Nuclear Physics

Overview

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

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

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

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

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

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

Highlights of the FY 2016 Budget Request

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

Nuclear Physics
Funding ($K)

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

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

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

SBIR/STTR:

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

Nuclear Physics
Explanation of Major Changes ($K)

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

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

Basic and Applied R&D Coordination

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

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

Program Accomplishments

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

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

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

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

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

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

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

Nuclear Physics
Medium Energy Nuclear Physics

Description

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

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

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

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

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

Research

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

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

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

Operations

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

Medium Energy Nuclear Physics

Activities and Explanation of Changes

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

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

Nuclear Physics
Heavy Ion Nuclear Physics

Description

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

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

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

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

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

Research

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

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

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

Operations

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

Heavy Ion Nuclear Physics

Activities and Explanation of Changes

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

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Operations $166,072,000	**Operations $174,935,000**	**Operations +$8,863,000**
RHIC operations provide for 2,770 beam hours (approximately 22 weeks or 68 percent utilization) in support of the planned RHIC research program that takes advantage of dramatic improvements in collider performance and versatility made possible by recent RHIC upgrades. Funds for experimental equipment, accelerator R&D, and materials and supplies are reduced in FY 2015 in order to optimize running levels.	RHIC operations will continue to provide for 2,770 beam hours (approximately 22 weeks or 68 percent utilization) in support of the planned RHIC research program that is taking advantage of dramatic improvements in collider performance and versatility made possible by recent RHIC upgrades. The FY 2016 run (Run-16) is essential to understand results on heavy quark propagation in the quark-gluon plasma discovered at RHIC. The high statistics data planned for Run-16 will address these phenomena and are required for researchers to interpret the data acquired from the last two years.	Funds for experimental equipment, accelerator R&D, and materials and supplies are restored in FY 2016 in order to reduce risk and optimize operations, and maintenance and critical staff are fully supported.

Nuclear Physics
Low Energy Nuclear Physics

Description

The Low Energy Nuclear Physics subprogram focuses on answering the overarching questions associated with two scientific thrusts, Nuclei and Nuclear Astrophysics, and Fundamental Symmetries that can be probed by studying neutrons and nuclei.

Questions associated with Nuclei and Nuclear Astrophysics include:

- What is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes?
- What is the origin of simple patterns in complex nuclei?
- What is the nature of neutron stars and dense nuclear matter?
- What is the origin of the elements in the cosmos?
- What are the nuclear reactions that drive stars and stellar explosions?

This subprogram addresses these questions through support of research to develop a comprehensive description of nuclei using beams of stable and rare isotopes to yield new insights and reveal new nuclear phenomena. The subprogram also measures the cross sections of the nuclear reactions that power stars and lead to spectacular stellar explosions, which are responsible for the synthesis of the elements.

Questions addressed in the area of Fundamental Symmetries that can be probed by studying neutrons and nuclei include:

- What experimental approach for a next generation, ton-scale neutrino-less double beta day detector is capable of achieving the sensitivity necessary to determine if the neutrino is its own anti-particle?
- Is there evidence from the electric-dipole moments of atomic nuclei and the neutron that demonstrate our current understanding of the fundamental laws governing nuclear physics is incomplete?
- Does evidence for parity violation in electron scattering and possible lepton number violation in the decay of nuclei indicate forces present at the dawn of the universe that disappeared from view as the universe evolved?

This subprogram addresses these questions through precision measurements primarily with neutrons and with neutrinos from nuclear decays. Beams of cold and ultracold neutrons are used to study fundamental properties of neutrons. Precision studies to observe or set a limit on violation of time-reversal invariance—the principle that the physical laws should not change if the direction of time is reversed—in nucleonic, nuclear, and atomic systems investigate fundamental questions in nuclear physics, astrophysics, and cosmology.

The ATLAS national scientific user facility has been pivotal in making progress in Nuclear Structure and Nuclear Astrophysics, serving a combined international community of approximately 400 scientists. ATLAS provides high-quality beams of all the stable elements up to uranium as well as selected beams of short-lived nuclei for experimental studies of nuclear properties under extreme conditions and reactions of interest to nuclear astrophysics. Although ATLAS is the world's premiere facility for stable beams, it also provides limited capabilities in radioactive or rare isotope beams.

HRIBF ceased operations in 2012. Disposition activities of this facility continue in FY 2016. Analysis of data from HRIBF on exotic nuclei that do not normally exist in nature and reactions of interest to nuclear astrophysics continues. The HRIBF user community has been turning to other facilities for available beam time, including the ATLAS facility. This increased demand is influencing the evolution of the scientific agenda at ATLAS and the need for increased beam time and experimental capabilities.

NP supports the LBNL 88-Inch Cyclotron jointly with the National Reconnaissance Office (NRO) and the U.S. Air Force (USAF). Accelerator operations are supported at two university Centers of Excellence with specific goals and unique physics programs: the Cyclotron Institute at Texas A&M University (TAMU) and accelerator facilities at the Triangle Universities Nuclear Laboratory (TUNL) at Duke University. A third university center, the Center for Experimental Nuclear Physics and Astrophysics (CENPA) at the University of Washington, provides unique expertise and capabilities for instrumentation development.

Progress in nuclear structure and nuclear astrophysics depends increasingly upon the availability of rare isotope beams. One of the highest priorities for the NP program is support for the construction of a facility with world-leading capabilities for short-lived radioactive beams, the Facility for Rare Isotope Beams (FRIB). FRIB is a next-generation machine being constructed at MSU that will advance understanding of rare nuclear isotopes and the evolution of the cosmos by providing beams of rare isotopes with neutron and proton numbers far from those of stable nuclei in order to test the limits of nuclear existence.

Research

Low Energy research groups are supported at ANL, BNL, LBNL, LANL, LLNL, ORNL, and PNNL, as well as 44 universities. The subprogram funds about 170 Ph.D. scientists and nearly 100 graduate students at the national laboratories and universities. About two-thirds of the supported scientists conduct nuclear structure and astrophysics research primarily using specialized instrumentation at the ATLAS national user facility as well as the smaller accelerator facilities at university-based Centers of Excellence. The remaining groups conduct research in fundamental symmetries, including experiments at the Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source, double beta-decay experiments such as the Cryogenic Underground Observatory for Rare Events (CUORE) experiment at Gran Sasso Laboratory in Italy and the Majorana Demonstrator R&D effort at the Sanford Underground Research Facility in Lead, South Dakota, a measurement of the neutrino mass with the Karlsruhe Tritium Neutrino (KATRIN) experiment at the Karlsruhe Institute of Technology in Karlsruhe, Germany, and limited R&D to measure the neutron electric dipole moment.

Operations

ATLAS provides stable and selected radioactive beams and utilizes specialized instrumentation for scientists to conduct research on nuclear structure and nuclear astrophysics, and is the premiere stable beam facility in the world. The Californium Rare Ion Breeder Upgrade (CARIBU) at ATLAS provides targeted unique capabilities to produce radioactive ion beams until FRIB becomes operational in the next decade. The ATLAS facility nurtures a core competency in accelerator science with superconducting radio frequency cavities for heavy ions that are relevant to the next generation of high-performance proton and heavy-ion linacs. This competency is important to the Office of Science mission and international stable and radioactive ion beam facilities.

Low Energy Nuclear Physics

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Low Energy Nuclear Physics $75,196,000	**$79,788,000**	**+$4,592,000**
Research $48,377,000	**Research $52,125,000**	**Research +$3,748,000**
University and laboratory nuclear structure and nuclear astrophysics efforts focus on research at ATLAS, university-based Centers of Excellence, and limited support for highest priority development efforts for instrumentation at FRIB. Commissioning of the Majorana Demonstrator continues and data taking is initiated. The international CUORE major item of equipment is completed. Support continues for the GRETINA detector maintenance and operations and KATRIN operations. The neutron program at the FNPB continues R&D on the feasibility of setting a world leading limit on nEDM.	University and laboratory nuclear structure and nuclear astrophysics efforts will continue to focus on research at ATLAS, university-based Centers of Excellence, as well as the highest priority instrumentation development efforts to realize unique scientific opportunities afforded by stopped, slow, and fast beams at FRIB. Data taking will continue at the Majorana Demonstrator to demonstrate technical feasibility of a next generation detector in double beta decay. Support will continue for maintenance and operations of the GRETINA detector, operations of the KATRIN experiment, and R&D at the FNPB on the feasibility of setting a world leading limit on the electric dipole moment of the neutron (nEDM).	Increased funding is requested to restore the highest priority research efforts at national laboratories and universities, to develop and implement instrumentation in nuclear structure and astrophysics at ATLAS and FRIB, and for neutrinoless double beta decay research and neutron science at the Sanford Underground Research Facility (SURF) and the Fundamental Neutron Physics Beamline (FNPB) at the Spallation Neutron Source (SNS).
Operations $26,819,000	**Operations $27,663,000**	**Operations +$844,000**
ATLAS will provide an estimated 5,900 hours (about 37 weeks) of beam time, 95 percent of optimal operations. The Electron Beam Ion Source AIP will be commissioned at ATLAS. Funding continues for equipment disposition activities at HRIBF.	Continued operation of ATLAS in a 7 day per week mode is a high priority as demand for ATLAS beam time continues to far exceed availability. FY 2016 funding will support 5,900 hours (about 37 weeks) of beam time, 95 percent of optimal operations, and a program of modest upgrades continues for the only operating DOE-supported scientific user facility in nuclear structure and astrophysics. Support will continue for equipment disposition activities at HRIBF.	Funding increases primarily for support of key personnel required to provide robust ATLAS operations, implement new capabilities of the accelerator and support the increasing demand from the user community for a wider variety of beams.

Description

The Nuclear Theory subprogram provides the theoretical support needed to interpret the wide range of data obtained from the experimental nuclear science subprograms and to advance new ideas and hypotheses that identify potential areas for future experimental investigations. Nuclear Theory addresses all three of NP's scientific thrusts. One major theme of theoretical research is the development of an understanding of the mechanisms and effects of quark confinement and deconfinement. A quantitative description of these phenomena through QCD is one of this subprogram's greatest intellectual challenges. New theoretical and computational tools are also being developed to describe nuclear many-body phenomena; these approaches will likely also see important applications in condensed matter physics and in other areas of the physical sciences. Another major research area is nuclear astrophysics, which includes efforts to understand the origins of the elements and the consequences that neutrino masses have for nuclear astrophysics.

This subprogram supports the Institute for Nuclear Theory (INT) at the University of Washington. A second round of five-year topical collaborations within the university and national laboratory communities to address high-priority topics in nuclear theory that merit a concentrated theoretical effort will be competed at the end of FY 2015 when the first round of collaborations comes to an end. The Nuclear Theory subprogram also supports the U.S. Nuclear Data Program (USNDP), which collects, evaluates, and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies and their development.

Much of the research supported by the Nuclear Theory subprogram requires extensive access to leading-edge supercomputers. One area that has a particularly pressing demand for large, dedicated computational resources is LQCD. LQCD calculations are critical for understanding and interpreting many of the experimental results from RHIC, LHC, and CEBAF. A five-year computer hardware project "LQCD-ext II" will start in FY 2015 and is being carried out jointly with HEP to ensure effective coordination. It follows the previous joint efforts that address the computational requirements of LQCD research by continuing to provide specialized computing resources for LQCD research. Both HEP and NP require this type of computing capability in order to conduct simulations that address their distinct science programs. The partnering of the two Offices ensures effective coordination to maximize the leverage available for this activity from the infrastructure and intellectual capital of both programs and to prevent duplication of effort on resource-intensive calculations inherently central to quantum chromodynamics and particle physics research.

SciDAC, a collaborative program with ASCR that partners scientists and computer experts in research teams to address major scientific challenges that require supercomputer facilities performing at current technological limits, is also supported within this subprogram. The NP SciDAC program operates on a five year cycle, and supports computationally intensive research projects jointly with other SC and DOE offices in areas of mutual interest. SciDAC-3 awards were made in FY 2012 and will continue through FY 2016.

Theory Research

The Nuclear Theory subprogram supports the research programs of approximately 160 university scientists and 120 graduate students at 50 universities, as well as nuclear theory groups at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF). This research has the goals of improving our fundamental understanding of nuclear physics, interpreting the results of experiments carried out under the auspices of the experimental nuclear physics program, and identifying and exploring important new areas of research. It is aligned with the experimental program through the program performance milestones established by the Nuclear Sciences Advisory Committee (NSAC). Three topical collaborations [JET (QCD in the heavy-ion environment); NuN (neutrinos and nucleosynthesis in hot and dense matter); and TORUS (low-energy nuclear reactions for unstable isotopes)] received their last year of funding in FY 2014. Based on the success and community support of this program, a new round of 5-year topical collaborations to bring together theorists to address specific high-priority theoretical challenges is planned to be competed late in FY 2015 with initial funding to be provided in FY 2016.

Nuclear Data

The USNDP provides current, accurate, and authoritative data for workers in pure and applied areas of nuclear science and engineering. It addresses this goal primarily through maintaining and providing public access to extensive nuclear physics databases, which summarize and cross-correlate the results of over 100 years of research on nuclear science. These databases are an important national and international resource, and currently respond to approximately three million retrievals of nuclear data annually. The USNDP also addresses important gaps in nuclear data through targeted experiments and the development and use of theoretical models. The program involves the combined efforts of approximately 50 nuclear scientists at 10 national laboratories and universities, and is managed by the National Nuclear Data Center (NNDC) at BNL.

Nuclear Theory

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Nuclear Theory $43,096,000	**$46,220,000**	**+$3,124,000**
Theory Research $35,715,000	**Theory Research $38,583,000**	**Theory Research +$2,868,000**
Funding supports the highest priority theoretical research at universities and national laboratories for the interpretation of experimental results obtained at NP facilities, including multi-dimensional fluctuating fluid-dynamical calculations to describe relativistic nuclear collisions. Efforts focus on nucleon and nuclear structure, spectroscopy, and reactions in preparation for the research program at the upgraded CEBAF 12 GeV facility, the research program at the planned FRIB facility, and on topics related to fundamental symmetries. Funding supports ongoing research efforts, the SciDAC-3 grants, and the LQCD ext-II computing project.	Funding will continue to support the highest priority theoretical research at universities and national laboratories for the interpretation of experimental results obtained at NP facilities. Theorists will concentrate on applying QCD to nucleon structure and hadron spectroscopy, to the force between nucleons, and to the structure of light nuclei. Advanced dynamic calculations to describe relativistic nuclear collisions, nuclear structure and reactions, and topics related to fundamental symmetries will focus on activities in preparation for the research program at the upgraded CEBAF 12 GeV facility, the research program at the planned FRIB facility, and ongoing and planned fundamental symmetries experiments. Funding will also continue to support ongoing SciDAC-3 grants and the LQCD ext-II computing project. Support will be provided for the second round of theory topical collaborations.	Funding increases to restore the highest priority nuclear theory research at universities and national laboratories and to support the first year of funding for the second round of high priority targeted theory topical collaborations, and computational research under SciDAC.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Nuclear Data $7,381,000	**Nuclear Data $7,637,000**	**Nuclear Data +$256,000**
Efforts continue to focus on updating online databases containing experimental and evaluated nuclear structure data, nuclear reaction cross sections, and nuclear science literature and on maintaining computing infrastructure needed to support important efforts across the National Nuclear Data program. Specifically, a new XML-based nuclear data structure model will be developed and incorporated into databases.	Nuclear data evaluation is the prime nuclear data product, combining experiment with theory and linking basic science with applications. The emphasis in FY 2016 will be on the compilation and evaluation of nuclear reaction and nuclear structure data which will include advanced nuclear reaction modeling and uncertainty quantification; maintaining and developing nuclear data formats and data verification codes; and archiving nuclear physics data and disseminating it using up to date technology.	Funding increases to avoid the loss of key personnel and to enable NNDC to continue to provide the highest quality nuclear data in support of basic science and users' needs in order to ensure safety, reliability, efficacy, and sustainability of nuclear technologies. This includes the safe and economical utilization of nuclear power, and R&D of innovative reactors and advanced fuel cycles.

Nuclear Physics
Isotope Development and Production for Research and Applications

Description

The Isotope Development and Production for Research and Applications subprogram (Isotope Program) supports the production, distribution, and development of production techniques for radioactive and stable isotopes in short supply and critical to the Nation. Isotopes are commodities of strategic importance for the Nation that are essential for energy exploration and innovation, medical applications, national security, and basic research. The goal of the program is to make key isotopes more readily available to meet U.S. needs. To achieve this goal, the program incorporates all capabilities, including facilities and technical staff, required for supply chain management of critically important isotopes. The subprogram also supports R&D efforts associated with developing new and more cost-effective and efficient production and processing techniques, and on the production of isotopes needed for research purposes. The R&D activities also provide collateral benefits for training, contributing to workforce development and helping to ensure a future U.S.-based expertise in the fields of nuclear chemistry and radiochemistry. These disciplines are foundational not only to radioisotope production but to many other critical aspects of basic and applied nuclear science as well.

The Isotope Program operates a revolving fund to maintain its financial viability by utilizing a combination of appropriations and revenues from the sale of isotopes and services. These resources are used to maintain the staff, facilities, and capabilities at user-ready levels and to support peer-reviewed research and development activities related to the production of isotopes. Isotopes sold to commercial customers are priced to recover the full cost of production, or the market price (whichever is higher). Research isotopes are sold at a reduced price to ensure high priority research requiring them does not become cost prohibitive. Investments in new capabilities are made to meet the growing demands of the Nation and foster future research in applications that will support national security and the health and welfare of the public.

Isotopes are critical national resources used to improve the accuracy and effectiveness of medical diagnoses and therapy, enhance national security, improve the efficiency of industrial processes, and provide precise measurement and investigative tools for materials, biomedical, environmental, archeological, and other research. Some examples are:

- strontium-82 for cardiac imaging;
- californium-252 for well logging, homeland defense, and energy security;
- germanium-68 for the development of gallium-68 radiopharmaceuticals for cancer imaging;
- berkelium-249, californium-251, and curium-244 use as targets for discovery of new superheavy elements;
- selenium-75 use in industrial radiography;
- actinium-225, bismuth-213, lead-212, thorium-227, and radium-223 use in cancer and infectious disease therapy research;
- nickel-63 use in molecular sensing devices and helium-3 (He-3) use in neutron detectors, both for applications in homeland defense;
- strontium-90 and cobalt-60 for cancer therapy;
- arsenic-73 use as a tracer for environmental research; and
- silicon-32 use in oceanographic studies related to climate modeling.

Stable and radioactive isotopes are vital to the mission of many Federal agencies including the National Institutes of Health (NIH), the National Institute of Standards and Technology, the Environmental Protection Agency, the Department of Agriculture, the Department of Homeland Security (DHS), NNSA, and DOE Office of Science programs. NP continues to work in close collaboration with these organizations to develop strategic plans for isotope production and to establish effective communication to better forecast isotope needs and leverage resources. For example, a five-year production strategy has been generated with the NIH that identifies the isotopes and projected quantities needed by the medical community in the context of the Isotope Program production capabilities. In addition, NP conducts an annual workshop, attended by representatives of all Federal agencies that require stable and radioactive isotopes to support research and applications within their realms of responsibility, to provide a comprehensive assessment of national needs for isotope products and services. Another example is participation in the White House Office of Science and Technology Policy (OSTP) working group on molybdenum-99 (Mo-99). While the Isotope Program is not responsible for the production of Mo-99, it recognizes the importance of this isotope for the Nation as a diagnostic in cardiac imaging and is working closely with NNSA, the lead entity responsible for domestic Mo-99 production, and is offering technical and management support. NP participates in the international High-Level Group on the Security of Supply of Medical Isotopes lead by the Organisation for Economic Co-operation and Development (OECD). Consistent with the National Defense Authorization Act for Fiscal Year 2013, NP also initiated and oversaw proceedings of the Nuclear Science Advisory Committee in response to a charge to assess progress by the NNSA GTRI program toward ensuring a domestic supply of Mo-99. NP participates in the Certified Reference Material Working Group which assures material availability for nuclear forensics applications that support national security missions. NP plays a lead role in a federal working group on the He-3 supply issue involving NNSA, DHS, the Department of Defense, NIH, and many other agencies. The objective of the working group is to ensure that the limited supply of He-3 will be distributed to the highest priority applications and basic research. The Isotope Program packages and distributes the isotope, and plays a lead role in working with all of the Federal agencies in forecasting demand for the gas and its allocation.

The National Isotope Development Center (NIDC) is a virtual center that interfaces with the user community and manages the coordination of isotope production across the facilities and business operations involved in the production, sale, and distribution of isotopes. The NIDC includes the Isotope Business Office, which is located at ORNL.

Research

Research is supported to develop new or improved production or separation techniques for high priority isotopes in short supply. Examples of isotope research required to meet national needs include positron-emitting radionuclides to support the rapidly growing area of medical imaging using positron emission tomography (PET), isotopes supporting medical research used to diagnose and treat diseases spread through acts of bioterrorism, research isotopes for various biomedical applications, enriched stable isotopes, and alternative isotope supplies for national security applications and advanced power sources. Priorities in research isotope production are informed by guidance from NSAC. One of the high priorities is to conduct R&D aimed at re-establishing a U.S. capability for stable isotope production. Another high priority is a long-term research effort to produce Ac-225, an isotope that shows great promise in the treatment of diffuse cancers and infections if it can be produced in sufficient quantity and quality. Also, in anticipation of the opportunity FRIB will provide as a unique source of many important isotopes for research and applications, scientists are exploring technologies to potentially harvest some of the isotopes that will be produced during physics research experiments. Isotope Program research also provides training opportunities for workforce development in the areas of nuclear chemistry and radiochemistry. These disciplines are essential to the long-term health of the fields of radioisotope production and applications.

Operations

The Isotope Program is steward of the Isotope Production Facility (IPF) at Los Alamos National Laboratory (LANL) and the Brookhaven Linac Isotope Producer (BLIP) facility at BNL and provides support for hot cell facilities for processing and handling irradiated materials and purified products at ORNL, BNL, and LANL. Facilities at other sites are used as needed, such as the Idaho National Laboratory reactor for the production of cobalt-60, the Pacific Northwest National Laboratory for processing and packaging strontium-90, the Y-12 National Security Complex for processing and packaging lithium-6 and lithium-7, and the Savannah River Site for the extraction and distribution of helium-3.

Isotope Development and Production for Research and Applications

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Isotope Development and Production for Research and Applications $19,850,000	**$21,664,000**	**+$1,814,000**
Research $4,815,000	**Research $6,133,000**	**Research +$1,318,000**
Support maintains research and development competitive awards and laboratory research groups at LANL, BNL, and ORNL. Development of production techniques for alpha-emitters continues to be a high priority, as is R&D aimed at re-establishing a domestic capability for research quantities of stable isotopes. Development for a 100 mA ion source and ion optics for production scale electromagnetic stable isotope separation is completed, which is critical for the re-establishment of enriched stable isotope production in the United States.	Support is continued for research and development competitive awards to universities and laboratories, as well as for support to laboratory research groups at LANL, BNL, and ORNL. Development of production techniques for alpha-emitting radionuclides for medical therapy will continue to be a priority, and is being implemented through a concerted collaborative R&D effort by experts at the national laboratories, particularly at BNL, LANL, and ORNL. Research at universities and national laboratories is also leading to new isotope production technologies and effectively engaging and training students and post-docs in nuclear chemistry and radiochemistry.	Funding increases to enhance core research capabilities at the national laboratories and universities, and the program of competitive R&D, in order to address the high priorities identified by NSAC, particularly with regard to the research effort to produce Ac-225.

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Operations $15,035,000	**Operations $15,531,000**	**Operations +$496,000**
Support is provided for infrastructure and maintenance of facilities, core competencies in isotope production and development, and for the NIDC. National laboratory operations are focused on essential activities required to maintain aging facilities in operational conditions. Funding is provided to support university-based operations in support of isotope production. The isotopes produced will represent a balance of commercial isotopes and high priority research isotopes, with prioritization informed by NSAC and the Federal workshop in November 2014. A major milestone will be the development of a rubidium metal target at the IPF for increased production of strontium-82 for medical heart imaging.	Support will provide for infrastructure and maintenance of facilities, core competencies in isotope production and development, and for the NIDC. The maintenance of aging facilities continues to be a funding priority to maintain isotope production capabilities. Funding for program investments and production of particular isotopes will be informed by the Nuclear Science Advisory Committee's updated long-range plan for the Isotope Program (to be completed in FY 2015) and the Federal workshop to be held in the fall of 2015.	Funding increases to maintain a constant level of effort for the Isotope Production Facility, the Brookhaven Linac Isotope Producer, and processing capabilities at ORNL, BNL, and LANL, and the NIDC.

Construction

Description

Funding in this subprogram provides for design and construction needed to meet overall objectives of the Nuclear Physics program. Currently NP is supporting two projects.

The 12 GeV CEBAF Upgrade at TJNAF, which was identified in the 2007 NSAC Long-Range Plan as the highest priority for the U.S. Nuclear Physics program, will enable scientists to address one of the mysteries of modern physics—the mechanism of quark confinement. FY 2016 is the last year of construction funding for the project; it is planned for completion in September 2017.

The Facility for Rare Isotope Beams will provide intense beams of rare isotopes for world-leading research opportunities in nuclear structure, nuclear astrophysics, and fundamental symmetry studies that will advance knowledge of the origin of the elements and the evolution of the cosmos. It offers a facility for exploring the limits of nuclear existence and identifying new phenomena, with the possibility that a broadly applicable theory of the structure of nuclei will emerge. FRIB will provide an essential scientific tool for over 1,300 scientists each year from across academic, industrial and government institutions. The project is funded through a cooperative agreement with Michigan State University and was established as a control point in the FY 2014 appropriation. Prior to that time, funding was provided within the Low Energy subprogram.

Construction

Activities and Explanation of Changes

FY 2015 Enacted	FY 2016 Request	Explanation of Changes FY 2016 vs. FY 2015
Construction $106,500,000	**$107,500,000**	**+$1,000,000**
06-SC-01, 12 GeV CEBAF Upgrade, TJNAF **$16,500,000**	**06-SC-01, 12 GeV CEBAF Upgrade, TJNAF** **$7,500,000**	**06-SC-01, 12 GeV CEBAF Upgrade, TJNAF** **-$9,000,000**
Experimental equipment in Halls B, C, and D continue to be procured, fabricated, installed, and commissioned. Project work associated with civil and accelerator construction, scheduled to be complete in the first quarter of FY 2015, was completed 5 months ahead of schedule; CD-4A (Approve Accelerator Project Completion and Start of Operations for the 12 GeV Project) was approved on July 30, 2014. The project continues to work towards completion CD-4B (Approve Experimental Equipment Project Completion and Start of Operations) by the end of FY 2017.	With the scheduled commissioning of the Hall D experimental equipment in FY 2015, the FY 2016 federal funds will support procurements, fabrication, installation, and commissioning of the experimental equipment primarily in Halls B and C; and address continuing project risks in order to optimize the successful completion of this project within the current TEC baseline. FY 2016 is the final year of TEC funding for the project as it works towards completion (CD-4B) by the end of FY 2017.	The decrease reflects the approved baseline profile for the project.
14-SC-50, Facility for Rare Isotope Beams (FRIB) **$90,000,000**	**14-SC-50, Facility for Rare Isotope Beams (FRIB)** **$100,000,000**	**14-SC-50, Facility for Rare Isotope Beams (FRIB)** **+$10,000,000**
Civil and technical construction, major procurements, and fabrication of components as required under the baselined FRIB scope continue.	Work on conventional facilities will continue with construction of items such as the linear accelerator (linac) tunnel and the target, linac support, and cryoplant areas. The technical systems will also be fully underway and will include efforts such as major procurements, fabrication, and assembly for technical components such as the linac, cryomodules, and experimental systems.	Federal funding ramps up for continued FRIB construction according to the Performance Baseline and funding profile established in August 2013.

Nuclear Physics
Performance Measure

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

	FY 2014	FY 2015	FY 2016
Performance Goal (Measure)	**NP Facility Operations—Average achieved operation time of NP user facilities as a percentage of total scheduled annual operation time.**		
Target	≥ 80%	≥ 80%	≥ 80%
Result	Met	TBD	TBD
Endpoint Target	Many of the research projects that are undertaken at the Office of Science's scientific user facilities take a great deal of time, money, and effort to prepare and regularly have a very short window of opportunity to run. If the facility is not operating as expected the experiment could be ruined or critically setback. In addition, taxpayers have invested millions or even hundreds of millions of dollars in these facilities. The greater the period of reliable operations, the greater the return on the taxpayers' investment.		
Performance Goal (Measure)	**NP Construction/MIE Cost & Schedule—Cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.**		
Target	< 10%	< 10%	< 10%
Result	Met	TBD	TBD
Endpoint Target	Adhering to the cost and schedule baselines for a complex, large scale, science project is critical to meeting the scientific requirements for the project and for being good stewards of the taxpayers' investment in the project.		
Performance Goal (Measure)	**Conduct fundamental research to discover, explore, and understand all forms of nuclear matter.**		
Target	Perform mass measurements and nuclear reaction studies to infer weak interaction rates in nuclei in order to constrain models of supernovae and stellar evolution	Measure bulk properties, particle spectra, correlations and fluctuations in gold + gold collisions at Relativistic Heavy Ion Collider (RHIC) to search for evidence of a critical point in the Quantum Chromodynamics (QCD) matter phase diagram.	Perform measurements for identified hadrons with heavy flavor valence quarks to constrain the mechanism for parton energy loss in the quark-gluon plasma at the Relativistic Heavy Ion Collider (RHIC).
Result	Met	TBD	TBD
Endpoint Target	Increase the understanding of the existence and properties of nuclear matter under extreme conditions, including that which existed at the beginning of the universe.		

Nuclear Physics
Capital Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
Capital Operating Expenses Summary							
Capital equipment	n/a	n/a	14,790	14,790	14,750	20,305	+5,555
General plant projects (GPP)	n/a	n/a	2,500	2,500	2,000	2,000	0
Accelerator improvement projects (AIP)	n/a	n/a	4,770	4,770	4,249	4,377	+128
Total, Capital Operating Expenses	**n/a**	**n/a**	**22,060**	**22,060**	**20,999**	**26,682**	**+5,683**
Capital Equipment							
Other capital equipment under $2 million TEC	n/a	n/a	14,790	14,790	14,750	20,305	+5,555
General Plant Projects							
General plant projects under $5 million TEC	n/a	n/a	2,500	2,500	2,000	2,000	0
Accelerator Improvement Projects (AIP)							
RHIC Low Energy Electron Cooling	9,900	1,300	2,300	2,300	2,300	2,369	+69
Other projects under $5 million TEC	n/a	n/a	2,470	2,470	1,949	2,008	+59
Total, Accelerator Improvement Projects	**n/a**	**n/a**	**4,770**	**4,770**	**4,249**	**4,377**	**+128**

Construction Projects Summary ($K)

	Total	Prior Years	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs FY 2015
06-SC-01, 12 GeV CEBAF Upgrade, TJNAF							
TEC	310,500	261,000	25,500	25,500	16,500	7,500	-9,000
OPC	27,500	13,000	4,500	4,500	4,500	4,500	0
TPC	338,000	274,000	30,000	30,000	21,000	12,000	-9,000
14-SC-50, Facility for Rare Isotope Beams							
DOE TPC	635,500[a]	73,000[b]	55,000	55,000	90,000	100,000	+10,000
Total, Construction (TPC)	**n/a**	**n/a**	**85,000**	**85,000**	**111,000**	**112,000**	**+1,000**

Funding Summary ($K)

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
Research	170,668	170,668	165,828	179,311	+13,483
Scientific User Facilities Operations	276,887	276,887	280,663	293,304	+12,641
Other Facility Operations	24,120	24,120	24,313	24,995	+682
Projects					
Major Items of Equipment	0	0	0	0	0
Facility for Rare Isotope Beams	55,000	55,000	90,000	100,000	+10,000
12 GeV Upgrade TEC	25,500	25,500	16,500	7,500	-9,000
Total Projects	80,500	80,500	106,500	107,500	+1,000
Other[c]	16,963	2,627	18,196	19,490	+1,294
Total Nuclear Physics	**569,138**	**554,802**	**595,500**	**624,600**	**+29,100**

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[a] This is the DOE TPC; MSU's cost share is $94,500,000 bringing the total project cost to $730,000,000. FRIB is funded with operating dollars through a Cooperative Agreement financial assistance award with a work breakdown structure (WBS) that is slightly different from typical federal capital assets. The WBS totals $730,000,000 including MSU's cost share. Because the WBS scope is not pre-assigned to DOE or MSU funds, DOE's baseline of $635,500,000 cannot be broken down between TEC and OPC.

[b] The PY funding was provided within the Low Energy subprogram. The FY 2014 appropriation established FRIB as a control point.

[c] Includes SBIR/STTR funding in FY 2014 Enacted and FY 2015–FY 2016.

Scientific User Facility Operations ($K)

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

Definitions:

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

Planned Operating Hours –

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

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

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

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

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

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
CEBAF (TJNAF)[a]	**$106,698**	**$106,698**	**$108,694**	**$111,196**	**$2,502**
Number of Users	1,245	1,245	1,235	1,210	N/A
Achieved operating hours	N/A	N/A	N/A	N/A	N/A
Planned operating hours	0	0	0	0	0
Optimal hours	0	0	0	0	0
Percent optimal hours	N/A	N/A	N/A	N/A	N/A
Unscheduled downtime hours	N/A	N/A	N/A	N/A	N/A

[a] During FY 2014-2016, there are no research hours to which the CEBAF facility will be held accountable while the 12 GeV upgrade is commissioned and reliability is expected to be low. In FY 2014, 14 weeks of beam development and tuning are supported as the facility comes back on from a prolonged shutdown. In FY 2015, approximately 19 weeks and in FY 2016, approximately 16 weeks of machine development are supported. The user community is expected to remain active during the shutdown with instrumentation and equipment implementation for the upgraded facility so they continue to be shown in these years.

	FY 2014 Enacted	FY 2014 Current	FY 2015 Enacted	FY 2016 Request	FY 2016 vs. FY 2015
TYPE A FACILITIES					
RHIC (BNL)	**$172,079**	**$172,079**	**$172,579**	**$181,999**	**$9,420**
Number of Users	1,200	1,200	1,200	1,200	N/A
Achieved operating hours	3,060[a]	3,060	N/A	N/A	N/A
Planned operating hours	2,770	2,770	2,770	2,770	0
Optimal hours	4,100	4,100	4,100	4,100	0
Percent optimal hours	74.6%	74.6%	67.6%	67.6%	N/A
Unscheduled downtime hours	0	0	N/A	N/A	N/A
ATLAS (ANL)[b]	**$22,462**	**$22,462**	**$21,682**	**$22,390**	**$708**
Number of Users	400	400	400	410	N/A
Achieved operating hours	3,820[c]	3,820	N/A	N/A	N/A
Planned operating hours	3,500	3,500	5,900	5,900	0
Optimal hours	4,200	4,200	6,200	6,200	0
Percent optimal hours	91.0%	91.0%	95.2%	95.2%	N/A
Unscheduled downtime hours	0	0	N/A	N/A	N/A
Total Scientific User Facility Operations	**$301,239**	**$301,239**	**$302,955**	**$315,585**	**$12,630**
Number of Users	2,845	2,845	2,835	2,820	N/A
Achieved operating hours	6,880	6,880	N/A	N/A	N/A
Planned operating hours	6,270	6,270	8,670	8,670	0
Optimal hours	8,300	8,300	10,300	10,300	0
Percent of optimal hours[d]	76.5%	76.5%	70.6%	70.6%	N/A
Unscheduled downtime hours	0	0	N/A	N/A	N/A

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[a] RHIC was able to deliver more hours than planned due to outstanding FY 2014 performance that exceeded the assumed machine reliability.

[b] The optimal hours at ATLAS in FY 2014–2016 vary due to downtime for installation of upgrades.

[c] During FY 2014, ATLAS exceeded the planned operating hours because operations restarted earlier than planned following installation of upgrades.

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

Scientific Employment

	FY 2014 Enacted	FY 2014 Current	FY 2015 Estimate	FY 2016 Estimate	FY 2016 vs. FY 2015
Number of permanent Ph.D.’s (FTEs)	695	695	685	695	+10
Number of postdoctoral associates (FTEs)	330	330	315	330	+15
Number of graduate students (FTEs)	495	495	480	495	+15
Other[a]	950	950	950	950	0

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

14-SC-50, Facility for Rare Isotope Beams (FRIB)
Michigan State University (MSU), East Lansing, MI
Project is for a Cooperative Agreement

1. Significant Changes and Summary

Significant Changes

This project data sheet (PDS) does not include a new start for the budget year; it is an update of the FY 2015 PDS.

Summary

The most recent approved Critical Decision (CD) for the Facility for Rare Isotope Beams (FRIB) project is CD-3B (Approve Start of Construction of the Accelerator and Experimental Systems) which was approved on August 26, 2014, with a DOE Total Project Cost (TPC) of $635,500,000 and CD-4 by 3Q FY 2022. In addition, Michigan State University (MSU) is providing a cost share of $94,500,000, bringing the total project cost to $730,000,000. Following enactment of the FY 2014 appropriation, the Acquisition Executive authorized the start of civil construction in January 2014 and an official groundbreaking ceremony was held on March 17, 2014. There are no changes in the scope, cost, and schedule since the establishment of the project's baseline.

FRIB is funded through a cooperative agreement financial assistance award with MSU per 10 CFR 600, and the project is required by this agreement to follow the principles of the DOE Order 413.3B. Funding tables contained in sections 3, 5, and 6 of this PDS differ slightly in how the baseline is presented from a traditional PDS for a federal capital asset construction project in that they include the MSU cost share. The table in section 7, Schedule of Appropriation Requests, displays only DOE funding.

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

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3A	CD-3B	D&D Complete	CD-4
FY 2011	2/9/2004		4Q FY 2010	TBD	TBD	TBD	TBD	N/A	FY 2017–2019
FY 2012	2/9/2004		9/1/2010	4Q FY 2012	TBD	TBD	TBD	N/A	FY 2018–2020
FY 2013	2/9/2004		9/1/2010	TBD	TBD	TBD	TBD	N/A	TBD
FY 2014	2/9/2004		9/1/2010	3Q FY 2013	TBD	3Q FY 2013	TBD	N/A	TBD
FY 2015	2/9/2004		9/1/2010	8/1/2013	4Q FY 2014	8/1/2013	4Q FY 2014	N/A	3Q FY 2022
FY 2016	2/9/2004	9/1/2010	9/1/2010	8/1/2013	8/26/2014[a]	8/1/2013	8/26/2014	N/A	3Q FY 2022

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3A – Approve Start of Civil Construction
CD-3B – Approve Start of Technical Construction

[a] This date represents when the design will be substantially complete to allow the start of technical construction (CD-3B). A limited amount of design effort will continue through 4Q FY 2017.

CD-4 – Approve Start of Operations or Project Closeout
D&D Complete – Completion Demolition & Decontamination

3. Project Cost History[a]

(dollars in thousands)

	Design/ Construction	R&D/Conceptual Design/NEPA	Pre-Operations	Total TPC	Less MSU Cost Share	DOE TPC
FY 2015	655,700	24,600	49,700	730,000	-94,500	635,500
FY 2016	655,700	24,600	49,700	730,000	-94,500	635,500

4. Project Scope and Justification

Scope

FRIB scope includes the design, construction, fabrication, assembly, testing, and commissioning of the civil and technical scope that will enable high intensity primary beams of stable isotopes to be accelerated up to a minimum energy of 200 MeV per nucleon by a superconducting linear accelerator (linac) capable of delivering 400 kW of beam power at full energy. The scope also includes the capability for secondary beams of rare isotopes to be produced "in-flight" and separated from unwanted fragments by magnetic analysis. In support of these capabilities, the civil construction portion includes a structure of approximately 220,000 square feet that will house the linac tunnel, target high bay area, linac support area, and cryoplant area. The technical scope includes a 2K/4.5K cryogenics plant, linac front end, cryomodules, and experimental systems.

CD-4 Key Performance Parameters

System	Parameter	Performance Criteria
Accelerator System	Accelerate heavy-ion beam	Measure FRIB driver linac Argon-36 beam with energy larger than 200 MeV per nucleon and a beam current larger than 20 pico nano amps (pnA).
Experimental Systems	Produce a fast rare isotope beam of Selenium-84	Detect and identify Selenium-84 isotopes in FRIB fragment separator focal plane
	Stop a fast rare isotope beam in gas and reaccelerate a rare isotope beam	Measure reaccelerated rare isotope beam energy larger than 3 MeV per nucleon
Conventional Facilities	Linac tunnel	Beneficial occupancy of subterranean tunnel structure of approximately 500 feet path length (minimum) to house FRIB driver linear accelerator
	Cryogenic helium liquefier plant—building and equipment	Beneficial occupancy of the cryogenic helium liquefier plant building and installation of the helium liquefier plant complete
	Target area	Beneficial occupancy of target area and one beam line installed and ready for commissioning

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[a] Because this project is funded with operating dollars through a financial assistance award, its baseline is categorized through a work breakdown structure (WBS), which is slightly different from typical federal capital assets. Note that the project's WBS totals $730,000,000 including MSU's cost share. The WBS scope is not pre-assigned to DOE or MSU funds.

As contractually required under the financial assistance award agreement, FRIB is being conducted in accordance with the project management principles in DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets, and all appropriate project management requirements have been met.

Justification

The science which underlies the FRIB mission is a core competency of nuclear physics: understanding how protons and neutrons combine to form various nuclear species; understanding how long chains of different nuclear species survive; and understanding how one nuclear species decays into another and what is emitted when that happens. Forefront knowledge and capability in this competency is essential, both for U.S. leadership in this scientific discipline and to provide the knowledge and workforce needed for numerous activities and applications relevant to national security and economic competitiveness.

FRIB will provide intense beams of rare isotopes for a wide variety of studies in nuclear structure, nuclear astrophysics, and other topics in nuclear physics. This facility will enable the study of the origin of the elements and the evolution of the cosmos, and offers an opportunity for exploring the limits of nuclear existence and identifying new phenomena, with the possibility that a more broadly applicable theory of nuclei will emerge. The facility will offer new glimpses into the origin of the elements, leading to a better understanding of key issues by creating exotic nuclei that, until now, have existed only in nature's most spectacular explosion, the supernova.

FRIB is optimized to produce large quantities of a wide variety of rare isotopes by breaking stable nuclei into rare isotopes. High intensity primary beams of stable isotopes are produced in Electron Cyclotron Resonator (ECR) ion sources and accelerated up to a minimum energy of 200 MeV per nucleon by a superconducting linear accelerator capable of delivering 400 kW of beam power at full energy. Secondary beams of rare isotopes are produced "in-flight" and separated from unwanted fragments by magnetic analysis. These rare isotope beams are delivered to experimental areas or stopped in a suite of ion-stopping stations where they can be extracted and used for experiments at low energy, or reaccelerated for astrophysical experiments or for nuclear structure experiments. The project includes the necessary infrastructure and support facilities for operations and the 1,000-person user community.

5. Financial Schedule[a]

(dollars in thousands)

	Appropriations	Obligations	Costs
DOE Total Project Cost (TPC)			
FY 2009	7,000	7,000	1,874
FY 2010	12,000	12,000	13,838
FY 2011	10,000	10,000	13,288
FY 2012	22,000	22,000	19,506
FY 2013	22,000	22,000	22,260
FY 2014[b]	55,000	55,000	48,369
FY 2015	90,000	90,000	88,000
FY 2016	100,000	100,000	100,000
FY 2017	100,000	100,000	105,000
FY 2018	97,200	97,200	100,200

[a] The funding profile represents DOE's portion of the baselined TPC to be provided through federal appropriations.

[b] The first project data sheet submitted for FRIB was in the FY 2015 Congressional Budget Request. It was established as a control point in the FY 2014 appropriation. Funding for the project in FY 2013 and prior years was provided within the Low Energy subprogram.

(dollars in thousands)

	Appropriations	Obligations	Costs
FY 2019	75,000	75,000	76,000
FY 2020	40,000	40,000	41,000
FY 2021	5,300	5,300	4,300
FY 2022	0	0	1,865
Total, DOE TPC	635,500	635,500	635,500

6. Details of Project Cost Estimate[a]

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Baseline
Design & Construction			
Management and Support	41,340	35,400	35,400
Conventional Facilities	165,720	165,300	165,300
Accelerator Systems	244,837	241,400	241,400
Experimental Systems	54,916	55,000	55,000
Contingency (DOE Held)	148,937	158,650	158,650
Total, Design & Construction	655,750	655,750	655,750
Other Costs			
Conceptual Design/Tech R&D/NEPA	24,640	24,600	24,600
Pre-ops/Commissioning/Spares	34,995	35,500	35,500
Contingency (DOE Held)	14,615	14,150	14,150
Total, Other Costs	74,250	74,250	74,250
Total, TPC	730,000	730,000	730,000
Less MSU Cost Share	-94,500	-94,500	-94,500
Total, DOE TPC	635,500	635,500	635,500
Total, Contingency (DOE Held)	163,552	172,800	172,800

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[a] This section shows a breakdown of the total project cost of $730,000,000, which includes MSU's cost share. The scope of work is not pre-assigned to DOE or MSU funds.

7. Schedule of Appropriation Requests[a]

(dollars in thousands)

		Prior Years	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	Outyears	Total
FY 2011	TPC	29,000	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
FY 2012	TPC	59,000	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
FY 2013	TPC	51,000	22,000	TBD	TBD	TBD	TBD	TBD	TBD	TBD
FY 2014	TPC	51,000	22,000	55,000	TBD	TBD	TBD	TBD	TBD	TBD
FY 2015 PB[b]	TPC	51,000	22,000	55,000	90,000	100,000	100,000	97,200	120,300	635,500
FY 2016	TPC	51,000	22,000	55,000	90,000	100,000	100,000	97,200	120,300	635,500

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy	3Q FY 2022
Expected Useful Life (number of years)	20
Expected Future Start of D&D of this capital asset	NA[c]

(Related Funding requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations[d]	90,000	N/A	1,800,000[e]	N/A

9. D&D Information

The FRIB project is being constructed at MSU under a cooperative agreement financial assistance award. The one-for-one requirement, which requires the demolition of a square foot of space for every square foot added, is not applicable, since this is not a federal capital acquisition.

10. Acquisition Approach

FRIB project activities will be accomplished following all procurement requirements, which include using fixed-priced competitive contracts with selection based on best value. MSU has contracted for the services of an architect-engineer firm for the design of the conventional facilities. The Driver Linac and Experimental System components will be self-performed by the MSU design staff with assistance from outside vendors and from DOE national laboratories that possess specific areas of unique expertise unavailable from commercial sources. Integration of the conventional facilities with the Driver Linac and Experimental Systems will be accomplished by the MSU FRIB Project Team.

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[a] The funding profile represents DOE's portion of the baselined TPC to be provided through federal appropriations.

[b] The Performance Baseline was approved August 1, 2013. The first project data sheet submitted for FRIB was in the FY 2015 Congressional Budget Request. It was established as a control point in the FY 2014 appropriation. Funding for the project prior to that time was provided within the Low Energy subprogram.

[c] Per the financial assistance award agreement, MSU is responsible for D&D.

[d] Utilities, maintenance, and repair costs are included within the Operations amounts.

[e] The total operations and maintenance (O&M) is estimated at an average annual cost of approximately $90,000,000 (including escalation) over 20 years.

06-SC-01, 12 GeV CEBAF Upgrade
Thomas Jefferson National Accelerator Facility, Newport News, Virginia
Project is for Design and Construction

1. Significant Changes and Summary

Significant Changes

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

Summary

The most recent DOE O 413.3B approved Critical Decision (CD) is CD-4A, Approve Accelerator Project Completion and Start of Operations, which was signed on July 30, 2014 following completion and confirmation of the project achieving the CD-4A Key Performance Parameters.

The FY 2016 TEC funding will allow the completion of the planned procurements, assemblies, and installations of the experimental equipment (i.e., detectors) primarily in Halls B and C, prior to their commissioning. In addition, a recent DOE/SC Office of Project Assessment review recognized that this final year of TEC funds will be required to address the continuing high project risks in order to successfully complete this project within the current TEC baseline.

In 2014, the Federal Project Director (FPD) certification level required for the 12 GeV was lowered to Level 2. Therefore, the FPD is certified at the appropriate level for this project.

2. Critical Milestone History

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4A	CD-4B
FY 2007	3/31/2004		1Q FY 2007	4Q FY 2007	4Q FY 2009	4Q FY 2008	N/A	N/A	1Q FY 2014
FY 2008	3/31/2004		2/14/2006[a]	4Q FY 2007	4Q FY 2009	4Q FY 2008	N/A	N/A	1Q FY 2015
FY 2009	3/31/2004		2/14/2006	11/9/2007	4Q FY 2009	4Q FY 2008	N/A	N/A	3Q FY 2015
FY 2010	3/31/2004		2/14/2006	11/9/2007	4Q FY 2009	9/15/2008	N/A	1Q FY 2015	3Q FY 2015
FY 2011	3/31/2004		2/14/2006	11/9/2007	1Q FY 2010	9/15/2008	N/A	1Q FY 2015	3Q FY 2015
FY 2012	3/31/2004		2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	1Q FY 2015	3Q FY 2015
FY 2013	3/31/2004		2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	1Q FY 2015	3Q FY 2015

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[a] CD-1 was approved on 2/14/2006. Engineering and design activities started in 4Q FY 2006 after Congress approved the Department of Energy’s request to reprogram $500,000 within the FY 2006 funding for Nuclear Physics, per direction contained in H.Rpt. 109–275.

(fiscal quarter or date)

	CD-0	Conceptual Design Complete	CD-1	CD-2	Final Design Complete	CD-3	D&D Complete	CD-4A	CD-4B
FY 2014	3/31/2004		2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	1Q FY 2015	3Q FY 2015
FY 2015	3/31/2004		2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	1Q FY 2015	4Q FY 2017
FY 2016	3/31/2004	2/14/2006	2/14/2006	11/9/2007	12/31/2009	9/15/2008	N/A	7/30/2014	4Q FY 2017

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of Construction
CD-4A – Approve Accelerator Project Completion and Start of Operations
CD-4B – Approve Experimental Equipment Project Completion and Start of Operations
D&D– Demolition & Decontamination

3. Project Cost History

(dollars in thousands)

	TEC, Design	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2007	21,000	TBD	TBD	11,000	TBD	TBD	TBD
FY 2008	21,000	TBD	TBD	10,500	TBD	TBD	TBD
FY 2009 PB	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2010	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2011	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2012	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2013	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2014	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2015[a]	21,000	289,500	310,500	27,500	N/A	27,500	338,000
FY 2016	21,000	289,500	310,500	27,500	N/A	27,500	338,000

4. Project Scope and Justification

Scope

The 12 GeV CEBAF Upgrade directly supports the Nuclear Physics mission and addresses the objective to measure properties of the proton, neutron, and simple nuclei for comparison with theoretical calculations to provide an improved quantitative understanding of their quark substructure.

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[a] The amounts reflect the revised baseline approved in September 2013. A Work-for-Others agreement was approved by DOE that provides $9,000,000 appropriated by the Commonwealth of Virginia to leverage the federal investment for an upgrade of the Jefferson Lab's research facilities. This funding is outside the DOE baseline cost and schedule.

The scope of the project includes upgrading the electron energy capability of the main accelerator from 6 GeV to 12 GeV, building a new experimental hall (Hall D: 11,110 sf) and associated counting house (3,601 sf) and beam-line, and enhancing the capabilities of the existing experimental halls to support the most compelling nuclear physics research.

CD-4A Key Performance Parameters

Subsystem	Technical Definition of Completion
Accelerator	12 GeV capable 5.5 pass machine installed
	11 GeV capable beam line to existing Halls A, B, and C installed
	12 GeV capable beam line to new Hall D tagger area installed
	Accelerator commissioned by transporting a ≥ 2 nA electron beam at 2.2 GeV (1pass)
Conventional Facilities	New Experimental Hall D and the Counting House: ≥ 10,500 square feet.

CD-4B Key Performance Parameters

Subsystem	Technical Definition of Completion
Hall B	Detector operational: events recorded with a ≥ 2 nA electron beam at > 6 GeV beam energy (3 pass)
Hall C	Detector operational: events recorded with a ≥ 2 nA electron beam at > 6 GeV beam energy (3 pass)
Hall D	Detector operational: events recorded with a ≥ 2 nA electron beam at > 10 GeV beam energy (5.5 pass)

Key Performance Parameters to achieve CD-4 are phased between the accelerator and conventional facilities (CD-4A) and the experimental equipment in Halls B, C, and D (CD-4B). The deliverables defining completion are identified in the Project Execution Plan and have not changed since CD-2. Mitigation plans exist for identified risks to help ensure successful project completion after approval of a baseline change proposal due to the directed change and technical challenges.

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

Justification

The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility is the world-leading facility for the experimental study of the structure of matter governed by the "strong force." The energy upgrade of CEBAF, first identified by the nuclear science community as a compelling scientific opportunity in the 2007 Long Range Plan for Nuclear Science, was reaffirmed as a high priority in the 2013 Report by the Nuclear Sciences Advisory Committee (NSAC) on Major Nuclear Physics Facilities for the next decade, which stated that the 12 GeV upgrade of CEBAF was "absolutely central" in terms of its ability to contribute to world-leading science in the next decade. In the 2007 Long Range Plan, NSAC concluded that completion of the 12 GeV CEBAF Upgrade project was the highest priority for the Nation's nuclear science program.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Cost (TEC)				
Design				

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
FY 2006	500	500	0	88
FY 2007	7,000	7,000	0	6,162
FY 2008	13,377[a]	13,377	0	9,108
FY 2009	123[a]	123	0	5,370
FY 2010	0	0	0	265
FY 2011	0	0	0	7
Total, Design	21,000	21,000	0	21,000
Construction				
FY 2009	28,500	28,500	0	5,249
FY 2009 Recovery Act	65,000	65,000	2,738	0
FY 2010	20,000	20,000	29,621	18,642
FY 2011[b]	35,928	35,928	25,890	40,801
FY 2012	50,000	50,000	5,203	45,537
FY 2013	40,572	40,572	1,545	51,211
FY 2014	25,500	25,500	3	29,755
FY 2015	16,500	16,500	0	21,000
FY 2016	7,500	7,500	0	11,500
FY 2017	0	0	0	805
Total, Construction	289,500	289,500	65,000	224,500
TEC				
FY 2006	500	500	0	88
FY 2007	7,000	7,000	0	6,162
FY 2008	13,377	13,377	0	9,108
FY 2009	28,623	28,623	0	10,619
FY 2009 Recovery Act	65,000	65,000	2,738	0
FY 2010	20,000	20,000	29,621	18,907
FY 2011	35,928	35,928	25,890	40,808
FY 2012	50,000	50,000	5,203	45,537
FY 2013	40,572	40,572	1,545	51,211
FY 2014	25,500	25,500	3	29,755
FY 2015	16,500	16,500	0	21,000
FY 2016	7,500	7,500	0	11,500
FY 2017	0	0	0	805
Total, TEC	310,500	310,500	65,000	245,500

[a] The baseline FY 2008 PED funding was reduced by $123,000 as a result of a FY 2008 rescission. This reduction was restored in FY 2009 to maintain the TEC and project scope.

[b] The baseline FY 2011 funding was reduced by $72,000 as a result of a FY 2011 rescission.

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Other Project Cost (OPC)				
OPC except D&D				
FY 2004	700	700	0	77
FY 2005	2,300	2,300	0	2,142
FY 2006	4,000	4,000	0	3,508
FY 2007	2,500	2,500	0	2,751
FY 2008	1,000	1,000	0	1,802
FY 2009	0	0	0	155
FY 2010	0	0	0	62
FY 2013	2,500	2,500	0	2,178
FY 2014	4,500	4,500	0	3,795
FY 2015	4,500	4,500	0	4,500
FY 2016	4,500	4,500	0	5,000
FY 2017	1,000	1,000	0	1,530
Total, OPC	27,500	27,500	0	27,500
Total Project Cost				
FY 2004	700	700	0	77
FY 2005	2,300	2,300	0	2,142
FY 2006	4,500	4,500	0	3,596
FY 2007	9,500	9,500	0	8,913
FY 2008	14,377	14,377	0	10,910
FY 2009	28,623	28,623	0	10,774
FY 2009 Recovery Act	65,000	65,000	2,738	0
FY 2010	20,000	20,000	29,621	18,969
FY 2011	35,928	35,928	25,890	40,808
FY 2012	50,000	50,000	5,203	45,537
FY 2013	43,072	43,072	1,545	53,389
FY 2014	30,000	30,000	3	33,550
FY 2015	21,000	21,000	0	25,500
FY 2016	12,000	12,000	0	16,500
FY 2017	1,000	1,000	0	2,335
Total, TPC[a]	338,000	338,000	65,000	273,000

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[a] The TPC reflects the revised baseline approved in September 2013.

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Estimate
Total Estimated Cost (TEC)			
Design			
Design	21,000	21,000	19,200
Contingency	0	0	1,800
Total, Design	21,000	21,000	21,000
Construction Phase			
Construction	30,295	30,347	27,450
Accelerator/Experimental Equipment/ Management	250,793	243,937	174,150
Contingency	8,412	15,216	64,900
Total, Construction	289,500	289,500	266,500
Total, TEC	310,500	310,500	287,500
Contingency, TEC	8,412	15,216	66,700
Other Project Cost (OPC)			
OPC except D&D			
Conceptual Design	3,445	3,445	3,500
R&D	7,052	7,052	6,400
Start-up	11,966	12,618	7,450
Contingency	5,037	4,385	5,150
Total, OPC	27,500	27,500	22,500
Contingency, OPC	5,037	4,385	5,150
Total, TPC	338,000	338,000[a]	310,000
Total, Contingency	13,449	19,601	71,850

7. Schedule of Appropriation Requests

(dollars in thousands)

		Prior Years	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	Total
FY 2007 (Design only)	TEC	21,000	0	0	0	0	0	0	0	0	21,000
	OPC	11,000	0	0	0	0	0	0	0	0	11,000
	TPC	32,000	0	0	0	0	0	0	0	0	32,000
FY 2008 (Design only)	TEC	21,000	0	0	0	0	0	0	0	0	21,000
	OPC	10,500	0	0	0	0	0	0	0	0	10,500
	TPC	31,500	0	0	0	0	0	0	0	0	31,500

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[a] The TPC reflects the revised baseline approved in September 2013.

(dollars in thousands)

		Prior Years	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	Total
FY 2009[a] PB	TEC	49,500	59,000	62,000	66,000	40,500	10,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	60,000	59,000	62,000	66,000	43,000	18,000	2,000	0	0	310,000
FY 2010[b]	TEC	114,500	22,000	34,000	66,000	40,500	10,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	125,000	22,000	34,000	66,000	43,000	18,000	2,000	0	0	310,000
FY 2011	TEC	114,500	20,000	36,000	66,000	40,500	10,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	125,000	20,000	36,000	66,000	43,000	18,000	2,000	0	0	310,000
FY 2012	TEC	114,500	20,000	36,000	66,000	40,500	10,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	125,000	20,000	36,000	66,000	43,000	18,000	2,000	0	0	310,000
FY 2013	TEC	114,500	20,000	35,928[c]	50,000	40,572	26,500	0	0	0	287,500
	OPC	10,500	0	0	0	2,500	7,500	2,000	0	0	22,500
	TPC	125,000	20,000	35,928	50,000	43,072	34,000	2,000	0	0	310,000
FY 2014	TEC	114,500	20,000	35,928	50,000	50,306	25,500	1,000	0	0	287,500
	OPC	10,500	0	0	0	0	4,500	5,000	0	0	22,500
	TPC[d]	125,000	20,000	35,928	50,000	50,306[e]	30,000	6,000	0	0	310,000
FY 2015	TEC	114,500	20,000	35,928	50,000	40,572	25,500	16,500	7,500	0	310,500
	OPC	10,500	0	0	0	2,500	4,500	4,500	4,500	1,000	27,500
	TPC[f]	125,000	20,000	35,928	50,000	43,072	30,000	21,000	12,000	1,000	338,000
FY 2016	TEC	114,500	20,000	35,928	50,000	40,572	25,500	16,500	7,500	0	310,500
	OPC	10,500	0	0	0	2,500	4,500	4,500	4,500	1,000	27,500
	TPC	125,000	20,000	35,928	50,000	43,072	30,000	21,000	12,000	1,000	338,000

[a] The FY 2009 Congressional Budget was the first project data sheet to reflect the CD-2 Performance Baseline which was approved in November 2007.

[b] The project received $65,000,000 from the American Recovery and Reinvestment Act of 2009 which advanced a portion of the baselined FY 2010 and FY 2011 planned funding. The FY 2010 and FY 2011 amounts reflect a total of $65,000,000 in reductions to the originally planned baselined funding profile to account for the advanced Recovery Act funding.

[c] The baseline FY 2011 funding was reduced by $72,000 as a result of the FY 2011 rescission.

[d] The TPC did not reflect the estimated impact resulting from the reduced FY 2012 funding, which has since been assessed and a rebaseline was approved in September 2013.

[e] The FY 2013 amount shown reflected the P.L. 112-175 continuing resolution level annualized to a full year. The TEC, TPC, and outyear appropriation assumptions had not been adjusted to reflect the final FY 2013 funding level; the FY 2013 Request level of $40,572,000 for TEC, $2,500,000 for OPC, and $43,072,000 for TPC was assumed.

[f] The TPC reflects the revised baseline approved in September 2013.

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	4Q FY 2017
Expected Useful Life (number of years)	15
Expected Future start of D&D for new construction (fiscal quarter)	N/A

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life cycle costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Operations	150,000	150,000	2,250,000[a]	2,250,000
Maintenance	Included above	Included above	Included above	Included above
Total, Operations & Maintenance	150,000	150,000	2,250,000	2,250,000

9. D&D Information

The new area being constructed in this project is not replacing existing facilities. The "one-for-one" requirement is met by offsetting 31,500 square feet of the 80,000 square feet of banked space that was granted to Jefferson Laboratory in a Secretarial waiver.

	Square Feet
Area of new construction	31,500
Area of existing facility(ies) being replaced and D&D'd by this project..............	0
Area of other D&D outside the project	0
Area of additional D&D space to meet the "one-for-one" requirement taken from the banked area.	31,500

10. Acquisition Approach

The Acquisition Strategy was approved February 14, 2006, with CD-1 approval. All acquisitions are managed by Jefferson Science Associates with appropriate Department of Energy oversight. Cost, schedule, and technical performance are monitored using an earned-value process that is described in the Jefferson Lab Project Control System Manual and consistent with DOE O 413.3B, Program and Project Management for the Acquisition of Capital Assets. The procurement practice uses firm fixed-price purchase orders and subcontracts for supplies, equipment, and services and makes awards through competitive solicitations. Project and design management, inspection, coordination, tie-ins, testing and checkout witnessing, and acceptance are performed by Jefferson Laboratory and Architectural-Engineering subcontractors as appropriate.

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[a] The total operations and maintenance (O&M) is estimated at an average annual cost of approximately $150,000,000 (including escalation) over 15 years. Almost 90% of the O&M cost would still have been required had the existing accelerator not been upgraded and instead continued operations at 6 GeV.