Science
($K)

FY 2017 Enacted	FY 2018 Annualized CR	FY 2019 Request
5,390,972	5,354,362[a]	5,390,972

Overview

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

SC accomplishes its mission and advances national goals by supporting:

- *The frontiers of science*—exploring nature's mysteries from the study of fundamental subatomic particles, atoms, and molecules that are the building blocks of the materials of our universe and everything in it to the DNA, proteins, and cells that are the building blocks of life. Each of the programs in SC supports research probing the most fundamental disciplinary questions.
- *The 21st Century tools of science*—providing the nation's researchers with 26 state-of-the-art national scientific user facilities - the most advanced tools of modern science - propelling the U.S. to the forefront of science, technology development and deployment through innovation.
- *Science for energy and the environment*—paving the knowledge foundation to spur discoveries and innovations for advancing the Department's mission in energy and environment. SC supports a wide range of funding modalities from single principal investigators to large team-based activities to engage in fundamental research on energy production, conversion, storage, transmission, and use, and on our understanding of the earth systems.

SC is an established leader of the U.S. scientific discovery and innovation enterprise. Over the decades, SC investments and accomplishments in basic research and enabling research capabilities have provided the foundations for new technologies, businesses, and industries, making significant contributions to our nation's economy, national security, and quality of life. Select scientific accomplishments in FY 2017 enabled by the SC programs are described in the program budget narratives. Additional descriptions of recent science discoveries can be found at http://science.energy.gov/news/highlights.

Highlights and Major Changes in the FY 2019 Request

The FY 2019 Request for SC is $5,391.0 million, the same as the FY 2017 Enacted level, to implement the Administration's objectives for achieving overall reductions in civilian, discretionary spending and address the Administration's research and development priorities in American Security, Prosperity, and Energy Dominance[b]. The FY 2019 Request supports a balanced research portfolio of basic scientific research probing some of the most fundamental questions in areas such as: high energy, nuclear, and plasma physics; materials and chemistry; biological and environmental systems; applied mathematics; next generation high-performance computing and simulation capabilities; and basic research for advancement in new energy technologies. The Request supports SC's basic research portfolio, which includes extramural grants and contracts supporting over 22,000 researchers located at over 300 institutions and the 17 DOE national laboratories, spanning all fifty states and the District of Columbia. In FY 2019, SC's suite of 26 scientific user facilities will continue to provide unmatched tools and capabilities for nearly 32,000 users per year from universities, national laboratories, industry, and international partners. The Request will also support the construction of new user facilities and the R&D necessary for future facilities and facility

[a] A full-year 2018 appropriation for this account was not enacted at the time the budget was prepared; therefore, the budget assumes this account is operating under the Continuing Appropriations Act, 2018 (Division D of P.L. 115-56, as amended). The amounts included for 2018 reflect the annualized level provided by the continuing resolution. (These amounts are shown only at the Congressional control level and above; below that level, a dash (—) is shown).

[b] M-17-30, OMB Memo: *FY 2019 Administration Research and Development Budget Priorities*

upgrades to continue to provide world class research capabilities to U.S. researchers. SC allocates Working Capital Fund charges for common administrative services to the research programs and the program direction account.

Highlights of the FY 2019 Request by Program Office include:

- *Advanced Scientific Computing Research (ASCR)* supports research to discover, develop, and deploy computational and networking capabilities to analyze, model, simulate, and predict complex phenomena important to the DOE and the United States. The ASCR Request of $899.0 million, is an increase of $252.0 million, or 39.0 percent, above the FY 2017 Enacted level. The increase supports activities to accelerate the Department's Exascale Computing Initiative (ECI) and intends to enable delivery of at least one exascale-capable system in 2021—reasserting U.S. leadership in this critical area. Within ASCR, ECI consists of two components, Office of Science Exascale Project (SC-ECP), which supports the research and development focused on addressing the challenges of exascale and the second component, preparations for the deployment of at least one exascale system at an ASCR Leadership Computing Facility (LCF) in 2021. To ensure continued progress during and after the ECI, this Request also increases support for ASCR's fundamental research in Applied Mathematics and Computational Partnerships with a focus on advanced technologies such as quantum information science, including quantum computing and networking, and on new methods, software and tools for scientific machine learning for discovery and decision support. Funding for the LCF's is significantly increased to continue site preparations and non-recurring engineering investment with their vendors that will allow them to deploy at least one exascale-capable system as rapidly as possible. The Argonne Leadership Computing Facility (ALCF) will procure a large developmental testbed to test activities from non-recurring engineering investments and to provide ECP applications and software technology projects to test their codes. The FY 2019 Request also supports the operations of the 200 petaflop (pf) Summit system at the Oak Ridge Leadership Computing Facility and the 10 petaflop (pf) Mira and 8.5 pf Theta systems at the ALCF for existing users while the ALCF upgrade project continues. The National Energy Research Scientific Computing Center (NERSC) will operate the 30 pf Cori supercomputer. Funds will support continued operations of the Energy Sciences Network and for the ESnet upgrade to address the rapidly growing volume of scientific data transmission.

- *Basic Energy Sciences (BES)* supports fundamental research to understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels to provide foundations for new energy technologies. The BES Request of $1,850.0 million is a decrease of $21.5 million, or 1.1 percent, below the FY 2017 Enacted level. The FY 2019 Request focuses resources toward early-stage fundamental research, on the operation and maintenance of a complementary suite of scientific user facilities, and in the highest priority facility upgrades. The highest priorities in core research are quantum information science (QIS), ultrafast science, computational materials and chemical sciences as part of the ECI, and materials and chemistry for future nuclear energy. In the remaining core research activities, BES will place emphasis on basic science areas with the potential to transform the understanding and control of matter and energy including emphasis on emerging high priorities in quantum materials and chemistry, catalysis science, synthesis, instrumentation science, and materials and chemical research related to interdependent energy-water issues. The Request provides funding for the two BES-supported Energy Innovation Hubs, *Batteries and Energy Storage* and *Fuels from Sunlight*, and for the DOE Established Program to Stimulate Competitive Research. In the BES suite of facilities, the Request provides funds for operating the Linac Coherent Light Source (LCLS) in support of the priority on ultrafast science and to fully fund the last year of the LCLS-II construction project per the project plan. To allow installation activities for the LCLS-II construction project to proceed, LCLS will be shut down for one year, starting around second quarter of FY 2019. The four remaining x-ray facilities, both BES-supported neutron sources, and five nanoscience centers will continue operations. Funding for the Advanced Photon Source Upgrade (APS-U) project increases per the project plan. The request includes funds to initiate the Advanced Light Source Upgrade (ALS-U) project and the Linac Coherent Light Source-II High Energy (LCLS-II-HE) project.

- *Biological and Environmental Research (BER)* supports transformative science and scientific user facilities to achieve a predictive understanding of complex biological, earth, and environmental systems for energy and infrastructure security, independence, and prosperity. The BER Request of $500.0 million is a decrease of $112.0 million, or 18.3 percent, below the FY 2017 Enacted level. The FY 2019 Request implements Administration priorities for early-stage fundamental research focused on biological and earth and environmental systems. The Biological Systems Science subprogram implements priority-shifts to the core research areas of Genomic Sciences, adding new efforts in secure

biosystems design to ongoing activities in systems biology and environmental genomics, and fully supports the second year of the recompeted four DOE Bioenergy Research Centers. Biomolecular Characterization and Imaging Science (formerly known as Mesoscale to Molecules and Structural Biology Infrastructure) research supports structural, spatial and temporal understanding of functional biomolecules and processes within living cells, including new efforts in characterization of QIS advanced sensors. In the Earth and Environmental Systems Sciences subprogram, the Request focuses on continuing to prioritize development of the DOE high-resolution earth system model and for model diagnostics and intercomparisons. The Request supports operations of BER's three scientific user facilities: the DOE Joint Genome Institute (JGI), the Environmental Molecular Sciences Laboratory (EMSL), and the Atmospheric Radiation Measurement Research Facility (ARM). BER also requests funding for the acquisition and replacement of the ARM aerial capability as a Major Item of Equipment (MIE).

- *Fusion Energy Sciences (FES)* supports research to expand the fundamental understanding of matter at very high temperatures and densities and to build the scientific foundation for fusion energy. The FES FY 2019 Request of $340.0 million is a decrease of $40.0 million, or 10.5 percent, below the FY 2017 Enacted level. FES investments in user facility operations focus on the completion of DIII-D facility improvements that began in FY 2018, followed by 12 weeks of research operation to exploit these new tools and address priority science areas identified by recent community workshops. In addition, the Request includes funding for NSTX-U at the Princeton Plasma Physics Laboratory to implement repairs and corrective actions required to obtain robust, reliable research operations, and enhanced collaborative research at other facilities to support NSTX-U research program priorities. Funding for high-performance scientific computing through the SciDAC partnership with ASCR increases to accelerate development of a whole-device modeling capability and increase readiness for the exascale era. The FY 2019 Request will continue support for leveraged research opportunities by U.S. scientists on international superconducting tokamak and stellarator facilities with unique capabilities. Funding will be provided for the Materials-Plasma Exposure eXperiment Major Item of Equipment (MIE) project; which will address critical fusion material science questions. FES will initiate scoping studies to evaluate plans for an upgrade to the Matter in Extreme Conditions end station at LCLS and to assess options for a neutron source to test materials in a fusion-like environment. The Request will emphasize support for core discovery plasma science experiments on intermediate-scale collaborative facilities. Support will continue for low-temperature plasma research and high energy density plasma research, with connections and spinoffs to U.S. industry. The FY 2019 Request includes funding for the ITER project focusing on the highest-priority, in-kind contributions.

- *High Energy Physics (HEP)* supports research to understand how the universe works at its most fundamental level by discovering the most elementary constituents of matter and energy, probing the interactions among them, and exploring the basic nature of space and time itself. The FY 2019 Request of $770.0 million is a decrease of $55.0 million, or 6.7 percent, below the FY 2017 Enacted level. The FY 2019 Request will focus support on the highest priority elements identified in the 2014 High Energy Physics Advisory Panel (HEPAP) Particle Physics Project Prioritization Panel (P5) Report. The P5 report identified the High-Luminosity Large Hadron Collider (HL-LHC) accelerator and A Toroidal LHC Apparatus (ATLAS) and Compact Muon Solenoid (CMS) Detector Upgrade Projects as the highest priority in the near-term, and Long-Baseline Neutrino Facility and Deep Underground Neutrino Experiment (LBNF/DUNE) as the highest-priority large project in its timeframe. To continue our strong international partnership with CERN, the FY 2019 Request will increase support to these high-priority projects. The Request will enhance support for the LBNF/DUNE far-site civil construction, including the excavation of the underground equipment caverns and connecting drift, and the continued design effort work for the near site, cryogenic systems, and DUNE detectors. The Request supports preliminary design and prototyping for the planned Proton Improvement Plan II (PIP-II) construction project. The Request will support most projects consistent with planned funding profiles: LBNF/DUNE, HL-LHC Accelerator Upgrade Project (HL-LHC AUP), Muon to Electron Conversion Experiment (Mu2e), the Large Underground Xenon (LUX)-ZonEd Proportional scintillation in LIquid Noble gases (ZEPLIN) experiment (LZ), Super Cryogenic Dark Matter Search at Sudbury Neutrino Observatory Laboratory (SuperCDMS-SNOLAB), and the Dark Energy Spectroscopic Instrument (DESI). The Mu2e and LZ projects will receive final funding needed to complete all remaining project deliverables. The Request provides funding for two new Major Items of Equipment (MIEs), the HL-LHC ATLAS Detector Upgrade and the HL-LHC CMS Detector Upgrade Projects. The Request will support the operation of the Fermi National Accelerator Laboratory (Fermilab) Accelerator Complex at 75% of optimal. The Request will also support design and fabrication for the Facility for Advanced Accelerator Experimental Tests II (FACET-II) project. R&D that requires long-term investments including Advanced

Technology R&D, Accelerator Stewardship, and QIS will also be given higher priority in order to sustain world-leading efforts and support Office of Science priorities.

- *Nuclear Physics (NP)* supports experimental and theoretical research to discover, explore, and understand all forms of nuclear matter. The FY 2019 Request of $600.0 million is a decrease of $22.0 million, or 3.5 percent, below the FY 2017 Enacted level. The FY 2019 Request will support the highest priority research and scientific user facilities to maintain U.S. leadership in nuclear science. The FY 2019 Request will provide for operations of the Relativistic Heavy Ion Collider (RHIC) to confirm the origin of intriguing new phenomena observed in quark gluon plasma formation, operations of the recently completed 12 GeV Upgrade at the Continuous Electron Beam Accelerator Facility (CEBAF) to unravel the mechanism of quark confinement, and operations of the Argonne Tandem Linac Accelerator System (ATLAS) to provide opportunities for research in nuclear structure and nuclear astrophysics. The Request will support the continued construction of the Facility for Rare Isotope Beams (FRIB) according to the performance baseline profile; FRIB will provide world-leading capabilities for nuclear structure and astrophysics. The Request also supports the Gamma-Ray Energy Tracking Array (GRETA) detector, which will exploit the world-leading science capabilities of FRIB, and the Stable Isotope Production Facility (SIPF) within available resources. The Request also supports the initiation of the Strongly Pioneering High Energy Nuclear Interaction eXperiment (sPHENIX) MIE, which will further explore the properties of the quark gluon plasma. The Request supports core research at universities and DOE national laboratories and the development of cutting-edge approaches for producing isotopes critical to the Nation.

Reorganization and Restructure Initiative

SC is currently reviewing all functions and the organizational structure to maximize efficiencies across all programs in an attempt to increase efficiencies and reduce the Federal footprint. Through workforce analysis and restructuring, we will continue to review, analyze and prioritize mission requirements and identify those organizations and functions most in line with the Administration and Department program objectives and SC strategic goals. Using available human capital workforce reshaping tools, we have focused on functional consolidation, elimination of positions, and hiring limitations to achieve necessary results. SC has completed two VERA/VSIP buyout exercises that have helped to streamline the organization. SC is reviewing the field operations to identify areas of efficiency and potential reductions for the Integrated Service Centers (ISC) and the site offices. SC is reviewing the potential to reorganize the ISCs by establishing functional centers of excellence under one manager. Also, there is currently one site office for each national laboratory. By combining some of the site offices, better efficiencies can occur. Other areas under review include consolidation of SC's Information Technology services with those of the Department to boost security and efficiency. Safety and Security Technical Services are being consolidated and moved to the ISCs for better management of resources. These actions are in the process of being reviewed and implemented within SC. The review process continues as SC looks for other areas to reorganize to become a more effective and efficient office.

Basic and Applied R&D Coordination

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

High-Risk, High-Reward Research[a]

SC incorporates high-risk, high-reward, basic research elements in all of its research portfolios; each SC 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, SC constructs and operates national scientific facilities and instruments that comprise the world's most sophisticated suite of research capabilities. SC's basic research is integrated within program portfolios, projects, and individual awards; as such, it is not possible to quantitatively

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

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. SC incorporates high-risk, high-reward basic research elements in its research portfolios to drive innovation and challenge current thinking, using a variety of mechanisms to develop topics: Federal advisory committees, triennial Committees of Visitors, program and topical workshops, interagency working groups, National Academies' studies, and special SC program solicitations. Many of these topics are captured in formal reports, e.g., *Building for Discovery: Strategic Plan for U.S. Particle Physics in the Global* Context, by the High Energy Physics Advisory Panel (HEPAP-P5) (2014)[a]; *Quantum Computing Testbed for Science,* ASCR workshop report (2017)[b]; *Basic Research Needs Workshop on Innovation and Discovery of Transformative Experimental Tools,* Basic Energy Sciences workshop report (2017) [c]; *Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science*, by BES Advisory Committee (BESAC) (2015)[d]; *Basic Research Needs Workshop on Quantum Materials for Energy Relevant Technology,* BES workshop report (2016)[e]; *Grand Challenges for Biological and Environmental Research: Progress and Future* Vision, by the BER Advisory Committee (BERAC) (2017)[f]; *Technologies for Characterizing Molecular and Cellular Systems*, BER workshop report (2016)[g]; *Plasma: at the Frontier of Scientific Discovery*, FES workshop report (2017)[h]; *Isotope Research and Production Opportunities and Priorities*, by the Nuclear Science Advisory Committee (NSAC) (2015)[i]; and *Nuclear Physics Long Range Plan*, by the NSAC (2015)[j]

Scientific Workforce

SC and its predecessors have fostered the training of a skilled scientific workforce for more than 60 years. In addition to the undergraduate and graduate research opportunities provided through SC's Office of Workforce Development for Teachers and Scientists (WDTS), the six SC research program offices train undergraduates, graduate students, and postdoctoral researchers through sponsored research awards at universities and the DOE national laboratories. The research program offices also support targeted, undergraduate and graduate-level experimental training in areas associated with scientific user facilities and not readily available in university academic departments, such as particle accelerator and detector physics, neutron and x-ray scattering, nuclear chemistry, and computational sciences at the leadership computing level. Lastly, SC supports the Early Career Research Program, which funds individual research programs by outstanding Ph.D. scientists early in their careers in the disciplines supported by SC[k]. SC coordinates with other DOE offices and other agencies on best practices for training programs and program evaluation through internal DOE working groups and active participation in the National Science and Technology Council's Committee on Science, Technology, Engineering, and Mathematics Education. SC also participates in the American Association for the Advancement of Science's Science & Technology Policy Fellowships program and the Presidential Management Fellows Program to bring highly qualified scientists and professionals to DOE headquarters for a maximum term of two years.

Cybersecurity

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

[a] http://science.energy.gov/~/media/hep/hepap/pdf/May%202014/FINAL_P5_Report_Interactive_060214.pdf
[b] https://science.energy.gov/~/media/ascr/pdf/programdocuments/docs/2017/QTSWReport.pdf
[c] https://science.energy.gov/~/media/bes/pdf/brochures/2017/Electrical_Energy_Brochure.pdf
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[i] https://science.energy.gov/~/media/ber/pdf/community-resources/Technologies_for_Characterizing_Molecular_and_Cellular_Systems.pdf
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[k] https://science.energy.gov/early-career/