Center for Accelerator Science and Education (CASE) in partnership with Stony Brook University. CASE takes advantage of the collaboration with BNL by providing opportunities for students to learn on the state-of-the-art accelerators at BNL and having BNL staff teach courses and advise students.

	FY 2010	FY 2012
RHIC Hours of Operation with Beam		
Achieved Operating Hours	3,580	N/A
Planned Operating Hours	3,350	3,040
Optimal Hours	4,100	4,100
Percent of Optimal Hours	87%	74%
Unscheduled Downtime	17%	N/A
Number of Users	1,200	1,200

- **RHIC Experimental Support** **35,260 36,813**

  Support is provided for the operation, maintenance, improvement, and enhancement of the RHIC experimental complex, including the STAR and PHENIX detectors, the experimental halls, and

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

the RHIC Computing Facility, as well as support for users. Funding maintains the level of effort. The STAR and PHENIX detectors provide complementary measurements, with some overlap, in order to cross-calibrate the measurements. Instrumentation advances by this community have led to practical applications in medical imaging and homeland security. Capital equipment funding is provided to maintain computing capabilities at the RHIC Computing Facility.

▪ **Other Operations**	**4,910**	**5,000**

The Nuclear Physics program provides funding to BNL for minor new fabrications, needed laboratory equipment (including general purpose equipment), and other expenses. Funding of this type is essential for maintaining the productivity and usefulness of DOE-owned facilities and for meeting its requirement for safe and reliable facilities operations.

Total, Heavy Ion Nuclear Physics	**205,063**	**219,984**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **University Research**	
The increase supports required M&O costs for research at the LHC heavy ion program and operational funding for the STAR Time of Flight MIE that was completed at the end of FY 2009.	+735
▪ **National Laboratory Research**	
• **BNL RHIC Research**	
Funding is increased relative to FY 2010 due to the planned increase for the fabrication of the STAR Heavy Flavor Tracker MIE project.	+2,153
• **Other National Laboratory Research**	
The decrease for the LHC Heavy Ion MIE according to the planned profile, is offset by increased support required for LHC M&O fees and computing costs, and for research efforts needed for the utilization of the recently completed Major Items of Equipment at RHIC and the LHC.	-1,244
Total, National Laboratory Research	**+909**
▪ **Other Research**	
• **SBIR and Other**	
Funding increases relative to FY 2010 because the mandated SBIR set-aside has been transferred out of the program in FY 2010 while those funds are included in the FY 2012 request.	+5,742

	FY 2012 vs. FY 2010 Current Approp. ($000)
• **Accelerator R&D Research**	
This increase reflects a shift of a portion of the funding from the Medium Energy subprogram for Accelerator R&D.	+30
Total, Other Research	**+5,772**
Total, Research	**+7,416**
Operations	
▪ **RHIC Operations**	
• **RHIC Accelerator Operations**	
The increase from FY 2010 to FY 2012 maintains staff, required materials and supplies, and power costs for effective operations of the facility.	+5,862
• **RHIC Experimental Support**	
The increase in FY 2012 is needed to effectively support the requirements of the RHIC scientific research program consistent with the planned level of operations.	+1,553
Total, RHIC Operations	**+7,415**
▪ **Other Operations**	
A small increase over FY 2010 is provided to maintain a constant level of purchases for BNL lab-wide general purpose equipment.	+90
Total, Operations	**+7,505**
Total Funding Change, Heavy Ion Nuclear Physics	**+14,921**

Low Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Low Energy Nuclear Physics		
Research		
University Research	25,624	21,295
National Laboratory Research	40,458	39,711
Other Research[a]	585	2,452
Total, Research	66,667	63,458
Operations	37,549	33,078
Facility for Rare Isotope Beams	12,000	30,000
Total, Low Energy Nuclear Physics	116,216	126,536

Description

The research effort supported by the Low Energy Nuclear Physics subprogram focuses primarily on answering the overarching questions associated with the second and third frontiers identified by NSAC. Questions associated with the second frontier, 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? Major goals of this subprogram are to develop a comprehensive description of nuclei across the entire nuclear chart, to utilize rare isotope beams to reveal new nuclear phenomena and structures unlike those gleaned from studies using stable nuclei, and to measure the cross sections of nuclear reactions that power stars and spectacular stellar explosions and are responsible for the synthesis of the elements.

The subprogram also investigates aspects of the third frontier, Fundamental Symmetries and Interactions, using neutrinos and neutrons as primary probes. Questions addressed in this frontier include: What is the nature of the neutrinos, what are their masses, and how have they shaped the evolution of the universe? Why is there now more visible matter than antimatter in the universe? What are the unseen forces that were present at the dawn of the universe but disappeared from view as the universe evolved? Neutrinos are now known to have small but non-zero masses. The subprogram seeks to measure or set a limit on the neutrino mass and to determine if the neutrino is its own anti-particle (a Majorana particle). These neutrino properties are believed to play a role in the evolution of the cosmos. Beams of cold and ultracold neutrons will be used for precision measurements of neutron lifetime and beta-decay parameters and to investigate the dominance of matter over antimatter in the universe in order to answer fundamental questions in nuclear and particle physics, astrophysics, and cosmology.

Funding supported both research and operations of the subprogram's two national user facilities, HRIBF and ATLAS, which serve an international community of approximately 700 users. The FY 2012 request

[a] In FY 2010, $1,426,000 was transferred to the SBIR program. This activity includes $1,528,000 for SBIR in FY FY 2012.

ceases operations of HRIBF as a national user facility in order to support higher priority activities within the Nuclear Physics program. Operations of ATLAS will continue to provide beams for nuclear structure and astrophysics studies and a strong training ground for the next generation Facility for Rare Isotope Beams (FRIB), which will be constructed at MSU. ATLAS possesses unique capabilities in an international context and has cutting edge instrumentation. With the commissioning of the Californium Rare Ion Breeder Upgrade (CARIBU) at ATLAS in FY 2011, the ATLAS research program will be optimized in FY 2012 to achieve the highest priority scientific goals for this field, and mitigate some of the impact of the reduced radioactive ion beam hours due to the cessation of operations at HRIBF.

Fabrication of the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA) MIE is on schedule for completion in FY 2011. GRETINA, a segmented germanium detector array with unparalleled position and energy resolution for nuclear structure studies with fast nuclear beams, will rotate to locations among the domestic low-energy facilities thereby increasing scientific productivity. NP also supports the LBNL 88-Inch Cyclotron for a small in-house nuclear physics and chemistry research program, while the National Reconnaissance Office (NRO) and U.S. Air Force (USAF) provide support towards improvements in radiation hardness of electronic circuit components against damage caused by cosmic rays. Support is terminated in FY 2012 for the Rare Isotope Beam Science Initiatives. A limited number of small research initiatives, selected by peer review, are being pursued in FY 2010.

In addition, the subprogram supports accelerator operations at two university Centers of Excellence including the Cyclotron Institute at Texas A&M University (TAMU), which will soon begin to provide a set of reaccelerated radioactive ion beams that are complementary to those available elsewhere in the U.S. The Cyclotron Institute receives significant additional funds from TAMU and private foundations in Texas. The subprogram also supports operations of the HIGS facility at the Triangle Universities Nuclear Laboratory (TUNL) at Duke University. At the University of Washington, the subprogram supports infrastructure to develop scientific instrumentation projects and to provide technical and engineering educational opportunities. These university Centers of Excellence each support 15–25 graduate students at different stages of their education. No funding is requested in FY 2012 for operations of the accelerator facility at Yale University; transition plans for the staff and facility are being developed.

Progress in both nuclear structure and nuclear astrophysics studies depends increasingly upon the availability of rare isotope beams. While ATLAS has capabilities for these studies, one of the highest priorities for the NP program is support of a facility with next-generation capabilities for short-lived radioactive beams. FRIB construction is supported with operating funding through a Cooperative Agreement with Michigan State University (MSU) and is following the management principles of DOE O 413.3B. While not a DOE capital asset (the facility will be owned by the university) it will be operated as a DOE national user facility upon completion. In FY 2012, engineering and design activities continue on FRIB and long-lead procurements that will reduce project risks are initiated. A phased construction start is also being considered in FY 2012 to reduce project risks.

In the area of neutrino physics, U.S. researchers are involved in several important efforts focused primarily on neutrino mass and whether the neutrino is its own anti-particle. The U.S. continues to participate in the fabrication of the Italian-led Cryogenic Underground Observatory for Rare Events (CUORE) experiment at the Gran Sasso Laboratory to search for evidence that the neutrino is its own antiparticle and measure or set a limit on the effective Majorana neutrino mass using the neutrinoless double beta decay (DBD) mechanism. Work will also continue in FY 2012 on the Majorana Demonstrator R&D effort to determine technical feasibility of using high purity, enriched germanium to explore the nature of the neutrino via DBD. Projects that study DBD with much increased sensitivity such as these will address two fundamental properties of the neutrino, the hierarchy of the masses and its particle-antiparticle nature, that are important for understanding the matter-antimatter asymmetry in the universe and the evolution of the cosmos. U.S. university scientists are also participating in the fabrication of the German-lead Karlsruhe Tritium Neutrino (KATRIN) experiment to determine the mass of the electron neutrino by measuring the beta decay spectrum of tritium.

The Low Energy subprogram supports studies of fundamental interactions and symmetries using neutrons or nuclei. Sensitive experiments are being prepared to be mounted at the Fundamental Neutron Physics Beamline (FNPB), which was completed in FY 2010 on cost and schedule at the Spallation Neutron Source. These include the neutron Electric Dipole Moment Experiment MIE currently being developed at Oak Ridge National Laboratory, which could shed light on why the universe is composed mostly of matter when the Big Bang Theory of cosmology suggests that the universe should contain equal amounts of matter and anti-matter. The NSAC has recently been charged to assess the national neutron physics program and provide guidance in terms of its optimization.

Finally, it is within the Low Energy subprogram, as well as the Theory subprogram, that the Applications for Nuclear Science and Technology initiative is supported. This effort, started in FY 2009 and augmented with Recovery Act funds, supports basic nuclear physics research that addresses high priority scientific goals and has practical applications to other fields, such as medicine, next-generation nuclear reactors, and homeland security.

The Low Energy subprogram is the most diverse within the NP portfolio, supporting research activities aligned with diverse scientific thrusts. It also currently supports the most instrumentation projects, as well as the Majorana Demonstrator R&D effort and the Cooperative Agreement to construct FRIB; most of these initiatives are international in nature and project profiles are optimized to take advantage of international commitments. The funding request in FY 2012 is driven by the FRIB profile, the funding profile for the Majorana Demonstrator R&D effort, and an investment to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided from the High Energy Physics program. Nuclear Physics will assess options for a future neutrinoless double beta decay experiment.

Selected FY 2010 Accomplishments

- An international team of scientists from Russia and the United States, including two DOE national laboratories and two universities, has discovered element-117, the newest super heavy element. Discovery of element-117 was accomplished following nearly three months of bombardment of a radioactive berkelium-249 target (produced at the High Flux Isotope Reactor at ORNL through the DOE Isotope Program) with intense beams of calcium-48 at the Joint Institute for Nuclear Research cyclotron in Dubna, Russia. This discovery represents the latest and the most challenging successful step in a decades-long journey to expand the periodic table.
- Tin-132, an unstable isotope, is one of the small and special group of nuclei with "magic" numbers of both protons and neutrons (magic numbers characterize shell structure of nuclei). In a recent experiment at HRIBF, researchers measured the properties of the single neutrons that were transferred from a deuterium target to a beam of radioactive tin-132 ions. The observed purity of the single-particle states provides evidence that tin-132 represents a text-book example of a doubly-magic nucleus. These results, reported in the journal *Nature*, are critical to benchmarking the nuclear shell model, to extrapolating theoretical nuclear models beyond the reach of current experimental facilities and to simulating the synthesis of nuclei heavier than iron in the cosmos.

- A new critical survey of the fastest known nuclear beta decays, which incorporates a substantial amount of new data as well as improved calculations of correction terms, places tighter constraints on models that aim at extending the Standard Model. These advances allow scientists to better understand the quark properties of nucleons.
- The new HELIcal Orbit Spectrometer (HELIOS) developed at the ATLAS Facility at ANL has recently been used to make the most precise measurements to date of the internal structure of two excited states of boron-13, an exotic nucleus containing an unusually high ratio of neutrons to protons. This study demonstrates that HELIOS can overcome the special challenges of studying reactions in inverse kinematics, where light target nuclei (e.g., deuterium) are bombarded by heavy exotic beams, in this case a boron-12 radioactive beam. The technique will play an essential role in investigations of the structural properties of the neutron-rich nuclei that will become available in abundance at the future FRIB facility.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	**66,667**	**63,458**
▪ **University Research**	**25,624**	**21,295**

Research aimed at addressing high priority scientific goals is supported for about 126 scientists and 98 graduate students at 35 universities. University research is held flat in FY 2012 and the Yale University accelerator facility is terminated, with the funds reallocated to other higher priorities within the NP program. About two-thirds of the supported university scientists have conducted nuclear structure and astrophysics research using specialized instrumentation at the ATLAS and HRIBF national user facilities. During FY 2012, university researchers who conducted research at HRIBF will complete analyses of data obtained in prior years, then will need to transition to other efforts.

Accelerator operations are supported primarily for in-house research programs at the Duke University and TAMU facilities. These Centers of Excellence have well-defined and unique physics programs, providing photons, neutrons, light or heavy ion beams, radioactive ion beams, specialized instrumentation, and opportunities for long-term measurements that complement the capabilities of the national laboratory user facilities; they also provide excellent training opportunities to junior scientists and engineers.

Funding in FY 2010 includes four university awards selected under the Rare Isotope Beam Science Initiatives to fabricate instrumentation creating forefront science opportunities at leading rare isotope beam facilities around the world. The initiative is terminated in FY 2012 to fund higher priority activities.

University scientists are supported to play key roles in the development of experiments using cold neutrons at the SNS FNPB, an experimental program which is being launched in FY 2011. The FY 2012 request also includes support for the international KATRIN project which is led by a university group.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **National Laboratory Research**	**40,458**	**39,711**

Support is provided for the research programs at six national laboratories (ANL, BNL, LBNL, LANL, LLNL, and ORNL). Scientists at these laboratories continue to develop and implement new instrumentation; provide maintenance and infrastructure support of the ATLAS, and perform analysis on HRIBF data in FY 2012; effectively utilize beam time for research; train junior scientists; develop and utilize non-accelerator experiments; and support the development and fabrication of FRIB. Funding decisions are influenced by the results of peer reviews of the national laboratory research groups and their subsequent ranking in terms of performance level.

• **National Laboratory User Facility Research**	**9,136**	**9,136**

Questions fundamental to the understanding of stellar nucleosynthesis—how the elements are manufactured in stars—require accelerators with low energy capabilities. Because many nuclear reactions that take place in stars are at very low energies, an accelerator capable of producing stable low energy beams is a requirement. Funding is provided for ANL researchers for nuclear structure studies using stable and selected radioactive beams from ATLAS coupled to specialized instrumentation. Modest capital equipment investments support the fabrication and implementation of small-scale detectors at the facility. The most recent addition to the unique instrumentation at ATLAS is the HELIOS, a novel superconducting solenoidal spectrometer that probes the structure of exotic nuclei.

Because stars generate heavier elements from lighter ones in a process that takes place in their cores, or through stellar explosions, many of the intermediate nuclei that are produced are short-lived and very unstable. To study them requires accelerators capable of producing beams composed of radioactive ions. The CARIBU source at ATLAS provides limited capabilities to produce radioactive ion beams, while FRIB will be the world-leading facility for rare ion beams when operational. In FY 2012, with the cessation of operations at HRIBF as a national user facility, ORNL researchers will be completing analyses of data obtained from HRIBF in prior years.

• **Other National Laboratory Research**	**31,322**	**30,575**

Scientists at BNL, LBNL, LLNL, LANL, and ORNL play lead roles in several ongoing accelerator- and non-accelerator-based projects (nEDM, CUORE, GRETINA, FNPB instrumentation, and KamLAND). Both nEDM and CUORE are joint DOE/NSF-supported projects, but are managed by DOE-supported scientists. In addition, DOE-supported scientists have the lead role in the R&D to demonstrate a proof of principle for a neutrino-less double beta decay experiment with germanium detectors, the Majorana Demonstrator. The total project cost of the Majorana R&D effort over four years (FY 2010- FY 2013) is approximately $20,000,000. Researchers are also supported to develop and implement neutron science experiments at the newly completed Fundamental Neutron Physics Beamline at the Spallation Neutron Source and to contribute to FRIB project development efforts. Funding in FY 2012 is increased for the Majorana Demonstrator R&D effort and for transitioning to operations of new MIE instrumentation projects as they come on-line or near completion, including, GRETINA and experiments at the FNPB. The profile for the Majorana R&D supports decision points aligned

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

with international efforts to make a technology choice and merge international collaborations for the most cost-effective approach to a future large-scale detector.

In addition, support is provided for ORNL to continue to play a leadership role in the development of the scientific and experimental program with neutrons at the FNPB to exploit new capabilities recently made available, which will deliver cold and ultra-cold neutrons at the highest intensities in the world for studying the fundamental properties of the neutron, leading to a refined characterization of the weak force.

Research efforts relevant to Applications of Nuclear Science and Technology continue in FY 2012. This initiative is competed among university and laboratory researchers and supports nuclear science research that is inherently relevant to a broad range of applications. Additional funds for this initiative are included in the Theory subprogram under Nuclear Data.

In FY 2012, funding for a number of the instrumentation MIEs supported within this activity decreases:

- ▸ Planned funding is reduced for the neutron Electric Dipole Moment (nEDM) MIE, an R&D intensive and technically challenging discovery experiment that is planned at the FNPB. The nEDM experiment is a joint DOE/NSF experiment to measure or set a limit on the electric dipole moment of the neutron, which could significantly constrain extensions of the Standard Model. R&D will continue in FY 2012 while NSAC reviews priorities in the U.S. neutron science portfolio.
- ▸ Funding is terminated for Rare Isotope Beam Science Initiatives in order to support other higher priority needs of the NP program. A limited number of the smaller initiatives, selected by peer review, are being supported in FY 2010 and FY 2011 (some of the funding was awarded under University Research above). The larger MIEs planned for initiation will no longer be pursued. These projects were intended to foster international collaboration in rare isotope science and provide opportunities to the domestic rare isotope beam science community as FRIB is being constructed.
- ▸ FY 2012 is the final year of funding for fabrication of the international CUORE experiment to search for neutrino-less double beta decay (DBD) of tellurium-130 isotope. This is a joint DOE/NSF project.

▪ **Other Research**	**585**	**2,452**

In FY 2010, $1,426,000 was transferred to the SBIR program. This activity includes $1,528,000 for SBIR in FY 2012. Funding is also provided for other established obligations including the Lawrence and Fermi Awards, which provide annual monetary awards to honorees selected by DOE for outstanding contributions to science. Starting in FY 2012, Lawrence Awards and Fermi Awards will be made each year; in the past, the awards were provided in alternating years.

Operations 37,549		**33,078**
▪ **ATLAS Operations**	**16,216**	**16,762**

The ATLAS Facility is the premiere stable beam facility in the world. ATLAS accelerator operations and experimental support provide for 5,900 beam hours of operation and continued cost-effective

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

7 day-a-week operations in FY 2012. The modest increase in funding in FY 2012 maintains level of effort support for scientific and technical personnel and required materials and supplies to operate the facility. The Californium Rare Ion Breeder Upgrade (CARIBU) accelerator improvement project will be completed in FY 2011, and will enhance the radioactive beam capabilities and productivity of ATLAS. Accelerator improvement projects in FY 2012 are focused on increasing the reliability and efficiency of operations. Modest capital equipment funding is provided for helium compressors and cryogenic system upgrades to improve operations. The ATLAS facility nurtures a core competency in accelerator expertise with superconducting radio frequency cavities for heavy ions that is relevant to the next generation of high-performance proton and heavy-ion linacs, and is important to the Office of Science mission and international stable and radioactive ion beam facilities. ANL accelerator physicists and scientists are working closely with MSU researchers in the development and fabrication of components for FRIB.

	FY 2010	FY 2012
ATLAS Hours of Operation with Beam		
Achieved Operating Hours	5,940	N/A
Planned Operating Hours	5,900	5,900
Optimal Hours	6,600	6,200[a]
Percent of Optimal Hours	90%	95%
Unscheduled Downtime	8%	N/A
Number of Users	410	430

- **HRIBF Operations** **17,080** **6,821**

Operation of HRIBF through FY 2011 provides unique capabilities for the production of intense radioactive beams by the Isotope-Separator-On-Line (ISOL) technique, and for reaccelerating medium mass nuclei to the Coulomb barrier. Core competencies developed through this research include high power target design and ISOL ion beam production techniques which will have importance for the future Facility for Rare Isotope Beams and other rare isotope beam facilities. HRIBF accelerator operations cease in FY 2012, and funding is provided for an orderly ramp down of the facility. Assessments are ongoing as to whether it may be possible to complete high priority experiments in FY 2012.

[a] Based on the most recent review of operations at ATLAS, the quality and quantity of the scientific output is best optimized with 6,200 operating hours.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request

	FY 2010	FY 2012
HRIBF Hours of Operation with Beam		
Achieved Operating Hours	5,270	N/A
Planned Operating Hours	5,200	0
Optimal Hours	6,100	0
Percent of Optimal Hours	86%	0%
Unscheduled Downtime	13%	N/A
Number of Users	260	0

- **Other Operations** **4,253** **9,495**

  The NRO and USAF will continue to jointly provide support for the 88-Inch Cyclotron for approximately 2,000 hours for their electronics testing program, and NP continues support in FY 2012 for approximately 3,000 hours for the in-house nuclear physics research program at LBNL consistent with the Interagency Agreement with NRO and USAF. Funding is also provided for maintenance of the Oak Ridge Electron Accelerator (ORELA).

  In FY 2012, $5,000,000 is provided to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided from the High Energy Physics program. Nuclear Physics will assess options for a future neutrinoless double beta decay experiment.

Facility for Rare Isotope Beams **12,000 30,000**

Funds are requested in FY 2012 to continue engineering and design efforts aimed at developing FRIB, and pursue long-lead procurements and possibly a phased construction start that will reduce project risks. MSU is undertaking a comprehensive R&D plan for FRIB, which includes utilizing core competencies developed by the NP-supported national laboratory groups. This facility will enable world-leading research opportunities in nuclear structure, nuclear astrophysics, and fundamental symmetry studies, and complement other rare isotope beam research programs at facilities elsewhere in the world. The FY 2012 funding supports the project profile as agreed upon between MSU and DOE (for additional details, see the Supporting Information section at the end of the NP budget).

Total, Low Energy Nuclear Physics **116,216 126,536**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **University Research**	
The major funding decreases relative to FY 2010 are: the termination of university Rare Isotope Beam initiatives in FY 2012; funding that was awarded to universities under Applications of Nuclear Science and Technology in FY 2010 but is held under Other National Laboratory Research in FY 2012 pending competitive peer review; and the end of operations of the accelerator facility at Yale University. The decreases are partially offset by increases for costs associated with operating the CUORE-0 tower and operational costs for the recently upgraded accelerator at Texas A&M University and the KATRIN experiment.	-4,329
▪ **National Laboratory Research**	
• **Other National Laboratory Research**	
The major funding decreases relative to FY 2010 are termination of Rare Isotope Beam Science Initiatives, which provided awards under this activity in FY 2010; planned project profiles for CUORE, which receives its last year of funding FY 2012, and GRETINA, which received its last year of funding in FY 2010; and a decrease in the profile for the nEDM MIE, which is less than originally planned. nEDM is slowed as funds are redirected to higher priority activities. The decreases are partially offset by increases for the Majorana Demonstrator R&D project which ramps to its planned peak funding year in FY 2012 to enable a technology choice with international collaborators; the development of experiments for the new neutron science program at the FNPB to exploit new capabilities recently made available with the completion of the FNPB MIE; operations of the GRETINA MIE, which will just be transitioning to operations in FY 2012; and the development of the double beta decay scientific effort which implements the Majorana R&D program.	-747
▪ **Other Research**	
• **SBIR and Other**	
Funding increases relative to FY 2010 because the mandated SBIR set-aside has been transferred out of the program in FY 2010 while those funds are included in the FY 2012 request. In addition, funding is increased to support annual Fermi and Lawrence awards.	+1,867
Total, Research	**-3,209**

	FY 2012 vs. FY 2010 Current Approp. ($000)
Operations	
▪ **ATLAS Operations**	
ATLAS Operations funding reflects an increase to maintain staff and effectively operate this national user facility.	+546
▪ **HRIBF Operations**	
HRIBF operations funding is reduced and the facility is closed as a national user facility in FY 2012.	-10,259
▪ **Other Operations**	
The majority of the increase is provided to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided from the High Energy Physics program. Nuclear Physics will assess options for a future neutrinoless double beta decay experiment.	
A modest increase in funding is also provided to maintain operations at the 88-Inch Cyclotron consistent with the Interagency Agreement with the NRO and USAF.	+5,242
Total, Operations	**-4,471**
Facility for Rare Isotope Beams	
Funding for the Facility for Rare Isotope Beams increases to continue engineering and design work, and pursue long-lead procurements and possibly a phased construction start.	+18,000
Total Funding Change, Low Energy Nuclear Physics	**+10,320**

Nuclear Theory

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Nuclear Theory		
Theory Research		
University Research	15,723	16,593
National Laboratory Research	14,611	16,181
Scientific Discovery through Advanced Computing (SciDAC)	2,689	1,000
Total, Theory Research	33,023	33,774
Nuclear Data Activities	6,929	8,392
Total, Nuclear Theory	39,952	42,166

Description

The Nuclear Theory subprogram supports theoretical research at universities and DOE national laboratories with the goal of improving 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.

This subprogram addresses all three of nuclear physics' scientific frontiers. A major theme of this subprogram is an understanding of the mechanisms and effects of quark confinement and de-confinement. A quantitative description of these phenomena starting from the fundamental theory of QCD remains one of this subprogram's great intellectual challenges. New theoretical and computational tools are being developed to describe nuclear many-body phenomena, which will likely have 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 (as in supernovae) and the consequences that neutrino masses have for nuclear astrophysics and for the current theory of elementary particles and forces.

One area of nuclear theory that has a particularly pressing demand for large dedicated computational resources is that of lattice quantum chromodynamics (LQCD). LQCD calculations are critical for understanding many of the experimental results from RHIC and CEBAF that involve the strong interaction between quarks and gluons. This subprogram provides researchers with access to powerful supercomputers for these studies, such as the high-performance computational facility at the National Energy Research Scientific Computing Center (NERSC) at LBNL, as well as specialized computers at other institutions. The Nuclear Theory subprogram and the High Energy Physics (HEP) Theory subprogram began joint development in FY 2006 of large-scale facilities to provide computing capabilities based on community cluster systems. This LQCD initiative was followed by the joint 5-year HEP/NP LQCD-ext project in FY 2010. The NP LQCD computing capability at TJNAF was also augmented with Recovery Act funding In FY 2011, this computing equipment will have increased the overall U.S. computing capability for LQCD to a minimum of 45 sustained teraflops.

The Nuclear Theory subprogram also sponsors the Institute for Nuclear Theory (INT) at the University of Washington, which carries out a range of activities in support of the work of the nuclear physics community. INT includes visiting scientists, research fellows, postdoctoral fellows, graduate students, and several leading nuclear theorists as permanent staff; its organizational structure promotes cost effective collaboration and educational opportunities. INT also hosts a series of specialized research programs on specific topics in nuclear theory and related fields that are identified by the research community as being of high priority. The Nuclear Theory subprogram also supports targeted investments in short-term topical theory collaborations within the university and national laboratory communities to facilitate cooperation and communication on specialized nuclear theory challenges that require concerted effort in order to advance the field.

Another component of the Nuclear Theory subprogram is the National Nuclear Data program, which compiles, evaluates, and disseminates nuclear data for basic research and applications in an online database that is readily accessible and user oriented.

The Nuclear Theory subprogram is strengthened by its interactions with complementary programs overseas, NSF-supported theory efforts, the HEP program, Japanese-supported theoretical efforts related to RHIC at the RIKEN Center at BNL, and the Japan-U.S. and France-U.S. Theory Institutes for Physics with Exotic Nuclei (JUSTIPEN and FUSTIPEN).

In FY 2012, the Nuclear Theory subprogram will continue to support research that addresses the three scientific frontiers of nuclear physics, i.e. QCD, nuclear structure and astrophysics, and fundamental symmetries. The need for increased support for nuclear theory in order to accurately interpret the collected experimental results throughout the NP program has been recognized consistently in NSAC Long Range Plans (LRP) over the years. The 2002 LRP recommended that funding for nuclear theory be significantly increased because it is essential for developing the full potential of the scientific program. The 2007 LRP recommended topical collaborations in theory to launch focused efforts on particular challenges, which NP has implemented in FY 2010 with 5-year awards, funded annually, for three collaborations. These modest topical theory collaborations bring together theorists nationwide to more effectively address theoretical challenges—the peak activity of these small groups is reached in FY 2012. The focus of FY 2012 nuclear theory research will be on providing the necessary theoretical preparation for the upgraded CEBAF 12 GeV and new FRIB facilities under construction in order to fully exploit them, and will advance new ideas and hypotheses that stimulate specific experiments at these facilities and elsewhere, including in the area of fundamental symmetries. The FY 2012 NP request continues support of SciDAC, though at a reduced level, and provides a modest increase for the second-generation LQCD project in partnership with the DOE High Energy Physics program, according to project plans.

Selected FY 2010 Accomplishments

- LQCD calculations continue to bring exciting physics results and computational advances. The Hadron Spectrum Collaboration provided new physics insight into how quarks are bound in mesons and hadrons through the calculation of the masses of states with exotic quantum numbers from dynamic LQCD. The quantum numbers of exotic meson states cannot be constructed from the conventional excitations of a bound quark-anti-quark pair, and the existence of these states may signal the explicit influence of the gluons that bind quarks together.
- In a recent computational advance, attained in the framework of the national USQCD collaboration and the SciDAC funded software infrastructure project for Lattice Field Theory, parallelization onto multiple graphical processing units enabled the analysis of large space-time lattices at a performance of over 3 teraflops, an order of magnitude increase in speed in critically important calculations. This was made possible by a project funded under the Recovery Act.

- Starting from the interaction between nucleons, ab initio no-core, full-configuration shell model calculations of nuclear structure and excitations were extended to such systems as the speculative proton-rich fluorine-14 nucleus, the existence of which is being sought experimentally. Such calculations provide important guidance for DOE-supported experiments, test the theory of strong interactions, and may be important for improved energy sources.
- An aspect of the fundamental problem of the origin of baryonic matter of the Universe was addressed in the context of the Minimal Supersymmetric Standard Model (MSSM) by exploring the implications of electroweak baryogenesis for future searches for permanent electric dipole moments (EDMs). This required the derivation and solution of a large set of coupled quantum Boltzmann equations to follow the appropriate chain of particle number changing reactions. The main result is that lower limits on the size of the EDMs are derived, typically of the same order (or above) as the expected sensitivity of proposed experimental searches. Thus, such experiments may be able to provide a test of MSSM electroweak baryogenesis.
- Theorists explored charge fluctuations associated with the spontaneous generation of domains filled with color electric and color magnetic fields in a new form of matter discovered at RHIC. Results from collisions of heavy ions that exhibit this phenomenon indicate the matter which is formed has unique characteristics which can advance knowledge of the fundamental symmetries of nature and universal properties of physical systems (for example collections of excited atoms) in which the constituents interact strongly with one another. In addition, similarities in the interaction between the constituents of the matter discovered at RHIC and the interaction between the constituents of some nano-materials (for example single layers of graphite, known as graphene) are being studied for possible analogy and insight into the use of graphene as a conductor of spin-polarized electric current. A press release on these results at the 2010 American Physical Society April meeting garnered worldwide interest with over 300 news articles in the popular media.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Theory Research	**33,023**	**33,774**
▪ **University Research**	**15,723**	**16,593**

The University Research activity supports the research of approximately 160 academic scientists and 120 graduate students through 76 research grants at 45 universities in 29 states and the District of Columbia. The overall nuclear theory effort is aligned with the experimental program through the program performance milestones established by NSAC.

Funding in FY 2012 will support the necessary level of theoretical effort needed for interpretation of experimental results obtained at the NP facilities and the training of next-generation nuclear theorists. The third year of funding is provided for the topical theory collaborations at the universities which received 5-year awards in FY 2010.

▪ **National Laboratory Research**	**14,611**	**16,181**

Research programs in nuclear theory are supported at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF) to achieve high priority scientific goals and interpret experimental results. The theoretical research at a given laboratory is primarily aligned to the experimental program at that laboratory, or in some cases to take advantage of the unique facilities

(dollars in thousands)

FY 2010 Current Appropriation	FY 2012 Request

or programs at that laboratory. In FY 2012, investments in LQCD computer capabilities are increased in a joint effort with High Energy Physics, LQCD-ext, and support is provided to build the theoretical research groups in preparation for Hall D operations at TJNAF. Starting in FY 2010, this budget category includes support for topical theory collaborations at the National Laboratories which received 5-year awards in FY 2010 after a peer-reviewed competition between groups formed by university-laboratory partnerships. Funding for university collaborators is shown in University Research, above. The funded topical collaborations address QCD in the heavy-ion environment (JET); neutrinos and nucleosynthesis in hot and dense matter (NuN); and low-energy nuclear reactions for unstable isotopes (TORUS).

In FY 2009, the base programs of the seven laboratory theory groups were evaluated on the significance of their accomplishments and planned future program; scientific leadership, creativity, and productivity of the personnel; and the overall cost-effectiveness of the group, and the results of this review are reflected in this budget request.

- **Scientific Discovery through Advanced Computing (SciDAC) 2,689 1,000**

  SciDAC, a collaborative program that partners scientists and computer experts in research teams to address major scientific challenges that require supercomputer facilities at the current technological limits, is supported at a reduced level in FY 2012. The NP SciDAC program supports jointly funded research projects with other offices in areas such as nuclear astrophysics, grid computing, lattice quantum chromodynamics, low energy nuclear structure and nuclear reaction theory, and advanced accelerator design.

Nuclear Data Activities 6,929 8,392

This effort involves the work of several national laboratories and universities and is guided by the DOE-managed National Nuclear Data Center (NNDC) at BNL. The NNDC relies on the U.S. Nuclear Data Network, a group of DOE-supported individual nuclear data professionals located in universities and national laboratories that perform assessment, and validate and estimate uncertainty, as well as developing modern network dissemination capabilities. The databases developed and maintained by the Nuclear Data program cover over 100 years of nuclear science research. The NNDC participates in the International Data Committee of the International Atomic Energy Agency and is an important national and international resource.

Independent of the core Nuclear Data activities, funding is also included to support initiatives in Applications of Nuclear Science and Technology, including efforts relevant to nuclear fuel cycles. This initiative is funded from both the Low Energy subprogram and the Nuclear Data program, and funding is split between the two pending competitive peer review and award. In FY 2010, one laboratory award was made in the area of Nuclear Data for cross section measurement and evaluation for nuclear applications. The balance of the university and laboratory funding was awarded under the Low Energy subprogram.

Total, Nuclear Theory 39,952 42,166

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Theory Research	
▪ **University Research**	
The increase in FY 2012 maintains university nuclear theory efforts, provides support for groups preparing for Hall D at CEBAF, and provides for the third year of the university component of topical theory collaborations.	+870
▪ **National Laboratory Research**	
The FY 2012 funding provides a planned increase in support of the LQCD initiative, LQCD-ext, which is jointly funded with HEP, and builds the theoretical research efforts in preparation of the Hall D experimental program at CEBAF. Funding is also provided for the third year of the national laboratory component of the topical theory collaborations.	+1,570
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	
NP's support of SciDAC is reduced in FY 2012 in order to reallocate funds to higher priority NP activities.	-1,689
Total, Theory Research	**+751**
• **Nuclear Data Activities**	
Increased funding relative to FY 2010 is almost entirely due to the funds in the Nuclear Data subprogram that will support new Applications of Nuclear Science and Technology awards in FY 2012 pending competitive peer review. The combined funding for these awards in Nuclear Data and Low Energy is slightly below FY 2010.	+1,463
Total Funding Change, Nuclear Theory	**+2,214**

Isotope Development and Production for Research and Applications

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Isotope Development and Production for Research and Applications		
Research		
National Laboratory Research	650	2,594
University Research	2,350	1,648
Other Research[a]	0	97
Total, Research	3,000	4,339
Operations		
University Operations	250	208
Isotope Production Facility Operations	1,068	1,072
Brookhaven Linac Isotope Producer Operations	500	536
National Isotope Development Center (NIDC)	1,915	2,227
Other National Laboratory Operations	12,383	11,852
Total, Operations	16,116	15,895
Total, Isotope Development and Production for Research and Applications	19,116	20,234

Description

The primary goal of this subprogram is to support research, development, and production of research and commercial isotopes that are of critical importance to the Nation and in short supply. To achieve this goal, the Isotope Development and Production for Research and Applications subprogram provides facilities and capabilities for the production of research and commercial stable and radioactive isotopes, scientific and technical staff associated with general isotope research and production, and a supply of critical isotopes to address the needs of the Nation. The immediate benefits of a viable isotope production component of the Isotope Development and Production for Research and Applications subprogram include the availability of research and commercial isotopes that otherwise would not have been possible, reduced dependence on foreign supplies, new scientific applications for isotopes not currently supplied, the development of more effective isotope production and processing techniques, and the ability to meet both present and future research needs for isotopes. The subprogram places an emphasis on the 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.

Stable and radioactive isotopes play a crucial role in basic research, medicine, industry, and homeland defense and are vital to the mission of many Federal agencies. Federal agencies utilizing isotopes produced by the program include the National Institutes of Health and their grantees, the National Institute of Standards and Technology, the Environmental Protection Agency, the Department of

[a] In FY 2010, $75,000 was transferred to the SBIR program and $9,000 was transferred for the STTR program. This activity includes FY $86,000 for SBIR and $11,000 for STTR in FY 2012.

Agriculture, the Department of Homeland Security, other Federal agencies, the National Nuclear Security Administration (NNSA), and other Office of Science programs.

Isotopes are 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 use for heart imaging; germanium-68 use for calibrating the growing numbers of imaging scanners; arsenic-73 use as a tracer for environmental research; silicon-32 use in oceanographic studies related to climate modeling; and nickel-63 use as a component in gas sensing devices or helium-3 as a component in neutron detectors, both for applications in homeland defense. Some isotopes are critical resources to very diverse operations in industry and science and have a profound impact on the Nation's economy and national security. Californium-252, for example, is used in a wide array of applications for medicine, homeland defense, and energy security. The consequences of shortages of radioactive and stable isotopes needed for research, medicine, homeland security, and industrial applications can be extremely serious, including decreased capacity to perform routine diagnostic medical procedures and treatments and the failure to detect terrorist threats.

Isotopes are primarily generated using the Brookhaven Linac Isotope Producer (BLIP) at BNL and the Isotope Production Facility (IPF) at LANL for which the subprogram has stewardship responsibilities. Hot cell facilities at Brookhaven, Oak Ridge, and Los Alamos National Laboratories are used and maintained for processing and handling irradiated materials and purified products. Facilities at other national laboratories are used as needed, such as the production of isotopes at Oak Ridge and Idaho National Laboratory reactors and processing and packaging strontium-90 from the Pacific Northwest National Laboratory. Over 50 researchers and staff at the national laboratories are supported to provide the technical expertise in research, development, and transportation of isotopes. Research and development includes target fabrication, enhanced processing techniques, radiochemistry, material conversions, and other related services.

The Nuclear Science Advisory Committee (NSAC) was charged in August 2008 to develop a prioritized list of research topics using isotopes, and to develop a long-range strategic plan for stable and radioactive isotope production. The first NSAC report, released in April 2009, includes federal, commercial, and community input and establishes priorities for the production of research isotopes. Following release of the report, NP issued a broad call to university, laboratory, and commercial facilities, inviting them to submit proposals describing their capabilities for producing these high priority research isotopes. These proposals were reviewed and selections were made based on cost and products in short supply; the result is that the Isotope Program is establishing new production capabilities at other laboratory sites and university facilities to optimize its ability to supply reliable sources of research isotopes at more affordable prices. An announcement through the National Isotope Development Center is now planned to notify the broad research community of the isotopes that can be produced at the increased suite of facilities and to solicit interest in the demand for these isotopes so that production schedules can be developed and coordinated. The second NSAC report on a long-range strategic plan was released in November 2009.[a]

NP continues to work in close collaboration with other federal agencies to develop strategic plans for isotope production. A goal of the program is to establish effective communication with federal agencies to better forecast isotope needs and leverage resources. For example, NP continues to work with the National Institutes of Health (NIH) on a federal working group NP assembled to address the

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[a] http://www.sc.doe.gov/np/nsac/nsac.html

recommendations of the recent National Academies report, *Advancing Nuclear Medicine through Innovation*, which identified several areas in isotope production warranting attention. A five-year production strategy has been generated which identifies the isotopes and projected quantities needed by the medical community in the context of the Isotope Program capabilities. While the Isotope Program is not responsible for the production of molybedenum-99 (Mo-99), it recognizes the importance of this isotope for the Nation and is working closely with NNSA, the lead entity responsible for domestic Mo-99 production, by participating in the OSTP working group and offering technical and management support. SC is also participating 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) on Radioisotopes.

NP has also facilitated the formation of a federal working group on the He-3 supply issue involving staff from NP, NNSA, the Department of Homeland Security, and the Department of Defense. The Isotope Program's role in helium-3 (He-3) is limited to packaging and distribution of the isotope. However, the objective of this working group is to ensure that the limited supply of He-3 will be distributed to the highest priority applications and basic research.

The program is extending its community outreach with the creation of the National Isotope Development Center. The program will be organizing its first annual meeting of federal stakeholders in FY 2011 to discuss isotope needs and strategic planning.

The Isotope Development and Production for Research and Applications subprogram, which operates under a revolving fund as established by the FY 1990 Energy and Water Development Appropriations Act (Public Law 101–101) as modified by Public Law 103–316, maintains its financial viability by utilizing a combination of Congressional 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. Commercial isotopes are priced at full cost. Research isotopes are priced at lower rates to allow scientific advances and are sold at a unit price, as opposed to a batch price. Investments in new capabilities are made to meet the growing demands of the Nation and foster research in the applications that will support the health and welfare of the public.

In FY 2012, efforts continue on supporting and organizing a stable and efficient workforce for the production of isotopes and R&D efforts. The suite of isotope production facilities is increasing to include other capabilities at national laboratories and university accelerator and reactor facilities which can provide cost-effective and unique capabilities; these include the Washington University, the University of California at Davis, and the Missouri University Research Reactor. Partnerships with industrial counterparts are pursued to leverage resources.

Selected FY 2010 Accomplishments

- Silicon-32 is a long-lived radioisotope with significant application in oceanographic research associated with the biogeochemical silicon cycle. The research supplies data important to climate modeling. The production of this isotope ended when the capability to do high energy proton spallation production was halted at Los Alamos in the mid-1990s. A collaborative project with the TRIUMF irradiation facility in Canada has been implemented to once again produce and supply this important research radionuclide. The target material for producing the isotope is being irradiated in the 500 MeV facility at TRIUMF, and will then be transported to the processing facility at Los Alamos where the silicon-32 will be recovered and purified using patented technology developed at Los Alamos. Silicon-32 from this process should be available by mid-calendar year 2011.

- Alpha emitting isotopes have shown strong potential in medical cancer therapy research. However, the current supply of alpha emitting isotopes is limited. Several R&D projects were initiated in 2010 to increase the supply. LANL scientists are exploring the accelerator production of actinium-225 from a thorium-232 target at LANL's Isotope Production Facility (IPF) at 100 MeV and the Brookhaven Linac Isotope Producer at 200 MeV. ORNL scientists are studying the accelerator production of thorium-229, a long half-life radioisotope that can be used as a source of actinium-225, one of its radioactive decay products. Both ORNL and PNNL are recovering and purifying actinium-227 from surplus actinium-beryllium neutron sources. The actinium-227 can be used as a source for the decay production of very high purity thorium-227 and radium-223, another medically important alpha-emitting isotope.
- Researchers at Oak Ridge National Laboratory completed the engineering design and begun procurement of components for the fabrication of a state-of-the-art research-scale prototype electromagnetic separator for stable isotope enrichment. This separator will use modern ion source and collector technologies that could lead to production scale separators for efficient, cost effective production of a portfolio of enriched essential enriched isotopes.
- Stable isotopes were purchased from Russian production facilities to partially replenish the Isotope Program inventory for both research and commercial applications. For example the stable isotope nickel-62 is used as target material for nickel-63. Nickel-63 is a reactor-produced isotope and is used for detection of explosives and as a power source for remote instrumentation. The stable isotopes acquired will help fill a gap in the existing stable isotope inventory, especially for research applications utilizing these isotopes.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	**3,000**	**4,339**

Research is supported to identify, design, and optimize production targets and separation methods. Examples for planned research include the need for positron-emitting radionuclides to support the rapidly growing area of medical imaging using PET, the development of isotopes that support medical research to be used to diagnose and treat diseases spread through acts of bioterrorism, the development of production methods for alpha-emitting radionuclides that exhibit great potential in disease treatment, the development and use of research isotopes for various biomedical applications, the development of stable isotope enrichment technologies, and the need for alternative isotope supplies for national security applications and advanced power sources. Priorities in research isotope production are informed by guidance from NSAC. All R&D activities are peer reviewed. Starting in FY 2012 funding reflects a redistribution of funds from Operations to Research efforts at the National Laboratories to more accurately capture the nature of the activities.

▪ **National Laboratory Research**	**650**	**2,594**

Support is provided for scientists at BNL, LANL, ORNL, INL, PNNL, and ANL to perform peer-reviewed experimental research on targets, separation technology maturation and development of isotope production techniques, and for the production of research isotopes at more affordable rates to the researcher. R&D activities also utilize the reactors at INL and ORNL and the accelerators at

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

LANL and BNL. Researchers provide unique expertise and facilities for data analysis. Funding reflects estimated amounts for the selection of national laboratory proposals following peer review, as well as the staff at the laboratories devoted to isotope R&D activities.

▪ **University Research**	**2,350**	**1,648**

Support is provided for scientists at universities and with industry to perform peer-reviewed experimental research on targets, separation technology maturation and development of isotope production techniques, and for the production of research isotopes at more affordable rates. Funding reflects estimated amounts for the selection of university and industry proposals.

▪ **Other Research**	**0**	**97**

In FY 2010, $75,000 was transferred to the Small Business Innovation Research (SBIR) program and $9,000 was transferred to the Small Business Technology Transfer (STTR) program. This activity includes $86,000 for SBIR and $11,000 for STTR in FY 2012.

Operations 16,1	**16**	**15,895**

Operations funding is provided to support the core facility scientists and engineers needed to effectively operate the Isotope Development and Production for Research and Applications facilities, and includes facility maintenance and investments in new facility capabilities. Starting in FY 2012, funding reflects a redistribution of some activities previously categorized as Operations at the National Laboratories to National Laboratory Research, as well as some internal realignments within Operations.

▪ **University Operations**	**250**	**208**

Funding is provided to academic institutions with reactors and cyclotrons for providing capabilities in the production and processing of isotopes to complement or increase the subprogram's isotope portfolio. Research isotope production at universities and national laboratories is supported under the research category above. Funding is reduced in FY 2012 as efforts with universities are also funded under Research and through collaborative work with the national laboratories.

▪ **Isotope Production Facility (IPF) Operations**	**1,068**	**1,072**

The IPF operates in a parallel-mode with the Los Alamos Neutron Science Center (LANSCE) operations of about 22 weeks in FY 2012 and is completely dependent upon the operations of LANSCE. The IPF produces isotopes such as germanium-68, strontium-82, and arsenic-73. Support is provided for the operation, maintenance, and improvement of the IPF, including radiological monitoring, facility inspections, and records management. FY 2012 funding maintains a constant effort, and reflects a realignment of some activities to Research.

Recent major isotope processing equipment purchases at LANL will greatly enhance accelerator-based isotope production. The LANL Hot Cell Chemical Processing Facility is in the midst of multiple facility upgrades including projects to refurbish hot cell windows, replace aging manipulators, upgrade a critical control panel, improve facility ventilation, replace critical cranes, and upgrade the facility train system. The LANL IPF is in the final stages of replacing the beam window that defines the boundary between the vacuum and the facility target cooling water system. Notably the demand for strontium-82 and germanium-68, used in the clinical imaging modality of

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request

positron emission tomography, has grown dramatically. NP is a primary supplier of both of these nuclides, and with the investments in upgrades in processing capability, NP has been able to reliably meet the increased demand.

▪ **Brookhaven Linac Isotope Producer (BLIP) Operations**	**500**	**536**

BLIP operates in parallel mode with the RHIC operating schedule and additionally in dedicated mode to meet customer needs. BLIP produces isotopes such as copper-67, germanium-68, and strontium-82. Support is provided in FY 2012 for the operation, maintenance, and improvement of BLIP, including radiological monitoring, facility inspections, and records management.

Recent major isotope processing equipment purchases at BNL will greatly enhance accelerator-based isotope production. BNL facility projects include purchase and installation of a portal contamination monitor, germanium gamma ray spectrometer, and a lifting device to assist with the manipulator replacement. This equipment will enhance isotope production and processing capabilities and ensure reliable operation of facilities to enable the program to better meet the need for isotopes in short supply. These investments have increased the capacity to produce accelerator-produced nuclides important to both commercial and research applications, including strontium-82 and germanium-68, used in the clinical imaging modality of positron emission tomography.

▪ **National Isotope Development Center (NIDC)**	**1,915**	**2,227**

The National Isotope Development Center (NIDC) is a recently created management information center for all national laboratories and universities in the subprogram's portfolio producing and distributing isotopes. The NIDC coordinates and integrates multi-laboratory isotope production schedules and isotope inventory balances, maintains transportation container inventory and certifications, and conducts various outreach and societal activities. The business office within the NIDC is located at ORNL and coordinates all customer data such as official quotations, account balances, shipping schedules and delivery tracking, and other pertinent information. Funding reflects a realignment of some efforts from Other National Laboratory Operations in FY 2012.

▪ **Other National Laboratory Operations**	**12,383**	**11,852**

The Isotope program makes intensive use of hot cell facilities at the three main isotope production sites: BNL, LANL, and ORNL. Funding is provided to each of these facilities for the technical expertise and hot cell facilities in order to support the handling and processing of radioactive materials. Support is provided for the Chemical and Material Laboratories at ORNL that are used for processing stable isotopes, as well as activities including radiological monitoring, facility inspections, records management, the certification of isotope shipping casks, and other related expenses. FY 2012 funding reflects a shift of some efforts to the NIDC in FY 2012.

Total, Isotope Development and Production for Research and Applications	**19,116**	**20,234**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **National Laboratory Research**	
The majority of the increase reflects a shift of laboratory personnel involved in R&D efforts from Operations to Research and the initiation of a research program at BNL in conjunction with operation of BLIP. In addition, there is a redistribution of the funds anticipated to be awarded to National Laboratories following a competitive solicitation and review, as explained under University Research below.	+1,944
▪ **University Research**	
Funding for research and development is guided by priorities in research isotope production developed by NSAC. FY 2010 funding for universities reflected a disproportionate share of the total Isotope Research funding because Recovery Act funds had been used to support research at the National Laboratories. Funding in FY 2012 represents an estimate of the funds anticipated to be awarded to universities following a competitive solicitation and review.	-702
▪ **Other Research**	
• **SBIR and Other**	
Funding increases relative to FY 2010 because the mandated SBIR set-aside has been transferred out of the program in FY 2010 while those funds are included in the FY 2012 request.	+97
Total, Research	**+1,339**
Operations	
▪ **University Operations**	
Funding decreases slightly relative to FY 2010 as most university activities currently supported are funded under Research.	-42
▪ **Isotope Production Facility (IPF) Operations**	
Increased funding is provided to maintain staff, materials, and required supplies to operate the facility.	+4
▪ **Brookhaven Linac Isotope Producer (BLIP) Operations**	
Increased funding is provided to maintain staff, materials, and required supplies to operate the facility.	+36

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **National Isotope Development Center (NIDC)**	
The increase relative to FY 2010 reflects the realignment of support from within Other National Laboratory Operations for the NIDC mission to coordinate isotope activities and customer data.	+312
▪ **Other National Laboratory Operations**	
The decrease relative to FY 2010 reflects a shift of laboratory personnel involved in R&D efforts from Operations to Research in FY 2012, as well as a realignment of some funding to NIDC. Funding is provided to maintain support for staff, materials, and required supplies to operate the facilities.	-531
Total, Operations	**-221**
Total Funding Change, Isotope Development and Production for Research and Applications	**+1,118**

Construction

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Construction		
06-SC-01, 12 GeV CEBAF Upgrade (PED/ Construction), TJNAF	20,000	66,000

Description

This subprogram provides for Project Engineering and Design (PED) and Construction needed to meet overall objectives of the Nuclear Physics program.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Crrent Appropriation	FY 2012 Request
06-SC-01, 12 GeV CEBAF Upgrade (PED/Construction), TJNAF 20,000		**66,000**

In FY 2012, funding is requested to continue construction of the 12 GeV CEBAF Upgrade. The upgrade was identified in the 2007 NSAC Long-Range Plan as the highest priority for the U.S. Nuclear Physics program. The upgrade will enable scientists to address one of the mysteries of modern physics—the mechanism of quark confinement.

FY 2012 is the peak funding year for this project and is consistent with the baselined profile. The original profile was reduced in FY 2010 and FY 2011 to account for the $65,000,000 received under the Recovery Act in FY 2009.

Total, Construction	**20,000**	**66,000**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
06-SC-01, 12 GeV CEBAF Upgrade (PED/Construction), TJNAF	
Increased support is provided to continue construction of the 12 GeV CEBAF Upgrade according to the planned project profile.	+46,000

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Operating Expenses	454,344	502,571
Capital Equipment	39,638	30,235
General Plant Projects	2,000	2,000
Accelerator Improvement Projects	6,478	4,494
Construction (12 GeV Upgrade)	20,000	66,000
Total, Nuclear Physics	522,460	605,300

Funding Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Research	175,365	198,101
Scientific User Facilities Operations	273,818	272,123
Other Facility Operations	20,369	25,390
Projects		
Major Items of Equipment	15,998	8,686
Facility for Rare Isotope Beams[a]	12,000	30,000
Construction Projects (12 GeV Upgrade)	20,000	66,000
Total Projects	47,998	104,686
Other	4,910	5,000
Total Nuclear Physics	522,460	605,300

Scientific User Facilities Operations and Research

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
CEBAF (TJNAF)		
Operations	83,327	83,930
Facility Research/MIEs	10,537	10,440
Total CEBAF	93,864	94,370

[a] FRIB is being funded with operating expense dollars through a Cooperative Agreement with Michigan State University (MSU).

	(dollars in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
RHIC (BNL)		
Operations	157,195	164,610
Facility Research/MIEs	10,032	12,185
Total RHIC	167,227	176,795
HRIBF (ORNL)		
Operations	17,080	6,821
Facility Research/MIEs	4,271	4,271
Total HRIBF	21,351	11,092
ATLAS (ANL)		
Operations	16,216	16,762
Facility Research/MIEs	4,865	4,865
Total ATLAS	21,081	21,627
Scientific User Facilities		
Operations	273,818	272,123
Facility Research/MIEs	29,705	31,761
Total Scientific User Facilities	303,523	303,884

Total Facility Hours and Users

	FY 2010 Current Appropriaton	FY 2012 Request
Hours of Operation with Beam		
CEBAF (TJNAF)		
Achieved Operating Hours	5,280	N/A
Planned Operating Hours	5,110	3,870
Optimal Hours	5,980	3,940
Percent of Optimal Hours	88%	98%
Unscheduled Downtime	9%	N/A
Number of Users	1,260	1,300

	FY 2010 Current Appropriaton	FY 2012 Request
RHIC (BNL)		
Achieved Operating Hours	3,580	N/A
Planned Operating Hours	3,350	3,040
Optimal Hours	4,100	4,100
Percent of Optimal Hours	87%	74%
Unscheduled Downtime	17%	N/A
Number of Users	1,200	1,200
HRIBF (ORNL)		
Achieved Operating Hours	5,270	N/A
Planned Operating Hours	5,200	0
Optimal Hours	6,100	0
Percent of Optimal Hours	86%	N/A
Unscheduled Downtime	13%	N/A
Number of Users	260	0
ATLAS (ANL)		
Achieved Operating Hours	5,940	N/A
Planned Operating Hours	5,900	5,900
Optimal Hours	6,600	6,200[a]
Percent of Optimal Hours	90%	95%
Unscheduled Downtime	8%	N/A
Number of Users	410	430
Total Facilities		
Achieved Operating Hours	20,070	N/A
Planned Operating Hours	19,560	12,810
Optimal Hours	22,780	14,170
Percent of Optimal Hours	88%	90%
Unscheduled Downtime	11%	N/A
Total Number of Users	3,130	2,930

[a] Based on the most recent review of operations at ATLAS, the quality and quantity of the scientific output is best optimized with 6,200 operating hours.

Major Items of Equipment

	(dollars in thousands)					
	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Heavy Ion Nuclear Physics						
Heavy Ion LHC Experiments, LBNL						
TEC	7,000	5,000	1,205	0	0	13,205
OPC	295	0	0	0	0	295
TPC	7,295	5,000	1,205	0	0	13,500
STAR Heavy Flavor Tracker, BNL						
TEC	0	2,400	2,900	4,550	5,350	15,200
OPC	0	280	0	0	0	280
TPC	0	2,680	2,900	4,550	5,350	16,500–17,800[a]
Low Energy Nuclear Physics						
GRETINA, Gamma-Ray Detector, LBNL						
TEC	16,570	430	0	0	0	17,000
OPC	1,500	300	0	0	0	1,800
TPC	18,070	730	0	0	0	18,800
Neutron Electric Dipole Moment (nEDM), ORNL						
TEC	4,047	4,500	2,900	1,100	TBD	TBD
OPC	933	0	0	0	TBD	TBD
TPC	4,980	4,500	2,900	1,100	TBD	17,600-40,000
Cryogenic Underground Observatory for Rare Events (CUORE), LBNL						
TEC	3,512	3,088	800	186	0	7,586
OPC	764	0	0	350	0	1,114
TPC	4,276	3,088	800	536	0	8,700
Rare Isotope Beam Science Initiatives[b]						
TEC	0	0	0	0	0	0
OPC	0	0	0	0	0	0
TPC	0	0	0	0	0	0

[a] This project received CD-1 approval in August 2010; the CD-1 TPC range is reflected, and includes $2,320,000 of additional funding that has been redirected within the RHIC research program.
[b] The first peer-reviewed awards were made under this initiative in FY 2010. The four university awards and two laboratory awards totaling $4,200,000 were all under the MIE threshold and, therefore, are not reflected in the MIE table.

	(dollars in thousands)					
	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Total MIEs						
TEC		15,418	7,805	5,836		
OPC		580	0	350		
TPC		15,998	7,805	6,186		

Heavy Ion Nuclear Physics MIEs

Heavy Ion LHC Experiment (ALICE EMCal), LBNL: This MIE fabricates a large electromagnetic calorimeter (EMCal) for the ALICE experiment at the LHC, and is a joint project with France and Italy. It received CD-2/3 approval in February 2008 and is scheduled to finish in FY 2011.

STAR Heavy Flavor Tracker (HFT), BNL: This MIE will fabricate a high-precision tracking and vertexing device based on ultra-thin silicon pixel and pad detectors in the STAR detector. It received CD-1 approval in August 2010 and is scheduled for completion in FY 2015.

Low Energy Nuclear Physics MIEs

GRETINA Gamma-Ray Detector, LBNL: This MIE fabricates an array of highly-segmented germanium crystals for gamma ray detection. It received CD-2/3 approval in October 2007 and is scheduled to finish in FY 2011. This detector will be shared by the Nation's low-energy accelerator facilities operated by both DOE and NSF.

Neutron Electric Dipole Moment (nEDM), ORNL: This MIE fabricates a cryogenic apparatus to measure the neutron electric dipole moment using ultra-cold neutrons from the FNPB. It received CD-1 approval in February 2007 with an estimated cost range of $17,600,000-$19,000,000. The profile is slowed and high priority R&D will continue in FY 2012 for this R&D intensive and technically challenging discovery experiment. The DOE total project cost (TPC) range has been refined to reflect current estimates for this joint DOE/NSF project with NSF contributing additional funds.

Cryogenic Underground Observatory for Rare Events (CUORE), LBNL: This MIE fabricates the U.S. contribution to the Italian-led CUORE experiment to measure fundamental neutrino properties. It received CD-2/3 approval in December 2009 and is scheduled to finish in FY 2015. This is a joint DOE/NSF project with NSF contributing additional funds.

Rare Isotope Beam Science Initiatives: Competitive awards were selected in FY 2010 following peer review. There were four university and two laboratory projects awarded totaling $4,200,000, all of which were under the MIE threshold; as a result, the FY 2010 funding is included in the appropriate categories under Low Energy Research and is no longer included as part of the MIE table. The individual initiatives selected will fabricate instrumentation creating forefront science opportunities at leading rare isotope beam facilities around the world. NP terminates support for this initiative in FY 2012 in order to support higher priority activities. A limited number of the smaller international research efforts, among those selected following peer review in FY 2010, will be completed, while the larger projects will not be pursued.

Construction Projects

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011	FY 2012 Request	Outyears	Total
12 GeV CEBAF Upgrade, TJNAF						
TEC	114,500	20,000	36,000	66,000	51,000	287,500
OPC	10,500	0	0	0	12,000	22,500
TPC	125,000	20,000	36,000	66,000	63,000	310,000

Scientific Employment

(estimated)

	FY 2010 Actual[a]	FY 2012 Request[b]
# University Grants	200	200
Average Size per year	$345,000	$345,000
# Laboratory Projects	33	34
# Permanent Ph.Ds	839	825
# Postdoctoral Associates	410	395
# Graduate Students	546	535
# Ph.D.s awarded	93	80

Facility for Rare Isotope Beams, Michigan State University, East Lansing, Michigan

1. Introduction

On February 9, 2004, the Nuclear Physics program received Critical Decision 0 (CD-0), Approve Mission Need, for construction of a Rare Isotope Accelerator Project with a preliminary cost estimate range of $900,000,000 to $1,100,000,000. As part of a subsequent alternatives analysis, the technical scope was reduced and the upper limit of the preliminary cost estimate to the federal government was revised to $550,000,000.

In June 2009, Michigan State University (MSU) was awarded a cooperative agreement to design and establish the Facility for Rare Isotope Beams (FRIB). The cooperative agreement between DOE and MSU identifies MSU providing $94,500,000 in cost share, and the preliminary cost estimate range to the federal government is $500,000,000 to $550,000,000. The final DOE federal investment will be determined when the project is more mature and ready to be baselined at CD-2. Critical Decision 1, Approve Alternative Selection and Cost Range, was approved in September 2010.

The National Environmental Policy Act (NEPA) requirements addressing the construction and operations of FRIB were satisfied in September 2010 with the approval of the Environmental Assessment and Finding of No Significant Impact (FONSI).

[a] FY 2010 is the first year that the Isotope Program is included in the Nuclear Physics Workforce Survey. An additional 69 Ph.Ds, 24 postdoctoral associates, and 8 graduate students were supported during FY 2010 with Recovery Act funding.
[b] This table does not reflect an additional reduction of an estimated 30 technicians and operations staff that will result from the closure of HRIBF.

FRIB is not a DOE line item construction project or capital asset and is being funded with operating expense dollars through a cooperative agreement with MSU. Although cooperative agreements are excluded under DOE O 413.3A, the management principles of DOE O 413.3A will be followed, including the approval of Critical Decisions. When completed, FRIB will be operated as a DOE national user facility. Consistent with 10 CFR 600, real property and equipment acquired with Federal funds shall be vested with MSU. However, such items will not be encumbered by MSU for as long as the Federal government retains an interest. When the property and equipment are no longer of interest to the government, MSU will be responsible for decontamination and decommissioning.

The FY 2012 request continues engineering and design activities in support of achieving CD-2 approval by the fourth quarter of FY 2012 and allows the pursuit of long-lead procurements that reduce the project's cost and schedule risks. Depending on advancement of the design and technical requirements, a phased construction start may begin in FY 2012. Provided sufficient funds are available, this effort would reduce project risk.

2. Design and Construction Schedule[a]

	CD-0	CD-1	Design Complete	CD-2	CD-3	CD-4
FY 2011	02/09/2004	4Q FY 2010	TBD	TBD	TBD	FY 2017–FY 2019
FY 2012	02/09/2004	9/1/2010	TBD	4Q FY 2012	TBD	FY 2018–FY 2020

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

3. Baseline and Validation Status (DOE only)[b]

(dollars in thousands)

	TEC, Engineering and Design	TEC, Construction	TEC, Total	OPC	TPC
FY 2011	58,000	TBD	TBD	19,000	TBD
FY 2012	54,300	TBD	TBD	19,000	TBD[c]

4. Project Description, Justification, and Scope

FRIB is based on a heavy-ion linac with a minimum energy of 200 MeV per nucleon for all ions at beam power of 400 kW. The proposed facility will have a production area, three-stage fragment separator, three ion stopping stations, and post accelerator capabilities.

This proposed facility is to provide intense beams of rare isotopes for a wide variety of studies in nuclear structure, nuclear astrophysics, and fundamental symmetries. This facility will impact the study of the origin of the elements and the evolution of the cosmos, and offers a laboratory for exploring the limits of nuclear existence and identifying new phenomena, with the possibility that a more broadly applicable

[a] This project does not have a performance baseline. The CD-4 schedule range is a preliminary estimate.
[b] This project does not have a performance baseline. The amounts shown reflect the requested DOE appropriations only and do not include the planned cost share from MSU.
[c] The preliminary DOE total project cost (TPC) range is \$500,000,000 to \$550,000,000 not including the MSU cost share of \$94,500,000.

theory of nuclei will emerge. The facility will offer new glimpses into the origin of the elements by 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. Experiments addressing questions of the fundamental symmetries of nature will similarly be conducted through the creation and study of certain exotic isotopes.

5. Financial Schedule (DOE only)

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
FY 2011[a]	10,000	10,000	8,157
FY 2012	30,000	30,000	30,000
FY 2013[b]	14,300	14,300	13,300
FY 2014	TBD	TBD	2,843
Outyears	TBD	TBD	TBD
Total, TEC[c]	54,300	54,300	54,300
Other Project Cost (OPC)			
FY 2009	7,000	7,000	1,874
FY 2010	12,000	12,000	13,283
FY 2011[a]	0	0	3,843
Total, OPC[d]	19,000	19,000	19,000
Total Project Cost			
FY 2009	7,000	7,000	1,874
FY 2010	12,000	12,000	13,283
FY 2011 [a]	10,000	10,000	12,000
FY 2012	30,000	30,000	30,000
FY 2013 [b]	14,300	14,300	13,300
FY 2014	TBD	TBD	2,843
Outyears	TBD	TBD	TBD
Total, TPC[e]	TBD	TBD	TBD

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).
[b] The TEC funding of $14,300,000 reflects engineering and design effort only in FY 2013. The FY 2013 budget request will identify additional funding for long-lead procurement and construction activities.
[c] The funding reflected in the operating funded TEC profile is for DOE's share only of engineering and design activities, and long-lead procurements and possibly phased construction start in FY 2012 that reduce project risks. The FY 2013 budget request will identify additional funding for long-lead procurements and construction activities.
[d] The funding reflected in the OPC profile is for DOE's share of R&D, conceptual design, and NEPA activities only. Future budget requests will identify additional funding for pre-operational activities.
[e] The preliminary DOE total project cost (TPC) range is $500,000,000 to $550,000,000, not including the MSU cost share of $94,500,000.

6. Details of Cost Estimate (DOE only)

	(dollars in thousands)		
	Current Total Estimate	Previous Total Estimate	Original Validated Estimate
Total Estimated Cost (TEC)[a]			
Design and engineering	45,900	42,500	N/A
Construction	TBD	TBD	N/A
Contingency	8,400	15,500	N/A
Total, Total Estimated Cost	54,300	58,000	N/A
Other Project Cost (OPC)			
Conceptual Design/NEPA	6,500	6,500	N/A
R&D	12,500	12,500	N/A
Contingency	0	0	N/A
Total, OPC[b]	19,000	19,000	N/A
Total, TPC[c]	TBD	TBD	N/A
Total, Contingency	TBD	TBD	N/A

[a] The TEC funding is for DOE's share only of engineering and design activities only, and long-lead procurements and possibly phased construction start in FY 2012 that reduce project risks. The FY 2013 budget request will identify additional funding for long-lead procurements and construction activities.
[b] The OPC funding is for DOE's share of R&D, conceptual design, and NEPA activities only. Future budget requests will identify additional funding for pre-operational activities.
[c] The preliminary DOE total project cost (TPC) range is $500,000,000 to $550,000,000, not including the MSU cost share of $94,500,000.

7. Funding Profile History (DOE Only)

(dollars in thousands)

Request Year		FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	Outyears	Total
FY 2010	TEC[a]	0	0	10,000	33,000	18,000[b]	TBD	TBD
	OPC[c]	7,000	9,000	0	0	0	TBD	TBD
	TPC[d]	7,000	9,000	10,000	33,000	18,000	TBD	TBD
FY 2011	TEC[a]	0	0	10,000	30,000	18,000[b]	TBD	TBD
	OPC[c]	7,000	12,000	0	0	0	TBD	TBD
	TPC[d]	7,000	12,000	10,000	30,000	18,000	TBD	TBD
FY 2012	TEC[a]	0	0	10,000[e]	30,000	14,300[b]	TBD	TBD
	OPC[c]	7,000	12,000	0	0	0	TBD	TBD
	TPC[d]	7,000	12,000	10,000	30,000	14,300	TBD	TBD

[a] The TEC funding is for DOE's share only of engineering and design activities, long-lead procurements and possibly phased construction start in FY 2012 that reduce project risks.
[b] The FY 2013 budget request will identify additional funding for long-lead procurements and construction activities.
[c] The OPC funding is for DOE's share of R&D, conceptual design, and NEPA activities only.
[d] The preliminary DOE total project cost (TPC) range is $500,000,000 to $550,000,000, not including the MSU cost share. The amounts shown reflect the requested DOE appropriations only and do not include the planned cost share of $94,500,000.
[e] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

06-SC-01, 12 GeV CEBAF Upgrade, Thomas Jefferson National Accelerator Facility Newport News, Virginia Project Data Sheet is for PED/Construction

1. Significant Changes

This Project Data Sheet (PDS) is an update of the FY 2011 PDS.

The most recent DOE O 413.3A approved Critical Decision (CD) is CD-3, Approve Start of Construction, which was signed on September 15, 2008, with a Total Project Cost (TPC) of $310,000,000 and a planned CD-4 in FY 2015. There have been no changes in project scope, cost, or schedule since the project was baselined. The project continues to manage all identified low, moderate, and high risks. Risks can change from month to month, and include issues with the procurement and installation of components, overall staffing levels and schedule, impacts of continuing resolutions, and claims from subcontractors. For each moderate and high risk a mitigation plan is developed in order to assure successful project completion. One particular high risk is associated with the Hall D Solenoid. A spare solenoid has been strongly recommended by various review panels external to the project. Costs and schedules for this solenoid are currently being determined but preliminary estimates indicate the cost at approximately $10 million, for which project contingency would be used.

A Federal Project Director at the appropriate level is assigned to this project.

2. Design, Construction, and D&D Schedule

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3	CD-4A	CD-4B	D&D
FY 2007	3/31/2004	1Q FY 2007	4Q FY 2009	4Q FY 2007	4Q FY 2008	N/A	1Q FY 2014	N/A
FY 2008	3/31/2004	2/14/2006[a]	4Q FY 2009	4Q FY 2007	4Q FY 2008	N/A	1Q FY 2015	N/A
FY 2009	3/31/2004	2/14/2006	4Q FY 2009	11/9/2007	4Q FY 2008	N/A	3Q FY 2015	N/A
FY 2010	3/31/2004	2/14/2006	4Q FY 2009	11/9/2007	9/15/2008	1Q FY 2015	3Q FY 2015	N/A
FY 2011	3/31/2004	2/14/2006	1Q FY 2010	11/9/2007	9/15/2008	1Q FY 2015	3Q FY 2015	N/A
FY 2012	3/31/2004	2/14/2006	12/31/2009	11/9/2007	9/15/2008	1Q FY 2015	3Q FY 2015	N/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 D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete –Completion of D&D work

[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.

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	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	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[a]

4. Project Description, Justification, and Scope

The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility is the world-leading facility in the experimental study of hadronic matter. An energy upgrade of CEBAF has been identified by the nuclear science community as a compelling scientific opportunity that should be pursued. In particular, the Nuclear Science Advisory Committee (NSAC) stated in the 1996 Long Range Plan that "…the community looks forward to future increases in CEBAF's energy, and to the scientific opportunities that would bring." 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.

- 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.
- 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) and associated beam-line, and enhancing the capabilities of the existing experimental halls to support the most compelling nuclear physics research.

Key Performance Parameters to achieve CD-4, *Approve Start of Operations or Project Closeout*, are phased around 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 to help ensure that the one high risk and three moderate risks will not impact the planned completion dates.

The project is being conducted in accordance with the project management requirements in DOE O 413.3A, *Program and Project Management for the Acquisition of Capital Assets*, and all appropriate project management requirements have been met.

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[a] The Commonwealth of Virginia provided $9,000,000 to Jefferson Science Associates, LLC to leverage the federal investment of $310 million for an upgrade of the Jefferson Lab's research facilities. The $9,000,000 received reduces project risks associated with cost and schedule and helps ensure timely completion of the project. Any adjustments to the federal government's share of the TPC as a result of the funding from the Commonwealth of Virginia will be evaluated by the SC Office of Project Assessment during one of the project's future annual reviews. The timing of any possible adjustment to the TPC will be considered after the project has progressed further, the majority of the risks have been minimized or retired, and with input and advice from the SC Office of Project Assessment. The 12 GeV Upgrade project is about 42% complete as of the beginning of January 2011.

5. Financial Schedule

(dollars in thousands)

App	ropriations	Obligations	Recovery Act Costs Costs	
Total Estimated Cost (TEC)				
PED				
FY 2006	500	500	0	88
FY 2007	7,000	7,000	0	6,162
FY 2008	13,377[a] 1	3,377	0	9,108
FY 2009	123[a]	123 0		5,370
FY 2010	0	0	0	265
FY 2011[b] 0		0	0	7
Total, PED	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 2	0,000	29,621 1	8,642
FY 2011[b]	36,000 3	6,000	24,800 4	3,750
FY 2012	66,000 6	6,000	7,841 5	8,300
FY 2013	40,500 4	0,500	0 5	5,000
FY 2014	10,500 1	0,500	0 1	7,500
FY 2015	0	0	0	3,059
Total, Construction	266,500 2	66,500	65,000 2	01,500
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 2	0,000	29,621 1	8,907
FY 2011 [b]	36,000 3	6,000	24,800 4	3,757
FY 2012	66,000 6	6,000	7,841 5	8,300
FY 2013	40,500 4	0,500	0 5	5,000
FY 2014	10,500 1	0,500	0 1	7,500
FY 2015	0	0	0	3,059

[a] The baseline FY 2008 PED funding was reduced by $123,000 as a result of the FY 2008 rescission. This reduction was restored in FY 2009 to maintain the TEC and project scope.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

(dollars in thousands)

App	ropriations	Obligations	Recovery Act Costs Costs	
Total, TEC	287,500 2	87,500	65,000 2	22,500
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	,403
FY 2014	7,500 7	,500	0 7	,000
FY 2015	2,000 2	,000	0 2	,600
Total, OPC	22,500	22,500	0	22,500
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 1	4,377	0 1	0,910
FY 2009	28,623	28,623	0	10,774
FY 2009 Recovery Act	65,000	65,000	2,738	0
FY 2010	20,000 2	0,000	29,621 1	8,969
FY 2011[a]	36,000 3	6,000	24,800 4	3,757
FY 2012	66,000 6	6,000	7,841 5	8,300
FY 2013	43,000 4	3,000	0 5	7,403
FY 2014	18,000 1	8,000	0 2	4,500
FY 2015	2,000 2	,000	0 5	,659
Total, TPC	310,000 3	10,000	65,000 2	45,000

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

6. Details of Project Cost Estimate

	(dollars in thousands)		
	Current Total Estimate	Previous Total Estimate	Original Validated Estimate
Total Estimated Cost (TEC)			
Design (PED)			
Design 2	1,000	21,000	19,200
Contingency 0		0	1,800
Total, PED (PED no. 06-SC-01)	21,000	21,000	21,000
Construction Phase			
Civil Construction	31,880	29,400	27,450
Accelerator/ Experimental Equipment/Management	191,463 17	5,200	174,150
Contingency 4	3,157	61,900	64,900
Total, Construction	266,500	266,500	266,500
Total, TEC	287,500	287,500	287,500
Contingency, TEC	43,157	61,900	66,700
Other Project Cost (OPC)			
OPC except D&D			
Conceptual Design	3,445	3,445	3,500
R&D 7,	052	7,020	6,400
Start-up 8	,195	7,635	7,450
Contingency 3,	808	4,400	5,150
Total, OPC	22,500	22,500	22,500
Contingency, OPC	3,808	4,400	5,150
Total, TPC	310,000	310,000	310,000
Total, Contingency	46,965	66,300	71,850

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2007 PED only	TEC 1	9,000	2,000	0	0	0	0	0	0	0	21,000
	OPC 1	1,000	0	0	0	0	0	0	0	0	11,000
	TPC 3	0,000	2,000	0	0	0	0	0	0	0	32,000
FY 2008 PED only	TEC 2	1,000	0	0	0	0	0	0	0	0	21,000
	OPC 1	0,500	0	0	0	0	0	0	0	0	10,500
	TPC 3	1,500	0	0	0	0	0	0	0	0	31,500

(dollars in thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2009[a] Performance Baseline	TEC 2	0,877	28,623	0	59,000	62,000	66,000	40,500	10,500 0		287,500
	OPC 1	0,500	0	0	0	0	0	2,500	7,500	2,000	22,500
	TPC 3	1,377	28,623	0	59,000	62,000	66,000	43,000	18,000 2	,000	310,000
FY 2010[b] TEC		20,877	28,623	65,000	22,000	34,000 6	6,000	40,500	10,500	0	287,500
O	PC	10,500	0	0	0	0	0	2,500	7,500	2,000	22,500
TPC		31,377	28,623	65,000	22,000	34,000 6	6,000	43,000	18,000	2,000	310,000
FY 2011	TEC	20,877 2	8,623 6	5,000 2	0,000	36,000	66,000	40,500	10,500	0	287,500
O	PC	10,500	0	0	0	0	0	2,500	7,500	2,000	22,500
TPC		31,377	28,623	65,000	20,000	36,000 6	6,000	43,000	18,000	2,000	310,000
FY 2012	TEC	20,877	28,623	65,000	20,000	36,000[c]	66,000	40,500	10,500 0		287,500
O	PC	10,500	0	0	0	0	0	2,500	7,500	2,000	22,500
TPC		31,377	28,623	65,000	20,000	36,000 6	6,000	43,000	18,000	2,000	310,000

8. Related Operation and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	3Q FY 2015
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
Total Project Costs	N/A	N/A	310,000	310,000
Operations	150,000	150,000	2,250,000[d]	2,250,000[c]
Maintenance Incl	uded above	Included above	Included above	Included above
Total, Operations & Maintenance	150,000	150,000	2,560,000	2,560,000

[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 FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).
[d] 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.

9. Required D&D Information

	Square Feet
Area of new construction	31,500
Area of existing facility(ies) being replaced	N/A
Area of any additional D&D space to meet the "one-for-one" requirement	31,500

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.

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. 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.

Workforce Development for Teachers and Scientists

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Appropriation FY	2012 Request
Workforce Development for Teachers and Scientists		
Student Programs	13,042	26,800
Educator Programs	5,771	2,600
Program Administration and Evaluation	1,865	6,200
Total, Workforce Development for Teachers and Scientists	20,678	35,600

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act of 1977"
Public Law 101–510, "DOE Science Education Enhancement Act of 1991"
Public Law 103–382, "The Albert Einstein Distinguished Educator Fellowship Act of 1994"
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

The mission of the Workforce Development for Teachers and Scientists (WDTS) program is to contribute to the effort aimed at ensuring that DOE and the Nation have a sustained pipeline of highly skilled and diverse science, technology, engineering, and mathematics (STEM) workers.

Background

DOE and its predecessor organizations have more than a sixty-year history of training and educating scientists, mathematicians, and engineers in the United States. These highly skilled workers are a key element of the Department's research enterprise and are largely supported through research grants and contracts at universities, the DOE national laboratories, and the private sector. This commitment to supporting the Nation's scientific and technical workforce has produced tens of thousands of leading scientists, engineers, and technicians who have dedicated their careers to addressing major national security, energy, and environmental challenges, while pursuing answers to many of the most important scientific questions in physics, chemistry, biology, and other areas of basic science.

DOE's seventeen national laboratories provide tremendous opportunities and resources for STEM training and education. The national laboratory system offers a unique learning environment with access to world-class scientists who serve as research mentors to students, as well as access to cutting-edge scientific instrumentation and facilities unavailable at universities or industry. On an annual basis, more than 250,000 K–12 students, 22,000 K–12 educators, 4,000 undergraduate interns, 3,000 graduate students, and 1,600 post-doctoral employees participate in education or training programs at the DOE national laboratories through funding provided by a wide range of sources, including WDTS.

WDTS leverages the unique capabilities at DOE's national laboratories to sponsor workforce training programs designed to motivate students and educators to pursue careers that will contribute to the Office of Science's mission in discovery science and science for the national need. WDTS programs provide a sustained pipeline for individuals to pursue STEM fields by rewarding and recognizing students from middle school through graduate school for their participation in areas of science and technology important to the Office of Science and to DOE.

In addition, WDTS encourages the participation of under-represented populations in all of its programs. WDTS works to strengthen the recruitment, retention, and workforce training opportunities of under-represented students and educators through strong partnerships with Minority Serving Institutions (MSIs) and scientific professional societies (such as the Society for Advancing Hispanics/Chicanos and Native Americans in Science (SACNAS), American Indian Higher Education Consortium, and the National Society of Black Physicists).

Subprograms

WDTS is organized into 3 subprograms: Student Programs, Educator Programs, and Program Administration and Evaluation.

- *Student Programs* focuses on encouraging middle school through graduate students to enter STEM careers and retaining them in the scientific and technical workforce.
- *Educator Programs* focuses on professional development experiences for middle school, high school, community college, and undergraduate educators.
- *Program Administration and Evaluation* develops and deploys evaluation and assessment for WDTS programs, and provides the framework for developing outreach programs to public and private sector organizations.

Benefits

Supporting the development of a skilled scientific workforce has been upheld by industry and academic leaders as essential for promoting sustained U.S. economic growth in the 21st century. WDTS programs provide participants a pathway to STEM careers in scientific disciplines relevant to DOE's mission in energy, environment, and national security, including careers at the Department and its national laboratories. These initiatives benefit society and promote the long-term economic health of our Nation by helping to create and strengthen a skilled and diverse scientific and technical workforce ready for current and emerging challenges in energy and the environment.

In addition, WDTS programs provide participants with the tools and knowledge they need to make an informed choice about STEM education and career options, including options that ultimately support the Office of Science mission goals. Internships, fellowships, competitions, and other activities are designed to introduce participants to world class scientific research and user facilities. Participants also have opportunities to engage in science directly tied to societal challenges, such as ensuring our Nation's energy and environmental security.

Program Planning and Management

In FY 2010, the WDTS program planning and management activities included:

- A review of the WDTS program by a Committee of Visitors (COV).[a] The Basic Energy Sciences Advisory Committee (BESAC) commissioned a COV subcommittee to examine WDTS business processes for their effectiveness and efficiency. The COV also assessed the quality of the WDTS portfolio, including its breadth and depth and national and international standing. WDTS reviewed the COV's findings and began the implementation of the COV's recommendations. The Office of

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[a] The complete COV report can be found at http://www.science.doe.gov/bes/BESAC/reports.html

Science conducts COV reviews of major programs every three years to ensure program quality. BESAC was charged by SC to do the COV review of WDTS as WDTS does not have its own Federal Advisory Committee.

- Evaluation of all WDTS programs, including a longitudinal workforce study and the development of six leading indicators that drive program improvement efforts: quality, scientific and technical content knowledge, leverage, competition with reward, retention, and diversity. WDTS has developed pre- and post-surveys for all of its programs and uses that information to conduct analyses of national laboratory performance, the impact of WDTS programs on participants, and ways that WDTS programs can be better aligned to Office of Science mission requirements.
- Expansion of efforts to provide STEM professional development opportunities for undergraduate faculty and students as a way to increase the participation of under-represented minorities and women in DOE programs.

Coordination of Education/Workforce Development Activities

WDTS participates in the Education Subcommittee of the National Science and Technology Council. Through this subcommittee and other venues, WDTS engages with the National Science Foundation (NSF), National Aeronautics and Space Administration (NASA), Department of Defense (DOD), National Institutes of Health (NIH), and other federal agencies to develop interagency efforts in STEM education.

WDTS also coordinates with other DOE program offices to develop workforce and STEM education efforts. These efforts leverage existing WDTS capabilities and resources, particularly those developed within the DOE national laboratory system. WDTS has established several program management systems and supporting infrastructure dedicated to STEM education and workforce efforts (an online application system, outreach efforts, etc.) that are of interest to other DOE program elements.

In FY 2010, WDTS worked with several programs as they developed workforce training and education initiatives: the Office of Energy Efficiency and Renewable Energy (EERE) was encouraged to hire an Einstein Fellow for a second year to provide needed educational technical expertise for their efforts, the National Nuclear Security Administration (NNSA) consulted with WDTS on diversity issues related to STEM, and the Office of Economic Impact and Diversity (ED) cooperated with WDTS on the placement of diverse candidates at DOE national laboratories.

Budget Overview

In FY 2012, increased funding for the DOE Office of Science Graduate Fellowship (SCGF) program will support a new cohort of graduate students. The SCGF is a three-year fellowship. The FY 2012 request will support a total of 320 fellowships: the first year of a new cohort of graduate students and the third year of the cohort awarded in FY 2010. Seventy graduate fellowships were awarded in FY 2010 with FY 2010 appropriated funds and 80 graduate fellowships were awarded using Recovery Act funds. These fellowships are awarded on a highly competitive basis. The graduate students awarded this fellowship are pursuing advanced science and engineering degrees in fields of basic research relevant to the Office of Science mission areas.

WDTS will increase support for core WDTS programs that the COV found exemplary: the Science Undergraduate Laboratory Internships, the Community College Institute, SCGF, Einstein Fellows, and National Science Bowl®. WDTS will discontinue three programs in FY 2012: DOE Academies Creating Teacher Scientists (DOE-ACTS), Pre-Service Teachers (PST), and High School Engineering. These changes are consistent with the 2010 COV recommendations and part of an overall strategy to build a STEM workforce pipeline that is better aligned with Office of Science mission needs.

Student Programs

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation FY	2012 Request
Student Programs		
Science Undergraduate Laboratory Internships	3,958	6,000
Community College Institute of Science and Technology	875	2,000
DOE Office of Science Graduate Fellowship	5,006	16,100
National Science Bowl® 2,	450	2,700
Pre-Service Teachers	453	0
High School Engineering	300	0
Total, Student Programs	13,042	26,800

Description

The Student subprogram encourages and enables middle school through graduate school students to pursue education, training, and, ultimately, career interests, in science, technology, mathematics, and engineering fields important to the Office of Science mission.

The DOE Office of Science Graduate Fellowship (DOE SCGF) program sponsors fellowships for outstanding U.S. graduate students pursuing advanced degrees in areas of basic research important to the Office of Science mission areas. The Science Undergraduate Laboratory Internships (SULI) and Community College Institute (CCI) programs introduce undergraduate students to the world-class researchers, user facilities, and other resources in the DOE national laboratory system through their intensive research participation as part of DOE research teams. The National Science Bowl® inspires middle and high school students to pursue STEM education and careers.

Selected FY 2010 Accomplishments

- The DOE SCGF program was successfully launched in FY 2010. Over 3,200 applicants applied for the 3-year fellowship awards. A rigorous merit-based review and selection process resulted in 150 awards to outstanding graduate students pursuing advanced degrees in areas of basic research relevant to Office of Science mission areas. The merit-based review process was conducted in collaboration with the six SC research programs. An August 2010 DOE SCGF research meeting and program orientation at Argonne National Laboratory was attended by the first cohort of 150 Fellows, who learned details about the SC-sponsored research programs and the scientific facilities at the laboratories; participated in scientific lectures and discussions; and met with DOE national laboratory representatives about research and career opportunities at the 17 DOE national laboratories.
- FY 2010 program evaluation of SULI and CCI confirmed that undergraduate research experiences at the DOE national laboratories significantly increased students' interest in pursuing a STEM career and increased their content knowledge in STEM fields of importance to DOE as a result of the experience. These evaluation findings validated the WDTS approach to STEM workforce

development, which relies heavily upon intensive research participation and strong mentoring experiences.

- The COV review of WDTS programs identified the National Science Bowl®, SCGF, SULI, and CCI as core exemplary programs and recommended increased support for these programs by redirecting funds from weaker WDTS programs.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Science Undergraduate Laboratory Internships	**3,958**	**6,000**

The Science Undergraduate Laboratory Internships (SULI) program supports a diverse group of students at DOE's national laboratories in individually mentored research experiences. Students spend an intensive 10–16 weeks working under the individual mentorship of resident scientists, produce an externally-reviewed abstract and research report, and attend seminars on science careers and how to become part of the scientific community. Goals and outcomes are measured based on students' research papers and abstracts, pre- and post-surveys, and an annual evaluation by a group of peers, both within and outside of DOE. The COV recommended expansion of this program due to its high quality and impact.

WDTS supported 570 SULI students in FY 2010, and will support an estimated 850 SULI students in FY 2012. In FY 2012, approximately 150 of these SULI undergraduates will participate in FaST.

Community College Institute of Science and Technology	**875**	**2,000**

The Community College Institute (CCI) of Science and Technology, which provides a mentored research internship at a DOE national laboratory for highly motivated community college students, is designed to address DOE's workforce shortages, particularly at the skilled technician level for DOE mission critical areas, such as scientific instrumentation development and operation. CCI students spend an intensive 10–16 weeks working under the individual mentorship of resident scientists, produce an abstract and formal research paper, and attend professional enrichment activities, workshops, and seminars on career options and how to become part of the scientific community, and enhance their professional skills. Goals and outcomes are measured based on students' research reports and abstracts, pre- and post-surveys, and external evaluation. The COV identified this program as worthy of major expansion because of its potential impact on diverse populations entering the STEM workforce pipeline at the DOE national laboratories and the contributions CCI students make towards the technical staff needs at the laboratories.

WDTS will support an estimated 125 CCI students in FY 2010 and 280 students in FY 2012.

DOE Office of Science Graduate Fellowship	**5,006**	**16,100**

The goal of the DOE SCGF program is to support outstanding U.S. students in their pursuit of research-focused graduate studies in physics, chemistry, biology, mathematics, computer and computational science, engineering, and environmental science—areas of basic research important to the DOE Office of Science mission. Applicants must be U.S. citizens pursing graduate studies at an accredited U.S. college or university. Awards are competitively selected on the basis of external merit-based peer review of applications using established merit review criteria. The Fellowship provides up to three years of support for a graduate student, including a stipend towards tuition and fees, an annual stipend for living expenses, and a research stipend that can be used for costs associated with the student's research and for travel to conferences and DOE scientific user facilities.

As part of the program, Fellows are introduced to the broad spectrum of research supported by the Office of Science and the DOE national laboratory system at an annual research meeting held at a different DOE laboratory each year. As part of the annual meeting, Fellows network with more seasoned researchers and their peers, share their research, attend lectures and poster sessions, tour laboratory facilities, and learn how to access the Office of Science user facilities for their research.

A strong connection with and direct access to the DOE national laboratory system is a unique feature of the program. A major goal of the annual research meeting is to encourage the Fellows to form collaborative research relationships with scientists at the DOE national laboratories and major SC-supported university research centers, and learn how they may advance their research with the scientific user facilities and other resources. This serves to strengthen the relationship between DOE national laboratories and universities that support the DOE science and technology mission.

Program evaluation will include surveys of current participants and longitudinal studies.

WDTS awarded its first DOE SCGF awards in FY 2010, with a total of 150 awards. Eighty fellowships were fully funded for three years with funds through the Recovery Act; the FY 2010 appropriation provided for the first year of funding for the other 70 three-year fellowships.[a]

In FY 2012, increased funding for the DOE Office of Science Graduate Fellowship (SCGF) program will support a new cohort of graduate students. The FY 2012 Request will support a total of 320 fellowships: the first year of a new cohort of graduate students and the third year of the cohort awarded in FY 2010. The goal of the SCGF program is to eventually support a total of 450 Fellows in steady state, with a new cohort of 150 Fellows each year.

**National Science Bowl® **	**2,450**	**2,700**

The National Science Bowl® is an internationally recognized, prestigious academic event for high school and middle school students. It has attained its level of recognition and participation through a grass-roots design, and encourages the voluntary participation of thousands of scientists, engineers, and educators from across the Nation. Students answer questions on topics in astronomy, biology, chemistry, mathematics, and physics in a highly competitive, Jeopardy®-style format.

In its 21-year history (1991–2011), more than 320,000 students from across the Nation have participated in regional and national competitions and have been encouraged to pursue careers in mathematics and science. The number of regional events remains relatively constant from one year to the next with 67 to 70 high school and 36 to 40 middle school teams participating in the national competition in recent years. About 22,000 middle and high school students participate at the regional and national competitions each year, along with more than 7,000 volunteers.

The COV praised the National Science Bowl® and recommended that WDTS focus on improving the diversity of regional competitions. In FY 2010 WDTS supported approximately 100 regional competitions and will support at least 110 in FY 2012 per the COV recommendation.

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[a] Information about the FY 2010 awardees can be found at http://science.energy.gov/scgf.

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
Pre-Service Teachers	**453**	**0**

In FY 2012, the Pre-Service Teachers (PST) program is discontinued consistent with the recommendation of the 2010 COV. The PST program prepared university students interested in pursuing STEM teaching careers. The COV recommended that funds from PST be reallocated to strengthen WDTS core programs (SULI, CCI, SCGF, etc.).

High School Engineering	**300**	**0**

The High School Engineering activity is not funded in FY 2012 per the recommendation of the 2010 COV. This activity was intended to provide a sharper focus on high school engineering education. The COV recommended that funds from this activity be reallocated to strengthen WDTS core programs (SULI, SCGF, CCI, etc.).

Total, Student Programs	**13,042**	**26,800**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Science Undergraduate Laboratory Internship	
The number of students participating in this program increases by 280, from 570 in FY 2010 to a total of 850 in FY 2012.	+2,042
Community College Institute of Science and Technology	
The number of students participating in this program increases by 155, from 125 in FY 2010 to 280 in FY 2012.	+1,125
DOE Office of Science Graduate Fellowship	
A total of 320 Fellows will be supported in FY 2012, an increase of 170 Fellows from FY 2010.	+11,094
National Science Bowl®	
The number of students participating in this program increases through the addition of at least 10 new regional competitions in high-needs areas.	+250
Pre-Service Teachers	
The Pre-Service Teachers program is eliminated in FY 2012 per the 2010 COV recommendation. -453	
High School Engineering	
The High School Engineering activity is not funded in FY 2012 per the 2010 COV recommendation. -300	
Total Funding Change, Student Programs	**+13,758**

Educator Programs

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation FY	2012 Request
Educator Programs		
DOE Academies Creating Teacher Scientists	3,752	0
Faculty and Student Teams	1,019	1,400
Albert Einstein Distinguished Educator Fellowship	1,000	1,200
Total, Educator Programs	5,771	2,600

Description

WDTS Educator Programs are intended to increase the size and quality of the STEM workforce by improving the the ability of educators to serve as mentors and teach science and engineering content. The Faculty and Student Teams (FaST) program is WDTS's premier mechanism to bring under-represented faculty and students into the mainstream of DOE's research enterprise. The Albert Einstein Distinguished Educator Fellowship benefits Federal agencies and Congressional offices because these outstanding educators provide their real-world classroom expertise and advice to national policy makers. The DOE Academies Creating Teacher Scientists (ACTS) program is discontinued in FY 2012 after consideration of the 2010 COV recommendations; WDTS will reevaluate effective mechanisms of STEM teacher training in collaboration with other Federal agencies and the scientific community.

Selected FY 2010 Accomplishments

- In FY 2010, WDTS increased support for diverse students and faculty through the FaST program. A partnership with NSF contributed to WDTS' ability to enable 65 faculty members and 150 students from under-represented institutions to participate in mentored research projects at DOE national laboratories. Faculty and students reported in evaluation surveys that their scientific content knowledge, research capacity, and understanding of how to pursue and further a research career increased as a result of the FaST experience.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
DOE Academies Creating Teacher Scientists	**3,752**	**0**

The DOE ACTS program is terminated in FY 2012 per the recommendation of the 2010 COV. The DOE ACTS program provided professional development opportunities for middle and high school educators at DOE national laboratories. The COV determined that the overall goal of the program was not clear; and questioned whether the program had significant impact in the classroom and on school systems. The COV recommended that funds from this activity be reallocated to strengthen WDTS core programs (SULI, CCI, SCGF, etc.). WDTS will reevaluate effective mechanisms of STEM teacher training in collaboration with other Federal agencies and the scientific community.

(dollars in thousands)		
	FY 2010 Current Appropriation	FY 2012 Request
Faculty and Student Teams	**1,019**	**1,400**

Faculty and Student Teams (FaST) provides an opportunity for faculty and students from under-represented colleges and universities to work on a mentor-intensive science research project at a DOE national laboratory. Faculty members are also encouraged to return to the laboratory in subsequent summer terms. The program has two key components: faculty professional development designed to encourage faculty with limited research experience to develop grant proposals and participate in DOE research programs and student cohorts who accompany the faculty member and participate in a mentored research effort. FaST activities at DOE national laboratories are also being conducted in collaboration with the NSF.

Surveys and other evaluation studies have revealed that faculty support of students at the DOE national laboratories is particularly important for Minority Serving Institutions (MSIs), which are primarily teaching institutions and may not currently support research activities at their home institutions. The FaST program enables the MSIs to build faculty research capabilities, encourages cohorts of diverse students to participate in DOE research, and improves the retention and recruitment of under-represented populations in the DOE system.

Undergraduate students participating in FaST are supported through the SULI and CCI programs, while the FaST budget request supports faculty participation. FaST supported 52 faculty in FY 2010, and will support at least 70 faculty in FY 2012.

Albert Einstein Distinguished Educator Fellowship	**1,000**	**1,200**

The Albert Einstein Distinguished Educator Fellowship for K–12 STEM educators brings classroom and education expertise to Congress, DOE, and other Federal agencies' education and outreach activities. These educators provide practical insights and real-world perspectives to policy makers and program managers. The Einstein Fellowship is also a valuable professional development opportunity for the educators because they return to the education field with knowledge of Federal programs and resources and an improved understanding of national education policies. WDTS manages the Einstein Fellowship on behalf of the Federal government and encourages participation by other Federal agencies.

Evaluation of the Einstein Fellowship program is conducted through longitudinal surveys of past participants, surveys of current participants, and reviews by external experts.

The FY 2012 WDTS request will directly support 7 Fellows. The funding also augments stipends and health insurance for the participants.

Total, Educator Programs	**5,771**	**2,600**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
DOE Academies Creating Teacher Scientists	
The DOE ACTS program is eliminated in FY 2012.	-3,752
Faculty and Student Teams	
The number of faculty supported increases by eighteen.	+381
Albert Einstein Distinguished Educator Fellowship	
The number of Fellows supported increases by one.	+200
Total Funding Change, Educator Programs	**-3,171**

Program Administration and Evaluation

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation FY	2012 Request
Program Administration and Evaluation		
Laboratory Equipment Donation Program	150	200
Evaluation Studies	227	5,000
Workforce Studies	300	0
Technology Development and On-Line Application	400	400
Outreach 688		500
Mentor Program	100	100
Total, Program Administration and Evaluation	1,865	6,200

Description

The Program Administration and Evaluation subprogram provides the data, analysis, and other resources required for effective WDTS program management and delivery. Analytical/evaluation studies are used to ensure the efficiency and effectiveness of WDTS programs. Non-financial resources, such as laboratory equipment and on-line applications, enable WDTS performers and participants to effectively participate in WDTS programs. In addition, WDTS has initiated a number of outreach efforts with universities, professional societies, the private sector, and other Federal agencies designed to leverage fully the WDTS investment in workforce development and STEM education programs.

Selected FY 2010 Accomplishments

- WDTS' effort to evaluate its programs in FY 2010 continued to emphasize an alignment of programmatic goals to leading indicators of success (retention, diversity, quality, content knowledge, competition with reward, and leveraging).
- In FY 2009–2010, WDTS successfully launched a beta version of the *ScienceEducation.gov* web portal, which provides a single location for students and faculty to identify content, experiments, and other materials that originate from WDTS, the DOE national laboratories, and other Federal mission agencies. This portal, developed in partnership with the DOE Office of Scientific and Technical Information (OSTI), provides educators and students with a single access point to educational resources from DOE, the National Oceanic and Atmospheric Administration, the National Aeronautics and Space Administration, the U.S. Department of Agriculture, the National Institutes of Health, and the U.S. Geological Survey.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Laboratory Equipment Donation Program	**150**	**200**

The Laboratory Equipment Donation Program provides excess equipment to faculty at institutions of higher education for energy sciences-related research. Through the Energy Asset Disposal System, DOE sites identify excess laboratory equipment and colleges and universities can then search for equipment of interest to them and apply via the website. DOE property managers approve or disapprove the applications. The equipment is free, but the receiving institution pays for shipping costs. "High needs" (as defined by the U.S. Department of Education) middle and high schools are also eligible, and WDTS pays for shipping costs to these institutions.

Evaluation Studies	**227**	**5,000**

In FY 2012, WDTS' Evaluation Studies and Workforce Studies activities are merged. Workforce studies are designed to be long-term sustained efforts that provide a baseline of data to effectively manage WDTS programs and set overall strategic direction. Continuing studies provide in-depth and systematic reviews of workforce requirements and help determine the long-term benefits of WDTS program investments by tracking the progress of STEM students and workers who participate in WDTS programs.

The Evaluation Studies activity is aligned with recommendations made by Congress through the passage of H.R. 2142, the GPRA Modernization Act of 2010, and the 2008 Congressionally-mandated Academic Competitiveness Council (ACC) initiative, which emphasize the need for Federal programs (including STEM education programs) to demonstrate their effectiveness through rigorous evaluation. WDTS is working cooperatively with NSF, NIH, Office of Science and Technology Policy (OSTP), and other Federal agencies to develop evaluation studies and data that will enable policymakers to assess the benefits and effectiveness of Federal investments.

In FY 2012, the Office of Science plans to initiate a research program to assess the effectiveness of investments in science, including those related to STEM workforce development, consistent with the Federal interagency Science of Science Policy (SoSP) initiative. The Office of Science has worked closely with OSTP, NSF, and other Federal agencies in the development of the SoSP effort, including the development of *The Science of Science Policy: A Federal Research Roadmap*, published in November 2008, and partnering in several community workshops. Research awards in FY 2012 will be competitively awarded on the basis of peer review.

Workforce Studies	**300**	**0**

Workforce Studies is merged into the Evaluation Studies budget in FY 2012.

Technology Development and On-Line Application	**400**	**400**

Technology Development and Online-Application Systems provides for a new IT architecture, which is a 3-year endeavor from FY 2010–2012, and is designed to enhance and maintain the WDTS application and electronic portfolio system. Funding in FY 2012 will support the on-going redesign of all of the websites, on-line applications, and surveys that participants complete during their internship/fellowship experiences.

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
Outreach	**688**	**500**

Outreach provides information to WDTS program alumni (from competitions, undergraduate research internships, educator programs, etc.) to encourage their continued participation in WDTS and SC programs; creates a common database of internship opportunities, fellowships, and other research-based educational opportunities offered by WDTS; assists in the coordination of outreach activities with other Federal agencies; and enhances communication about WDTS programs to the public. A major emphasis of the outreach effort is to increase the participation of under-represented groups and institutions in WDTS programs. WDTS has established relationships with major associations representing under-represented groups and has been working with other Federal agencies, including NSF, to develop cooperative programs that leverage WDTS funds. The FY 2012 increase in funding responds to the COV recommendation to increase outreach to women, minorities, and other under-represented groups.

Mentor Program	**100**	**100**

The Mentor Program has two components: a professional development effort designed to recruit and train mentor scientists at DOE national laboratories, and a recognition/rewards program that will provide incentives for mentor participation in WDTS programs. Scientist mentors are the key resource for WDTS programs and must be nurtured and rewarded in a systematic manner to ensure a sufficient supply of mentors.

Total, Program Administration and Evaluation	**1,865**	**6,200**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Laboratory Equipment Donation Program	
Funding is increased to provide support to high needs high schools.	+50
Evaluation Studies	
Increased funding reflects the integration of all evaluation and workforce studies into one activity and support for research grants related to the interagency Science of Science Policy (SoSP) effort designed to improve WDTS's evaluation of the benefits and effectiveness of its programs.	+4,773
Workforce Studies	
Decreased funding reflects merging of activities into the Evaluation Studies program.	-300

	FY 2012 vs. FY 2010 Current Approp. ($000)
Outreach	
WDTS will engage in additional cooperative outreach programs with other federal agencies to leverage WDTS funding, with a focus on reaching under-served populations.	-188
Total Funding Change, Program Administration and Evaluation	**+4,335**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

	(dollars in thousands)	
FY	2010 Current Appropriation FY	2012 Request
Operating Expenses	20,678	35,600

Science Laboratories Infrastructure

Funding Profile by Subprogram

(dollars in thousands)

FY	2010 Current Appropriation FY	2012 Request
Science Laboratories Infrastructure		
Infrastructure Support	6,599	6,878
Construction	121,001	104,922
Total, Science Laboratories Infrastructure	127,600	111,800

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

The Science Laboratories Infrastructure (SLI) program's mission is to support scientific and technological innovation at the Office of Science (SC) laboratories by funding and supporting mission-ready infrastructure and fostering safe and environmentally responsible operations. Paramount among these is the provision of infrastructure necessary to ensure world leadership by the SC national laboratories in the area of basic scientific research now and in the future. SLI also supports SC stewardship responsibilities for the Oak Ridge Reservation and the Federal facilities in the city of Oak Ridge, and provides Payments in Lieu of Taxes to local communities around the Argonne, Brookhaven, and Oak Ridge National Laboratories.

Background

In FY 2009, SC began an initiative to revitalize its laboratories, with the goal of providing the modern laboratory infrastructure needed to deliver the advances in science the Nation requires in order to remain competitive in the 21st century. Through this initiative, SC is ensuring that its laboratories have state-of-the-art facilities and utilities that are flexible, reliable, and sustainable, with environmentally stable research space and high performance computing space needed to support scientific discovery. New and renovated buildings and utilities will include the latest temperature and humidity controls, clean power, and isolation from vibration and electromagnetic interference where needed. Facility designs will ensure collaborative and interactive work environments and allow for the integration of basic and applied research and development. Once modernized, SC laboratory infrastructure will also aid in the recruitment and retention of the "best and brightest" to work at world-class laboratories.

Despite past investments in infrastructure, many SC laboratory facilities and utility systems are not adequate to support the scientific mission because they do not meet the requirements of modern research described above. The Infrastructure Modernization Initiative will provide capital investment through the SLI program to make these needed improvements. The goals of the Infrastructure Modernization Initiative are to:

- Provide the modern laboratory infrastructure needed to deliver advances in science the Nation requires to remain competitive in the 21st century and

- Correct longstanding deficiencies, while ensuring laboratory infrastructure provides a safe and quality workplace.

The Infrastructure Modernization Initiative currently includes a portfolio of more than 30 projects across all ten SC laboratories. These projects will provide modern laboratory space, renovate space that does not meet research needs, replace facilities that are no longer cost-effective to renovate or operate, modernize utility systems to prevent failures and ensure efficiency, and remove excess facilities to allow safe and efficient operations. The completion of these projects is critical to ensuring the continued mission readiness of SC laboratories. Mission readiness of a laboratory's facilities and infrastructure is the capability of those assets to effectively support the scientific mission assigned to the laboratory. The current and future mission readiness of each SC laboratory is evaluated using a peer review process which focuses on the ability of each laboratory infrastructure element to meet the needs of scientific research.

Subprograms

The Infrastructure Support subprogram provides operating funds for SC stewardship of the Oak Ridge Reservation and for Payments in Lieu of Taxes (PILT). The Construction subprogram provides funding for line item projects under the Infrastructure Modernization Initiative.

Benefits

The SLI program provides state-of-the-art research space in modern, safe, and sustainable laboratory facilities. Subsequent research and development in these revitalized laboratories will facilitate scientific discoveries and the development of new technologies and concepts, which are expected to result in long-term economic growth and job creation in the American economy. Funding for stewardship of the Oak Ridge Reservation and for PILT supports the communities in which SC laboratories are located.

Program Planning and Management

To plan and manage the Infrastructure Modernization Initiative effectively, SLI relies on the SC Annual Laboratory Plans. These plans integrate scientific planning with infrastructure and operational planning by directly tying proposed investments to identified mission capability gaps. The plans provide a clear picture of the mission readiness of each laboratory, the capability gaps, and the investments necessary to fill those gaps. The investments proposed form the basis for projects included in the Initiative.

Projects included in the Initiative are rigorously managed in accordance with the requirements of DOE Order 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, as well as the Office of Science policies and procedures, including Independent Project Reviews. The SLI program managers work closely with the SC Budget and Project Assessment offices during project planning and execution.

Budget Overview

The primary focus of the SLI budget is the on-going Infrastructure Modernization Initiative to ensure the mission readiness of SC Laboratories. Projects funded under the Infrastructure Modernization Initiative will, in many cases, include funds for removal of aged and outdated facilities that are being replaced by new ones. Other small facility decontamination and decommissioning and cleanup projects not included in the Infrastructure Modernization Initiative will be funded with laboratory overhead. The FY 2012 budget request will provide funds for the continuation of 5 previously initiated construction projects, of which 2 projects are scheduled to receive final funding. The projects expected to be fully funded in FY 2012 are the Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II project at Lawrence Berkeley National Laboratory (LBNL) and the Technology and

Engineering Development Facility project at Thomas Jefferson National Accelerator Facility (TJNAF). There is also one new construction project start supported: the Science and User Support Building at SLAC National Accelerator Laboratory (SLAC). This project directly supports the science mission at SLAC.

Infrastructure Support

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation FY	2012 Request
Infrastructure Support		
Oak Ridge Landlord	5,214	5,493
Payments in Lieu of Taxes	1,385	1,385
Total, Infrastructure Support	6,599 6,	878

Description

The Infrastructure Support subprogram provides SC stewardship responsibilities for the Oak Ridge Reservation and the Federal facilities in the city of Oak Ridge, Tennessee, and Payments in Lieu of Taxes (PILT) to local communities around the Argonne, Brookhaven, and Oak Ridge National Laboratories. In the past, the subprogram also provided operating funds for the cleanup and removal of excess facilities at SC laboratories. This activity is now funded through laboratory overhead or embedded in line item construction projects.

Selected FY 2010 Accomplishments

- *Demolition of the Building 51 and Bevatron Demolition Project at Lawrence Berkeley National Laboratory*. The project is eliminating a legacy accelerator which ceased operation in 1993, freeing up approximately three acres of much needed land at the site for programmatic use, and was fully funded as of the FY 2009 appropriation. In FY 2010, the project removed and disposed of shielding blocks (approximately 13,000 tons of concrete) and completed removal of the Bevatron accelerator (approximately 12,000 tons of steel).

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Oak Ridge Landlord	**5,214**	**5,493**

Funding supports landlord responsibilities, including infrastructure for the 24,000 acres of the Oak Ridge Reservation outside of the Y-12 plant, ORNL, and the East Tennessee Technology Park, and DOE facilities in the city of Oak Ridge. Supported activities include maintenance of roads, grounds and other infrastructure; support and improvement of environmental protection, safety, and health; and PILT to Oak Ridge communities. These activities maintain continuity of operations at the Oak Ridge Reservation and the DOE facilities in Oak Ridge and minimize interruptions due to infrastructure or other systems failures.

Payments in Lieu of Taxes	**1,385**	**1,385**

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

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
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.		
Total, Infrastructure Support	**6,599**	**6,878**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Oak Ridge Landlord	
Increase supports reservation road repairs and other critical maintenance needs.	+279
Total Funding Change, Infrastructure Support	**+279**

Construction

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation FY	2012 Request
Construction		
Science and User Support Building at SLAC (12-SC-70)	0	12,086
Research Support Building and Infrastructure Modernization at SLAC (10-SC-70) 6	,900	12,024
Energy Sciences Building at ANL (10-SC-71)	8,000	40,000
Renovate Science Laboratories, Phase II, at BNL (10-SC-72)	5,000	15,500
Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, at LBNL (09-SC-72)	34,027	12,975
Interdisciplinary Science Building, Phase I, at BNL (09-SC-73)	39,387	0
Technology and Engineering Development Facility at TJNAF (09-SC-74) 2	7,687	12,337
Total, Construction	121,001 10	4,922

Description

The SLI Construction subprogram funds line item construction projects to maintain and enhance the general purpose infrastructure at SC laboratories. Infrastructure Modernization Initiative investments are funded in this subprogram and are focused on the accomplishment of long-term science goals and strategies at each SC laboratory. Projects are selected using a collaborative approach involving SC Site Office Managers, laboratory Chief Operating Officers, the SC Deputy Directors for Field Operations and Science Programs, and the SC research program Associate Directors.

Selected FY 2010 Accomplishments

- In FY 2010, all five new structures were completed and accepted for occupancy for the Physical Sciences Facility (PSF) construction project at Pacific Northwest National Laboratory (PNNL), which received the last year of DOE funding in FY 2009 and final Department of Homeland Security funding in FY 2010. This project is necessary to ensure continued research capabilities at this laboratory as existing space is cleaned up and demolished by the Office of Environmental Management. Renovations of Building 325 are ongoing, and the project is on schedule to be completed in February 2011.
- In FY 2010, the ORNL Modernization of Laboratory Facilities project made significant progress, completing steel erection and exterior precast panel and window installation, as well as rough mechanical and electrical work. Final funding was provided in FY 2009 and the project is planned for completion in the first quarter of FY 2012.
- Construction began on the renovation portion of the Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II project at LBNL. Specifically, early demolition work was commenced in the existing Life Sciences building in preparation for modernizing this facility.

- Early procurements and site preparation also began on the Technology and Engineering Development Facility (TEDF) at TJNAF.
- The Interdisciplinary Science Building at BNL completed relocation of site utilities and replacement of unsuitable soil. Final funding was provided in FY 2010 on this project and the project is planned for completion in FY 2013.

Detailed Justification

(dollars in thousands)	FY 2010 Current Appropriation	FY 2012 Request
Science and User Support Building at SLAC (12-SC-70)	**0**	**12,086**

The SLAC Science and User Support building will serve as the main entrance to the laboratory, the first stop for all visitors and users at SLAC, and will bring together many of the laboratory's visitors, users, and administrative services. This will enhance scientific productivity and collaboration that supports the laboratory's cutting-edge discoveries and exceptional user research program.

Research Support Building and Infrastructure Modernization at SLAC (10-SC-70)	**6,900**	**12,024**

SLAC National Accelerator Laboratory has evolved from a single program to a multi-program laboratory. This transition, combined with the condition and age of SLAC facilities drives the need to consolidate core research groups and modernize key support buildings. The Research Support Building and Infrastructure Modernization project will replace substandard modular buildings and trailers that are well beyond their intended useful life with a new Research Support Building and will also modernize existing buildings onsite.

Energy Sciences Building at ANL (10-SC-71)	**8,000**	**40,000**

Argonne National Laboratory research capabilities are currently hampered by antiquated, scientifically inadequate, and inefficient research space. This project will provide environmentally stable, specialized, and flexible space by constructing the new Energy Sciences Building to replace some of the oldest and least effective research space for energy-related sciences.

Renovate Science Laboratories, Phase II, at BNL (10-SC-72)	**5,000**	**15,500**

A large number of scientists and researchers at Brookhaven National Laboratory are conducting science in laboratories built over forty years ago. Two such buildings are Building 510 (Physics) and Building 555 (Chemistry). Although their basic building core and shell construction is sound, the lab and office spaces and their utilities and environmental support systems are obsolete. This project will modernize unsuitable laboratory space in these two buildings, allowing them to continue supporting research in Basic Energy Sciences, Nuclear Physics, and High Energy Physics.

(dollars in thousands)		
	FY 2010 Current Appropriation	FY 2012 Request
Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, at LBNL (09-SC-72)	**34,027**	**12,975**

Lawrence Berkeley National Laboratory is located near the Hayward Fault. Building evaluations conducted in FY 2007 identified more than 30 buildings that would not survive a major earthquake without significant damage to the structure and appreciable life safety hazard to their occupants. This project will remedy high seismic life-safety risks by replacing seismically-poor buildings and trailers with a new general purpose laboratory/office building supporting Life Sciences. This project will also seismically upgrade the site-wide Hazardous Waste Handling Facility and modernize an existing Life Sciences building (Building 74).

Interdisciplinary Science Building, Phase I, at BNL (09-SC-73)	**39,387**	**0**

This project at Brookhaven National Laboratory will provide high accuracy laboratories (e.g., equipped with precise temperature, humidity, and vibration controls), offices, and support space for energy-related research and development in a new interdisciplinary facility. It is part of a broader modernization plan for the laboratory that includes construction of new facilities where capabilities cannot be incorporated into existing buildings or where extensive life-extension work is not cost efficient, and renovation of existing building and utilities where the infrastructure can be made conducive to meet mission needs. This project includes demolition of offsetting space.

Technology and Engineering Development Facility at TJNAF (09-SC-74)	**27,687**	**12,337**

The Technology and Engineering Development Facility project will ensure TJNAF facilities can reliably support production of advanced cryomodules with the quality required for ongoing and future projects and sustain the current high demand for mounting numerous unique large-scale particle detectors. It includes construction of new industrial assembly, laboratory, and office space to eliminate overcrowding and improve workflow and productivity by co-locating the engineering and technical functions currently spread across the laboratory. This project will also renovate existing space in the Test Lab Building, to provide efficient workflow, a safe and sustainable work environment, and functional efficiencies. Demolition of inadequate and obsolete work space is also included.

Total, Construction	**121,001**	**104,922**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Science and User Support Building at SLAC (12-SC-70)	
Project Engineering and Design and early construction activities are initiated.	+12,086
Research Support Building and Infrastructure Modernization at SLAC (10-SC-70)	
Increased project funding per the planned profile in the Project Execution Plan.	+5,124
Energy Sciences Building at ANL (10-SC-71)	
Increased project funding per the planned profile in the Project Execution Plan.	+32,000
Renovate Science Laboratories, Phase II, at BNL (10-SC-72)	
Increased project funding per the planned profile in the Project Execution Plan.	+10,500
Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, at LBNL (09-SC-72)	
Decreased project funding per the planned profile in the Project Execution Plan.	-21,052
Interdisciplinary Science Building, Phase I at BNL (09-SC-73)	
Decreased project funding per the Project Execution Plan.	-39,387
Technology and Engineering Development Facility at TJNAF (09-SC-74)	
Decreased project funding per the planned profile in the Project Execution Plan.	-15,350
Total Funding Change, Construction	**-16,079**

Supporting Information

Operating Expenses, Capital Equipment, and Construction Summary

(dollars in thousands)

	FY 2010 Current Appropriation FY	2012 Request
Operating Expenses	6,499	6,778
General Plant Projects	100	100
Construction 12	1,001	104,922
Total, Science Laboratories Infrastructure	127,600	111,800

Construction Projects

(dollars in thousands)

	Prior Years	FY 2010 Current Approp. FY	2011[a]	FY 2012 Request Ou	tyears	Total
Science & User Support Building at SLAC (12-SC-70)						
TEC 0		0	0	12,086	46,914-51,914	59,000-64,000
OPC[b]	0 0		500	300	200	1,000
TPC 0		0	500	12,386	47,114–52,114	60,000-65,000[c]
Research Support Building and Infrastructure Modernization at SLAC (10-SC-70)						
TEC 0		6,900	40,776	12,024	36,300	96,000
OPC[b] 7	00	0	150	100	450	1,400
TPC 7	00	6,900	40,926	12,124	36,750	97,400
Energy Sciences Building at ANL (10-SC-71)						
TEC 0		8,000	15,000	40,000	32,000	95,000
OPC[b] 9	56	44	0	0	0	1,000
TPC 9	56	8,044	15,000	40,000	32,000	96,000
Renovate Science Laboratories, Phase II, at BNL (10-SC-72)						
TEC 0		5,000	15,000	15,500	14,500	50,000
OPC[b] 7	37	63	0	0	0	800
TPC 7	37	5,063	15,000	15,500	14,500	50,800

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.
[b] Other Project Costs shown are funded through laboratory overhead.
[c] This project has not yet established a performance baseline. Cost and schedule estimates are preliminary.

(dollars in thousands)

	Prior Years	FY 2010 Current Approp. FY	2011[a]	FY 2012 Request Ou	tyears	Total
Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, at LBNL (09-SC-72)						
TEC 2	7,495	34,027	20,103	12,975	0	94,600
OPC[b] 2	,254	2	0	74	150	2,480
TPC 2	9,749	34,029	20,103	13,049	150	97,080
Interdisciplinary Science Building, Phase I, at BNL (09-SC-73)						
TEC	26,913	39,387	0 0 0			66,300
OPC[b]	500	0	0 0 0			500
TPC	27,413	39,387	0 0 0			66,800
Technology and Engineering Development Facility at TJNAF (09-SC-74)						
TEC 3	,700	27,687	28,476	12,337	0	72,200
OPC[b]	823	177	0 0 0			1,000
TPC 4	,523	27,864	28,476	12,337	0	73,200
Total, Construction						
TEC		121,001	119,355	104,922		
OPC[b]		286	650	474		
TPC		121,287	120,005	105,396		

Indirect Costs and Other Items of Interest for the Office of Science

Institutional General Plant Projects (IGPP)

Institutional General Plant Projects are miscellaneous construction projects that have a total cost less than $10,000,000 in FY 2012 and are of a general nature (cannot be allocated to a specific program). IGPPs support multi-programmatic and/or inter-disciplinary programs and are funded through site overhead. Examples of IGPPs include site-wide maintenance facilities and utilities, such as roads and grounds outside the plant fences or a telephone switch that serves the entire facility.

The following displays IGPP funding by site:

(dollars in thousands)

	FY 2010	FY 2012
IGPP		
Argonne National Laboratory	10,012	14,334
Brookhaven National Laboratory	10,891	8,732
Fermi National Accelerator Laboratory	0	0

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.
[b] Other Project Costs shown are funded through laboratory overhead.

	(dollars in thousands)	
	FY 2010	FY 2012
Lawrence Berkeley National Laboratory	5,147	5,500
Oak Ridge National Laboratory	20,382	15,000
Pacific Northwest National Laboratory	3,620	10,850
SLAC National Accelerator Laboratory 2,067		5,829
Total IGPP	52,119	60,245

Facilities Maintenance and Repair

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. The Department's facilities maintenance and repair activities are tied to its programmatic missions, goals, and objectives. Facilities Maintenance and Repair activities funded at SC laboratories are displayed in the following tables.

Indirect-Funded Maintenance and Repair

Facilities maintenance and repair activities funded indirectly through overhead charges at SC laboratories are displayed below. 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 FY 2010 figures are actual expenditures; the FY 2012 figure is projected expenditures.

	(dollars in thousands)	
	FY 2010	FY 2012
Indirect-Funded Maintenance and Repair		
Ames Laboratory	1,142	1,147
Argonne National Laboratory	40,451	45,136
Brookhaven National Laboratory	35,477	37,691
Fermi National Accelerator Laboratory	14,342	15,670
Lawrence Berkeley National Laboratory	21,558	17,008
Lawrence Livermore National Laboratory	2,614	2,719
Los Alamos National Laboratory	113	117
Oak Ridge Institute for Science and Education	634	343
Oak Ridge National Laboratory	59,768	53,840
Oak Ridge National Laboratory facilities at Y-12	897	614
Pacific Northwest National Laboratory	3,696	5,098
Princeton Plasma Physics Laboratory	6,739	6,698
Sandia National Laboratories	2,450	2,548

	(dollars in thousands)	
	FY 2010	FY 2012
SLAC National Accelerator Laboratory 8,997		13,970
Thomas Jefferson National Accelerator Facility	4,828	4,280
Total, Indirect-Funded Maintenance and Repair	203,706	206,879

Direct-Funded Maintenance and Repair

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.

	(dollars in thousands)	
	FY 2010	FY 2012
Direct-Funded Maintenance and Repair		
Brookhaven National Laboratory	4,907	5,491
Fermilab National Accelerator Facility	178	130
Notre Dame Radiation Laboratory	140	171
Oak Ridge National Laboratory	17,216	17,621
Oak Ridge Office	5,213	5,109
Office of Scientific and Technical Information	253	355
SLAC National Accelerator Laboratory 4,397		13,358
Thomas Jefferson National Accelerator Facility	71	63
Total, Direct-Funded Maintenance and Repair	32,375	42,298

Deferred Maintenance Backlog Reduction

The total deferred maintenance backlog at the end of FY 2010 at SC sites is estimated to be $465,000,000. SC is working to reduce the backlog of deferred maintenance at its laboratories. The table below shows an estimate of deferred maintenance reduction funding. These funding amounts are included in the previous tables on direct and indirect funded maintenance.

	(dollars in thousands)	
	FY 2010	FY 2012
Deferred Maintenance Backlog Reduction		
Ames Laboratory	25 0	
Argonne National Laboratory	3,955 8,	074
Brookhaven National Laboratory	10,900 1	1,660
Fermi National Accelerator Laboratory	1,560 1,	560
Lawrence Berkeley National Laboratory	2,000 2,	500
Oak Ridge National Laboratory	9,000 2,	000

	(dollars in thousands)	
	FY 2010	FY 2012
Oak Ridge Institute for Science and Education	40 40	
Oak Ridge Office	1,000 2	50
Pacific Northwest National Laboratory	98 98	
Princeton Plasma Physics Laboratory	340 0	
SLAC National Accelerator Laboratory	1,300 2,	000
Thomas Jefferson National Accelerator Facility	1,857 2	50
Total, Deferred Maintenance Backlog Reduction	32,075 2	8,432

The primary strategy for reducing deferred maintenance is SC's Infrastructure Modernization Initiative, which will modernize the general purpose infrastructure at SC laboratories. The initiative focuses on funding for line item construction projects which will result in significant additional reductions to the deferred maintenance backlog. These reductions are not included in the table above, nor does the table include reductions resulting from IGPP, GPP and programmatic line items.

12-SC-70, Science and User Support Building
SLAC National Accelerator Laboratory, Menlo Park, California
Project Data Sheet is for PED/Construction

1. Significant Changes

DOE O 413.3B Critical Decision (CD) CD-0 was approved August 26, 2010, with a preliminary Total Estimated Cost (TEC) range of $59,000,000 to $64,000,000. Total Project Cost is estimated to range between $60,000,000 to $65,000,000.

A Federal Project Director at the appropriate certification level will be assigned to this project prior to CD-1.

This Project Data Sheet is new for PED/Construction.

2. Design, Construction, and D&D Schedule

(dollars in thousands)

	CD-0	CD-1	PED Complete	CD-2/3	CD-4	D&D Start	D&D Complete
FY 2012[a]	8/26/2010	2Q FY 2012	4Q FY 2013	TBD	TBD	TBD	TBD

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2/3 – Approve Performance Baseline; Approve Start of Construction
CD-4 – Approve Start of Operations or Project Closeout
D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete – Completion of D&D work

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	TEC Construction	TEC, Total	OPC[b] Except D&D	OPC, D&D	OPC, Total	TPC
FY 2012[c]	5,000 5	9,000	64,000	1,000	TBD	1,000 6	5,000

4. Project Description, Justification, and Scope

SLAC National Accelerator Laboratory is an Office of Science 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's state-of-the-art facilities for ultra-fast nanoscience result in the need for modern, collaborative infrastructure to support this research and the user community. Because of early LCLS success, new instruments at the SSRL, and future plans related to accelerator research,

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[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 are funded through laboratory overhead.
[c] This project is pre-CD-2 and cost estimates are preliminary. The preliminary Total Estimated Cost (TEC) range for this project is $59,000,000 to $64,000,000. The preliminary Total Project Cost (TPC) range for this project is $60,000,000 to $65,000,000.

the demand to use SLAC's unique research facilities is increasing rapidly. This has resulted in a critical gap in SLAC's mission capability due to inadequate centralized support for its user community and lack of modern, collaborative infrastructure to support a world-class research program.

To close the mission capability gap and ensure that the world-class research conducted by SLAC scientific staff and users is supported by modern, mission-ready facilities, a Science and User Support Building (SUSB) is proposed, located at the entrance to the Laboratory. This facility will be the first stop for all users and visitors to SLAC, and will bring together many of the Laboratory's user, visitor, and administrative services to enhance productivity and collaboration.

The proposed building is estimated to range between $60,000,000 and $65,000,000 in Total Project Cost. A range of alternatives will be considered; however, the current proposed approach is to construct a building that will house a centrally located user support hub; the visitor's center; a new cafeteria; office space needed to centralize SLAC communications, security, and laboratory administration; and a state-of-the-art auditorium and conference space.

FY 2012 PED funding will be used for design of the project, including project management and all associated support functions. FY 2012 construction funding will support early procurement and construction activities on this project, such as site preparation, including project management and all associated support functions.

The project will be conducted in accordance with the project management requirements in DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets, and all appropriate project management requirements have been met.

5. Financial Schedule

(dollars in thousands)

App	ropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2012	5,000	5,000	4,500
FY 2013	0	0	500
Total, PED	5,000	5,000	5,000
Construction			
FY 2012	7,086	7,086	4,000
Outyears TBD		TBD	TBD
Total, Construction	TBD	TBD	TBD

(dollars in thousands)

App	ropriations	Obligations	Costs
TEC[a]			
FY 2012	12,086	12,086	8,500
Outyears TBD		TBD	TBD
Total, TEC	TBD	TBD	TBD
Other Project Cost (OPC)[b]			
OPC except D&D			
FY 2011	500	500	500
FY 2012	300	300	300
FY 2013	200	200	200
Total, OPC except D&D	1,000	1,000	1,000
Total Project Cost (TPC)[a]			
FY 2011	500	500	500
FY 2012	12,386	12,386	8,800
Outyears TBD		TBD	TBD
Total, TPC	TBD	TBD	TBD

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design 4	,150	N/A	N/A
Contingency	850	N/A	N/A
Total, PED	5,000	N/A	N/A
Construction			
Construction 5,	669	N/A	N/A
Contingency 1,	417	N/A	N/A
Total, Construction	7,086	N/A	N/A

[a] This project is pre-CD-2 and cost estimates are preliminary. The preliminary TEC range for this project is $59,000,000 to $64,000,000. The preliminary TPC range for this project is $60,000,000 to $65,000,000.
[b] Other Project Costs are funded through laboratory overhead.

	(dollars in thousands)		
	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total, TEC	TBD N	/A	N/A
Contingency, TEC	2,267	N/A	N/A
OPC[a]			
Other OPC	500	N/A	N/A
Start-Up 3	00	N/A	N/A
Contingency 20	0	N/A	N/A
Total, OPC	1,000	N/A	N/A
Total, TPC	10,619[b] N/A		N/A
Total, Contingency	2,467	N/A	N/A

7. Funding Profile History

(dollars in thousands)

Request Year		FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2012	TEC	0	12,086 TBD TBD TBD				TBD[c]
OPC	[b]	500 3	00 2	00	0	0	1,000
	TPC	500	12,386 TBD TBD TBD				TBD[c]

8. Related Operations and Maintenance Funding Requirements

Not applicable. Project does not yet have CD-2 approval.

9. Required D&D Information

Not applicable. Project does not yet have CD-2 approval.

10. Acquisition Approach

Design will be performed by an architect-engineer (A-E) with the subcontract managed by the SLAC operating contractor.

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[a] Other Project Costs are funded through laboratory overhead.

[b] This project has not yet received approval of CD-2; therefore, construction, TEC, and TPC displayed in table 6 only include anticipated activities through FY 2012.

[c] This project is pre-CD-2 and cost estimates are preliminary. The preliminary TEC range for this project is $59,000,000 to $64,000,000. The preliminary Total Project Cost (TPC) range for this project is $60,000,000 to $65,000,000.

10-SC-70, Research Support Building and Infrastructure Modernization, SLAC National Accelerator Laboratory, Menlo Park, California
Project Data Sheet is for PED/Construction

1. Significant Changes

The most recent DOE O 413.3B Critical Decision (CD) is CD-2/3A, Approve Performance Baseline and Start of Construction, which was approved on December 20, 2010, with a Total Estimated Cost (TEC) of $96,000,000.

A Federal Project Director with certification level III has been assigned to this project.

This Project Data Sheet is for PED/Construction. This PDS is an update of the FY 2011 PDS. Since that submittal, the estimate for project engineering and design (PED) activities has been revised downward from $8,900,000 to $6,900,000. The construction estimate has been revised upward by an equal amount such that there is no net increase in the TPC.

2. Design, Construction, and D&D Schedule

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2/3A	CD-3B	CD-4	D&D Start	D&D Complete
FY 2010	10/10/2008	1Q FY 2010	2Q FY 2011	TBD	TBD	TBD	TBD	TBD
FY 2011	10/10/2008	11/3/2009	4Q FY 2011	4Q FY 2010	4Q FY 2012	1Q FY 2015	4Q FY 2011	2Q FY 2015
FY 2012	10/10/2008	11/3/2009	4Q FY 2011	12/20/2010	2Q FY 2013	3Q FY 2015	2Q FY 2011	4Q FY 2014

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2/3A – Approve Performance Baseline; RSB (Building 52) and Building 28
CD-3B – Approve Start of Construction; Building 41
CD-4 – Approve Start of Operations or Project Closeout
D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete – Completion of D&D work

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	TEC Construction	TEC, Total	OPC[a] Except D&D	OPC, D&D	OPC, Total	TPC
FY 2010	8,900	TBD	TBD	1,400	TBD	TBD	TBD
FY 2011	8,900	87,100	96,000	1,400	N/A	1,400	97,400
FY 2012	8,900	87,100	96,000	1,400	N/A	1,400	97,400

4. Project Description, Justification, and Scope

SLAC National Accelerator Laboratory is an Office of Science laboratory that supports a large national and international community of scientific users performing cutting edge research in support of the Department of Energy mission. Success of that mission is directly coupled to the general purpose

[a] Other Project Costs are funded through laboratory overhead.

infrastructure necessary to conduct this research. At SLAC, accomplishment of that mission is currently at risk given substandard buildings that do not provide the appropriate environment to conduct world class science or mission support functions.

SLAC has moved from a single-program to a multi-program laboratory; this transition, combined with the condition and age of SLAC facilities, drives the need to better align core research functions and modernize key support buildings. The most pressing infrastructure gaps are the lack of appropriate space to house and co-locate accelerator scientists and key mission support staff who are currently spread across the laboratory in outdated and inefficient facilities.

To correct these deficiencies, a new building is proposed to house the laboratory's accelerator scientists. This new building will replace numerous 40-year-old trailers that currently support these scientists. This will enable integration of the accelerator science and technology community across programmatic boundaries, allowing these scientists to better support the science missions at the laboratory. In addition, renovation of existing buildings is proposed. These buildings house key mission support functions and were part of the original construction of the laboratory in the mid-1960s. Although the basic core and shell construction are sound, their interior and exterior spaces and utility systems are obsolete. Overall, the proposed project will upgrade working conditions for over 20% of the laboratory staff in a way that supports the laboratory vision of a unified culture with a strong sense of community between all scientific and support functions across the laboratory.

The new building construction is anticipated to be in the range of 53,000 to 64,000 square feet; a minimum of 53,000 square feet of existing space will undergo renovation, and demolition of approximately 20,000 square feet will be completed to provide the site for the new construction. The remaining balance of gross square feet to be demolished to meet the one-for-one replacement will be from banked excess.

FY 2012 funding will be used for construction activities, including project management and all associated support functions.

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.

5. Financial Schedule

(dollars in thousands)

App	ropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2010	6,900	6,900	4,800
FY 2011[a] 0		0	2,100
Total, PED	6,900	6,900	6,900

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

App	ropriations	Obligations	Costs
	(dollars in thousands)		
Construction			
FY 2011[a]	40,776 4	0,776	15,800
FY 2012	12,024	12,024	35,000
FY 2013	36,300	36,300	19,500
FY 2014	0	0	18,200
FY 2015	0	0	600
Total, Construction	89,100	89,100	89,100
TEC			
FY 2010	6,900	6,900	4,800
FY 2011[a]	40,776 4	0,776	17,900
FY 2012	12,024	12,024	35,000
FY 2013	36,300	36,300	19,500
FY 2014	0	0	18,200
FY 2015	0	0	600
Total, TEC	96,000	96,000	96,000
Other Project Cost (OPC)[b]			
OPC except D&D			
FY 2009	700	700	700
FY 2010	0	0	0
FY 2011[a]	150 1	50	150
FY 2012	100	100	100
FY 2013	250	250	250
FY 2014	200	200	200
Total, OPC	1,400	1,400	1,400
Total Project Cost (TPC)			
FY 2009	700	700	700
FY 2010	6,900	6,900	4,800
FY 2011[a]	40,926 4	0,926	18,050
FY 2012	12,124	12,124	35,100
FY 2013	36,550	36,550	19,750
FY 2014	200	200	18,400
FY 2015	0	0	600
Total, TPC	97,400	97,400	97,400

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.
[b] Other Project Costs are funded through laboratory overhead.

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate[a]	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design 6	,306	6,675	6,306
Contingency	594	2,225	594
Total, PED	6,900	8,900	6,900
Construction			
Construction 7	2,494	69,900	72,494
Contingency 1	6,606	17,200	16,606
Total, Construction	89,100	87,100	89,100
Total, TEC	96,000	96,000 9	6,000
Contingency, TEC	17,200	19,425	17,200
OPC[b]			
Other OPC	700	900	700
Start-Up 5	14	300	514
Contingency 1	86	200	186
Total, OPC	1,400	1,400	1,400
Total, TPC	97,400	97,400	97,400
Total, Contingency	17,386	19,625	17,386

7. Funding Profile History

(dollars in thousands)

Request Year		FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	Total
FY 2010	TEC	0	8,900	TBD	TBD	TBD	TBD	TBD
	OPC	500	900	TBD	TBD	TBD	TBD	TBD
	TPC	500	9,800	TBD	TBD	TBD	TBD	TBD
FY 2011	TEC	0	6,900 3	3,100 1	9,700 3	6,300	0 9	6,000
	OPC	700	100 1	00 1	50 3	00	50	1,400
	TPC	700	7,000 3	3,200 1	9,850 3	6,600	50 9	7,400

[a] Previous estimates shown only included partial funding.
[b] Other Project Costs are funded through laboratory overhead.

Request Year		(dollars in thousands) FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	Total
FY 2012	TEC	0	6,900 4	0,776 1	2,024 3	6,300	0 9	6,000
OPC	[a]	700	0 1	50 1	00 2	50 2	00	1,400
TPC		700 6	,900	40,926[b]	12,124 3	6,550	200 9	7,400

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	FY 2014
Expected Useful Life	50 years
Expected Future Start of D&D of this capital asset	FY 2064

(Related Funding requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations 1	46	399	7,300	10,266
Maintenance 6	33	1,722	31,650	44,481
Total, Operations & Maintenance	779	2,121	38,950	54,747

9. Required D&D Information

This project will include demolition of approximately 20,000 square feet to clear the proposed site for the new construction. The remaining balance of gross square feet to be demolished to meet the one-for-one replacement will be from banked excess.

10. Acquisition Approach

Design is being performed by an architect-engineer (A-E) with the subcontract managed by the SLAC operating contractor. The A-E subcontractor was competitively selected based on demonstrated competence and qualifications to perform the required design services at a fair and reasonable price. A design-build approach will be used to procure construction of the new Research Support Building, and a traditional design-bid-build approach will be used for remaining portions of the construction. Competitive construction bids will be sought by the SLAC operating contractor.

[a] Other Project Costs are funded through laboratory overhead.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

10-SC-71, Energy Sciences Building, Argonne National Laboratory, Argonne, IL
Project Data Sheet is for PED/Construction

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-2, Approve Performance Baseline, which was approved on January 10, 2011, with a Total Estimated Cost (TEC) $95,000,000.

A Federal Project Director with a certification level II has been assigned to this project.

This Project Data Sheet is for PED/Construction. This PDS is an update of the FY 2011 PDS.

2. Design, Construction, and D&D Schedule

(fiscal quarter or date)

	CD-0	CD-1	PED Complete	CD-2	CD-3A	CD-3B	CD-4
FY 2010	10/10/2008	4Q FY 2009	2Q FY 2011	TBD	TBD	TBD	TBD
FY 2011	10/10/2008	09/02/2009	2Q FY 2011	2Q FY 2011	2Q FY 2011	2Q FY 2012	4Q FY 2014
FY 2012	10/10/2008	09/02/2009	2Q FY 2011	01/20/2011	N/A	3Q FY 2011	4Q FY 2014

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Ranges
CD-2 – Approve Performance Baseline
CD-3A – Approve Start of Site Preparation – Updated tailoring strategy has eliminated CD-3A
CD-3B – Approve Start of Building Construction – Updated tailoring strategy has changed CD-3B to CD-3
CD-4 – Approve Start of Operations or Project Closeout

(fiscal quarter or date)

	D&D Start	D&D Complete
FY 2010	TBD	TBD
FY 2011	N/A	N/A
FY 2012	N/A	N/A

D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete –Completion of D&D work

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	TEC, Construction	TEC, Total	OPC[a] Except D&D	OPC, D&D	OPC, Total	TPC
FY 2010	10,000	TBD	TBD	1,000	TBD	TBD	TBD
FY 2011	10,000	85,000	95,000	1,000	N/A	1,000	96,000
FY 2012	10,000	85,000	95,000[a]	1,000	N/A	1,000	96,000

4. Project Description, Justification, and Scope

This project will provide between 125,000 and 165,000 gross square feet of new energy efficient and environmentally sustainable laboratory space at Argonne National Laboratory (ANL). The new facility

[a] Other Project Costs are funded through laboratory overhead.

will provide modern, 21st century, high-accuracy laboratories for energy-related research and development (R&D) and associated space for support functions. The design will utilize modern, efficient laboratory planning benchmarks as the basis for determining the size and configuration of space types. The design of the space will also emphasize more open, collaborative environments and flexibility to respond to future mission changes. In addition to the research laboratories, the building will include office space for researchers, small group conference rooms, equipment areas, restrooms, circulation space, and supporting infrastructure.

The objective of the Energy Sciences Building (ESB) project is to provide high-accuracy, flexible, and sustainable laboratory and office space 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 available at ANL. The scope of the project includes design, construction, and necessary furniture and equipment for the new facility as well as extension of existing site utilities to the new building.

Key areas of energy research to be housed in the ESB include discovery synthesis, biomimetics, solar energy, catalysis, fuel cell research, and electrical energy storage. These research areas currently lack modern scientific space needed for seamless multi-disciplinary collaborative research, the hallmark of 21st century science and engineering.

ANL research buildings dedicated to the SC energy research mission are all more than 40 years old. They require constant repair and frequently compromise or halt scientific research and are unable to meet modern standards for high resolution apparatus requiring vibration, electromagnetic, and thermal stability. Electrical power in these facilities is unstable and insufficient for modern synthesis and measurement instruments to operate at rated performance levels. Temperature and humidity controls were designed for human comfort only and not for state-of-the-art experimental performance, resulting in erratic temperature and humidity fluctuations over a few hours requiring frequent recalibration of apparatus to achieve sufficient measuring accuracy. Several key laboratories can operate only at night because of excessive vibration, temperature, and power fluctuations in the daytime, significantly impeding productivity. In addition to the functional inadequacies described above, safety and building code non-compliances further compromise ANL's ability to support SC and the Department's long-term energy goals. Antiquated and outdated electrical, fire protection, and ventilation systems have resulted in numerous National Electric and National Fire Protection Association code deficiencies. The age of these facilities and systems as well as the inability to obtain replacement parts has limited ANL's ability to correct these deficiencies via replacement or capital improvements.

FY 2012 construction funding will support construction activities on this project, including project management and all associated support functions.

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.

5. Financial Schedule

(dollars in thousands)

App	ropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED[a]			
FY 2010	8,000	8,000	4,400
FY 2011[b] 2,	000	2,000	5,600
Total, PED	10,000	10,000	10,000
Construction			
FY 2011[b]	13,000 1	3,000	6,000
FY 2012	40,000	40,000	42,000
FY 2013	32,000	32,000	TBD
FY 2014	0	0	TBD
Total, Construction	85,000	85,000	85,000
TEC			
FY 2010	8,000	8,000	4,400
FY 2011[b]	15,000 1	5,000	11,600
FY 2012	40,000	40,000	42,000
FY 2013	32,000	32,000	TBD
FY 2014	0	0	TBD
Total, TEC	95,000	95,000[c]	95,000
Other Project Cost (OPC)[c]			
OPC except D&D			
FY 2009	956	956	956
FY 2010	44	44	44
Total, OPC	1,000	1,000	1,000
Total Project Cost (TPC)			
FY 2009	956	956	956
FY 2010	8,044	8,044	4,400
FY 2011[b]	15,000 1	5,000	11,600
FY 2012	40,000	40,000	42,000
FY 2013	32,000	32,000	TBD
FY 2014	0	0	TBD
Total, TPC	96,000	96,000	96,000

[a] All design will be complete in less than 18 months.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.
[c] Other Project Costs are funded through laboratory overhead.

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate[a]	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)[b]			
Design 8	,334	8,334	N/A
Contingency 1,	666	1,666	N/A
Total, PED	10,000	10,000	N/A
Construction			
Other Construction	70,707	70,707	N/A
Contingency 1	4,293	14,293	N/A
Total, Construction	85,000	85,000	N/A
Total, TEC	95,000	95,000	N/A
Contingency, TEC	15,959	15,959	N/A
Other Project Cost (OPC)[c]			
OPC except D&D			
Conceptual Planning	263	263	N/A
Conceptual Design	737	737	N/A
Contingency 0		0	N/A
Total, OPC	1,000	1,000	N/A
Total, TPC	96,000	96,000	N/A
Total, Contingency	15,959	15,959	N/A

7. Funding Profile History

(dollars in thousands)

Request Year		FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	Total
FY 2010	TEC	0	10,000	TBD TBD TBD			TBD
OPC	[c]	1,000 0		0 0 0			TBD
	TPC	1,000	10,000	TBD TBD TBD			TBD
FY 2011	TEC	0	8,000	15,000 4	5,000 2	7,000	95,000
OPC	[c]	956	44	0 0 0			1,000
	TPC	956	8,044	15,000 4	5,000 2	7,000	96,000

[a] Previous estimates shown only included partial funding.
[b] All design will be complete in less than 18 months.
[c] Other Project Costs are funded through laboratory overhead.

Request Year		FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	Total
		(dollars in thousands)					
FY 2012	TEC	0	8,000	15,000 4	0,000 3	2,000	95,000
OPC	[a]	956	44	0 0 0			1,000
TPC		956	8,044	15,000[b] 4	0,000	32,000	96,000

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	FY 2014
Expected Useful Life	50 years
Expected Future Start of D&D of this capital asset	FY 2064

(Related Funding requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations	733 7	33	96,182	96,182
Maintenance	1,153 1,	153	37,363	37,363
Total, Operations & Maintenance	1,886	1,886	133,545	133,545

9. Required D&D Information

This project has secured "banked space" from prior Nuclear Footprint Reduction efforts at Argonne as well as demolition projects at other Office of Science facilities to meet the one for one requirement for offsetting space.

10. Acquisition Approach

The ESB project Acquisition Strategy was approved on January 7, 2009.

The M&O contractor, Argonne University of Chicago, LLC, will have prime responsibility for oversight of both the design and construction subcontracts.

Various acquisition alternatives were 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 services through the industrial partnership, and construction by a general contractor, all led by the M&O contractor integrated project team, was deemed to 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 ES&H management systems in the acquisition of scientific facilities.

[a] Other Project Costs are funded through laboratory overhead.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

10-SC-72, Renovate Science Laboratories, Phase II, Brookhaven National Laboratory (BNL), Upton, New York
Project Data Sheet is for PED/Construction

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-2/3a, Approve Performance Baseline and Start of Site Preparation, which was approved on December 20, 2010, with a Total Estimated Cost (TEC) of $50,000,000.

A Federal Project Director with certification level II has been assigned to this project.

This Project Data Sheet is for PED/Construction. This PDS is an update of the FY 2011 PDS. Since that submittal, the estimate for project engineering and design (PED) activities has been revised downward from $7,000,000 to $6,000,000. The construction estimate has been revised upward by an equal amount such that there is no net change to the TPC.

2. Design, Construction, and D&D Schedule

(fiscal quarter to date)

	CD-0	CD-1 (Design Start)	PED Complete	CD-2/3a	CD-3b	CD-4
FY 2010	10/10/2008	4Q FY 2009	3Q FY 2011	TBD	TBD	TBD
FY 2011	10/10/2008	9/2/2009	2Q FY 2011	1Q FY 2011	4Q FY 2011	2Q FY 2014
FY 2012	10/10/2008	9/2/2009	2Q FY 2011	12/20/2010	4Q FY 2011	3Q FY 2014

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2/3a – Approve Performance Baseline and Start of Site Preparation
CD-3b – Approve Start of Construction
CD-4 – Approve Start of Operations or Project Closeout

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	TEC, Construction	TEC, Total	OPC Except D&D[a]	OPC, D&D	OPC, Total	TPC
FY 2010	7,000	TBD	TBD	800	TBD	TBD	TBD
FY 2011	7,000	43,000	50,000	800	TBD	800	50,800
FY 2012	6,000	44,000	50,000	800	N/A	800	50,800

4. Project Description, Justification, and Scope

A large number of scientists and researchers at BNL are conducting science in laboratories built over forty years ago. Although their basic building core and shell construction is sound, the lab and office spaces and their utilities and environmental support systems are totally obsolete.

The laboratories in Building 510 for the Physics Department were constructed in 1962 and are desperately in need of renovation and modernization in order to keep pace with the highly complex and

[a] Other Project Costs are funded through laboratory overhead.

rapidly changing technologies required for work on advanced new detectors. This work involves sophisticated electronics, high precision mechanical assemblies, and extremely clean work areas for detectors such as silicon or gas filled devices. A task force conducted a condition assessment of the laboratories and developed a list of deficiencies that included damaged floors and ceilings, roof and ceiling leaks, old and unused plumbing, poor lighting levels, decrepit lab facilities, poor temperature control and ventilation, significant particulate discharge from heating, ventilation, and air conditioning systems, high electromagnetic interference noise on electrical power in certain laboratories, and lack of fire sprinkler protection.

Building 555 has a robust design for chemical sciences research, but was constructed in 1966 and now has a number of substantial limitations for current research needs. While Building 555 has an effective design for wet chemistry, it needs to be renovated to address very serious infrastructure quality issues that have grown over the years. Its design can also accommodate the evolving need for laser and instrumentation space for many of the physical methods in use, but an upgrade of facilities for air, water, and electrical is critical, and selective lab reconfiguration is needed to best meet advanced instrumentation needs.

The Renovate Science Laboratories, Phase II project will upgrade and rehabilitate existing, obsolete, and unsuitable BNL laboratory facilities into modern, efficient laboratory spaces compatible with world-class scientific research. This project will revitalize and modernize laboratories and support space located in each of 2 buildings, Building 510 Physics and Building 555 Chemistry.

FY 2012 construction funds will be used to continue construction.

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)

App	ropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2010	5,000	5,000	3,000
FY 2011[a]	1,000 1,	000	3,000
Total, PED	6,000	6,000	6,000
Construction			
FY 2011[a] 1	4,000	14,000	2,000
FY 2012	15,500	15,500	19,000
FY 2013	14,500	14,500	22,500
FY 2014	0	0	500
Total, Construction	44,000	44,000	44,000

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

(dollars in thousands)

App	ropriations	Obligations	Costs
TEC			
FY 2010	5,000	5,000	3,000
FY 2011[a]	15,000 1	5,000	5,000
FY 2012	15,500	15,500	19,000
FY 2013	14,500	14,500	22,500
FY 2014	0	0	500
Total, TEC	50,000	50,000	50,000
Other Project Cost (OPC)[b]			
OPC except D&D			
FY 2009	737	737	737
FY 2010	63	63	63
Total, OPC	800	800	800
Total Project Cost (TPC)			
FY 2009	737	737	737
FY 2010	5,063	5,063	3,063
FY 2011[a]	15,000 1	5,000	5,000
FY 2012	15,500	15,500	19,000
FY 2013	14,500	14,500	22,500
FY 2014	0	0	500
Total, TPC	50,800	50,800	50,800

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design 5	,007	6,200	5,007
Contingency 9	93	800	993
Total, PED	6,000	7,000	6,000

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.
[b] Other Project Costs are funded through laboratory overhead

	(dollars in thousands)		
	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Construction			
Other Construction	36,363	34,400	36,363
Contingency 7,	637	8,600	7,637
Total, Construction	44,000	43,000	44,000
Total, TEC	50,000	50,000	50,000
Contingency, TEC	8,630	9,400	8,630
Other Project Cost (OPC)[a]			
OPC except D&D			
Conceptual Planning	150	150	150
Conceptual Design	650	650	650
Contingency 0		0	0
Total, OPC	800	800	800
Total, TPC	50,800	50,800 5	0,800
Total, Contingency	8,630	9,400	8,630

7. Funding Profile History

(dollars in thousands)

Request Year		FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	Total
FY 2010	TEC	0	7,000 TBD TBD TBD				TBD
OPC	[a]	800 0 0 0 0					800
	TPC	800	7,000 TBD TBD TBD				TBD
FY 2011	TEC	0	5,000 1	5,000 2	2,000	8,000	50,000
OPC		737	63 0 0 0				800
	TPC	737	5,063 1	5,000 2	2,000	8,000	50,800
FY 2012	TEC	0	5,000 1	5,000 1	5,500 1	4,500	50,000
	OPC	737	63 0 0 0				800
TPC		737	5,063	15,000[b] 1	5,500	14,500	50,800

[a] Other Project Costs are funded through laboratory overhead.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

8. Related Operations and Maintenance Funding Requirements

Project is a renovation of existing space within existing buildings.

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	3Q FY 2014
Expected Useful Life (number of years)	30
Expected Future Start of D&D of this capital asset (fiscal quarter)	N/A

9. Required D&D Information

The project will not require demolition of a sufficient amount of excess facilities to meet space offsetting requirements for a new building at the BNL site. The project is a renovation of existing space. No new space will be constructed.

10. Acquisition Approach

Design will be performed by an architect-engineer (A-E) with the subcontract managed by the BNL operating contractor. The A-E will be competitively selected based on qualifications. After completion of the design, the BNL operating contractor will solicit offers from prospective large and small business general construction firms, and award a firm fixed price construction subcontract. Evaluation of offers will include consideration of each offeror's relative experience, safety record, past performance in successfully completing similar construction projects, and cost. Award will then be made to one qualified responsible, responsive offeror.

09-SC-72, Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, Lawrence Berkeley National Laboratory (LBNL), Berkeley, California
Project Data Sheet is for PED/Construction

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-2C, Approve Performance Baseline for Remainder of Project, which was approved on August 30, 2010. This project has a Total Estimated Cost (TEC) of $94,600,000.

A Federal Project Director with a certification level II has been assigned to this project.

This Project Data Sheet (PDS) is for PED/Construction. This PDS is an update of the FY 2011 PDS.

The Project has added supporting space for a connected utility building to facilitate the approved location of the General Purpose Laboratory facility.

2. Design, Construction, and D&D Schedule

(fiscal quarter or date)

	CD-0	CD-1	(PED Complete)	CD-2A/B	CD-2C	CD-3A	CD-3B	CD-3C
FY 2009	9/18/2007	2Q FY 2009	3Q FY 2010	N/A	TBD	N/A	N/A	TBD
FY 2010	9/18/2007	9/23/2008	4Q FY 2010	N/A	TBD	N/A	N/A	TBD
FY 2011	9/18/2007	9/23/2008	1Q FY 2011	8/21/2009	4Q FY 2010	8/21/2009	2Q FY 2010	4Q FY 2011
FY 2012	9/18/2007	9/23/2008	10/29/2010	8/21/2009	8/30/2010	8/21/2009	3/15/2010	4Q FY 2011

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2A/2B – Approve Performance Baseline for Building 74 Demolition and Long Lead Procurement; and for Building 74 Modernization and Building 25 Demolition
CD-2C – Approve Performance Baseline for Remainder of Project
CD-3A – Approve Start of Building 74 Demolition and Long Lead Procurement
CD-3B – Approve Start of Construction for Building 74 Modernization and Building 25 Demolition
CD-3C – Approve Start of Construction for Remainder of Project

(fiscal quarter or date)

	CD-4A/B	CD-4C	D&D Start	D&D Complete
FY 2009	TBD	TBD	TBD	TBD
FY 2010	TBD	TBD	TBD	TBD
FY 2011	1Q FY 2013	2Q FY 2015	4Q FY 2010	3Q FY 2014
FY 2012	1Q FY 2013	3Q FY 2015	9/30/2010	1Q FY 2014

CD-4A/4B – Complete Building 74 Demolition and Long Lead Procurement, and Approve Start of Operations for Building 74 Modernization and Building 25 Demolition
CD-4C – Approve Start of Operations
D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete – Completion of D&D work for Remainder of Project

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	TEC, Construction	TEC, Total	OPC[a] Except D&D	OPC, D&D	OPC, Total	TPC
FY 2009	8,680	TBD	TBD	2,300	TBD	TBD	TBD
FY 2010	9,680	TBD	TBD	2,300	TBD	TBD	TBD
FY 2011	9,680	84,920	94,600	2,480	N/A	2,480	97,080
FY 2012	9,680	84,920	94,600	2,480	N/A	2,480	97,080

4. Project Description, Justification, and Scope

The objective of this project is to replace seismically unstable, high maintenance facilities at the Lawrence Berkeley National Laboratory (LBNL) with modern, seismically stable, state-of-the-art laboratory space in support of the mission requirements of the Office of Science.

This project includes the modernization of Building 74, including upgrades to building systems and laboratory/office space; construction of a General Purpose Laboratory (GPL) and supporting space for a utility building; seismic upgrades and slope stabilization for Building 85, the site-wide Hazardous Waste Handling Facility; and demolition of offsetting space. The project includes all necessary design and construction activities and start-up of operations for both the new facility and Building 74.

LBNL is an Office of Science multi-program national laboratory with a mission to perform leading multidisciplinary research in the fields of energy sciences, general sciences, and life sciences. The laboratory's research makes use of multidisciplinary collaboration and advanced engineering, computation, communications, fabrication, and other support facilities characteristic of a national laboratory. The laboratory's facilities are planned, constructed, and maintained to support the research programs and scientific goals, while maintaining compatibility with the university community and the surrounding physical setting. Research at LBNL is directly tied to the quality of its facilities and site improvements through a proactive building and utility maintenance program.

LBNL completed seismic evaluations of all permanently owned and occupied LBNL buildings in FY 2007. These evaluations have revealed that several buildings are seismically unsafe, and would not be able to survive a major earthquake without significant damage to the structure and appreciable life safety hazard to their occupants. The U.S. Geological Survey has estimated the probability of a major seismic event in the San Francisco Bay Area at 67% in the next 30 years. LBNL is located less than one kilometer from the Hayward Fault and will be subjected to severe shaking during a major seismic event on this fault.

This project, through the provision of the new GPL and the upgrades to the existing building systems, will provide safe, modern, and energy efficient laboratories for multidisciplinary science. The research performed in these facilities will support and enhance work conducted at LBNL user facilities including the Advanced Light Source, the National Center for Electron Microscopy, and the Molecular Foundry. Additionally, a number of scientific areas of research will benefit from being co-located as a result of this project.

FY 2012 funding will be used to complete construction.

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[a] Other Project Costs are funded through laboratory overhead.

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.

5. Financial Schedule

(dollars in thousands)

App	ropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Costs				
PED				
FY 2009	8,680	8,680	0	2,673
FY 2010	1,000	1,000	0	5,444
FY 2011[a] 0		0	0	1,563
Total Design	9,680	9,680	0	9,680
Construction				
FY 2009	3,815	3,815 0 0		
FY 2009 Recovery	15,000	15,000 1 0		
FY 2010	33,027	33,027 3	,656 1	,908
FY 2011[a]	20,103 2	0,103	11,344	8,444
FY 2012	12,975	12,975	0	37,396
FY 2013	0	0	0	20,888
FY 2014	0	0	0	1,284
Total Construction	84,920	84,920 1	5,000 6	9,920
TEC				
FY 2009	12,495	12,495	0	2,673
FY 2009 Recovery	15,000	15,000	0	0
FY 2010	34,027	34,027	3,656	7,352
FY 2011[a]	20,103 2	0,103	11,344	10,007
FY 2012	12,975	12,975	0	37,396
FY 2013	0	0	0	20,888
FY 2014	0	0	0	1,284
Total, TEC	94,600	94,600 1	5,000 7	9,600
Other Project Cost (OPC)[b]				
OPC except D&D				
FY 2008	1,945	1,945	0	1,945
FY 2009	309	309	0	309

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.
[b] Other Project Costs are funded through laboratory overhead.

(dollars in thousands)

App	ropriations	Obligations	Recovery Act Costs Costs	
FY 2010	2	2	0	2
FY 2011[a]	0 0		0	0
FY 2012	74	74	0	74
FY 2013	150	150	0	150
Total, OPC	2,480	2,480	0	2,480
Total Project Cost (TPC)				
FY 2008	1,945	1,945	0	1,945
FY 2009	12,804	12,804	0	2,982
FY 2009 Recovery	15,000	15,000	1	0
FY 2010	34,029	34,029	3,656	7,354
FY 2011[a]	20,103 2	0,103	11,344	10,007
FY 2012	13,049	13,049	0	37,470
FY 2013	150	150	0	21,038
FY 2014	0	0	0	1,284
Total, TPC	97,080	97,080	15,000	82,080

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Total Estimated Cost (TEC)			
Design (PED)			
Design	9,481 8	,311 9	,481
PED Contingency	199	1,369	199
Total, PED	9,680 9,	680 9,	680
Construction			
Site Preparation	10,367	9,394	10,367
Other Construction	61,608 6	0,758 6	1,608
Construction Contingency	12,945 1	4,768 1	2,945
Total Construction	84,920 8	4,920 8	4,920
Total TEC	94,600 9	4,600 9	4,600
Contingency, TEC	13,144 1	6,137 1	3,144

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Other Project Cost (OPC)[a]			
OPC except D&D			
Conceptual Planning and Design	2,256	2,300	2,256
Startup and Testing	150	150	150
Contingency	74 30	74	
Total, OPC	2,480 2,	480 2,	480
Contingency, OPC	74 30	74	
Total, TPC	97,080	97,080 9	7,080
Total Contingency	13,218 1	6,167 1	3,218

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	Total
FY 2009	TEC	0	12,495	0 TBD TBD TBD TBD TBD					
	OPC	2,250	50	0 TBD TBD TBD TBD TBD					
	TPC	2,250	12,545	0 TBD TBD TBD TBD TBD					
FY 2010	TEC	0 1	2,495 1	5,000 3	4,027	TBD	TBD	TBD	TBD
	OPC	2,250	50 0 0			TBD	TBD	TBD	TBD
	TPC	2,250 1	2,545 1	5,000 3	4,027	TBD	TBD	TBD	TBD
FY 2011	TEC	0 1	2,495 1	5,000	34,027 2	0,103 1	2,975	0 9	4,600
	OPC	1,945	309 0 2			104 0		120	2,480
	TPC	1,945 1	2,804 1	5,000 3	4,029 2	0,207 1	2,975	120 9	7,080
FY 2012	TEC	0 1	2,495 1	5,000	34,027 2	0,103 1	2,975	0 9	4,600
OPC	[a]	1,945	309 0 2 0				74	150	2,480
	TPC	1,945 1	2,804 1	5,000 3	4,029 2	0,103[b] 1	3,049	150	97,080

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	2Q FY 2015
Expected Useful Life (number of years)	30
Expected Future Start of D&D of this capital asset (fiscal quarter)	2Q FY 2045

[a] Other Project Costs are funded through laboratory overhead.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

(Related Funding requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations 6	40	640	19,203	19,203
Maintenance 1	,407	1,407	42,219	42,219
Total, Operations & Maintenance	2,047	2,047	61,422	61,422

9. Required D&D Information

Square	Feet
Area of new construction	35,000
Area of existing facility(s) being replaced	20,663[a]
Area of additional D&D space to meet the "one-for-one" requirement[b] 1	4,337

10. Acquisition Approach

A building program and design criteria has been developed by the LBNL Facilities Department incorporating detailed functional requirements for all phases (A, B, and C) of the project. An architect and engineering firm with appropriate multidisciplinary design experience was selected, based on qualifications, for design services. A lump sum construction management/general contracting (CM/GC) subcontract has been negotiated and awarded by the University of California. Independent reviews of the structural design and construction cost estimate have been arranged by LBNL.

[a] Building 25 (20,303 SF) and Building 25B (360 SF) will be demolished to make way for the new General Purpose Laboratory.

[b] This project includes demolition of appropriate offsetting space to meet this requirement prior to CD-4.

09-SC-74, Technology and Engineering Development Facility, Thomas Jefferson National Accelerator Facility, Newport News, Virginia Project Data Sheet is for PED/Construction

1. Significant Changes

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-3B, Approve Start of General Construction, which was approved on August 4, 2010, with the Total Estimated Cost (TEC) of $72,200,000.

A Federal Project Director with certification level II has been assigned to this project.

Project Data Sheet (PDS) is for PED/Construction. This PDS is an update of the FY 2011 PDS.

2. Design, Construction, and D&D Schedule

(fiscal quarter or date)

CD-0		CD-1	PED Complete	CD-2 CD-3	A	CD-3B
FY 2009	09/18/2007	09/23/2008	TBD	TBD N	/A TBD	
FY 2010	09/18/2007	09/23/2008	3Q FY 2010	TBD	N/A	TBD
FY 2011	09/18/2007	09/23/2008	3Q FY 2010	11/12/2009	2Q FY 2010	4Q FY 2010
FY 2012	09/18/2007	09/23/2008	05/31/2010	11/12/2009 0	3/26/2010 0	8/04/2010

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3A – Approve Start of Early Construction and Long Lead Procurements
CD-3B – Approve Start of General Construction

(fiscal quarter to date)

CD-4	A	CD-4B
FY 2009	N/A	TBD
FY 2010	N/A	TBD
FY 2011	2Q FY 2012	2Q FY 2014
FY 2012	2Q FY 2012	2Q FY 2014

CD-4A – Approve Start of Operations for New Construction
CD-4B – Approve Start of Operations for Renovation
D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete –Completion of D&D work

3. Baseline and Validation Status

(dollars in thousands)

TEC,	PED	TEC, Construction	TEC, Total	OPC[a] Except D&D	OPC, D&D	OPC, Total	TPC
FY 2009	3,700	TBD	TBD	1,000	TBD TBD TBD		
FY 2010	3,700	TBD	TBD	1,000	N/A	TBD	TBD

[a] Other Project Costs are funded through laboratory overhead.

(dollars in thousands)

TEC,	PED	TEC, Construction	TEC, Total	OPC[a] Except Except D&D	OPC, D&D	OPC, Total	TPC
FY 2011	3,700	68,500	72,200	1,000 N	/A 1	,000	73,200
FY 2012	3.700	68,500	72,200	1,000 N	/A 1	,000	73,200

4. Project Description, Justification, and Scope

The proposed project renovates Building 58—the Test Lab, removes an estimated inadequate and obsolete work space in and adjacent to the Test Lab, and allows for removal of dilapidated trailers that are characterized as inefficient poor quality work environments that do not meet current commercial standards. The project also includes new construction which will add needed workspace for critical technical support functions including mechanical and electrical engineering; cryogenics engineering and fabrication; and environment, safety, and health.

The project will significantly improve the efficiency of workflow and provide a safer and sustainable work environment for multi-program functions such as superconducting radio frequency (SRF) R&D, multi-program cryomodule assembly and testing, and large accelerator and experimental equipment assembly. The project will implement functional efficiencies in areas such as clean rooms, chemistry facilities, high bays, laboratories, and office space. It also corrects numerous safety and building codes to ensure compliance and will reduce energy consumption of the existing building by approximately 30%. The design will incorporate all current applicable codes, standards, and best management practices. The design will meet sustainability principles and environmental, safety, and health features, and will implement Integrated Safety Management at all levels per DOE Policy 225.1.

The approved Thomas Jefferson National Accelerator Facility (TJNAF) Secretarial Waiver (9/15/2006) provides offsetting space for the Technology and Engineering Development Facility (TEDF) project. The removal of inadequate and obsolete work space in and next to the 42-year-old Test Lab plus removal of dilapidated trailers will offset the space added by this project.

TJNAF has identified projects needed as a platform for the science and technology mission of the laboratory. SRF research and production is located in the Test Lab building, making correction of the performance gap in this building a high priority. The related engineering and support facilities to incorporate this technology into accelerator operations are equally important.

To enable further advancement of TJNAF state-of-the-art production processes, it is necessary to reconfigure the layout of all the laboratory, shop, clean room, and office areas to provide efficient and effective work flow and assure safe working conditions throughout the building. The Test Lab Rehabilitation along with construction of additional technical space under this project will address many of these limitations by streamlining the production process, renovating or replacing obsolete infrastructure, relocating critical production and testing facilities to more appropriate locations, and consolidating emerging and development functions.

It is anticipated that, as a result of TJNAF's reputation and as a National SRF Center of Excellence, TJNAF will be used in the design and construction of cryomodules for future Office of Science accelerator projects. Renovation of the Test Lab will ensure that TJNAF facilities can reliably support production of advanced cryomodules with the quality required for future projects.

[a] Other Project Costs are funded through laboratory overhead.

Mechanical and electrical systems over 40 years old contribute to the deteriorated condition of the Test Lab. Numerous components in these current systems are no longer commercially available. The building has never undergone a major rehabilitation of its systems or components. The three main air handlers serving the High Bay area are well past the end of their design life and a number of other air handlers that were installed in 1987 are nearing the end of their life cycles. The HVAC renovation included in this project will replace these systems and upgrade all systems to full electronic control, improving maintainability and energy management capabilities. The electrical systems are of the same vintage. As this equipment degrades and becomes unreliable, it poses increasing risk of fire or arc flash hazards. Renovation of the electrical distribution system as part of this project will increase safety and enable improved load distribution and flexibility for future power utilization.

Environmental management functions such as waste water treatment, waste acid neutralization, and air handling are complicated by the piecemeal evolution of the facilities with multiple systems of differing vintage trying to work together to maintain safe and environmentally responsible conditions. A significant portion of plumbing in the Test Lab remains from the original construction and needs rehabilitation to ensure future reliability of services and to assure integrity for dependable environmental protection.

Numerous work items are required to bring the Test Lab building up to current codes and standards. Many aspects of the building, while meeting code at the time of construction, do not meet current safety code standards, regulations, and practices. Currently, in order to comply with code requirements, administrative controls are required in certain work areas. To bring the building up to current safety and accessibility standards a number of upgrades to stairways, walkways, guardrails, the fire alarm system, fire doors, fire walls, door hardware, and signage will be implemented as part of this project.

The improvements to the work environment this project provides will improve the morale of staff currently in areas not intended as work space such as in service buildings or in offices built on large concrete shielding enclosures with access by suspended walkways. This project will also enhance the laboratory's ability to attract and retain world-class scientists by providing a quality work environment. In addition, mechanical and electrical upgrades will result in reduced energy cost.

FY 2012 funds will be used to complete the construction and renovation.

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.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
PED			
FY 2009	3,700	3,700	1,900
FY 2010	0	0	1,800
Total PED	3,700	3,700	3,700

App	ropriations	Obligations	Costs
	(dollars in thousands)		
Construction			
FY 2010	27,687	27,687	8,000
FY 2011[a] 2	8,476	28,476	35,000
FY 2012	12,337	12,337	20,000
FY 2013	0	0	5,500
Total, Construction	68,500	68,500	68,500
TEC			
FY 2009	3,700	3,700	1,900
FY 2010	27,687	27,687	9,800
FY 2011[a]	28,476 2	8,476	35,000
FY 2012	12,337	12,337	20,000
FY 2013	0	0	5,500
Total, TEC	72,200	72,200	72,200
Other Project Cost (OPC)[b]			
OPC except D&D			
FY 2008	314	314	314
FY 2009	509	509	509
FY 2010	177	177	177
Total OPC except D&D	1,000	1,000	1,000
Total Project Cost (TPC)			
FY 2008	314	314	314
FY 2009	4,209	4,209	2,409
FY 2010	27,864	27,864	9,977
FY 2011[a]	28,476 2	8,476	35,000
FY 2012	12,337	12,337	20,000
FY 2013	0	0	5,500
Total, TPC	73,200	73,200	73,200

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.
[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 (PED)			
Design 3	,350	3,350	3,350
Contingency 3	50	350	350
Total, PED	3,700	3,700	3,700
Construction			
Site Preparation/Early Proc.	4,411	4,411	4,411
Equipment 1,	966	1,966	1,966
Other Construction	50,295	50,295	50,295
Contingency 1	1,828	11,828	11,828
Total Construction	68,500	68,500	68,500
Total, TEC	72,200	72,200	72,200
Contingency, TEC	12,178	12,178	12,178
Other Project Cost (OPC)[a]			
OPC except D&D			
Conceptual Planning	200	200	200
Conceptual Design	800	800	800
Contingency 0		0	0
Total, OPC	1,000	1,000	1,000
Total, TPC	73,200	73,200	73,200
Total, Contingency	12,178	12,178	12,178

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2009	FY 2010	FY 2011	FY 2012	Total
FY 2009	TEC	0	3,700 TBD TBD TBD TBD				
	OPC	1,000	0 0 0 0				1,000
	TPC	1,000	3,700 TBD TBD TBD TBD				

[a] Other Project Cost are funded through laboratory overhead.

		(dollars in thousands)					
Request Year		Prior Years	FY 2009	FY 2010	FY 2011	FY 2012	Total
FY 2010	TEC	0	3,700	27,687 TBD TBD TBD			
	OPC	1,000	0 0 0 0				1,000
	TPC	1,000	3,700	27,687 TBD TBD TBD			
FY 2011	TEC	0	3,700 2	7,687 2	0,800 2	0,013 7	2,200
	OPC	287	509	204 0 0			1,000
	TPC	287	4,209 2	7,891 2	0,800 2	0,013 7	3,200
FY 2012	TEC	0	3,700 2	7,687 2	8,476 1	2,337 7	2,200
OPC	[a]	314	509	177 0 0			1,000
	TPC	314	4,209 2	7,864 2	8,476[b] 1	2,337	73,200

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	
New Construction	2Q FY 2012
Renovation	2Q FY 2014
Expected Useful Life	50 years
Expected Future Start of D&D of this capital asset	1Q FY 2064

(Related Funding requirements)

	(dollars in thousands)			
	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations 4	78	478	23,900	23,900
Maintenance 1	,120	1,120	56,000	56,000
Total, Operations & Maintenance	1,598	1,598	79,900	79,900

9. Required D&D Information

The approved TJNAF Secretarial Waiver (9/15/2006) provides offsetting space for the TEDF Project. The removal of inadequate and obsolete work space in and next to the 42-year-old Test Lab plus removal of dilapidated trailers will help offset the space added by this project.

10. Acquisition Approach

Design is being performed by an architect-engineer (A-E) with the subcontract managed by the TJNAF operating contractor, Jefferson Science Associates (JSA). The A-E subcontractor was competitively selected based on demonstrated competence and qualifications to perform the required design services at a fair and reasonable price.

[a] Other Project Costs are funded through laboratory overhead.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution.

A construction management/general contractor (CM/GC) subcontract will be awarded by JSA during the final phase of design. The CM/GC subcontractor will be competitively selected based on the demonstrated competence and qualifications of potential firms to perform the required CM/GC services at a fair and reasonable price. The subcontract with the CM/GC will be for two phases of fixed-price work. The base contract will be for the CM/GC to provide support services to the A-E, including input regarding material selection, equipment, construction feasibility, and factors relating to construction and cost estimates including cost estimates of alternative designs or materials. The CM/GC will also provide TJNAF with cost and schedule validation services and provide recommendations of actions designed to minimize the impact of labor or material shortages, and time duration estimates for scheduling procurements and construction activities. The contract option will be to execute the construction project, including the management, ES&H oversight, and the administration of construction subcontracts. The option will be inclusive of all material, labor, equipment, etc. necessary to perform the work in accordance with the contractual requirements in order to meet the defined scope and schedule.

All work performed by the CM/GC will be monitored by TJNAF personnel, with support from the A-E. The site office will provide oversight to ensure safety and quality performance.

Safeguards and Security

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Appropriation FY	2012 Request
Safeguards and Security		
Protective Forces	35,059	37,147
Security Systems	11,896	10,435
Information Security	4,655	4,595
Cyber Security	16,119	15,042
Personnel Security	5,835[a] 6,	905[a]
Material Control and Accountability	2,319	2,379
Program Management	7,117	7,397
Total, Safeguards and Security	83,000	83,900

Public Law Authorizations:

Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"
Public Law 111–358, "America COMPETES Act of 2010"

Program Overview

Mission

The mission of the Office of Science (SC) Safeguards and Security (S&S) program is to support the Departmental research missions at SC laboratories by ensuring appropriate levels of protection against unauthorized access, theft, or destruction of Department assets, and hostile acts that may cause adverse impacts on fundamental science, national security, and the health and safety of DOE and contractor employees, the public, and the environment.

Background

The S&S program ensures that the SC mission can be conducted in an environment that is secure and free from acts which may cause adverse impacts on the continuity of the program. Because SC laboratories collaborate with universities and research facilities in every corner of the globe, the physical and virtual security posture at SC laboratories must be flexible and supportive of these information exchanges and collaborative efforts. As a result, the S&S program is built on a foundation that enables each facility to design varying degrees of protection commensurate with the risks and consequences for that facility.

[a] For security investigations, FY 2010 includes direct appropriations funding of $184,000 for federal field personnel; an estimated additional $5,816,000 for contractors investigations are funded through chargebacks to the programs requiring the clearances. The corresponding FY 2012 amounts are $272,000 and $5,000,000.

In FY 2010, SC evaluated best practices in security at similar federal and private institutions. Based on that study, SC defined a standard set of security measures, the SC Security Baseline Level of Protection, that provide appropriate protection. The security posture at individual laboratories can be tailored, using the SC Security Baseline Level of Protection as a point of departure, to respond to their individual risks and consequences, while maximizing open collaboration. The end result is an individual security posture at each laboratory, rooted in the SC Security Baseline Level of Protection, that forms the basis for site security operations and funding decisions.

The Security Baseline Level of Protection is being implemented in FY 2011. SC is evaluating each site's security posture by conducting a gap analysis between the current posture and the baseline, and identifying the activities and equipment necessary to implement the security posture appropriate for each laboratory. Execution of FY 2011 and FY 2012 funding, as well as future budget requests, will be based on the outcome of those evaluations.

To accomplish its mission, 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.

- The *Protective Forces* element supports security officers/access control officers and security policy officers assigned to protect S&S interests. Activities within this element include the conduct of access control and security response operations as well as physical protection of the Department's critical assets and SC facilities. In addition, activities to maintain operations are aimed at providing effective response to emergency situations; random prohibited article inspections; security alarm monitoring; the collection and destruction of classified information; and constant testing of the protective force to respond to various event scenarios.

- The *Security Systems* element provides for physical protection of Departmental material, equipment, property, and facilities, including buildings, 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 and other interests of national security.

  This element is responsible for entry and access control to ensure individuals entering and leaving facilities are authorized and do not introduce prohibited articles into or remove DOE property. This includes managing barriers, security storage, and lock programs to restrict, limit, delay, or deny entry.

- The *Information Security* element provides support for execution of the administrative policies and procedures to ensure that sensitive and classified information is accurately and consistently identified, reviewed, marked, and appropriately protected 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.

- The *Cyber Security* element provides appropriate security controls for electronically processed, transmitted, or stored sensitive and classified information. Security controls ensure that information systems, including the information contained within the systems, maintain confidentiality, integrity, and availability in a manner consistent with laboratory missions and possible threats.

- The *Personnel Security* element encompasses the processes for security clearance determinations at each site to ensure that individuals are eligible for access to classified information or matter. This element also includes the management of clearance programs, adjudication, security education and awareness programs for DOE federal and contractor employees, and processing and hosting approved foreign visitors.
- The *Material Control and Accountability (MC&A)* element provides assurance that Departmental materials are properly controlled and accounted for at all times. This element also supports (MC&A) administration, including assessing the levels of protection, control, and accounting required for the types and quantities of materials at each facility; documenting facility plans for materials control and accounting; assigning authorities and responsibilities for MC&A functions; ensuring that facility MC&A personnel are trained and qualified to perform their responsibilities; establishing programs to report occurrences such as material theft, the loss of control or inability to account for materials, or evidence of malevolent acts; conducting performance testing of required program elements; and establishing facility programs to conduct and document internal assessments of their operations and MC&A programs.

  MC&A programs are designed to deter theft and diversion of nuclear material by both outside and inside adversaries. The level of control and accountability is graded based on the consequences of their loss.
- The *Program Management* element coordinates the management of Protective Forces, Security Systems, Information Security, Personnel Security, Cyber Security, and Material Control and Accountability to achieve and ensure appropriate levels of protection.
- SC develops S&S plans to implement S&S requirements, conducts surveys to determine whether the requirements have been implemented, responds to national and local threats, and performs a vulnerability analysis that measures the risk of S&S assets. Program Management also supports participation in the quality panel process, which raises issues from the field to headquarters managers and ensures staff is properly educated with respect to security matters.

Benefits

Global information sharing and open scientific collaboration is required for SC to successfully produce scientific breakthroughs. As a result, campuses and networks have been established to allow the world to exchange and access scientific information. These efforts present security challenges across the national laboratory system. The SC Safeguards and Security program is designed to ensure that appropriate measures are in place to address these challenges.

Program Planning and Management

The S&S program established the following goals and priorities in support of the S&S mission:

- Protect special, source, and other nuclear material, radioactive material, and classified and unclassified controlled information at SC laboratories;
- Provide physical controls to SC national laboratory facilities to mitigate other security risks, including risks to facilities and laboratory employees;
- Provide cyber security controls for SC national laboratory information systems to protect data while enabling the mission; and
- Assure site security programs result in the secure workplace required to facilitate scientific advances.

The program is managed using the proven program management principles and approaches applied to other SC programs. To ensure close integration with laboratory operations, S&S employs a fully collaborative and transparent partnership with site offices and laboratory managers.

Budget Overview

The FY 2012 budget request allows sites to maintain program elements at balanced levels and implement an appropriate security posture at each laboratory. In order to ensure S&S program funds are used to support the DOE mission, laboratories will recover costs for any unique security needs required to support Work for Others customers. An estimate of those costs are shown below.

Estimates of Security Cost Recovered by Science, Safeguards and Security

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Safeguards and Security		
Ames National Laboratory	0	40
Argonne National Laboratory	0	1,440
Brookhaven National Laboratory	0	950
Lawrence Berkeley National Laboratory	0	1,547
Oak Ridge Institute for Science and Education	0	400
Oak Ridge National Laboratory	0	4,734
Pacific Northwest National Laboratory	0	3,249
Princeton Plasma Physics Laboratory	0	35
SLAC National Accelerator Laboratory	0	2,794
Thomas Jefferson National Accelerator Facility	0	50
Total, Security Cost Recovered	**0**	**15,239**

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Protective Forces	**35,059**	**37,147**

Funding for Protective Forces provides for protective forces in place at SC laboratories where they are needed. Services provided by these forces include screening people and materials for site/facility entry; patrolling the laboratory in search of unauthorized persons and evidence of crime; and monitoring, assessing, and dispatching a response to investigate alarms and reported events. Protective forces also provide emergency management support for natural disasters, and traffic and crowd control for events.

In FY 2012, funding will be used to maintain the protective forces currently in place at a consistent level of effort and will provide for the salaries and benefits for S&S personnel and the equipment, facilities, and training necessary to ensure effective performance.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Security Systems	**11,896**	**10,435**

Funding for Security Systems provides for the installation, operation, and maintenance and repair of security systems (e.g., alarms, automated access controls, communications equipment, and explosives detection equipment) at SC laboratories. Funding in this sub-element also provides services to ensure the effectiveness of these systems, including activities like performance testing, intrusion detection and assessment, and access enrollment.

In FY 2012, funding will be used to operate and maintain the systems currently in place, including S&S personnel required to operate and service them. In addition, funding supports the required investments in federal access control systems and upgrades (e.g., badge card readers and access system software and hardware) necessary to address the new Homeland Security Presidential Directive-12 (HSPD-12).

Information Security	**4,655**	**4,595**

Funding for Information Security provides for personnel, equipment and systems necessary to ensure sensitive information (e.g., classified documents, unclassified controlled nuclear information, and personal identity information) is properly safeguarded at SC laboratories. Activities include document and material classification and declassification, document marking and storage, and assessing and reporting security infractions.

In FY 2012, funding will be used to provide for S&S personnel, as well as equipment such as alarm systems and technical security countermeasures.

Cyber Security	**16,119**	**15,042**

Funding for Cyber Security provides for the necessary activities to protect SC laboratory computing resources and data against unauthorized access or modification of information, as well as ensuring data availability. These activities include such items as threat assessments, risk management, configuration management, certification/accreditation, training, and network monitoring. For SC, these activities are implemented by an Information Systems Security Manager, a Certification Agent, and full time Information System Security Officer(s).

Funds requested for FY 2012 represent a reduction from FY 2010 levels. Consistent with agency-wide guidance, SC continues to clarify the delineation between Information Technology functions and cyber security functions. As a result, some functions previously charged to Cyber Security (e.g. Plans of Action and Milestones to address vulnerabilities) have been removed from this request and will instead be funded by SC laboratory overhead. FY 2012 funding permits SC to implement a Cyber Security program that ensures that field sites are providing appropriate Cyber Security levels.

Personnel Security	**5,835**	**6,905**

Funding for Personnel Security provides the necessary laboratory S&S personnel to grant individuals access to classified matter and/or special nuclear material and to allow foreign nationals access to SC facilities, consistent with agency procedures. This element also funds security investigations for federal field personnel and security awareness programs for employees.

Funds requested in FY 2012 will be used to maintain support efforts at all SC laboratories.

	(dollars in thousands) FY 2010 Current Appropriation	FY 2012 Request
Material Control and Accountability	**2,319**	**2,379**

Funding for Material Control and Accountability provides for establishing, controlling, and tracking inventories of special nuclear material and other accountable nuclear material at SC laboratories.

Activities supported by these funds include measurements, quality assurance, accounting, containment, surveillance, and physical inventory.

Funding requested in FY 2012 will ensure that proper protection of material is sustained.

Program Management	**7,117**	**7,397**

Funding for Program Management provides for the oversight, administration, and planning for security programs at SC laboratories. Planning activities include developing annual operating plans and site S&S plans, conducting vulnerability analyses and performance testing, managing security incident reporting, and conducting surveys and self-assessments.

In FY 2012, funding will be used to maintain direction, oversight, administration, and security program planning.

Total, Safeguards and Security	**83,000**	**83,900**

Explanation of Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Protective Forces	
Funding maintains the protective forces currently in place at a consistent level of effort and the equipment, facilities, and training necessary to ensure effective performance.	+2,088
Security Systems	
Funding operates and maintains the systems currently in place, including the S&S personnel required to operate and service the systems. The FY 2012 decrease is due to the one-time infrastructure investments that were funded in FY 2010.	-1,461
Information Security	
Funding will be used to provide for the salaries and benefits for S&S personnel, as well as equipment such as alarm systems and technical security countermeasures.	-60
Cyber Security	
Some functions previously charged to cyber security have been removed from this request and will instead be funded by SC laboratory overhead consistent with agency-wide guidance.	-1,077

	FY 2012 vs. FY 2010 Current Approp. ($000)
Personnel Security	
Funds requested in FY 2012 will be used to maintain support for Personnel Security at all SC laboratories. The increased request is for anticipated increases in access and badging costs.	+1,070
Material Control & Accountability	
Funding requested in FY 2012 will ensure that proper protection of material is sustained.	+60
Program Management	
Funding will be used to maintain direction, oversight and administration, and security program planning.	+280
Total Funding Change, Safeguards and Security	**+900**

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

FY	2010 Current Appropriation FY	2012 Request
Operating Expenses	81,620	83,900
Capital Equipment	734	0
General Plant Projects	646 0	
Total, Safeguards and Security	83,000	83,900

Science Program Direction

Funding Profile by Category

	(dollars in thousands/whole FTEs)	
	FY 2010 Current Appropriation FY	2012 Request
Science Program Direction		
Salaries and Benefits	144,660	158,522
Travel 3,	666	4,551
Support Services	17,358	23,523
Other Related Expenses	23,693	30,267
Total, Science Program Direction	189,377	216,863
Full Time Equivalents[a] 1,	030	1,095

Program Overview

Mission

The Science Program Direction (SCPD) mission is to strategically support and sustain a skilled and motivated Federal workforce that oversees Office of Science (SC) investments in world-leading scientific research. The SC workforce is responsible for developing and shaping the science program, executing and managing science funding, and overseeing construction and maintenance of large scientific user facilities. Oversight also includes the health and safety of the workforce and overall security requirements. Additionally, the Federal workforce provides administrative, business, legal, and technical management of research grants and contracts, oversight of the management and operating (M&O) contracts for 10 of the 17 DOE national laboratories, and public access to the Department's research and development (R&D) results.

Background

Carrying out SC's mission requires not only highly skilled scientific and technical expert program and project managers, but experts in the areas of acquisition, finance, legal, construction and infrastructure management, as well as environment, safety, and health oversight. With growing national challenges in energy, environmental stewardship, and nuclear security, and the need to maintain U.S. innovation and scientific competitiveness, SC continues to be called upon to support transformational basic research. Oversight of DOE's basic research portfolio, which includes grants and contracts supporting approximately 27,000 researchers located at about 300 universities and 17 national laboratories, as well as supervision of major construction projects, is an exclusively Federal responsibility that requires a diverse set of knowledge and skills. The Office of Science directly funds, oversees, and manages complex research programs in condensed matter and materials physics, chemistry, biology, climate and environmental sciences, applied mathematics, computer and computational science, high energy physics, nuclear physics, plasma physics, and fusion energy sciences. SC also provides the nation's researchers with state-of-the-art user facilities—the large machines of modern science. These facilities offer capabilities that are unmatched anywhere in the world and enable U.S. researchers and industries to remain at the forefront of science, technology, and innovation.

[a] FY 2010 reflects actual FTE usage, whereas FY 2012 reflects the FTE ceiling.

With a highly skilled and experienced Federal workforce, SC is able to plan, execute, and manage science programs that meet critical national needs. Specifically:

Headquarters (HQ) Federal Workforce Duties

- Strategically maintain a balanced research portfolio that includes high-risk, high-reward research to maximize the program's potential to achieve mission goals and objectives.
- Provide direct oversight of Federal funds awarded to about 300 universities, 17 DOE national laboratories, and private research institutions supporting about 27,000 scientific professionals.
- Conduct scientific program planning, execution, and management across a broad spectrum of scientific disciplines and program offices, and communication of research interests and priorities to the scientific community.
- Assure rigorous external merit review of research proposals, selection of appropriate peer review experts, development of award recommendations informed by peer review, and regularly evaluate research programs. SC program managers typically manage over 6,000 laboratory, university, nonprofit, and private industry proposals and receive a total of 10,000 to 12,000 new proposal (peer) reviews and renewals annually.
- Provide oversight of design, construction, and operation of 28 large-scale scientific user facilities at laboratories and universities that support approximately 26,000 users.
- Manage a workforce development program to sustain a pipeline of highly trained science, technology, engineering, and mathematics (STEM) professionals for the U.S. workforce.
- Provide oversight and management of the Science Laboratories Infrastructure program and the maintenance and operational integrity of 10 SC laboratories.
- Provide human relations, information technology, grants and contracts, budget, and related business management support and oversight for over 300 Federal Headquarters employees.

Site Office Federal Workforce Duties

SC Site Office personnel are Federal staff charged with maintaining the business and management infrastructure necessary to support the scientific mission of 10 SC field sites. This includes conducting day-to-day business transactions of contract funding modifications, approvals to operate hazardous facilities, safety and security oversight, leases, property transfers, sub-contracts above defined thresholds, sub-awards, and activity approvals required by laws, regulations, and DOE policy. As part of this, the Site Office personnel:

- Maintain a comprehensive contract management program to assure contractual mechanisms supporting nearly $4 billion per year of mission work, performed by over 22,000 contractors at 10 national laboratories, are effectively managed within all appropriate guidelines and regulations by highly qualified contracting officers and contracting officer representatives;
- Provide qualified technical staff to evaluate complex integrated laboratory activities, often including nuclear, radiological, and other complex hazards; and,
- Provide qualified Federal project directors to facilitate execution of line item and other construction projects.

Integrated Support Center (ISC) Federal Workforce Duties

The ISC, co-located at the Chicago and Oak Ridge Offices, provides administrative, business, legal, and technical support across the entire SC enterprise, including financial management; human resources;

grant and contract processing; safety, security, and health management; labor relations, intellectual property and patent management; environmental compliance; infrastructure operations and maintenance; and information systems development and support. As part of this, the ISC:

- Serves as a legal DOE allottee that manages multi-appropriation, multi-program allotments for all SC national laboratories with responsibility for greater than 93% of SC funds;
- Executes a human resource management program to recruit staff for the Site Offices, as required by documented workload, in the areas of information management, environment, safety, health, safeguards, security, and legal support; and
- Provides support to SC and other DOE programs for solicitations and funding opportunity announcements, as well as responsibility for the negotiation, award, administration, and closeout of contracts and financial assistance awards using contracting officers and professional acquisition staff. The ISC processed and managed approximately 4,800 actions in FY 2010; this number had increased over the past seven years primarily due to increased program complexity and is commensurate with total annual SC budget.

Office of Scientific and Technical Information (OSTI) Federal Workforce Duties

- OSTI fulfills the Department's legislative mandate to provide public access to the unclassified results of DOE's research program as well as the White House Open Government Directive to encourage collaboration and increase transparency (http://energy.gov/open). OSTI's collection from the mid-1990s to date is available entirely on-line and currently generates in excess of 100 million transactions annually. In FY 2012, OSTI plans to initiate the digitization of approximately 1 million pre-1990 technical reports representing approximately $400 billion in DOE and predecessor agency R&D investments. This increased access will more fully leverage DOE's historic R&D investments and facilitate their contribution to scientific progress.
- OSTI also collects, protects, and provides secure access to DOE's classified research outcomes. OSTI works closely with National Nuclear Security Administration laboratories and facilities to collect classified R&D information and to provide secure access through the Enterprise Secure Network.
- Beyond traditional text-based R&D information, scientific results are increasingly recorded in numeric data sets and multimedia. OSTI is developing tools and processes that provide searchable access to these new forms of R&D information, including audio-indexed search engines where every spoken word in large audio/video files can be searched.
- Recognizing that science research is also performed by other Federal agencies and, indeed, at counterpart organizations around the world, OSTI has built broad collaborations, both within the U.S. and internationally, to enable a single point of access to nearly 400 million pages of scientific information.

Benefits

Utilizing about 4% of the SC budget, SCPD strives to provide an efficient corporate infrastructure for effective business management and stewardship of the resources necessary for SC to execute its mission. Maintaining a highly skilled workforce enables SC to develop and sustain world-class science programs that deliver the scientific discoveries and technological innovations needed to solve our Nation's energy and environmental challenges, and enable the U.S. to maintain its global competitiveness. Providing easy access to scientific findings leverages the Federal science investment and advances the scientific enterprise. With adequate staffing levels and a workforce balanced with appropriate skills, education, and experience, SC is an effective and efficient steward of taxpayer dollars for maximum national benefit.

Program Planning

The following factors influenced the FY 2012 SCPD budget request:

- *Maintenance for SC research and scientific facilities investment*. The FY 2012 SCPD request will support maintenance and operations for existing research capabilities, and allow adequate hiring of Federal Full Time Equivalents (FTEs) at Headquarters to provide scientific oversight and management while sustaining Field staffing levels.
- *Challenges and expectations facing the current SC workforce*. The ongoing need for highly skilled Federal program and project management requires an SCPD budget that keeps pace with growth in science program funding. Prior to the FY 2011 budget request, SCPD budgets and workforce had not kept pace with total SC budget increases. From FY 2006 to FY 2010, total SC funding grew at an annualized growth rate of 8.3%; in contrast, SCPD funding increased at an annualized rate of 4.4% for the same timeframe. The FY 2012 SCPD request, an increase of 14.5% over FY 2010, will sustain staffing and operations at the FY 2010 salary freeze level and provide additional scientific program managers and technical support at Headquarters for modest portfolio expansion. However, with the FY 2012 increase in the total SC budget of 9.1% over FY 2010, the proportional gap between the SC annualized growth rate and SCPD funding has decreased.
- *Succession planning across SC.* Currently the average age of SC employees is 51, with 321 (32%) eligible for voluntary retirement by the end of FY 2011. The FY 2012 request supports limited retention strategies and specialized recruitment efforts such as local job fairs, Student Career Experience Program, Student Temporary Employment Program, and Intern Programs to attract and retain the best and brightest needed to maintain the U.S. preeminent position in science and technology. New professionals will participate in SC mentorship programs led by current high-performing Federal managers.
- *Committee of Visitors' (COV) report findings.* SC charges its Federal Advisory Committees every three years to convene COVs to externally review its research programs, including how those programs are being managed. Since FY 2002, almost every SC program has been reviewed twice. Reports cited ample evidence of the need for additional staffing. The most recent reviews for each SC program (occurring from 2008-2010) cited that current staffing levels are insufficient to meet programmatic needs and the mandated workload. The COV reports recommend additional SC HQ program managers to provide scientific oversight in addition to support staff with specialized skills, e.g., Federal contract management, for the majority of research program offices.
- *Workload Indicator Project.* In an effort to understand more fully the impact of workload on the SCPD budget and to better align future staffing needs with budget planning, SC launched a workforce/workload indicator study using methodology found useful at the National Science Foundation and other government agencies. Preliminary results of the study characterize mission critical workload measures that drive staffing requirements and other elements of the SCPD budget. Phase One of the Workload Study, Benchmarking Against Other Federal Research Organizations, is complete. The full report, which refines the study as it relates to field operations, will be complete in mid-2011.

Budget Overview

The FY 2012 SCPD budget request includes support for salaries and benefits for 1,095 FTEs responsible for executing, managing, and overseeing SC sponsored research programs and providing required regulatory and management oversight. The SCPD request also supports required travel of SC Advisory Committee members, and Federal employees in addition to support services, including information management and grants and contract management systems, career development related training, and educational opportunities.

The total increase of $27,486,000, or 14.5%, over FY 2010 will sustain steady-state research operations and staffing at FY 2010 salary freeze levels and an increase of 65 FTEs over the FY 2010 actual FTE usage.

Detailed Justification

(dollars in thousands)		
	FY 2010 Current Appropriation	FY 2012 Request
Salaries and Benefits	**144,660**	**158,522**

The FY 2012 request for 1,095 FTEs sustains support across the SC complex and includes an additional 65 FTEs over the FY 2010 actual FTE usage of 1,030, for scientific program management, technical and administrative support associated with modest portfolio expansion in areas such as clean energy. The increased funding level from FY 2010 assumes a continued pay freeze in FY 2012 and will support increases to Federal employee benefits such as health insurance and retirement allocations. This funding level will support staff with responsibility for science program development and management; program and project execution and management that typically requires specialized expertise in multiple areas of science as well as contract, legal and advanced information technology; administrative, business, and technical management of research grants and contracts; oversight and maintenance of 10 of the 17 DOE national laboratories; and providing public access to the DOE's R&D results.

This FTE level maintains a skilled and motivated Federal workforce that provides effective oversight in world-leading research and research capabilities for the scientific community.

Travel	**3,666**	**4,551**

A key element in the SC research program is the effective management of a broad spectrum of scientific research programs, construction, operation, and maintenance of user facilities, and contractor oversight at geographically dispersed facilities located at 10 national laboratories, and about 300 universities throughout the Nation. Since SC senior program managers are not co-located with grantees or on-site at all national laboratories, staff travel is required to ensure scientific management, compliance oversight, and external review of research funding across all SC programs. Travel is also required for facility visits where the use of electronic telecommunications is not practical for mandated on-site inspections and operations reviews. Further, the review of large and complex research or facility proposals requires on-site visits to perform assessments during the course of the peer review process. Additionally travel by Federal staff is essential to assure implementation of new DOE orders and regulatory requirements, including required attendance at project and program reviews; internal audits, compliance reviews, oversight of sensitive investigations and administrative proceedings, and operational policy and process reviews.

The request also provides for travel expenses for more than 150 members who compose the six SC Federal Advisory Committees (FACs). Committee members include representatives from universities, national laboratories, and industry representing a diverse balance of disciplines, professional experience, and geography. Each of the six advisory committees meets three to four times annually and provides

(dollars in thousands)		
	FY 2010 Current Appropriation	FY 2012 Request

valuable, independent advice to the Department regarding the complex scientific and technical issues that arise in the planning, management, and implementation of SC programs.

Support Services	**17,358**	**23,523**

Support Services provide multiple levels of technical expertise and general administrative services and activities as follows: maintenance, operation, and cyber security management of SC mission-specific information management systems and infrastructure and SC-corporate Enterprise Architecture and Capital Planning Investment Control management; accessibility to DOE's multi-billion dollar R&D program through E-Gov 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, evaluate, and monitor both legacy and current field work proposals; day-to-day operations, including mailroom services, travel processing, administration of the Small Business Innovation Research/Small Business Technology Transfer program, grants and contract processing and close-out activities, copy centers, directives coordination, and filing and retrieving records; training and education of Federal staff, including continuing education and career development training; reports or analyses directed toward improving the effectiveness, efficiency, and economy of management and general administrative services; and staffing for 24-hour emergency communications centers and safeguards and security oversight functions.

Other Related Expenses	**23,693**	**30,267**

Other Related Expenses provide the SC contribution to the Department's Working Capital Fund (WCF) for common administrative services at HQ, such as rent and building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, copying, mail, contract closeout, purchase card surveillance, and per the Department's new policy for FY 2012, salary and benefit expenses for Federal employees who administer the WCF business lines. In addition, WCF services assessed to and used by HQ, OSTI, and the Field include online training, the Corporate Human Resource Information System, payroll processing, the Project Management Career Development Program, and support for Funds Distribution System (FDS) 2.0 and Implementation Plans.

Expenses in the Field include fixed requirements associated with rent, utilities, and telecommunications and are paid directly, as are requirements such as building and grounds maintenance, computer/video maintenance and support, printing and graphics, equipment leases, purchases, and maintenance, as well as, site-wide health care units.

$750,000 is provided for the Under Secretary of Science to sponsor studies and workshops in furtherance of the role of the Office of Science as defined by the Energy Policy Act of 2005 in 42 USC 7132(b)(4), subparagraphs (A)-(F). These roles include serving as the Science and Technology Advisor to the Secretary, identifying any undesirable duplication or gaps in R&D programs, monitoring the well-being and management of the multipurpose laboratories, examining the effectiveness of grants and other forms of financial assistance, and leading the long-term planning, coordination, and development of a strategic R&D framework for the Department. These responsibilities are not exclusively related to programs within SC.

Total, Science Program Direction	**189,377**	**216,863**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Salaries and Benefits	
Salaries and Benefits represents 73% of the total FY 2012 SCPD Budget. The FY 2012 increase will support a total of 1,095 FTEs which reflects staffing at the FY 2010 frozen salary level plus the addition of 65 FTEs over the FY 2010 actual FTE usage. No pay increase is assumed in FY 2012. Additional funds will also provide other payroll-related expenses such as increases in health coverage costs and employee-driven retirement allocation increases in the Federal Employees Retirement System.	+13,862
Travel	
Travel represents 2% of the total FY 2012 SCPD budget. The increase over the two year period from FY 2010 reflects an increase in travel and trip costs for travel required by SC HQ and the FACs. OSTI and the Field will realize a small reduction of $165,000.	+885
Support Services	
Support Services represents 11% of the total FY 2012 SCPD budget. The increase for the two year period from FY 2010 provides continued support for a broad range of specialized technical and administrative support commensurate with science program complexity. Training will be increased $21,000 consistent with emphasis on career development and retention. The Field will realize a small reduction of $145,000.	+6,165
Other Related Expenses	
Other Related Expenses represents 14% of the total FY 2012 SCPD budget. The increase from FY 2010 includes $734,000 for the FY 2012 change in Department policy to enable full-cost recovery of WCF federal salary and benefits and $1,100,000 to support the Funds Distribution System 2.0 and Implementation Plans. $615,000 of the increase is related to WCF fixed cost increases at HQ. $4,063,000 will maintain the FY 2010 level of effort and associated cost increases from the two year period through FY 2012 at HQ. An increase of $62,000 supports OSTI and the Field.	+6,574
Total Funding Change, Science Program Direction	+27,486

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Operating Expenses	189,377	216,863

Funding Profile by Category by Site

(dollars in thousands/whole FTEs)

	FY 2010 Current Approp.	FY 2012 Request
Headquarters		
Salaries and Benefits	51,970	60,459
Travel 2,	290	3,340
Support Services	6,101	12,247
Other Related Expenses	11,450	17,962
Total, Headquarters	71,811	94,008
Full Time Equivalents[a] 3	06	370
Office of Scientific and Technical Information		
Salaries and Benefits	6,884	7,410
Travel 109		85
Support Services	697	861
Other Related Expenses	1,226	921
Total, Office of Scientific and Technical Information	8,916	9,277
Full Time Equivalents	56	57
Field Offices		
Chicago Office		
Salaries and Benefits	24,295	25,320
Travel 3	35	299
Support Services	3,705	2,869
Other Related Expenses	2,999	3,750
Total, Chicago Office	31,334	32,238
Full Time Equivalents	192	190

[a] FY 2010 reflects actual FTE usage, whereas FY 2012 reflects the FTE ceiling.

	(dollars in thousands/whole FTEs)	
	FY 2010 Current Approp.	FY 2012 Request
Oak Ridge Office		
Salaries and Benefits	28,444	28,577
Travel 3	60	412
Support Services	3,625	4,684
Other Related Expenses	6,265	6,837
Total, Oak Ridge Office	38,694	40,510
Full Time Equivalents	258	246
Ames Site Office		
Salaries and Benefits	509	581
Travel 19		18
Total, Ames Site Office	528	599
Full Time Equivalents	4	4
Argonne Site Office		
Salaries and Benefits	3,194	3,591
Travel 6		15
Support Services	130	324
Other Related Expenses	88	219
Total, Argonne Site Office	3,418	4,149
Full Time Equivalents	21	23
Berkeley Site Office		
Salaries and Benefits	3,610	4,356
Travel 44		6
Support Services	643	45
Other Related Expenses	162	8
Total, Berkeley Site Office	4,459	4,415
Full Time Equivalents	22	25

(dollars in thousands/whole FTEs)	FY 2010 Current Approp.	FY 2012 Request
Brookhaven Site Office		
Salaries and Benefits	4,044	4,539
Travel 94		96
Support Services	435	452
Other Related Expenses	559	148
Total, Brookhaven Site Office	5,132	5,235
Full Time Equivalents	25	27
Fermi Site Office		
Salaries and Benefits	2,176	2,430
Travel 0		61
Support Services	53	76
Other Related Expenses	47	34
Total, Fermi Site Office	2,276	2,601
Full Time Equivalents	15	16
New Brunswick Laboratory		
Salaries and Benefits	4,291	4,767
Travel 79		91
Support Services	1,261	1,714
Other Related Expenses	501	148
Total, New Brunswick Laboratory	6,132	6,720
Full Time Equivalents	28	30
Oak Ridge National Laboratory Site Office		
Salaries and Benefits	4,030	4,333
Travel 90		15
Support Services	388	59
Other Related Expenses	111	9
Total, Oak Ridge National Laboratory Site Office	4,619	4,416
Full Time Equivalents	29	30

	(dollars in thousands/whole FTEs)	
	FY 2010 Current Approp.	FY 2012 Request
Pacific Northwest Site Office		
Salaries and Benefits	4,934	5,365
Travel 106		78
Support Services	169	173
Other Related Expenses	162	155
Total, Pacific Northwest Site Office	5,371	5,771
Full Time Equivalents	34	36
Princeton Site Office		
Salaries and Benefits	1,738	1,896
Travel 8		22
Support Services	1	5
Other Related Expenses	0	58
Total, Princeton Site Office	1,747	1,981
Full Time Equivalents	11	12
SLAC Site Office		
Salaries and Benefits	2,632	2,837
Travel 55		2
Support Services	140	5
Other Related Expenses	44	1
Total, SLAC Site Office	2,871	2,845
Full Time Equivalents	16	16
Thomas Jefferson Site Office		
Salaries and Benefits	1,909	2,061
Travel 71		11
Support Services	10	9
Other Related Expenses	79	17
Total, Thomas Jefferson Site Office	2,069	2,098
Full Time Equivalents	13	13

	(dollars in thousands/whole FTEs)	
	FY 2010 Current Approp.	FY 2012 Request
Total Field Offices		
Salaries and Benefits	85,806	90,653
Travel 1,	267	1,126
Support Services	10,560	10,415
Other Related Expenses	11,017	11,384
Total, Field Offices	108,650	113,578
Full Time Equivalents	668	668
Total SCPD		
Salaries and Benefits	144,660	158,522
Travel 3,	666	4,551
Support Services	17,358	23,523
Other Related Expenses	23,693	30,267
Total, SCPD	189,377	216,863
Full Time Equivalents	1,030	1,095

Support Services by Category

	(dollars in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
Technical Support		
Development of Specifications	150	197
System Review and Reliability Analyses	425	558
Surveys or Reviews of Technical Operations	1,168	1,902
Total, Technical Support	1,743	2,657
Management Support		
Automated Data Processing	7,591	11,094
Training and Education	805	826
Reports and Analyses, Management, and General Administrative Services	7,219	8,946
Total, Management Support	15,615	20,866
Total, Support Services	17,358	23,523

Other Related Expenses by Category

	(dollars in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
Other Related Expenses		
Rent to GSA	1,201	942
Rent to Others	1,138	1,392
Communications, Utilities, and Miscellaneous	1,962	2,481
Printing and Reproduction	34	5
Other Services	4,640	6,944
Operation and Maintenance of Equipment	1,365	818
Operation and Maintenance of Facilities	1,996	2,398
Supplies and Materials	1,324	768
Equipment 1,	566	3,610
Working Capital Fund	8,467	10,909
Total, Other Related Expenses	23,693	30,267

Congressionally Directed Projects

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Approp. FY	2012 Request
Congressionally Directed Projects	74,737[a] 0	

Description

The Energy and Water Development and Related Agencies Appropriations Act, 2010 included 76 congressionally directed projects within the Office of Science. Funding for these projects was appropriated as a separate funding line although specific projects may relate to ongoing work in other programmatic areas.

Detailed Justification

(dollars	in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
Congressionally Directed Projects		
▪ Advanced Artificial Science and Engineering Research Infrastructure (TX)	292	0
▪ Advanced Manufacturing and Engineering Equipment (IN)	972	0
▪ Alaska Climate Center (AK)	972	0
▪ Algae to Biodiesel, Carlsbad (NM)	729	0
▪ Antibodies Research, University of North Dakota (ND)	2,916	0
▪ Applied Biomechanical Engineering Graduate Program (IN)	388	0
▪ Bethune-Cookman University STEM Research Lab (FL)	243	0
▪ Building Surface Science Capacity to Serve the Automobile Industry in Southeastern Michigan (MI)	486	0
▪ Carbon Nanotube Technology Center (CANTEC) (OK)	972	0
▪ Center for Advanced Bio-Based Binders (CABB) and Pollution Reduction Technologies (IA)	923	0
▪ Center for Advanced Scientific Computing and Modeling (CASCAM) (TX)	680	0
▪ Center for Diagnostic Nanosystems, Marshall University, Huntington (WV)	2,916	0

[a] In FY 2010, $1,922,250 and $230,670 were transferred to the SBIR and STTR programs, respectively, for continuation of the SBIR and STTR programs that are mandated by Congress.

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
▪ Center for Nanomedicine and Cellular Delivery, School of Pharmacy, University of Maryland, Baltimore (MD)	486	0
▪ Center for Sustainable Energy at Bronx Community College, Bronx, NY (NY)	486	0
▪ Clean Energy Infrastructure Educational Initiative (OH)	486	0
▪ Clean Energy Storage, Conversion, and Generation Research (IL) 486		0
▪ Clemson University Cyberinstitute (SC)	486	0
▪ Climate Model Evaluation Program (AL)	1,750	0
▪ College of Saint Elizabeth (NJ)	972	0
▪ Computational Modeling of Drug-Resistant Bacteria (TN)	889	0
▪ Computing Capability (ND)	4,860	0
▪ Development of Ultrafiltration Membrane-Separation Technology for Energy-Efficient Water Treatment (NV)	777	0
▪ Energy Efficiency & Water Institute Research Facility, Purdue University-Calumet (IN)	1,944	0
▪ Energy Systems Engineering Institute (PA)	486	0
▪ Enhancement for the Intermountain Center for River Restoration and Rehabilitation (UT)	583	0
▪ Environmental Quality Monitoring and Analysis (IL)	486	0
▪ Fourier Transform Nuclear Magnetic Resonance (FTNMR) Spectrometer (NY)	486	0
▪ Fuel Cell Research, Brown University (RI)	1,458	0
▪ Functional MRI Science Research, University of Vermont College of Medicine, Burlington (VT)	1,166	0
▪ Fusion Energy Spheromak Turbulent Plasma Experiment (STPX) (FL)	486	0
▪ Green Manufacturing and Energy Conscious Design Program (MI) 972		0
▪ Idaho Accelerator Center Production of Medical Isotopes (ID)	1,458	0
▪ Idaho National Laboratory Center for Advanced Energy Studies (ID)	972	0
▪ Institute for Collaborative Sciences Research (FL)	1,166	0
▪ Institute for Integrated Sciences at Boston College (MA)	1,944	0

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
▪ Kansas University Cancer Research Equipment (KS)	3,888	0
▪ Landfill Leachate Recirculation and Gas to Energy Project (NC) 486		0
▪ Marine Systems Energy/Environmental Sustainability Research (MA)	292	0
▪ Martin County Microfiber Hydrogen Fuel Cell Technology Development (NC)	972	0
▪ Material Science Smart Coatings (NE)	486	0
▪ Meteorology and Atmospheric Science Program at the University of Louisville (KY)	340	0
▪ Nanotechnology Initiative (CT)	729	0
▪ Nevada Water Resources Data, Modeling, and Visualization (DMV) Center (NV)	729	0
▪ Notre Dame Innovation Park, South Bend (IN)	559	0
▪ Performance Assessment Institute (NV)	972	0
▪ Physical and Biological Sciences Laboratory Learning Center (FL) 389		0
▪ Pioneer Valley Life Science Institute Translational Biomedical Research (MA)	389	0
▪ Renovation and Development of the Louisiana State University Nuclear Science Building (LA)	972	0
▪ Ribonucleic Acid Interference Research (RNAi) (MA)	292	0
▪ Rockland Community College Science Lab Upgrade (NY)	292	0
▪ Science Center Equipment and Energy Efficient LEED Technology (UT)	875	0
▪ Science Lab Expansion (NY)	535	0
▪ Smart Grid Communications Security Project (CO)	972	0
▪ Smart Grid Simulation Laboratory (CO)	875	0
▪ Southern Utah University Science Center Energy Efficiency Modernization and Enhancement Project (UT)	972	0
▪ State-of-the-Art Large-Scale Testing for Wind to Enhance Infrastructure Resiliency and Develop Energy-Efficient Buildings (FL)	972	0
▪ STEM Infrastructure Improvement Project (SC)	1,458	0

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
▪ STEM Minority Graduate Program (PA)	4,374	0
▪ Susquehanna University, Equipment for New Science Center (PA) 972		0
▪ Sustainable Biofuels Development Center (CO)	486	0
▪ Targeted Radiotherapy for Melanoma (MA)	292	0
▪ Technology Transfer & Commercialization of Technologies at DOE Laboratories (NM)	729	0
▪ The New School Green Building (NY)	972	0
▪ Transylvania University Brown Science Center Equipment (KY) 632		0
▪ Twin Tower Observatory (CA)	194	0
▪ Ultra Fast Power Processor for Smart Grid (CA)	972	0
▪ Unique Methodologies for Nano/Micro Manufacturing and Job Training for Nanotechnology (IL)	486	0
▪ University of Delaware Energy Institute (DE)	486	0
▪ University of Illinois at Chicago High Performance Computing (IL) 972		0
▪ University of Massachusetts Integrative Science Building (MA) 1,944		0
▪ University of Rhode Island Regional Earth Systems Institute (RI) 729		0
▪ University of South Dakota Catalysis Group for Alternative Energy (SD)	1,069	0
▪ University of Tulsa Algae to Green Fuels Energy Project (OK)	729	0
▪ University Park and Research Center in Chula Vista, (CA)	972	0
▪ Whitworth University STEM Equipment (WA)	292	0
▪ Yttrium-90 Microspheres Research (WA)	1,215	0
Total, Congressionally Directed Projects	**74,737**	**0**

Isotope Production and Distribution Program Fund

Program 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 Appropriations Act (Public Law 101–101), as modified by Public Law 103–316. The combination of an annual direct appropriation and cash collections/ advance payments from isotope sales are deposited in the Isotope Production and Distribution Program Fund, the revolving fund. This revolving fund allows continuous and smooth operations of isotope production, sales, and distribution independent of the federal budget cycle. The fund's revenues and expenses are audited annually consistent with Government Auditing Standards and other relevant laws, such as the Chief Financial Officers Act of 1990 and the Government Performance and Results Act of 1993.

The Program's fiscal year appropriation is received via transfer from the Office of Science's Nuclear Physics program (see the Isotope Development and Production for Research and Applications section of the Nuclear Physics program within the Office of Science appropriation). Appropriated funds are used to support the scientists and engineers needed to carry out the Isotope Program and to operate and maintain isotope facilities to assure reliable production. In addition, the appropriation provides support for R&D activities associated with the development of new production and processing techniques for isotopes, operations support for the production of research isotopes, and support for the training of new personnel in isotope production and development. Each of the sites' production expenses for processing and distributing isotopes is offset by revenue generated from sales. The combination of appropriated funds and revenue from sales maintain the financial viability of the program. Of the total resources available annually in the revolving fund, about 75 percent is used for operations, maintenance, and isotope production, with roughly 25 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.

Isotopes are primarily produced and processed at three facilities, which are stewarded by the Isotope Program: the Isotope Production Facility at Los Alamos National Laboratory, the Brookhaven Linac Isotope Producer at Brookhaven National Laboratory, and processing facilities at Oak Ridge National Laboratory (ORNL). In addition, the Isotope Program is planning to use the hydraulic tube at the Advanced Test Reactor at the Idaho National Laboratory for radioisotope production. This upgrade will provide additional capability to produce short-lived medical and scientific research isotopes in short supply. At the Pacific Northwest National Laboratory (PNNL), the Isotope Program will continue to distribute strontium-90, a byproduct material of the past weapons programs, and is reviewing the possibility of processing other byproduct material stored at PNNL. Additional capability is provided by the High Flux Isotope Reactor, which is presently producing californium-252 for the Isotope Program. The Isotope Program is increasing productivity by broadening the suite of production facilities to include university accelerator and reactor facilities and other Federal agency facilities which can provide cost-effective and unique production capabilities; these include the Washington University, the University of California at Davis, and the Missouri University Research Reactor.

Background

The Department has supplied isotopes and related services for more than 50 years. These isotope products and services are used by medical institutions, universities, research organizations, and industry for a wide array of purposes. Isotopes are also provided to many Federal agencies, either directly or indirectly, including the National Institutes of Health and its grantees, the Environmental Protection Agency, and the Department of Homeland Security.

As the range of available isotopes and the recognized uses for them increased, new or improved isotope products contributed to progress in medical research and treatment, new industrial processes, and scientific investigation. Substantial national and international scientific, medical, and research infrastructure has relied upon the use of isotopes and is strongly dependent on the Department's products and services. Isotopes are now used for hundreds of research, biomedical, homeland security, and industrial applications that benefit society every day such as heart imaging, cancer therapy, smoke detectors, neutron detectors, explosives detection, oil exploration, and tracers for climate related research.

Isotope applications are widely used in medical research, diagnosis, and therapies, which are a growing component of the U.S. health care system. It is estimated that the treatment of one in every three people at a hospital makes use of a radioisotope in laboratory tests, diagnoses, or therapy. Each day, over 40,000 medical patients receive nuclear medicine procedures in the United States. Such nuclear procedures are among the safest diagnostic tests available. They enhance patient care by avoiding exploratory surgery and similar procedures. For example, it has been demonstrated that the use of myocardial perfusion imaging in emergency room chest pain centers can reduce the duration of stay on average from 46 hours to 12 hours. Adequate supplies of medical and research isotopes are essential to the Nation's health care system and to basic research and industrial applications that contribute to national economic competitiveness.

Isotope uses in homeland security applications are also increasing and include radiation portal monitors used to find unshielded or lightly shielded radiological material, imaging systems used to find densely shielded material, systems to detect the presence of nitrogen-based chemical explosives, and other forms of explosives detection.

The total budgetary resources available in the revolving fund in FY 2010 were $37.8 million. This consisted of $19.1 million from the FY 2010 direct Nuclear Physics appropriation, and collections of $18.7 million, which were used to cover expenses, support research into alternative production and processing techniques, and develop new production capabilities. Collections increase or decrease depending on customer demand, production efficiencies, and the availability of facilities. The collections in FY 2010 represent a decrease relative to FY 2009 due to large advance payments made in FY 2009 for californium-252. However, compared to recent years, sales and production of californium-252, selenium-75, and strontium-82 continue to increase. Californium-252 has a variety of industrial and medical applications, selenium-75 is used as a radiography source, and strontium-82 has gained worldwide acceptance for use in heart imaging which has resulted in increased sales over the last several years. Effective management of the Isotope Program requires constant diligence as factors which influence the program are dynamic by their nature. For example, sales are not static; they can fluctuate on a monthly basis, presenting a challenge for managing a productive and optimized staff involved in commercial isotope production.

In FY 2010, the Isotope Program served over 140 customers including major pharmaceutical companies, industrial users, and over 100 researchers at hospitals, national laboratories, universities, and private companies. There are about ten high-volume and moderately priced isotopes among the many produced by the Program; the remaining isotopes are low-volume research isotopes and thus more expensive to produce. Progress has been made in the past year in evaluating the pricing of isotopes in an effort to make research isotopes more affordable; these efforts are continuing. Commercial isotopes will continue to be priced to recover full cost. Research isotopes will be provided at a reduced price that will provide compensation to the government while encouraging research and development. For example, some expenses that were paid traditionally by the researcher are now being supported with appropriated funds, reducing the price of the research isotope to the customer. Improved communication with the user community and federal agencies has improved the ability to forecast demand of needed isotopes, which positions the Isotope Program to better meet the projected needs of the community, resulting in a more reliable supply of research isotopes.

Of the isotopes produced by the Isotope Program, the majority are for medical research. Over 420 shipments were made in FY 2010. Roughly a third of these shipments were to foreign countries with the remainder sold domestically, including 10% or less to other Federal agencies. Customer satisfaction with product specifications has traditionally been very high with over 98% of products and services provided meeting the terms of the contract/sales order in FY 2010.

Selected FY 2010 Accomplishments

- The demand for californium-252 continues to grow. A fourth sealed source manufacturer has met the requirements and has been added to the californium-252 contract arrangement with the three original industrial partners. Californium-252 is used for nuclear reactor start-up sources, mining and cement manufacturing, nuclear fuel interrogation, medicine, research, and homeland and national security. This isotope is only produced in the U.S. and Russia.
- Selenium-75 production increased about 30% over FY 2009 due to a new target design that permits a larger number of customer-provided capsules to be irradiated in the HFIR at ORNL. Selenium-75 is used for gamma radiography and is an alternative to iridium-192 for some applications.
- Stronium-82, used in heart imaging, continues to have significant worldwide growth in usage. For example, in FY 2010, the Isotope Program produced and shipped over 82,000 millicuries of this commercial medical isotope, which was a 303% increase over FY 2005. Demand continues to grow in FY 2011 for this Positron Emission Tomography (PET) imaging isotope, partly because it is an alternative for some of the molybdenum-99/technetium-99m modalities.

Budget Overview

For FY 2012 and the future, the Department foresees more than moderate growth in isotope demand, coupled with the possible need for new isotope products for homeland security, medicine, and industry. In order to satisfy the needs of its customers, the program seeks to meet supply requirements for year-round availability of isotopes for scientific and medical research and, in particular, for human clinical trials. The program's production capability may be called upon for initial ramp-up of production of major new isotope products until market forces bring in private producers that are willing to invest and produce the needed isotopes.

GENERAL PROVISIONS

SEC. 301. 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. 302. None of the funds in this or any other Act for the Administrator of the Bonneville Power Administration may be used to enter into any agreement to perform energy efficiency services outside the legally defined Bonneville service territory, with the exception of services provided internationally, including services provided on a reimbursable basis, unless the Administrator certifies in advance that such services are not available from private sector businesses.

SEC. 303. When the Department of Energy makes a user facility available to universities or other potential users, or seeks input from universities or other potential users regarding significant characteristics or equipment in a user facility or a proposed user facility, the Department shall ensure broad public notice of such availability or such need for input to universities and other potential users. When the Department of Energy considers the participation of a university or other potential user as a formal partner in the establishment or operation of a user facility, the Department shall employ full and open competition in selecting such a partner. For purposes of this section, the term "user facility" includes, but is not limited to: (1) a user facility as described in section 2203(a)(2) of the Energy Policy Act of 1992 (42 U.S.C. 13503(a)(2)); (2) a National Nuclear Security Administration Defense Programs Technology Deployment Center/User Facility; and (3) any other Departmental facility designated by the Department as a user facility.

SEC. 304. 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 2012 until the enactment of the Intelligence Authorization Act for fiscal year 2012.

SEC. 305. Not to exceed 5 per centum, or $100,000,000, of any appropriation, whichever is less, made available for Department of Energy activities funded in this Act or subsequent Energy and Water Development and Related Agencies Appropriation Acts may hereafter be transferred between such appropriations, but no appropriation, except as otherwise provided, shall be increased or decreased by more that 5 per centum by any such transfers, and any such proposed transfers shall be submitted to the Committee on Appropriations of the House and Senate.

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. To the extent practicable funds made available in this Act should be used to purchase light bulbs that are "Energy Star" qualified or have the "Federal Energy Management Program" designation.

Note.—A full-year 2011 appropriation for this account was not enacted at the time the budget was prepared; therefore, this account is operating under a continuing resolution (P.L. 111–242, as amended). The amounts included for 2011 reflect the annualized level provided by the continuing resolution.