Nuclear Physics

Funding Profile by Subprogram

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Nuclear Physics		
Medium Energy Nuclear Physics	122,113	130,380
Heavy Ion Nuclear Physics	205,063	219,984
Low Energy Nuclear Physics[a]	116,216	126,536
Nuclear Theory	39,952	42,166
Isotope Development and Production for Research and Applications	19,116	20,234
Subtotal, Nuclear Physics	502,460	539,300
Construction	20,000	66,000
Total, Nuclear Physics	522,460[b]	605,300

Public Law Authorizations:

Public Law 95–91, “Department of Energy Organization Act”, 1977
Public Law 101–101, “1989 Energy and Water Development Appropriations Act,” establishing the Isotope Production and Distribution Program Fund)
Public Law 103–316, “1995 Energy and Water Development Appropriations Act,” amending the Isotope Production and Distribution Program Fund to provide flexibility in pricing without regard to full-cost recovery
Public Law 109–58, “Energy Policy Act of 2005”
Public Law 110–69, “America COMPETES Act of 2007”
Public Law 111–358, “America COMPETES Act of 2010”

Program Overview

Mission

The mission of the Nuclear Physics (NP) program is to discover, explore, and understand all forms of nuclear matter. The fundamental particles that compose nuclear matter—quarks and gluons—are relatively well understood, but exactly how they fit together and interact to create different types of matter in the universe is still largely not understood. To solve this mystery, NP supports experimental and theoretical research—along with the development and operation of particle accelerators and advanced technologies—to create, detect, and describe the different forms and complexities of nuclear matter that can exist, including those that are no longer commonly found in our universe.

Background

It is one of the enduring mysteries of the universe: What, really, is matter? What are the units that matter is made of, and how do they fit together to give matter the properties we observe? These are questions which philosophers have wrestled with for millennia. Over two thousand years ago, the Greek

[a] Funding for the establishment of the Facility for Rare Isotope Beams is included within the Low Energy Nuclear Physics subprogram.
[b] Total is reduced by $12,540,000: $11,197,000 of which was transferred to the Small Business Innovation Research (SBIR) program and $1,343,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

philosopher Democritus suggested that if one were to divide matter into smaller and smaller pieces, one would eventually be left with indivisible entities called atoma. It was not until the 1800s, however, that scientists had solid evidence that such atoma—or atoms—actually existed, and it was not until the early 1900s that techniques were developed that made it possible to examine their composition.

In 1909 the physicist Ernest Rutherford fired a beam of helium ions at a thin sheet of gold foil and measured how the ions scattered, showing that each atom has at its center, a small, dense, positively charged core, which Rutherford named the nucleus. Scientists later determined that the nucleus is surrounded by a cloud of tiny negatively charged electrons that account for less than 0.1% of the total mass of the atom. Upon closer inspection, researchers found that the nucleus was composed of even smaller particles: the positively charged proton and the electrically neutral neutron. Research showed that protons and neutrons—or nucleons—are bound in the nucleus by a fundamental force named the strong force because it is far stronger than either gravity or electromagnetism, although it operates on smaller distance scales. As scientists delved further into the properties of the proton and neutron, they discovered that each proton and neutron is composed of three tiny particles called quarks. Quarks are bound together by yet other particles called gluons, which are believed to be the generators of the strong force. One of the major goals of nuclear physics is to understand precisely how quarks and gluons bind together to create protons, neutrons, and other hadrons (the generic name for particles composed of quarks) and, in turn, to determine how all hadrons fit together to create nuclei and other types of matter.

The quest to understand matter takes place through theory and experiment, with both being necessary to develop a full understanding of the properties and behavior of matter. In the theoretical approach, scientists have developed a precise mathematical description of how the quarks and gluons in nuclear matter interact, referred to as Quantum Chromodynamics (QCD). On the experimental side, scientists accumulate a great deal of experimental data about the behavior of quarks and gluons as well as protons, neutrons, and nuclei in a variety of settings. Unlike Rutherford's table-top experiment, most of the experiments today require large facilities spanning acres. These particle accelerators slam bits of matter into each other, and scientists observe the results. The main differences from Rutherford's time are the ability to accelerate the bits of matter to much higher speeds, the variety of types of matter that can be used, and the sophistication of the instruments used in the observations. The careful integration and comparison of experimental measurements with theoretical calculations provides both insight into the behavior of matter and the information needed to test the validity of theoretical models.

Nuclear physics seeks to understand matter in all of its manifestations—not just the familiar forms of matter we see around us, but also such exotic forms as the matter that existed in the first moments after the creation of the universe and the matter that exists today inside neutron stars—and to understand why matter takes on the particular forms that it does. Nuclear physics has come to focus on three broad yet tightly interrelated areas of inquiry. These three areas are described in *The Frontiers of Nuclear Science*[a], a long range plan for nuclear science released in 2007 by the Nuclear Science Advisory Committee (NSAC). The plan represents a consensus within the nuclear science community about compelling scientific thrusts. The three frontiers the long range plan identified are:

- **Quantum Chromodynamics:** The focus of this frontier is to develop a complete understanding of how quarks and gluons assemble themselves into the various forms of matter and, as part of that process, to search for yet undiscovered forms of matter. While nuclear scientists want to know how quarks and gluons assemble to form matter, they also want to understand what happens when nucleons "melt." QCD predicts that nuclear matter can change its state in somewhat the same way that ordinary matter can change from solid to liquid to gas. This can happen when nucleons are

[a] http://www.sc.doe.gov/np/nsac/nsac.html

compressed well beyond the density of atomic nuclei, as in the core of a neutron star, or when they are heated to the kind of extreme temperatures found in the early universe. One of the most startling recent discoveries is the creation of a new form of matter, thought to have existed only moments after the birth of the universe under conditions of extreme temperature and density, and the fact that it behaves as an almost perfect liquid instead of a dilute gaseous plasma as originally hypothesized.

- **Nuclei and Nuclear Astrophysics:** Nuclear physicists seek to understand how protons and neutrons combine to form atomic nuclei and how these nuclei have arisen during the 13.7 billion years since the birth of the cosmos. The forces that bind protons and neutrons together into nuclei are immensely strong, with the result being that nuclear processes such as nuclear fusion and fission can release huge amounts of energy. Looking inward, nuclear scientists seek a comprehensive description of the behavioral characteristics of multi-nucleon systems and marginally stable exotic nuclei not naturally found on earth. Looking outward, nuclear scientists seek to understand the nuclear processes that have shaped the cosmos, from the origin of the elements, the evolution of stars, and the detonation of supernovae, to the structure of neutron stars and the nature of matter at extreme densities. Nuclear scientists have made great strides in nuclear astrophysics, for example by decreasing the limits of the age of the universe by about one billion years through studies of the reaction cross sections that control hydrogen burning in stars.
- **Fundamental Symmetries and Neutrinos:** Although the strong force plays the dominant role in the nucleus, it is not the only force that nuclear physicists must consider. Because protons (and quarks) are electrically charged, electromagnetism comes into play in such circumstances as proton-proton interactions, and the weak force is responsible for the transformation of protons into neutrons and vice versa. The three forces have been unified by a single theory, referred to as the Standard Model, which does an excellent job of explaining the interactions of the various fundamental particles. However, certain inadequacies of that theory have led physicists to begin developing a New Standard Model. In particular, nuclear physicists are interested in developing a better understanding of the fundamental properties of the neutron and of the neutrino, the nearly undetectable fundamental particle produced by the weak interaction that was first indirectly detected in nuclear beta decay. One of the most surprising results to come out of neutrino studies in the past decade was the discovery that electron neutrinos produced in the Sun are changing into a different type of neutrino, thus explaining the puzzling shortage of events seen in previous solar neutrino detectors. These results confirm models for solar energy production and indicate that these elusive messengers from the cosmos do indeed have mass.

In addition to the three frontiers identified in the long range plan, NP also has responsibility for **Isotope Development and Production for Research and Applications**. For over 50 years, this program and its predecessors have been at the forefront of the development and production of stable and radioactive isotope products that are now used world-wide. DOE applies its unique expertise and capabilities to address technology issues associated with the application, production, handling, and distribution of isotopes. Adequate supplies of medical and research isotopes are essential to maintain effective diagnosis, treatment, and research capabilities in the U.S. The program's products and services are sold to over 20 countries. The program produces isotopes only where there is no U.S. private sector capability or other production capacity is insufficient to meet U.S. needs.

Subprograms

To accomplish its mission and address the scientific challenges described above, NP is organized into five subprograms: Medium Energy Nuclear Physics, Heavy Ion Nuclear Physics, Low Energy Nuclear Physics, Nuclear Theory, and Isotope Development and Production for Research and Applications.

- The *Medium Energy* subprogram primarily explores the frontier of QCD with research conducted at two NP national user facilities and other facilities worldwide. The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) provides high quality beams of polarized electrons that allow scientists to extract information on the quark and gluon structure of protons and neutrons. CEBAF also uses polarized electrons to make precision measurements of parity violating processes that can provide information relevant to the development of the New Standard Model. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) provides colliding beams of spin-polarized protons to probe the spin structure of the proton, another important aspect of the QCD frontier. This subprogram supports one of the Nuclear Physics program's university Centers of Excellence at the Massachusetts Institute of Technology that has infrastructure capabilities to develop advanced instrumentation and accelerator equipment.
- The *Heavy Ion* subprogram also investigates the frontier of QCD, but with a different approach—by trying to recreate and characterize new and predicted forms of matter and other new phenomena that might occur in extremely hot, dense nuclear matter and which have not existed since the Big Bang. Measurements are carried out primarily using relativistic heavy ion collisions at RHIC. Participation in the heavy ion program at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) provides U.S. researchers the opportunity to search for new states of matter under substantially different initial conditions than those provided by RHIC, yet still provide information regarding the matter that existed during the infant universe. New results announced on the properties of the perfect liquid of quarks and gluons discovered at RHIC garnered worldwide attention in scientific and popular literature in April 2010.
- The *Low Energy* subprogram studies two nuclear science frontiers—Nuclear Structure and Astrophysics and Fundamental Symmetries and Neutrinos. Two NP national user facilities have been pivotal in making progress in these frontiers. The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) is used to study questions of nuclear structure by providing high-quality beams of all the stable elements up to uranium and selected beams of short-lived nuclei for experimental studies of nuclear properties under extreme conditions and reactions of interest to nuclear astrophysics. The Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) has provided beams of short-lived radioactive nuclei that scientists use to study exotic nuclei that do not normally exist in nature. HRIBF has also been used to explore reactions of interest to nuclear astrophysics. The future Facility for Rare Isotope Beams (FRIB) at Michigan State University (MSU) is a next-generation machine that will advance the understanding of rare nuclear isotopes and the evolution of the cosmos by providing beams of rare isotopes with neutron and proton abundances far from those of stable nuclei in order to test the limits of nuclear existence and models of stellar evolution. The subprogram also supports three university Centers of Excellence, two with unique low energy accelerator facilities and one with infrastructure capabilities for developing advanced instrumentation. These university Centers of Excellence provide outstanding hands-on science, technology, and engineering educational opportunities for students at various stages in their career. In addition, the program partners with the National Reconnaissance Office and the United States Air Force to support limited operations of the 88-Inch Cyclotron at the Lawrence Berkeley National Laboratory (LBNL) for a small in-house research program and to meet national security needs.

  Finally, within the portfolio of this subprogram there are experiments designed to develop a better understanding of the properties of neutrons and neutrinos and, in particular, of the neutrino mass. Neutrino science is typically explored with large detectors sited underground to shield them from cosmic background radiation so that they can detect rare particle signals. Measurements of symmetry properties of the neutron are carried out by nuclear physicists at the Spallation Neutron Source at ORNL.

- The *Nuclear Theory* subprogram provides the theoretical underpinning needed to support the interpretation of a wide range of data obtained from all the other nuclear science subprograms and to advance new ideas and hypotheses that stimulate experimental investigations. This subprogram supports one of the program's university Centers of Excellence, the Institute for Nuclear Theory (INT) at the University of Washington, where leading nuclear theorists are assembled from across the Nation to focus on key frontier challenges in nuclear physics. Five-year topical collaborations were established in FY 2010 to address high-priority topics in nuclear theory that require concerted effort to advance the field. The subprogram also collects, evaluates, and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies with its support of the National Nuclear Data Center (NNDC). The extensive nuclear databases produced by this effort are an international resource consisting of carefully organized scientific information gathered from over 100 years of low-energy nuclear physics research worldwide.
- The *Isotope Development and Production for Research and Applications* subprogram supports the production, distribution, and development of production techniques of radioactive and stable isotopes that are in short supply and critical to the Nation. Isotopes are commodities of strategic importance for the Nation that are essential for energy exploration and innovation, medical applications, national security, and basic research. A goal of the program is to make key isotopes more readily available to meet domestic U.S. needs. This subprogram is steward of the Isotope Production Facility (IPF) at Los Alamos National Laboratory (LANL), the Brookhaven Linac Isotope Producer (BLIP) facility at BNL, and hot cell facilities for processing isotopes at ORNL, BNL, and LANL. In addition, the subprogram has begun to coordinate and support isotope production at a suite of university, other national laboratory, and commercial accelerator and reactor facilities throughout the Nation to promote a reliable supply of domestic isotopes. The National Isotope Development Center (NIDC) at ORNL interfaces with the user community and manages the coordination of isotope production across the facilities and business operations involved in the production, sale, and distribution of isotopes.

Benefits

NP supports a wide range of facilities, instruments, and research that create forefront scientific knowledge and state-of-the-art tools to serve the Nation. Nuclear science basic research and the advancement of knowledge of nuclear matter and its properties are inherently relevant to and intertwined with a broad range of applications including nuclear power, waste disposal, nuclear medicine, commerce, medical physics, space exploration, finance, geology, environmental sciences, and national security. NP also develops advanced instrumentation, accelerator technologies, and analytical and computational techniques that are needed for nuclear science research which have broad societal and economic benefits, including reliable, timely, and economical delivery of stable and radioactive isotopes for commercial application and research. The development and construction of facilities and advanced instrumentation and accelerator technology needed to reach the performance goals of the program not only contribute technically to other research and applied sciences, but also provide tools and research opportunities essential for workforce development, helping to ensure that a technically and scientifically capable generation of new scientists will be available to meet national challenges and help promote U.S. economic competitiveness in the future. In addition, the process of overcoming challenging technical problems to achieve the goals of the basic research program in nuclear science provide an engine for game-changing innovation which supports applications directly aligned with national needs and priorities.

Research into the nucleus has led to a number of valuable applications with practical benefits to society. The realization that the nucleus contains a tremendous amount of energy led to the development of both nuclear power and the atomic bomb. Some of the cutting-edge instrumentation being developed for nuclear physics experiments, such as high-resolution gamma ray detectors, can provide improved imaging techniques with important applications in combating terrorism. The discovery and understanding of nuclear spin made possible the development of techniques for the study of molecular structure and dynamics through nuclear magnetic resonance (NMR) and development of magnetic resonance imaging (MRI) for medical use. Medical imaging, cancer therapy, and biochemical studies all rely on isotopes produced in accelerators that were first developed for nuclear research. Particle beams are used in a broad range of materials science studies and for cancer therapy.

Valuable applications have resulted from isotope availability and nuclear radiation, which made possible the entire field of nuclear medicine used today in both the diagnosis and treatment of disease. Enhancements in isotope production and processing techniques have fueled the development of new uses of isotopes, including those for neutron detectors, special nuclear material and explosives detection, oil exploration, industrial radiography, heart and lung imaging, cancer therapy, smoke detectors, and tracers for climate change research. The various applications resulting from isotope availability have improved the ability of physicians to diagnose illnesses, improved the quality of life and longevity for innumerable patients, and strengthened national security.

Another societal benefit of the NP program is the boost to the Nation's R&D workforce through its support of undergraduate researchers, graduate students working toward an advanced degree, and postdoctoral associates developing their research and management expertise. These researchers provide new research talent and help meet the demand for skilled personnel in a wide variety of scientific, technical, medical, security, and industrial fields that require the unique problem-solving abilities and the computational and technical skills developed through an education and experience in nuclear science. Each year several national laboratory junior scientists within the NP program have been recognized with Presidential Early Career Awards for Scientists and Engineers for their outstanding contributions to nuclear and accelerator physics research and their promise as future leaders of the field.

The potential for new high tech jobs is significant. The Office of Nuclear Physics provides support for tools, facilities, and research opportunities which challenge the imagination and the scientific and technical abilities of U.S. scientists and the international scientific community. In the process of stretching to reach the ground breaking advances made possible as a result of these strategic investments, scientists and technical experts produce new innovations and new technologies. In addition to producing new knowledge and important applications such as isotopes for medicine, business, and research, these innovations and technologies are helping to transition the character of the U.S. workforce by creating high tech jobs which are resilient to offshore outsourcing. Current examples include:

- Technical developments in super conducting radio frequency (SRF) particle acceleration technology, a collateral benefit of meeting the challenges of the basic research programs in nuclear and high energy physics, have advanced the technology for accelerator driven sub-critical (ADS) reactors, a potential innovation for nuclear power generation and waste transmutation. New companies have already formed to industrialize SRF technology.
- Using Accelerator Mass Spectroscopy (AMS) technology developed to achieve the goals of the basic research program in nuclear science, NP supported scientists are collaborating with scientists from the Office of Nuclear Energy to understand how to design fuel for future nuclear reactors that burns

more completely, is proliferation resistant, and has reduced long-lived waste products. Innovation in this area supports the goal of deploying next generation nuclear reactor technology in the U.S.

- The future Facility for Rare Isotope Beams will produce knowledge on nuclear reaction cross sections not presently measureable anywhere in the world. Scientifically, this knowledge will inform the understanding of the evolution of stars and the makeup and evolution of the inter-stellar medium. As a practical matter, this knowledge will revolutionize the field of nuclear forensics, creating new technical expertise and innovation.

These are just three examples of how stretching beyond the limits of present day science and technology to realize the groundbreaking advances made possible by strategic investments in the basic nuclear science research program is driving innovation in areas important for a secure energy future and for the national and economic security of the United States. Ultimately, about half of the workforce trained in the U.S. nuclear science program will find long term careers and positions of responsibility in business, government, industry, and medicine, extending the impacts of basic nuclear science research well beyond the traditional boundaries of the nuclear science community itself.

Program Planning and Management

To ensure that funding is allocated as effectively as possible, NP has developed a rigorous and comprehensive process for strategic planning and priority setting that relies heavily on input from groups of outside experts. All activities within the subprograms are peer reviewed and performance is assessed on a regular basis. Priority is given to those research activities which support the most compelling scientific opportunities. NP has also instituted a number of peer review and oversight measures designed to assess productivity and maintain effective communication and coordination among participants in NP activities. On an as-needed basis, the program has taken the initiative to establish interagency working groups to tackle issues of common interest and enhance communication. NP takes all of this input into account in its budget requests, making decisions to maximize scientific impact, productivity, quality, and cost-effectiveness within available resources.

NP works closely with the National Science Foundation (NSF) to jointly charter the Nuclear Science Advisory Committee (NSAC) for advice regarding compelling opportunities and productivity of the national nuclear science program. NP develops its strategic plan for the field with input from the scientific community via long range plans produced by NSAC every five to six years. These plans provide retrospective assessments of major accomplishments, assess and identify scientific opportunities, and set priorities for the next decade. NSAC provides NP with additional guidance in the form of reviews of subfields, special interest topics, and assessment of the management of the NP program itself. In 2009, NSAC completed a report that identifies *Compelling Research Opportunities Using Isotopes,*[a] and a second report that lays out a strategic plan for the Isotope Development and Production for Research and Applications subprogram, *Isotopes for the Nation's Future—A Long Range Plan.*[a] NSAC conducted a Committee of Visitors (COV) review of NP management processes in January 2010. The general finding of the COV in the report transmitted to NP was that the operations of the office and decisions made in the context of the Long Range Plan position the Nuclear Physics program to lead the world in this critical area of research. NP's response to the recommendations contained in the COV report is on the Office of Science website.[b]

NP strategic plans are also influenced by National Academies reports and Office of Science and Technology Policy (OSTP) and National Security Council (NSC) Interagency Working Group (IWG)

[a] http://www.sc.doe.gov/np/nsac/nsac.html
[b] http://www.science.doe.gov/SC-2/COV-NP/NP_Reviews.htm

efforts, the latter two under the auspices of the White House Executive Office of the President. The 2007 National Academies study *Advancing Nuclear Medicine through Innovation*[a] motivated NP to establish a federal working group with the National Institutes of Health (NIH), along with the SC Biological and Environmental Research program, to better coordinate radioisotope production and to address other issues important to nuclear medicine. The National Academies embarked on a new decadal study of nuclear science in 2009. In order to optimize interagency activities, NP is involved in five OSTP or NSC IWG's: *Large Scale Science*, *Forensic Science*, *Molybdenum-99 Production*, *Helium-3 Shortage*, and *The Physics of the Universe*.

NP peer reviews all of its activities. Annual science and technology reviews of the national user facilities and isotope production facilities with panels of international peers assess operations, performance, and scientific productivity. These results influence budget decisions and NP's assessment of laboratory performance as documented in annual SC laboratory appraisals. The institutions are held accountable for responding to the peer review recommendations. Annual reviews of instrumentation projects focus on scientific merit, technical status and feasibility, cost and schedule, and effectiveness of management approach. NP conducted 27 reviews with panels of national and international experts in FY 2010. All NP baselined projects are currently on cost and on schedule. Performance of instrumentation projects is also assessed on a monthly and quarterly basis.

One of the most pressing priority-setting issues at the national user facilities is how to allocate available beam time, or time spent doing experiments on a facility's accelerator. Facility directors seek advice from facility Program Advisory Committees to determine the allocation of this valuable scientific resource. The facility Program Advisory Committees review research proposals requesting resources and time at the facilities and then provide advice on the scientific merit, technical feasibility, and personnel requirements of the proposals.

University grants are proposal driven. NP funds the best and most promising ideas submitted in response to grant solicitation notices. Proposals are reviewed by external scientific peers and competitively awarded according to the guidelines published in 10 CFR 605. The quality and productivity of university grants are peer reviewed on a three-year basis. Laboratory groups performing research are peer reviewed on a four-year basis to examine the quality of research and to identify needed changes, corrective actions, or redirections of effort. Funding decisions in this budget request are influenced by the results of these periodic peer reviews of the national laboratory research efforts. The laboratory research groups in the Medium Energy laboratory research groups were reviewed in 2010. A review of the Low Energy laboratory research program is planned for 2011.

Basic and Applied R&D Coordination

The knowledge, data, techniques, and methods of nuclear science are utilized in a broad portfolio of applications, including nuclear power, waste disposal, nuclear medicine, commerce, medical physics, space exploration, finance, geology, environmental sciences, national security, and others. In FY 2009, NP initiated support for targeted initiatives in Applications of Nuclear Science and Technology, the primary goal of which is to pursue forefront nuclear science research and development important to the NP mission, but inherently relevant to applications. One of the goals of this initiative was to help bridge the gap between basic research and applied science. The first 22 awards under this initiative were funded in FY 2009 using appropriated base funding and Recovery Act funds, and an additional five awards were made in FY 2010. Projects include: nuclear physics research that is relevant to the development of advanced fuel cycles for next generation nuclear power reactors; advanced and cost-effective accelerator

[a] http://dels.nas.edu/dels/rpt_briefs/advancing_nuclear_medicine.pdf

technology and particle detection techniques for medical diagnostics and treatment; and research in developing neutron, gamma and particle beam sources with applications in cargo screening and nuclear forensics. These initiatives are peer reviewed with participation from the applied sciences community. The integration of the underpinning nuclear science advances, resulting from innovative basic research with the applied sciences, optimizes cross fertilization, cost effectiveness, performance, and technology transfer.

The Isotope Development and Production for Research and Applications subprogram is an excellent example of basic and applied R&D coordination. The subprogram produces commercial and research isotopes that are important for basic research and applications. NP has taken significant steps in aligning the industrial and research stakeholders of the isotope program with each other and with the nuclear science research community, all of whom can contribute collectively in advancing the technology of this field. To ascertain current and future demands of the research community, NP continues to develop working groups with the National Nuclear Security Administration and other federal agencies, foster interactions between researchers and Isotope Program staff, obtain data from site visits, attend society exhibitions, and develop strategic plans and priorities with community input. Examples include: participating in an interagency working group for prioritizing requested allocations of helium-3 and seeking alternative supplies; participating in the joint DOE/National Institutes of Health (NIH) federal working group to develop a strategic plan and priorities for medical isotope production; participating in the OSTP Interagency and the Organization for Economic Cooperation and Development (OECD) international working group to address the supply of molybedenum-99; and working with industry to ensure continued availability of californium-252, an isotope of strategic and economic importance to the Nation. NP is also working to establish cooperative isotope supply contracts with universities to increase the Department's ability to meet researchers' requests by improving product availability and reliability.

The Isotope Development and Production for Research and Applications subprogram also supports research for the development of alternative production and extraction techniques of stable and radioactive isotopes, and the production of research isotopes identified by NSAC as needed for high priority research opportunities across a broad range of scientific disciplines.

Budget Overview

NP is the largest federal steward for basic research in nuclear science, operating four national user facilities through FY 2011, as well as supporting isotope production and development for the Nation. The FY 2012 budget request continues support for the two highest priorities in the 2007 Long Range Plan for Nuclear Science: an energy upgrade of the Thomas Jefferson National Accelerator Facility (TJNAF) Continuous Electron Beam Accelerator Facility (CEBAF) and the Facility for Rare Isotope Beams (FRIB). These investments in forefront facilities for new research capability, the first in the NP program in over ten years, will secure global U.S. leadership in research on the quark structure of nucleons, nuclear structure, and nuclear astrophysics. The increase of $70,300,000 relative to the FY 2010 Appropriation (including SBIR/STTR) is dominated by a $64,000,000 increase in the profiles of large construction projects: a $46,000,000 increase for the 12 GeV CEBAF Upgrade project, consistent with the baselined funding profile, and an $18,000,000 increase for FRIB, consistent with the cooperative agreement with Michigan State University. The increases required for these two high priority projects have required strategic decisions elsewhere in the program, most notably the closure of HRIBF as a national user facility in FY 2012. Also terminated in FY 2012 is the Rare Isotope Beam Science Initiatives MIE. The profile of the neutron Electric Dipole Moment Experiment MIE is slowed down relative to project plans approved at Critical Decision-1. Operations of the national user facilities are below optimal levels. At the heart of the NP program are groups of highly trained scientists who conceive, plan, execute, and interpret the numerous experiments carried out at various nuclear physics facilities. NP supports scientists at both universities and national laboratories and is involved in a variety of international collaborations. The program supports approximately two-thirds of the Nation's university researchers and graduate students who are doing fundamental nuclear physics research. More than 2,000 researchers and students at approximately 100 U.S. academic, Federal, and private-sector institutions are supported. With the FY 2012 request, research activities are conducted at approximately 90 academic institutions located in 35 states and the District of Columbia, as well as at 9 DOE laboratories in 8 states. Approximately 80 Ph.D. degrees are granted annually to students for research supported by the program. Five university Centers of Excellence, each with different capabilities and expertise, provide excellent hands-on training opportunities for junior scientists.

Research at nine national laboratories is guided by the DOE mission and priorities and is the underpinning of strategic core competencies needed to achieve the goals of the NP program. The national laboratory scientists work and collaborate with academic scientists, other national laboratory experimental researchers, and those carrying out theoretical investigations. The national laboratory scientists collect and analyze data as well as support and maintain the detectors and facilities used in these experiments. The national laboratories also provide state-of-the-art resources for detector and accelerator R&D for future upgrades and new facilities.

Investigating the frontiers of nuclear physics requires being able to accelerate various particles, such as protons, electrons, and a variety of ions, up to nearly the speed of light, smashing them into other particles, and then observing the results of the collisions. Exploring the various areas of nuclear physics demands having a variety of accelerators, each designed to examine the subatomic world in its own unique way and employing a variety of particle detectors and other equipment. Thus, NP supports facilities that complement one another and provide a variety of approaches to producing and collecting data about matter at the level of the nucleus, as well as the sub-nuclear level. The necessary facilities and equipment are large, complex, and expensive to build and operate, and thus they account for a significant portion of the program's budget—approximately 67 percent of the FY 2012 request. NP also supports collaborative work at foreign accelerator facilities, as well as joint development of instrumentation.

NP supported four national user facilities (RHIC, CEBAF, ATLAS, and HRIBF) in FY 2011, each with capabilities found nowhere else in the world, that provide research time for scientists at universities and other federal laboratories. These major scientific facilities provide research beams for a user community of approximately 3,200 scientists from all over the world, with more than 2,500 of the users utilizing RHIC and CEBAF. Approximately 38 percent of the users are from institutions outside of the U.S., and they often provide experimental equipment or instrumentation. A number of other SC programs, DOE offices (National Nuclear Security Administration and Nuclear Energy), Federal agencies (NSF, NASA, and Department of Defense), and industries use the NP user facilities to carry out their own research programs.

The FY 2012 budget request closes HRIBF, a national user facility with unique capabilities for studies of nuclear structure and astrophysics at the Oak Ridge National Laboratory, in order to support higher priorities within the program. The closure of HRIBF will impact a university and laboratory international community of 260 users The request supports operations at the three remaining NP national user facilities at levels that will allow significant progress towards achieving performance goals defined by the 2008 *Report to NSAC of the Subcommittee on Performance Measures*[a] for nuclear science. The facilities will provide an estimated 12,810 hours of beam time for research, 90% of optimal for the operating facilities, but a decrease of about 7,260 hours compared with the beam hours achieved in

[a] http://www.sc.doe.gov/np/nsac/nsac.html

FY 2010 as a result of the HRIBF closure; a planned shutdown period at CEBAF associated with the construction of the 12 GeV CEBAF Upgrade project at TJNAF; and a decrease in operations at RHIC. The scientific user facilities will be maintained and operated so that the unscheduled operational downtime will be kept to less than 20 percent, on average, of total scheduled operating time. Investments will be made in programmatic infrastructure, facility equipment, and accelerator improvement projects that will increase productivity, reliability, and cost-effectiveness, and provide new capabilities to pursue high discovery science.

Construction of the 12 GeV CEBAF Upgrade project, the highest priority in the NSAC Long Range Plan for Nuclear Science, continues in FY 2012. Because the project is of high priority, over $50,000,000 is redirected from the base CEBAF program towards the construction over the lifetime of the project.

Less than 1.5 percent of the total NP budget in FY 2012 is invested in a handful of ongoing small-scale Major Item of Equipment (MIE) projects in order to position the program strategically for the future to address compelling scientific opportunities identified by NSAC. The majority of these MIEs are collaborative in nature, with the DOE investment leveraged by contributions from other agencies and international partners. One MIE, the Rare Isotope Beam Science Initiatives, is terminated in FY 2012.

The proposed Facility for Rare Isotope Beams (FRIB), a next-generation nuclear structure and astrophysics machine that will map out the nuclear landscape, is supported with operating funds through a Cooperative Agreement with MSU. Although the FRIB property will not be a capital asset to the Federal Government and will be owned by the university, FRIB will be operated as a DOE national user facility upon completion around the start of the next decade. In FY 2012, funds are requested to support engineering and design activities for FRIB, pursue long-lead procurements, and possibly a phased construction start that will reduce project risks.

Significant Program Shifts

Strategic decisions and significant shifts are required within the Nuclear Physics FY 2012 budget as a result of the priority given to investments in major new research capability for the Nation's future nuclear science program.

Operations of the HRIBF national user facility cease in order to support higher priorities within the program.

The Rare Isotope Beam Science Initiatives MIE, for cutting edge nuclear structure and nuclear astrophysics research at international facilities during the lead-up and execution of FRIB construction, is terminated in FY 2012 to direct funds to higher priority activities. A limited number of the smaller international research efforts, among those selected following peer review in FY 2010, will be completed with funding in FY 2010 and FY 2011, while the larger projects will not be pursued.

The funding for the nEDM MIE is slowed relative to the most recent approved funding profile as support is redirected to higher priority activities and NSAC reviews priorities in the U.S. neutron science portfolio.

Funding is provided within the Low Energy subprogram under Other Operations to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided from the High Energy Physics program. Nuclear Physics will assess options for a future neutrinoless double beta decay experiment.

Finally, operation of one university accelerator Center of Excellence is terminated to direct funds to higher priority activities.

Annual Performance Targets and Results

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

Medium Energy Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Medium Energy Nuclear Physics		
Research		
University Research	19,422	20,222
National Laboratory Research	16,908	17,710
Other Research[a]	2,456	8,518
Total, Research	38,786	46,450
Operations		
TJNAF Operations	83,327	83,930
Total, Medium Energy Nuclear Physics	122,113	130,380

Description

The Medium Energy Nuclear Physics subprogram focuses primarily on questions having to do with the first scientific frontier, Quantum Chromodynamics (QCD) and the behavior of quarks inside protons and neutrons, although it touches on all three scientific frontiers. Specific questions addressed include: What is the internal landscape of the nucleons? What does QCD predict for the properties of strongly interacting matter? What governs the transition of quarks and gluons into pions and nucleons? What is the role of gluons and gluon self-interactions in nucleons and nuclei? One major goal, for example, is to achieve an experimental description of the substructure of the proton and the neutron. In pursuing that goal the Medium Energy subprogram supports different experimental approaches that seek to determine such things as the distribution of up, down, and strange quarks in the nucleons; the roles of the gluons that bind the quarks; the role of the "sea" of virtual quarks and gluons, which makes a significant contribution to the properties of protons and neutrons; the effects of the quark and gluon spins within the nucleon; and the effect of the nuclear environment on the quarks and gluons. The subprogram also measures the excited states of hadrons (composite particles made of quarks, including nucleons) in order to identify which properties of QCD determine the dynamic behavior of the quarks.

The subprogram also supports investigations into a few aspects of the second frontier, Nuclei and Nuclear Astrophysics, such as the question: What is the nature of the nuclear force that binds protons and neutrons into stable nuclei? Finally, this subprogram examines certain aspects of the third area, Fundamental Symmetries and Nuclei, including the questions: Why is there now more visible matter than antimatter in the universe? What are the unseen forces that were present at the dawn of the universe, but disappeared from view as it evolved?

Funding for this subprogram supports both research and operations of the subprogram's primary research facility, CEBAF, as well as research that is supported at RHIC. CEBAF is a facility with capabilities unique world-wide; the upgrade in energy opens up compelling new scientific opportunity

[a] In FY 2010, $4,034,000 was transferred to the SBIR program and $1,334,000 was transferred to the STTR program. This activity includes FY $4,105,000 for SBIR and $1,356,000 for STTR in FY 2012.

and secures continued world leadership in the U.S. for this physics arena. Research support at both facilities includes the laboratory and university personnel needed to implement and run experiments and to conduct the data analysis necessary to publish results. Individual experiments are supported at the High Intensity Gamma Source (HIγS) at Triangle Universities Nuclear Laboratory, at Fermi National Accelerator Laboratory (Fermilab), and at several facilities in Europe. All these facilities produce beams of sufficient energy (that is, of small enough wavelength) to see details smaller than the size of a nucleon. In addition, research is supported at the Research and Engineering Center at the Massachusetts Institute of Technology which has infrastructure capabilities to develop advanced instrumentation and accelerator equipment.

Construction of the 12 GeV CEBAF Upgrade project is a priority. CEBAF operations are reduced from 5,280 hours achieved in FY 2010 to 3,870 hours, reflecting the maximum level of operations possible in FY 2012 while accommodating installation of components for the 12 GeV CEBAF Upgrade project. Modest funding is provided to develop a group of scientists that will operate and utilize the new experimental hall being constructed for the 12 GeV CEBAF Upgrade project.

Selected FY 2010 Accomplishments

- Scientists have known for decades that the quark structure of protons in nuclei differs from that of free protons. The explanation of this effect has remained elusive, but new TJNAF precision results on light nuclei such as helium show that this difference is not dependent on the mass or density of the entire nucleus, as previously suggested, but that the quark structure of the protons changes according to the nuclear density in their immediate neighborhood within the nucleus, thus being a relatively short range effect.
- TJNAF designed and constructed a new polarized electron beam source that suppresses correlations between the beam parameters and the spin of the electrons by at least two orders of magnitude. Such high quality polarized electron beams are needed for a new generation of demanding parity-violation experiments planned for the facility to further test the limitations of the Standard Model of subatomic physics. A compact “inverted insulator” in the new design reduces field emission and thus prolongs the photocathode lifetime of the source.
- Data taken in two experiments at TJNAF using the highly polarized electron beam capability of the facility and a highly polarized target allowed the separated extraction of two functional form factors needed to describe the spin and transverse spatial distributions of the quarks in the proton. This result demonstrates the feasibility of a key part of TJNAF’s plans to do proton “tomography” and map out the quark structure of the proton with the 12 GeV CEBAF Upgrade.
- A crucial part of the RHIC spin program is the study of intermediate vector (W) boson production in high-energy collisions of polarized proton beams. To produce W bosons in sufficient quantity, RHIC must operate at its maximum possible energy for proton-proton collisions (500 GeV). Collisions at this energy were provided at RHIC in the 2009 run and data was analyzed in FY 2010. Although this was a first commissioning run, both the PHENIX and STAR collaborations detected a sufficient number of W bosons to allow the first spin dependent measurements of their production.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Research	**38,786**	**46,450**
▪ **University Research**	**19,422**	**20,222**

This activity supports about 160 scientists and 125 graduate students at 33 universities in 21 states and the District of Columbia studying QCD and the behavior of quarks inside protons and neutrons. The university scientists conduct experiments at CEBAF and RHIC and participate in the development and fabrication of advanced instrumentation for utilization at these facilities. These state-of-the-art detectors often have relevance to applications in medicine and homeland security. Included in this activity is support for the Massachusetts Institute of Technology's Research and Engineering (R&E) Center that has specialized infrastructure for fabrication of scientific instrumentation. The Center has unique expertise in the study of high current, polarized electron sources.

The FY 2012 request holds research approximately flat, relative to FY 2010, although an increase is provided to start building the university groups that will be needed to support the new CEBAF experimental hall (Hall D) upon completion of the 12 GeV project.

▪ **National Laboratory Research**	**16,908**	**17,710**

This funding supports research groups at TJNAF, BNL, ANL, LBNL, and LANL that carry out research at CEBAF and RHIC. It also supports two experiments at Fermilab and nuclear research using laser trapping technology at ANL. Funding decisions are influenced by the results of periodic peer reviews of the national laboratory research groups and their subsequent ranking in terms of performance level. The FY 2012 request relative to FY 2010 is essentially flat, although a small increment is provided to start building the support needed for the new CEBAF experimental hall (Hall D) upon completion of the 12 GeV project.

• **TJNAF Research**	**6,200**	**6,473**

TJNAF staff research efforts include developing experiments, acquiring data, and performing data analysis in the three existing CEBAF experimental Halls. Funding is provided in FY 2012 to develop a scientific group for the new experimental Hall D that is being constructed as part of the 12 GeV CEBAF Upgrade project. Scientists also are identifying the scientific opportunities and developing the scientific goals for next generation facilities. In addition, funding supports an active visiting scientist program at the laboratory and bridge positions with regional universities, which is a cost-effective approach to augmenting scientific expertise at the laboratory and boosts educational opportunities in the southeast region of the Nation. Detectors developed for nuclear physics research supported at TJNAF have found applications in medical imaging instrumentation.

• **Other National Laboratory Research**	**10,708**	**11,237**

Argonne National Laboratory scientists continue their primary research program at TJNAF and are leading an experiment at Fermilab to distinguish the different quark contributions to the structure of the proton. These measurements are also important to interpreting the RHIC proton spin measurements. ANL scientists are also using their unique laser atom-trapping technique to

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

make a precision measurement of the atomic electric dipole moment that could shed light on the excess of matter over antimatter in the universe. This technology at ANL has found practical applications in geology and environmental fields, for example, in tracking ground water flows in Egypt.

Support is provided to the RHIC spin physics research groups at BNL, LBNL, and LANL, which have important roles and responsibilities in the RHIC program. These groups play lead roles in determining the spin structure of the proton by development and fabrication of advanced instrumentation, as well as data acquisition and analysis efforts.

At LANL, support is provided to allow scientists and collaborators to complete the Fermilab MiniBooNE anti-neutrino running and analysis. A present discrepancy between the anti-neutrino and neutrino data needs to be resolved with additional anti-neutrino running. If these results are confirmed, they could unveil new physics beyond the Standard Model. The results of these efforts will drive future research directions of this group.

The FY 2012 request holds other national laboratory research approximately flat for all these efforts, with the exception of growth of about one Full-Time-Equivalent scientist (FTE) to develop the 12 GeV experimental program and implement the ANL experiment at Fermilab.

▪ **Other Research**	**2,456**	**8,518**
• **SBIR/STTR and Other**	**1,666**	**7,818**

In FY 2010, $4,034,000 was transferred to the Small Business Innovation Research (SBIR) program and $1,334,000 was transferred to the Small Business Technology Transfer (STTR) program. This activity includes $4,105,000 for SBIR and $1,356,000 for STTR in FY 2012, as well as funds needed to meet other obligations required of the Nuclear Physics program.

• **Accelerator R&D Research**	**790**	**700**

The Medium Energy Accelerator R&D research at universities and laboratories will develop the knowledge, technologies, and trained scientists to design and build the next-generation NP accelerator facilities. These programmatic activities are of relevance to machines being developed by other domestic and international programs and can lead to technological advances that are relevant to a variety of applications. Allocation of these funds is determined by peer review and competed amongst university and laboratory proposals.

Operations	**83,327**	**83,930**
▪ **TJNAF Operations**	**83,327**	**83,930**

CEBAF is a unique facility with unparalleled capabilities using polarized electron beams to study quark structure; there is no other facility in the world like it and its user community has a strong international component. Funding supports CEBAF operations and experimental support for 3,870 hours and a 3-Hall operations schedule. The run time is near the maximum possible considering the planned one-year shutdown beginning in the latter half of FY 2012 as part of the 12 GeV CEBAF Upgrade project installation schedule.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
• **TJNAF Accelerator Operations**	**50,755**	**53,550**

Support is provided for the accelerator physicists that operate the facility as well as operations, power costs, capital infrastructure investments, and accelerator improvements of the CEBAF accelerator complex. While the facility is only partially operating in FY 2012 during the planned installation of components for the 12 GeV Upgrade, the funding will support opportunities for increased maintenance during this period. There is a redistribution of funds from experimental support to accelerator operations to properly reflect the efforts during the shutdown; in total, funding for TJNAF Operations is essentially flat relative to FY 2010.

Support is also provided to maintain efforts in developing advances in superconducting radiofrequency (SRF) technology. The core competency in SRF technology that is nurtured at this laboratory plays a crucial role in many DOE projects and facilities outside of nuclear physics and has broad applications in medicine and homeland security. For example, SRF research and development at TJNAF has led to techniques for detection of buried land mines using terahertz radiation and carbon nanotube and nano-structure manufacturing techniques for the manufacture of super-lightweight composites such as aircraft fuselages.

TJNAF also has a core competency in cryogenics and has developed award-winning techniques that have led to more cost-effective operations at TJNAF and several other Office of Science facilities.

TJNAF accelerator physicists are also strongly engaged in educating the next generation of accelerator physicists, with graduate students integrated into research programs and eleven staff members with university affiliations. TJNAF started a Center for Accelerator Science at Old Dominion University (ODU) where staff members teach courses and the laboratory jointly supports the ODU Director position.

Investments in accelerator improvement projects are aimed at increasing the productivity, cost-effectiveness, and reliability of the facility. Capital equipment investment is targeted towards instrumentation needed to support the laboratory's core competencies in SRF and cryogenics.

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

	FY 2010	FY 2012
CEBAF Hours of Operation with Beam		
Achieved Operating Hours	5,280	N/A
Planned Operating Hours	5,110	3,870
Optimal Hours	5,980	3,940[a]
Percent of Optimal Hours	88%	98%
Unscheduled Downtime	9%	N/A
Number of Users	1,260	1,300

• **TJNAF Experimental Support**	**32,572**	**30,380**

Experimental Support is provided for the scientific and technical staff, as well as for materials, and services for CEBAF experiments and to integrate assembly, modification, and disassembly of large and complex experiments. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment. Capital equipment investments for experimental support at TJNAF provide scientific instrumentation for the major experiments, including data acquisition computing and supporting infrastructure (e.g., targets, mechanical structures, power supplies, gas systems, and cooling equipment). In FY 2012, TJNAF expects to run experiments distributed among all three halls that address compelling physics including a precision measurement of the weak charge of the proton to help constrain new physics beyond the Standard Model, an important experiment for the laboratory's search for missing excited states of the neutron, and experiments that will help develop the laboratory's research program using the 12 GeV CEBAF Upgrade. Funds are redistributed to accelerator operations to better align with ongoing activities during the period of 12 GeV installation efforts.

The FY 2012 funding focuses on efforts to implement high priority experiments before the completion of the current 6 GeV experimental program and prior to the 12 GeV CEBAF Upgrade project installation.

Total, Medium Energy Nuclear Physics	**122,113**	**130,380**

[a] The approach in previous years was to reflect the maximum hours a facility could conceivably operate. As a result, while the maximum operations for CEBAF remained at 5,980 hours in FY 2011, the optimal number of hours the facility can actually operate in FY 2011 is 4,090 hours due to the planned shutdown for installation of 12 GeV components. In FY 2012, the optimal hours are adjusted to reflect the hours the facility can operate that year after taking into account planned downtime for upgrades and maintenance.

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **University Research**	
Funding for university research is held flat relative to FY 2010 with the exception of an increase to start building the university groups that will be involved in Hall D experiments upon completion of the 12 GeV CEBAF Upgrade.	+800
▪ **National Laboratory Research**	
• **TJNAF Research**	
Funding is increased modestly to complete the highest priority 6 GeV experiments at CEBAF and to start developing the scientific group for the new experimental Hall D that is being constructed as part of the 12 GeV CEBAF Upgrade project.	+273
• **Other National Laboratory Research**	
Funding is provided to complete the highest priority 6 GeV experiments at CEBAF, develop the scientific groups for the new experimental Hall D that is being constructed as part of the 12 GeV CEBAF Upgrade project, and implement the ANL-led Drell-Yan experiment at Fermilab.	+529
Total, National Laboratory Research	+802
▪ **Other Research**	
• **SBIR/STTR and Other**	
Funding increases relative to FY 2010 primarily because the mandated SBIR/STTR set-asides have been transferred out of the program in FY 2010 while those funds are included in the FY 2012 request. Increased funding is also included for other obligations and mandatory requirements of the Nuclear Physics program.	+6,152
• **Accelerator R&D Research**	
A portion of the funding reflected within Medium Energy shifts to Accelerator R&D under the Heavy Ion subprogram.	-90
Total, Other Research	**+6,062**
Total, Research	**+7,664**

	FY 2012 vs. FY 2010 Current Approp. ($000)
Operations	
▪ **TJNAF Operations**	
• **TJNAF Accelerator Operations**	
FY 2012 funding operates CEBAF at near the maximum allowable schedule, considering a planned shutdown for 12 GeV CEBAF Upgrade project component installation. FY 2012 funding of accelerator operations is increased to provide high reliability for completing the 6 GeV program in addition to maintaining existing systems at the high performance required for the 12 GeV program. Funds are redistributed from experimental support to better align with activities in FY 2012; the overall staffing levels do not increase.	+2,795
• **TJNAF Experimental Support**	
Funding is decreased as the 6 GeV experimental program completes its running in existing experimental configurations. Funds are redistributed to accelerator operations to better align with planned activities in FY 2012.	-2,192
Total, Operations	**+603**
Total Funding Change, Medium Energy Nuclear Physics	**+8,267**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Heavy Ion Nuclear Physics		
Research		
University Research	14,466	15,201
National Laboratory Research	27,222	28,131
Other Research[a]	1,270	7,042
Total, Research	42,958	50,374
Operations		
RHIC Operations	157,195	164,610
Other Operations	4,910	5,000
Total, Operations	162,105	169,610
Total, Heavy Ion Nuclear Physics	205,063	219,984

Description

The Heavy Ion Nuclear Physics subprogram focuses on studies of nuclear matter at extremely high densities and temperatures. A program of research on hot nuclear matter began at the Relativistic Heavy Ion Collider (RHIC) at BNL in 2000 when the first collisions of counter-circulating gold nuclei were observed at beam energies ten times higher than those available at any other facility in the world. At RHIC, beams of gold nuclei are accelerated to close to the speed of light and then slammed head on into one another in order to create extremely high-energy collisions between pairs of gold nuclei. In the aftermath of these collisions researchers have seen signs of the same quark-gluon plasma that is believed to have existed shortly after the Big Bang. With careful measurements, scientists accumulate data that offer insights into those brief moments immediately following the creation of the universe and begin to understand how the protons, neutrons, and other bits of normal matter developed from that plasma.

The RHIC facility places heavy ion research at the energy frontier of nuclear physics. RHIC serves two large-scale international experiments called PHENIX and STAR. In these experiments, scientists are now trying to determine the physical characteristics of the recently discovered perfect liquid of quarks and gluons. A 10-fold enhancement in the heavy ion beam collision rate and detector upgrades are expected to be completed within the next five years. Accelerator R&D is being conducted at RHIC in a number of advanced areas including cooling of high-energy hadron beams; high intensity polarized electron sources; and high-energy, high-current energy recovery linear (ERL) accelerators. The RHIC facility is used by about 1,200 DOE, NSF, and foreign agency supported researchers.

The Large Hadron Collider (LHC) at CERN offers opportunities for making new discoveries in relativistic heavy ion physics. LHC will provide a 30-fold increase in center-of-mass energy over what is available now. U.S. scientists are preparing to conduct research using ALICE (A Large Ion Collider Experiment) and the Compact Muon Spectrometer (CMS). U.S. researchers are fabricating a large

[a] In FY 2010, $5,662,000 was transferred to the SBIR program. This activity includes $5,673,000 for SBIR in FY FY 2012.

Electromagnetic Calorimeter (EMCal) detector to be installed in phases in the ALICE experiment over the next few years. First heavy ion beam operations at the LHC started in late 2010.

The RHIC and LHC research programs are directed primarily at answering the overarching questions that define the first frontier identified by the nuclear science community—Quantum Chromodynamics (QCD). The fundamental questions addressed include: What are the phases of strongly interacting matter, and what roles do they play in the cosmos? What governs the transition of quarks and gluons into pions and nucleons? What determines the key features of QCD, and what is their relation to the nature of gravity and space-time?

The funding for this subprogram in FY 2012 will operate RHIC to address the highest priority scientific opportunities and goals, meet commitments to the LHC heavy ion program, and implement the STAR Heavy Flavor Tracker MIE project.

Selected FY 2010 Accomplishments

- Previous RHIC results demonstrated that collisions of gold nuclei at nearly light speed produce matter in an exotic state believed to have dominated the universe a few microseconds after its birth in the Big Bang. New results show particles composed exclusively from "strange" quarks, as opposed to the much lighter "up" and "down" quarks that are the dominant constituents of normal matter, also exhibit similar fluid-flow patterns. These results indicate that the nearly perfect liquid is created very quickly, before the quarks condense into observable particles.
- New results provided hints of a predicted form of symmetry breaking in the hot liquid of quarks and gluons produced in RHIC's most energetic collisions. These results, reported in the journal Physical Review Letters, suggest that "bubbles" formed within this hot liquid may internally disobey the so-called "mirror symmetry," or parity, that normally characterizes the interactions of quarks and gluons. RHIC may have a unique opportunity to test some crucial features of symmetry-altering bubbles that are speculated to have played important roles in the evolution of the early universe. Studies of this effect are expected to be an important topic in future RHIC experiments.
- New results obtained from high-energy collisions of deuterium with gold nuclei provide the strongest experimental evidence to date that all matter, at its heart, is dominated by an ultra-strong force field arising from a dense ensemble of gluons (the ghostly particles exchanged between quarks to confine them inside protons and neutrons). This intense gluon field is predicted by Quantum Chromodynamics (QCD)—the fundamental theory describing the interactions of quarks and gluons.
- In 2008, RHIC accelerator physicists were the first to use the bunch beam stochastic cooling technique along the beam direction to compensate for the tendency of beam bunches to lengthen (heat-up) as they circulate. As the beam ions spread, the number of protons and neutrons colliding—and the amount of useful data—declines. In 2010, RHIC physicists demonstrated stochastic cooling in the transverse direction for the first time. Computer simulations show that combining the two stochastic cooling techniques should increase collision rates by a factor of five, thus avoiding much more expensive upgrade options to achieve the collision rates required in the future.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Research	**42,958**	**50,374**
▪ **University Research**	**14,466**	**15,201**

Research support is provided for about 120 scientists and 100 graduate students at 30 universities in 19 states. Funding supports research efforts at RHIC and the continuation of a modest program at the LHC with heavy ions. The university groups provide scientific personnel and graduate students needed for running the RHIC and LHC heavy ion experiments, as well as for data analysis and publishing RHIC results, and designing and fabricating the RHIC and LHC heavy ion detector upgrades. For example, university personnel led the effort in the fabrication of the STAR Time-of-Flight detector, an MIE which was completed on cost and schedule in FY 2009.

The FY 2012 request holds research flat with the exception of fulfilling the NP commitment with the international ALICE experiment by providing for an increase of required M&O costs associated with the LHC instrumentation.

▪ **National Laboratory Research**	**27,222**	**28,131**

This funding supports research groups at BNL, LBNL, LANL, ORNL, and LLNL that carry out research primarily at RHIC and a modest program at the LHC that supports the high priority scientific goals for the field of heavy ion physics. The FY 2012 request holds the heavy ion research efforts at laboratories flat, but fulfills the NP commitment with the international ALICE experiment by providing for an increase of required M&O costs associated with the LHC instrumentation, and provides support as planned for implementation of instrumentation. These scientists provide essential personnel for designing, fabricating, and operating the RHIC detectors; analyzing RHIC data and publishing scientific results; conducting R&D of innovative detector designs; project management and fabrication of MIEs; and planning for future experiments. Also, BNL and LBNL provide substantial computing infrastructure for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development. Some of the new research topics that will be investigated at RHIC in the next several years include determining the speed of sound in the quark-gluon plasma and trying to discover the critical point in the QCD phase diagram; discovering the speed of sound and the QCD critical point could revolutionize the quantitative understanding of the QCD phase diagram. Funding decisions are influenced by the results of periodic peer reviews of the national laboratory research groups and their subsequent ranking in terms of performance level.

• **BNL RHIC Research**	**10,032**	**12,185**

The FY 2012 budget request holds research activities flat. BNL scientists will continue to develop and implement new instrumentation needed to effectively utilize the RHIC beam time for research, develop and implement new instrumentation for RHIC's future, train junior scientists, and develop the computing infrastructure used by the scientific community.

The PHENIX Silicon Vertex Tracker (VTX) MIE, a joint project with Japan, received its final funding increment under the Recovery Act and was completed in 2010. It consists of a barrel of silicon pixel and strip detectors that will provide precision measurement of heavy quark production to study the thermalization process in heavy ion collisions. The PHENIX Forward Vertex Detector (FVTX) MIE also received its final funding under the Recovery Act and is on

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

track for completion in FY 2011. Important for both the heavy ion and spin programs, this detector will provide new vertex tracking capabilities to PHENIX by adding two silicon endcaps.

The STAR Heavy Flavor Tracker (HFT), an MIE initiated in FY 2010, is an ultra-thin, high-precision tracking detector that will provide direct reconstruction of short-lived particles containing heavy quarks. Support for this cutting-edge device ramps up in FY 2012; the funding profile for this MIE is the only increase in this funding category relative to FY 2010.

• **Other National Laboratory Research**	**17,190**	**15,946**

Researchers at LANL, LBNL, LLNL, and ORNL provide support for the RHIC and LHC experiments and develop new instrumentation. They also provide unique expertise and facilities for RHIC and LHC detector upgrades and analyses of data. For example, at LBNL, the large scale computational system, Parallel Distributed Systems Facility (PDSF), is a major resource used for the analysis of RHIC and LHC data, in alliance with the National Energy Research Scientific Computing Center (NERSC). At LLNL, computing resources are made available for the LHC data analysis. LBNL leads the fabrication of the LHC Heavy Ion MIE, a joint project with France and Italy that adds a large Electromagnetic Calorimeter (EMCal) to the CERN ALICE heavy ion experiment to provide the capability to study energy loss in the quark-gluon plasma. Funding support for the EMCal is completed in FY 2011 according to the planned profile. Funding requested in FY 2012 holds research funding and efforts at the national laboratories flat relative to FY 2010, but supports increased mandatory LHC fees.

▪ **Other Research**	**1,270**	**7,042**
• **SBIR and Other**	**0**	**5,742**

In FY 2010, $5,662,000 was transferred to the Small Business Innovative Research (SBIR) program. This activity includes $5,673,000 for SBIR in FY 2012, as well as other established obligations of the Nuclear Physics program.

• **Accelerator R&D Research**	**1,270**	**1,300**

The Heavy Ion Accelerator R&D research at universities and laboratories will develop the knowledge, technologies, and trained scientists to design and build the next-generation NP accelerator facilities. These programmatic activities are of relevance to machines being developed by other domestic and international programs and can lead to technological advances that are relevant to a variety of applications. Allocation of these funds is competed among university and laboratory proposals and is determined by peer review.

Operations	**162,105**	**169,610**
▪ **RHIC Operations**	**157,195**	**164,610**

RHIC operations are supported for an estimated 3,040 hour operating schedule (74 percent utilization) in FY 2012, a decrease of 540 hours from that achieved in FY 2010, which will be focused on addressing the highest priority scientific opportunities and goals of this program for this year.

The Electron Beam Ion Source (EBIS) construction project was completed in FY 2010 and its implementation, along with detector upgrades, will allow the RHIC program to make incisive

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

measurements leading to better insights into the discovery of strongly interacting quark gluon matter and to establish whether other phenomena, such as a color glass condensate or chiral symmetry restoration exist in nature. EBIS will also lead to more cost-effective operations of the facility as it replaces the aging Tandems as part of the RHIC injector. DOE and NASA partnered on the construction of EBIS, and this project will also provide new capabilities to the NASA Space Radiation Laboratory Program.

• **RHIC Accelerator Operations**	**121,935**	**127,797**

Funding continues to operate RHIC and maintains the level of effort. Support is provided for the operations, power costs, capital infrastructure investments, and accelerator improvement projects of the RHIC accelerator complex. This includes the new EBIS injector, the Booster, and AGS accelerators that together serve as the injector for RHIC. Modest support is provided for R&D of electron beam cooling and other luminosity enhancement technologies. Funding is also provided to reduce the backlog of infrastructure items that most impede the cost-effective and efficient operations of the facility. Operations of RHIC also support parallel and cost-effective operations of the NASA Space Radiation Laboratory Program, for the study of space radiation effects applicable to human space flight, and the Brookhaven Linac Isotope Production Facility (BLIP), for the production of research and commercial isotopes critically needed by the Nation. BNL has nurtured important core competencies in accelerator physics techniques, which have had applications in industry, medicine, homeland security, and other scientific projects outside of NP. The RHIC accelerator physicists have been leading the effort to address technical feasibility issues of relevance to a possible next-generation collider, including beam cooling techniques and energy recovery linacs. RHIC accelerator physicists also play an important role in the education of next generation accelerator physicists, with support of graduate and post-doctoral students. The laboratory supports the Center for Accelerator Science and Education (CASE) in partnership with Stony Brook University. CASE takes advantage of the collaboration with BNL by providing opportunities for students to learn on the state-of-the-art accelerators at BNL and having BNL staff teach courses and advise students.

	FY 2010	FY 2012
RHIC Hours of Operation with Beam		
Achieved Operating Hours	3,580	N/A
Planned Operating Hours	3,350	3,040
Optimal Hours	4,100	4,100
Percent of Optimal Hours	87%	74%
Unscheduled Downtime	17%	N/A
Number of Users	1,200	1,200

• **RHIC Experimental Support**	**35,260**	**36,813**

Support is provided for the operation, maintenance, improvement, and enhancement of the RHIC experimental complex, including the STAR and PHENIX detectors, the experimental halls, and

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

the RHIC Computing Facility, as well as support for users. Funding maintains the level of effort. The STAR and PHENIX detectors provide complementary measurements, with some overlap, in order to cross-calibrate the measurements. Instrumentation advances by this community have led to practical applications in medical imaging and homeland security. Capital equipment funding is provided to maintain computing capabilities at the RHIC Computing Facility.

▪ **Other Operations**	**4,910**	**5,000**

The Nuclear Physics program provides funding to BNL for minor new fabrications, needed laboratory equipment (including general purpose equipment), and other expenses. Funding of this type is essential for maintaining the productivity and usefulness of DOE-owned facilities and for meeting its requirement for safe and reliable facilities operations.

Total, Heavy Ion Nuclear Physics	**205,063**	**219,984**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **University Research**	
The increase supports required M&O costs for research at the LHC heavy ion program and operational funding for the STAR Time of Flight MIE that was completed at the end of FY 2009.	+735
▪ **National Laboratory Research**	
• **BNL RHIC Research**	
Funding is increased relative to FY 2010 due to the planned increase for the fabrication of the STAR Heavy Flavor Tracker MIE project.	+2,153
• **Other National Laboratory Research**	
The decrease for the LHC Heavy Ion MIE according to the planned profile, is offset by increased support required for LHC M&O fees and computing costs, and for research efforts needed for the utilization of the recently completed Major Items of Equipment at RHIC and the LHC.	-1,244
Total, National Laboratory Research	**+909**
▪ **Other Research**	
• **SBIR and Other**	
Funding increases relative to FY 2010 because the mandated SBIR set-aside has been transferred out of the program in FY 2010 while those funds are included in the FY 2012 request.	+5,742

	FY 2012 vs. FY 2010 Current Approp. ($000)
• **Accelerator R&D Research**	
This increase reflects a shift of a portion of the funding from the Medium Energy subprogram for Accelerator R&D.	+30
Total, Other Research	**+5,772**
Total, Research	**+7,416**
Operations	
▪ **RHIC Operations**	
• **RHIC Accelerator Operations**	
The increase from FY 2010 to FY 2012 maintains staff, required materials and supplies, and power costs for effective operations of the facility.	+5,862
• **RHIC Experimental Support**	
The increase in FY 2012 is needed to effectively support the requirements of the RHIC scientific research program consistent with the planned level of operations.	+1,553
Total, RHIC Operations	**+7,415**
▪ **Other Operations**	
A small increase over FY 2010 is provided to maintain a constant level of purchases for BNL lab-wide general purpose equipment.	+90
Total, Operations	**+7,505**
Total Funding Change, Heavy Ion Nuclear Physics	**+14,921**

Low Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Low Energy Nuclear Physics		
Research		
University Research	25,624	21,295
National Laboratory Research	40,458	39,711
Other Research[a]	585	2,452
Total, Research	66,667	63,458
Operations	37,549	33,078
Facility for Rare Isotope Beams	12,000	30,000
Total, Low Energy Nuclear Physics	116,216	126,536

Description

The research effort supported by the Low Energy Nuclear Physics subprogram focuses primarily on answering the overarching questions associated with the second and third frontiers identified by NSAC. Questions associated with the second frontier, Nuclei and Nuclear Astrophysics, include: What is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes? What is the origin of simple patterns in complex nuclei? What is the nature of neutron stars and dense nuclear matter? What is the origin of the elements in the cosmos? What are the nuclear reactions that drive stars and stellar explosions? Major goals of this subprogram are to develop a comprehensive description of nuclei across the entire nuclear chart, to utilize rare isotope beams to reveal new nuclear phenomena and structures unlike those gleaned from studies using stable nuclei, and to measure the cross sections of nuclear reactions that power stars and spectacular stellar explosions and are responsible for the synthesis of the elements.

The subprogram also investigates aspects of the third frontier, Fundamental Symmetries and Interactions, using neutrinos and neutrons as primary probes. Questions addressed in this frontier include: What is the nature of the neutrinos, what are their masses, and how have they shaped the evolution of the universe? Why is there now more visible matter than antimatter in the universe? What are the unseen forces that were present at the dawn of the universe but disappeared from view as the universe evolved? Neutrinos are now known to have small but non-zero masses. The subprogram seeks to measure or set a limit on the neutrino mass and to determine if the neutrino is its own anti-particle (a Majorana particle). These neutrino properties are believed to play a role in the evolution of the cosmos. Beams of cold and ultracold neutrons will be used for precision measurements of neutron lifetime and beta-decay parameters and to investigate the dominance of matter over antimatter in the universe in order to answer fundamental questions in nuclear and particle physics, astrophysics, and cosmology.

Funding supported both research and operations of the subprogram's two national user facilities, HRIBF and ATLAS, which serve an international community of approximately 700 users. The FY 2012 request

[a] In FY 2010, $1,426,000 was transferred to the SBIR program. This activity includes $1,528,000 for SBIR in FY FY 2012.

ceases operations of HRIBF as a national user facility in order to support higher priority activities within the Nuclear Physics program. Operations of ATLAS will continue to provide beams for nuclear structure and astrophysics studies and a strong training ground for the next generation Facility for Rare Isotope Beams (FRIB), which will be constructed at MSU. ATLAS possesses unique capabilities in an international context and has cutting edge instrumentation. With the commissioning of the Californium Rare Ion Breeder Upgrade (CARIBU) at ATLAS in FY 2011, the ATLAS research program will be optimized in FY 2012 to achieve the highest priority scientific goals for this field, and mitigate some of the impact of the reduced radioactive ion beam hours due to the cessation of operations at HRIBF.

Fabrication of the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA) MIE is on schedule for completion in FY 2011. GRETINA, a segmented germanium detector array with unparalleled position and energy resolution for nuclear structure studies with fast nuclear beams, will rotate to locations among the domestic low-energy facilities thereby increasing scientific productivity. NP also supports the LBNL 88-Inch Cyclotron for a small in-house nuclear physics and chemistry research program, while the National Reconnaissance Office (NRO) and U.S. Air Force (USAF) provide support towards improvements in radiation hardness of electronic circuit components against damage caused by cosmic rays. Support is terminated in FY 2012 for the Rare Isotope Beam Science Initiatives. A limited number of small research initiatives, selected by peer review, are being pursued in FY 2010.

In addition, the subprogram supports accelerator operations at two university Centers of Excellence including the Cyclotron Institute at Texas A&M University (TAMU), which will soon begin to provide a set of reaccelerated radioactive ion beams that are complementary to those available elsewhere in the U.S. The Cyclotron Institute receives significant additional funds from TAMU and private foundations in Texas. The subprogram also supports operations of the HIGS facility at the Triangle Universities Nuclear Laboratory (TUNL) at Duke University. At the University of Washington, the subprogram supports infrastructure to develop scientific instrumentation projects and to provide technical and engineering educational opportunities. These university Centers of Excellence each support 15–25 graduate students at different stages of their education. No funding is requested in FY 2012 for operations of the accelerator facility at Yale University; transition plans for the staff and facility are being developed.

Progress in both nuclear structure and nuclear astrophysics studies depends increasingly upon the availability of rare isotope beams. While ATLAS has capabilities for these studies, one of the highest priorities for the NP program is support of a facility with next-generation capabilities for short-lived radioactive beams. FRIB construction is supported with operating funding through a Cooperative Agreement with Michigan State University (MSU) and is following the management principles of DOE O 413.3B. While not a DOE capital asset (the facility will be owned by the university) it will be operated as a DOE national user facility upon completion. In FY 2012, engineering and design activities continue on FRIB and long-lead procurements that will reduce project risks are initiated. A phased construction start is also being considered in FY 2012 to reduce project risks.

In the area of neutrino physics, U.S. researchers are involved in several important efforts focused primarily on neutrino mass and whether the neutrino is its own anti-particle. The U.S. continues to participate in the fabrication of the Italian-led Cryogenic Underground Observatory for Rare Events (CUORE) experiment at the Gran Sasso Laboratory to search for evidence that the neutrino is its own antiparticle and measure or set a limit on the effective Majorana neutrino mass using the neutrinoless double beta decay (DBD) mechanism. Work will also continue in FY 2012 on the Majorana Demonstrator R&D effort to determine technical feasibility of using high purity, enriched germanium to explore the nature of the neutrino via DBD. Projects that study DBD with much increased sensitivity such as these will address two fundamental properties of the neutrino, the hierarchy of the masses and its particle-antiparticle nature, that are important for understanding the matter-antimatter asymmetry in the universe and the evolution of the cosmos. U.S. university scientists are also participating in the fabrication of the German-lead Karlsruhe Tritium Neutrino (KATRIN) experiment to determine the mass of the electron neutrino by measuring the beta decay spectrum of tritium.

The Low Energy subprogram supports studies of fundamental interactions and symmetries using neutrons or nuclei. Sensitive experiments are being prepared to be mounted at the Fundamental Neutron Physics Beamline (FNPB), which was completed in FY 2010 on cost and schedule at the Spallation Neutron Source. These include the neutron Electric Dipole Moment Experiment MIE currently being developed at Oak Ridge National Laboratory, which could shed light on why the universe is composed mostly of matter when the Big Bang Theory of cosmology suggests that the universe should contain equal amounts of matter and anti-matter. The NSAC has recently been charged to assess the national neutron physics program and provide guidance in terms of its optimization.

Finally, it is within the Low Energy subprogram, as well as the Theory subprogram, that the Applications for Nuclear Science and Technology initiative is supported. This effort, started in FY 2009 and augmented with Recovery Act funds, supports basic nuclear physics research that addresses high priority scientific goals and has practical applications to other fields, such as medicine, next-generation nuclear reactors, and homeland security.

The Low Energy subprogram is the most diverse within the NP portfolio, supporting research activities aligned with diverse scientific thrusts. It also currently supports the most instrumentation projects, as well as the Majorana Demonstrator R&D effort and the Cooperative Agreement to construct FRIB; most of these initiatives are international in nature and project profiles are optimized to take advantage of international commitments. The funding request in FY 2012 is driven by the FRIB profile, the funding profile for the Majorana Demonstrator R&D effort, and an investment to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided from the High Energy Physics program. Nuclear Physics will assess options for a future neutrinoless double beta decay experiment.

Selected FY 2010 Accomplishments

- An international team of scientists from Russia and the United States, including two DOE national laboratories and two universities, has discovered element-117, the newest super heavy element. Discovery of element-117 was accomplished following nearly three months of bombardment of a radioactive berkelium-249 target (produced at the High Flux Isotope Reactor at ORNL through the DOE Isotope Program) with intense beams of calcium-48 at the Joint Institute for Nuclear Research cyclotron in Dubna, Russia. This discovery represents the latest and the most challenging successful step in a decades-long journey to expand the periodic table.
- Tin-132, an unstable isotope, is one of the small and special group of nuclei with “magic” numbers of both protons and neutrons (magic numbers characterize shell structure of nuclei). In a recent experiment at HRIBF, researchers measured the properties of the single neutrons that were transferred from a deuterium target to a beam of radioactive tin-132 ions. The observed purity of the single-particle states provides evidence that tin-132 represents a text-book example of a doubly-magic nucleus. These results, reported in the journal *Nature*, are critical to benchmarking the nuclear shell model, to extrapolating theoretical nuclear models beyond the reach of current experimental facilities and to simulating the synthesis of nuclei heavier than iron in the cosmos.

- A new critical survey of the fastest known nuclear beta decays, which incorporates a substantial amount of new data as well as improved calculations of correction terms, places tighter constraints on models that aim at extending the Standard Model. These advances allow scientists to better understand the quark properties of nucleons.
- The new HELIcal Orbit Spectrometer (HELIOS) developed at the ATLAS Facility at ANL has recently been used to make the most precise measurements to date of the internal structure of two excited states of boron-13, an exotic nucleus containing an unusually high ratio of neutrons to protons. This study demonstrates that HELIOS can overcome the special challenges of studying reactions in inverse kinematics, where light target nuclei (e.g., deuterium) are bombarded by heavy exotic beams, in this case a boron-12 radioactive beam. The technique will play an essential role in investigations of the structural properties of the neutron-rich nuclei that will become available in abundance at the future FRIB facility.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	**66,667**	**63,458**
▪ **University Research**	**25,624**	**21,295**

Research aimed at addressing high priority scientific goals is supported for about 126 scientists and 98 graduate students at 35 universities. University research is held flat in FY 2012 and the Yale University accelerator facility is terminated, with the funds reallocated to other higher priorities within the NP program. About two-thirds of the supported university scientists have conducted nuclear structure and astrophysics research using specialized instrumentation at the ATLAS and HRIBF national user facilities. During FY 2012, university researchers who conducted research at HRIBF will complete analyses of data obtained in prior years, then will need to transition to other efforts.

Accelerator operations are supported primarily for in-house research programs at the Duke University and TAMU facilities. These Centers of Excellence have well-defined and unique physics programs, providing photons, neutrons, light or heavy ion beams, radioactive ion beams, specialized instrumentation, and opportunities for long-term measurements that complement the capabilities of the national laboratory user facilities; they also provide excellent training opportunities to junior scientists and engineers.

Funding in FY 2010 includes four university awards selected under the Rare Isotope Beam Science Initiatives to fabricate instrumentation creating forefront science opportunities at leading rare isotope beam facilities around the world. The initiative is terminated in FY 2012 to fund higher priority activities.

University scientists are supported to play key roles in the development of experiments using cold neutrons at the SNS FNPB, an experimental program which is being launched in FY 2011. The FY 2012 request also includes support for the international KATRIN project which is led by a university group.

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
▪ **National Laboratory Research**	**40,458**	**39,711**

Support is provided for the research programs at six national laboratories (ANL, BNL, LBNL, LANL, LLNL, and ORNL). Scientists at these laboratories continue to develop and implement new instrumentation; provide maintenance and infrastructure support of the ATLAS, and perform analysis on HRIBF data in FY 2012; effectively utilize beam time for research; train junior scientists; develop and utilize non-accelerator experiments; and support the development and fabrication of FRIB. Funding decisions are influenced by the results of peer reviews of the national laboratory research groups and their subsequent ranking in terms of performance level.

• **National Laboratory User Facility Research**	**9,136**	**9,136**

Questions fundamental to the understanding of stellar nucleosynthesis—how the elements are manufactured in stars—require accelerators with low energy capabilities. Because many nuclear reactions that take place in stars are at very low energies, an accelerator capable of producing stable low energy beams is a requirement. Funding is provided for ANL researchers for nuclear structure studies using stable and selected radioactive beams from ATLAS coupled to specialized instrumentation. Modest capital equipment investments support the fabrication and implementation of small-scale detectors at the facility. The most recent addition to the unique instrumentation at ATLAS is the HELIOS, a novel superconducting solenoidal spectrometer that probes the structure of exotic nuclei.

Because stars generate heavier elements from lighter ones in a process that takes place in their cores, or through stellar explosions, many of the intermediate nuclei that are produced are short-lived and very unstable. To study them requires accelerators capable of producing beams composed of radioactive ions. The CARIBU source at ATLAS provides limited capabilities to produce radioactive ion beams, while FRIB will be the world-leading facility for rare ion beams when operational. In FY 2012, with the cessation of operations at HRIBF as a national user facility, ORNL researchers will be completing analyses of data obtained from HRIBF in prior years.

• **Other National Laboratory Research**	**31,322**	**30,575**

Scientists at BNL, LBNL, LLNL, LANL, and ORNL play lead roles in several ongoing accelerator- and non-accelerator-based projects (nEDM, CUORE, GRETINA, FNPB instrumentation, and KamLAND). Both nEDM and CUORE are joint DOE/NSF-supported projects, but are managed by DOE-supported scientists. In addition, DOE-supported scientists have the lead role in the R&D to demonstrate a proof of principle for a neutrino-less double beta decay experiment with germanium detectors, the Majorana Demonstrator. The total project cost of the Majorana R&D effort over four years (FY 2010- FY 2013) is approximately $20,000,000. Researchers are also supported to develop and implement neutron science experiments at the newly completed Fundamental Neutron Physics Beamline at the Spallation Neutron Source and to contribute to FRIB project development efforts. Funding in FY 2012 is increased for the Majorana Demonstrator R&D effort and for transitioning to operations of new MIE instrumentation projects as they come on-line or near completion, including, GRETINA and experiments at the FNPB. The profile for the Majorana R&D supports decision points aligned

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

with international efforts to make a technology choice and merge international collaborations for the most cost-effective approach to a future large-scale detector.

In addition, support is provided for ORNL to continue to play a leadership role in the development of the scientific and experimental program with neutrons at the FNPB to exploit new capabilities recently made available, which will deliver cold and ultra-cold neutrons at the highest intensities in the world for studying the fundamental properties of the neutron, leading to a refined characterization of the weak force.

Research efforts relevant to Applications of Nuclear Science and Technology continue in FY 2012. This initiative is competed among university and laboratory researchers and supports nuclear science research that is inherently relevant to a broad range of applications. Additional funds for this initiative are included in the Theory subprogram under Nuclear Data.

In FY 2012, funding for a number of the instrumentation MIEs supported within this activity decreases:

- ▸ Planned funding is reduced for the neutron Electric Dipole Moment (nEDM) MIE, an R&D intensive and technically challenging discovery experiment that is planned at the FNPB. The nEDM experiment is a joint DOE/NSF experiment to measure or set a limit on the electric dipole moment of the neutron, which could significantly constrain extensions of the Standard Model. R&D will continue in FY 2012 while NSAC reviews priorities in the U.S. neutron science portfolio.
- ▸ Funding is terminated for Rare Isotope Beam Science Initiatives in order to support other higher priority needs of the NP program. A limited number of the smaller initiatives, selected by peer review, are being supported in FY 2010 and FY 2011 (some of the funding was awarded under University Research above). The larger MIEs planned for initiation will no longer be pursued. These projects were intended to foster international collaboration in rare isotope science and provide opportunities to the domestic rare isotope beam science community as FRIB is being constructed.
- ▸ FY 2012 is the final year of funding for fabrication of the international CUORE experiment to search for neutrino-less double beta decay (DBD) of tellurium-130 isotope. This is a joint DOE/NSF project.

▪ **Other Research**	**585**	**2,452**

In FY 2010, $1,426,000 was transferred to the SBIR program. This activity includes $1,528,000 for SBIR in FY 2012. Funding is also provided for other established obligations including the Lawrence and Fermi Awards, which provide annual monetary awards to honorees selected by DOE for outstanding contributions to science. Starting in FY 2012, Lawrence Awards and Fermi Awards will be made each year; in the past, the awards were provided in alternating years.

Operations	**37,549**	**33,078**
▪ **ATLAS Operations**	**16,216**	**16,762**

The ATLAS Facility is the premiere stable beam facility in the world. ATLAS accelerator operations and experimental support provide for 5,900 beam hours of operation and continued cost-effective

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

7 day-a-week operations in FY 2012. The modest increase in funding in FY 2012 maintains level of effort support for scientific and technical personnel and required materials and supplies to operate the facility. The Californium Rare Ion Breeder Upgrade (CARIBU) accelerator improvement project will be completed in FY 2011, and will enhance the radioactive beam capabilities and productivity of ATLAS. Accelerator improvement projects in FY 2012 are focused on increasing the reliability and efficiency of operations. Modest capital equipment funding is provided for helium compressors and cryogenic system upgrades to improve operations. The ATLAS facility nurtures a core competency in accelerator expertise with superconducting radio frequency cavities for heavy ions that is relevant to the next generation of high-performance proton and heavy-ion linacs, and is important to the Office of Science mission and international stable and radioactive ion beam facilities. ANL accelerator physicists and scientists are working closely with MSU researchers in the development and fabrication of components for FRIB.

	FY 2010	FY 2012
ATLAS Hours of Operation with Beam		
Achieved Operating Hours	5,940	N/A
Planned Operating Hours	5,900	5,900
Optimal Hours	6,600	6,200[a]
Percent of Optimal Hours	90%	95%
Unscheduled Downtime	8%	N/A
Number of Users	410	430

- **HRIBF Operations** **17,080** **6,821**

Operation of HRIBF through FY 2011 provides unique capabilities for the production of intense radioactive beams by the Isotope-Separator-On-Line (ISOL) technique, and for reaccelerating medium mass nuclei to the Coulomb barrier. Core competencies developed through this research include high power target design and ISOL ion beam production techniques which will have importance for the future Facility for Rare Isotope Beams and other rare isotope beam facilities. HRIBF accelerator operations cease in FY 2012, and funding is provided for an orderly ramp down of the facility. Assessments are ongoing as to whether it may be possible to complete high priority experiments in FY 2012.

[a] Based on the most recent review of operations at ATLAS, the quality and quantity of the scientific output is best optimized with 6,200 operating hours.

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

	FY 2010	FY 2012
HRIBF Hours of Operation with Beam		
Achieved Operating Hours	5,270	N/A
Planned Operating Hours	5,200	0
Optimal Hours	6,100	0
Percent of Optimal Hours	86%	0%
Unscheduled Downtime	13%	N/A
Number of Users	260	0

- **Other Operations** **4,253** **9,495**

  The NRO and USAF will continue to jointly provide support for the 88-Inch Cyclotron for approximately 2,000 hours for their electronics testing program, and NP continues support in FY 2012 for approximately 3,000 hours for the in-house nuclear physics research program at LBNL consistent with the Interagency Agreement with NRO and USAF. Funding is also provided for maintenance of the Oak Ridge Electron Accelerator (ORELA).

  In FY 2012, $5,000,000 is provided to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided from the High Energy Physics program. Nuclear Physics will assess options for a future neutrinoless double beta decay experiment.

Facility for Rare Isotope Beams **12,000** **30,000**

Funds are requested in FY 2012 to continue engineering and design efforts aimed at developing FRIB, and pursue long-lead procurements and possibly a phased construction start that will reduce project risks. MSU is undertaking a comprehensive R&D plan for FRIB, which includes utilizing core competencies developed by the NP-supported national laboratory groups. This facility will enable world-leading research opportunities in nuclear structure, nuclear astrophysics, and fundamental symmetry studies, and complement other rare isotope beam research programs at facilities elsewhere in the world. The FY 2012 funding supports the project profile as agreed upon between MSU and DOE (for additional details, see the Supporting Information section at the end of the NP budget).

Total, Low Energy Nuclear Physics **116,216** **126,536**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **University Research**	
The major funding decreases relative to FY 2010 are: the termination of university Rare Isotope Beam initiatives in FY 2012; funding that was awarded to universities under Applications of Nuclear Science and Technology in FY 2010 but is held under Other National Laboratory Research in FY 2012 pending competitive peer review; and the end of operations of the accelerator facility at Yale University. The decreases are partially offset by increases for costs associated with operating the CUORE-0 tower and operational costs for the recently upgraded accelerator at Texas A&M University and the KATRIN experiment.	-4,329
▪ **National Laboratory Research**	
• **Other National Laboratory Research**	
The major funding decreases relative to FY 2010 are termination of Rare Isotope Beam Science Initiatives, which provided awards under this activity in FY 2010; planned project profiles for CUORE, which receives its last year of funding FY 2012, and GRETINA, which received its last year of funding in FY 2010; and a decrease in the profile for the nEDM MIE, which is less than originally planned. nEDM is slowed as funds are redirected to higher priority activities. The decreases are partially offset by increases for the Majorana Demonstrator R&D project which ramps to its planned peak funding year in FY 2012 to enable a technology choice with international collaborators; the development of experiments for the new neutron science program at the FNPB to exploit new capabilities recently made available with the completion of the FNPB MIE; operations of the GRETINA MIE, which will just be transitioning to operations in FY 2012; and the development of the double beta decay scientific effort which implements the Majorana R&D program.	-747
▪ **Other Research**	
• **SBIR and Other**	
Funding increases relative to FY 2010 because the mandated SBIR set-aside has been transferred out of the program in FY 2010 while those funds are included in the FY 2012 request. In addition, funding is increased to support annual Fermi and Lawrence awards.	+1,867
Total, Research	**-3,209**

	FY 2012 vs. FY 2010 Current Approp. ($000)
Operations	
▪ **ATLAS Operations**	
ATLAS Operations funding reflects an increase to maintain staff and effectively operate this national user facility.	+546
▪ **HRIBF Operations**	
HRIBF operations funding is reduced and the facility is closed as a national user facility in FY 2012.	-10,259
▪ **Other Operations**	
The majority of the increase is provided to support minimal, sustaining operations for one year at the Homestake mine in South Dakota. Additional funds are provided from the High Energy Physics program. Nuclear Physics will assess options for a future neutrinoless double beta decay experiment.	
A modest increase in funding is also provided to maintain operations at the 88-Inch Cyclotron consistent with the Interagency Agreement with the NRO and USAF.	+5,242
Total, Operations	**-4,471**
Facility for Rare Isotope Beams	
Funding for the Facility for Rare Isotope Beams increases to continue engineering and design work, and pursue long-lead procurements and possibly a phased construction start.	+18,000
Total Funding Change, Low Energy Nuclear Physics	**+10,320**

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Nuclear Theory		
Theory Research		
University Research	15,723	16,593
National Laboratory Research	14,611	16,181
Scientific Discovery through Advanced Computing (SciDAC)	2,689	1,000
Total, Theory Research	33,023	33,774
Nuclear Data Activities	6,929	8,392
Total, Nuclear Theory	39,952	42,166

Description

The Nuclear Theory subprogram supports theoretical research at universities and DOE national laboratories with the goal of improving fundamental understanding of nuclear physics, interpreting the results of experiments carried out under the auspices of the experimental nuclear physics program, and identifying and exploring important new areas of research.

This subprogram addresses all three of nuclear physics' scientific frontiers. A major theme of this subprogram is an understanding of the mechanisms and effects of quark confinement and de-confinement. A quantitative description of these phenomena starting from the fundamental theory of QCD remains one of this subprogram's great intellectual challenges. New theoretical and computational tools are being developed to describe nuclear many-body phenomena, which will likely have important applications in condensed matter physics and in other areas of the physical sciences. Another major research area is nuclear astrophysics, which includes efforts to understand the origins of the elements (as in supernovae) and the consequences that neutrino masses have for nuclear astrophysics and for the current theory of elementary particles and forces.

One area of nuclear theory that has a particularly pressing demand for large dedicated computational resources is that of lattice quantum chromodynamics (LQCD). LQCD calculations are critical for understanding many of the experimental results from RHIC and CEBAF that involve the strong interaction between quarks and gluons. This subprogram provides researchers with access to powerful supercomputers for these studies, such as the high-performance computational facility at the National Energy Research Scientific Computing Center (NERSC) at LBNL, as well as specialized computers at other institutions. The Nuclear Theory subprogram and the High Energy Physics (HEP) Theory subprogram began joint development in FY 2006 of large-scale facilities to provide computing capabilities based on community cluster systems. This LQCD initiative was followed by the joint 5-year HEP/NP LQCD-ext project in FY 2010. The NP LQCD computing capability at TJNAF was also augmented with Recovery Act funding In FY 2011, this computing equipment will have increased the overall U.S. computing capability for LQCD to a minimum of 45 sustained teraflops.

The Nuclear Theory subprogram also sponsors the Institute for Nuclear Theory (INT) at the University of Washington, which carries out a range of activities in support of the work of the nuclear physics community. INT includes visiting scientists, research fellows, postdoctoral fellows, graduate students, and several leading nuclear theorists as permanent staff; its organizational structure promotes cost effective collaboration and educational opportunities. INT also hosts a series of specialized research programs on specific topics in nuclear theory and related fields that are identified by the research community as being of high priority. The Nuclear Theory subprogram also supports targeted investments in short-term topical theory collaborations within the university and national laboratory communities to facilitate cooperation and communication on specialized nuclear theory challenges that require concerted effort in order to advance the field.

Another component of the Nuclear Theory subprogram is the National Nuclear Data program, which compiles, evaluates, and disseminates nuclear data for basic research and applications in an online database that is readily accessible and user oriented.

The Nuclear Theory subprogram is strengthened by its interactions with complementary programs overseas, NSF-supported theory efforts, the HEP program, Japanese-supported theoretical efforts related to RHIC at the RIKEN Center at BNL, and the Japan-U.S. and France-U.S. Theory Institutes for Physics with Exotic Nuclei (JUSTIPEN and FUSTIPEN).

In FY 2012, the Nuclear Theory subprogram will continue to support research that addresses the three scientific frontiers of nuclear physics, i.e. QCD, nuclear structure and astrophysics, and fundamental symmetries. The need for increased support for nuclear theory in order to accurately interpret the collected experimental results throughout the NP program has been recognized consistently in NSAC Long Range Plans (LRP) over the years. The 2002 LRP recommended that funding for nuclear theory be significantly increased because it is essential for developing the full potential of the scientific program. The 2007 LRP recommended topical collaborations in theory to launch focused efforts on particular challenges, which NP has implemented in FY 2010 with 5-year awards, funded annually, for three collaborations. These modest topical theory collaborations bring together theorists nationwide to more effectively address theoretical challenges—the peak activity of these small groups is reached in FY 2012. The focus of FY 2012 nuclear theory research will be on providing the necessary theoretical preparation for the upgraded CEBAF 12 GeV and new FRIB facilities under construction in order to fully exploit them, and will advance new ideas and hypotheses that stimulate specific experiments at these facilities and elsewhere, including in the area of fundamental symmetries. The FY 2012 NP request continues support of SciDAC, though at a reduced level, and provides a modest increase for the second-generation LQCD project in partnership with the DOE High Energy Physics program, according to project plans.

Selected FY 2010 Accomplishments

- LQCD calculations continue to bring exciting physics results and computational advances. The Hadron Spectrum Collaboration provided new physics insight into how quarks are bound in mesons and hadrons through the calculation of the masses of states with exotic quantum numbers from dynamic LQCD. The quantum numbers of exotic meson states cannot be constructed from the conventional excitations of a bound quark-anti-quark pair, and the existence of these states may signal the explicit influence of the gluons that bind quarks together.
- In a recent computational advance, attained in the framework of the national USQCD collaboration and the SciDAC funded software infrastructure project for Lattice Field Theory, parallelization onto multiple graphical processing units enabled the analysis of large space-time lattices at a performance of over 3 teraflops, an order of magnitude increase in speed in critically important calculations. This was made possible by a project funded under the Recovery Act.

- Starting from the interaction between nucleons, ab initio no-core, full-configuration shell model calculations of nuclear structure and excitations were extended to such systems as the speculative proton-rich fluorine-14 nucleus, the existence of which is being sought experimentally. Such calculations provide important guidance for DOE-supported experiments, test the theory of strong interactions, and may be important for improved energy sources.
- An aspect of the fundamental problem of the origin of baryonic matter of the Universe was addressed in the context of the Minimal Supersymmetric Standard Model (MSSM) by exploring the implications of electroweak baryogenesis for future searches for permanent electric dipole moments (EDMs). This required the derivation and solution of a large set of coupled quantum Boltzmann equations to follow the appropriate chain of particle number changing reactions. The main result is that lower limits on the size of the EDMs are derived, typically of the same order (or above) as the expected sensitivity of proposed experimental searches. Thus, such experiments may be able to provide a test of MSSM electroweak baryogenesis.
- Theorists explored charge fluctuations associated with the spontaneous generation of domains filled with color electric and color magnetic fields in a new form of matter discovered at RHIC. Results from collisions of heavy ions that exhibit this phenomenon indicate the matter which is formed has unique characteristics which can advance knowledge of the fundamental symmetries of nature and universal properties of physical systems (for example collections of excited atoms) in which the constituents interact strongly with one another. In addition, similarities in the interaction between the constituents of the matter discovered at RHIC and the interaction between the constituents of some nano-materials (for example single layers of graphite, known as graphene) are being studied for possible analogy and insight into the use of graphene as a conductor of spin-polarized electric current. A press release on these results at the 2010 American Physical Society April meeting garnered worldwide interest with over 300 news articles in the popular media.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Theory Research	**33,023**	**33,774**
▪ **University Research**	**15,723**	**16,593**

The University Research activity supports the research of approximately 160 academic scientists and 120 graduate students through 76 research grants at 45 universities in 29 states and the District of Columbia. The overall nuclear theory effort is aligned with the experimental program through the program performance milestones established by NSAC.

Funding in FY 2012 will support the necessary level of theoretical effort needed for interpretation of experimental results obtained at the NP facilities and the training of next-generation nuclear theorists. The third year of funding is provided for the topical theory collaborations at the universities which received 5-year awards in FY 2010.

▪ **National Laboratory Research**	**14,611**	**16,181**

Research programs in nuclear theory are supported at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF) to achieve high priority scientific goals and interpret experimental results. The theoretical research at a given laboratory is primarily aligned to the experimental program at that laboratory, or in some cases to take advantage of the unique facilities

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

or programs at that laboratory. In FY 2012, investments in LQCD computer capabilities are increased in a joint effort with High Energy Physics, LQCD-ext, and support is provided to build the theoretical research groups in preparation for Hall D operations at TJNAF. Starting in FY 2010, this budget category includes support for topical theory collaborations at the National Laboratories which received 5-year awards in FY 2010 after a peer-reviewed competition between groups formed by university-laboratory partnerships. Funding for university collaborators is shown in University Research, above. The funded topical collaborations address QCD in the heavy-ion environment (JET); neutrinos and nucleosynthesis in hot and dense matter (NuN); and low-energy nuclear reactions for unstable isotopes (TORUS).

In FY 2009, the base programs of the seven laboratory theory groups were evaluated on the significance of their accomplishments and planned future program; scientific leadership, creativity, and productivity of the personnel; and the overall cost-effectiveness of the group, and the results of this review are reflected in this budget request.

▪ **Scientific Discovery through Advanced Computing (SciDAC)**	**2,689**	**1,000**

SciDAC, a collaborative program that partners scientists and computer experts in research teams to address major scientific challenges that require supercomputer facilities at the current technological limits, is supported at a reduced level in FY 2012. The NP SciDAC program supports jointly funded research projects with other offices in areas such as nuclear astrophysics, grid computing, lattice quantum chromodynamics, low energy nuclear structure and nuclear reaction theory, and advanced accelerator design.

Nuclear Data Activities	**6,929**	**8,392**

This effort involves the work of several national laboratories and universities and is guided by the DOE-managed National Nuclear Data Center (NNDC) at BNL. The NNDC relies on the U.S. Nuclear Data Network, a group of DOE-supported individual nuclear data professionals located in universities and national laboratories that perform assessment, and validate and estimate uncertainty, as well as developing modern network dissemination capabilities. The databases developed and maintained by the Nuclear Data program cover over 100 years of nuclear science research. The NNDC participates in the International Data Committee of the International Atomic Energy Agency and is an important national and international resource.

Independent of the core Nuclear Data activities, funding is also included to support initiatives in Applications of Nuclear Science and Technology, including efforts relevant to nuclear fuel cycles. This initiative is funded from both the Low Energy subprogram and the Nuclear Data program, and funding is split between the two pending competitive peer review and award. In FY 2010, one laboratory award was made in the area of Nuclear Data for cross section measurement and evaluation for nuclear applications. The balance of the university and laboratory funding was awarded under the Low Energy subprogram.

Total, Nuclear Theory	**39,952**	**42,166**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Theory Research	
▪ **University Research**	
The increase in FY 2012 maintains university nuclear theory efforts, provides support for groups preparing for Hall D at CEBAF, and provides for the third year of the university component of topical theory collaborations.	+870
▪ **National Laboratory Research**	
The FY 2012 funding provides a planned increase in support of the LQCD initiative, LQCD-ext, which is jointly funded with HEP, and builds the theoretical research efforts in preparation of the Hall D experimental program at CEBAF. Funding is also provided for the third year of the national laboratory component of the topical theory collaborations.	+1,570
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	
NP's support of SciDAC is reduced in FY 2012 in order to reallocate funds to higher priority NP activities.	-1,689
Total, Theory Research	**+751**
• **Nuclear Data Activities**	
Increased funding relative to FY 2010 is almost entirely due to the funds in the Nuclear Data subprogram that will support new Applications of Nuclear Science and Technology awards in FY 2012 pending competitive peer review. The combined funding for these awards in Nuclear Data and Low Energy is slightly below FY 2010.	+1,463
Total Funding Change, Nuclear Theory	**+2,214**

Isotope Development and Production for Research and Applications

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Isotope Development and Production for Research and Applications		
Research		
National Laboratory Research	650	2,594
University Research	2,350	1,648
Other Research[a]	0	97
Total, Research	3,000	4,339
Operations		
University Operations	250	208
Isotope Production Facility Operations	1,068	1,072
Brookhaven Linac Isotope Producer Operations	500	536
National Isotope Development Center (NIDC)	1,915	2,227
Other National Laboratory Operations	12,383	11,852
Total, Operations	16,116	15,895
Total, Isotope Development and Production for Research and Applications	19,116	20,234

Description

The primary goal of this subprogram is to support research, development, and production of research and commercial isotopes that are of critical importance to the Nation and in short supply. To achieve this goal, the Isotope Development and Production for Research and Applications subprogram provides facilities and capabilities for the production of research and commercial stable and radioactive isotopes, scientific and technical staff associated with general isotope research and production, and a supply of critical isotopes to address the needs of the Nation. The immediate benefits of a viable isotope production component of the Isotope Development and Production for Research and Applications subprogram include the availability of research and commercial isotopes that otherwise would not have been possible, reduced dependence on foreign supplies, new scientific applications for isotopes not currently supplied, the development of more effective isotope production and processing techniques, and the ability to meet both present and future research needs for isotopes. The subprogram places an emphasis on the R&D efforts associated with developing new and more cost-effective and efficient production and processing techniques, and on the production of isotopes needed for research purposes.

Stable and radioactive isotopes play a crucial role in basic research, medicine, industry, and homeland defense and are vital to the mission of many Federal agencies. Federal agencies utilizing isotopes produced by the program include the National Institutes of Health and their grantees, the National Institute of Standards and Technology, the Environmental Protection Agency, the Department of

[a] In FY 2010, $75,000 was transferred to the SBIR program and $9,000 was transferred for the STTR program. This activity includes FY $86,000 for SBIR and $11,000 for STTR in FY 2012.

Agriculture, the Department of Homeland Security, other Federal agencies, the National Nuclear Security Administration (NNSA), and other Office of Science programs.

Isotopes are used to improve the accuracy and effectiveness of medical diagnoses and therapy, enhance national security, improve the efficiency of industrial processes, and provide precise measurement and investigative tools for materials, biomedical, environmental, archeological, and other research. Some examples are: strontium-82 use for heart imaging; germanium-68 use for calibrating the growing numbers of imaging scanners; arsenic-73 use as a tracer for environmental research; silicon-32 use in oceanographic studies related to climate modeling; and nickel-63 use as a component in gas sensing devices or helium-3 as a component in neutron detectors, both for applications in homeland defense. Some isotopes are critical resources to very diverse operations in industry and science and have a profound impact on the Nation's economy and national security. Californium-252, for example, is used in a wide array of applications for medicine, homeland defense, and energy security. The consequences of shortages of radioactive and stable isotopes needed for research, medicine, homeland security, and industrial applications can be extremely serious, including decreased capacity to perform routine diagnostic medical procedures and treatments and the failure to detect terrorist threats.

Isotopes are primarily generated using the Brookhaven Linac Isotope Producer (BLIP) at BNL and the Isotope Production Facility (IPF) at LANL for which the subprogram has stewardship responsibilities. Hot cell facilities at Brookhaven, Oak Ridge, and Los Alamos National Laboratories are used and maintained for processing and handling irradiated materials and purified products. Facilities at other national laboratories are used as needed, such as the production of isotopes at Oak Ridge and Idaho National Laboratory reactors and processing and packaging strontium-90 from the Pacific Northwest National Laboratory. Over 50 researchers and staff at the national laboratories are supported to provide the technical expertise in research, development, and transportation of isotopes. Research and development includes target fabrication, enhanced processing techniques, radiochemistry, material conversions, and other related services.

The Nuclear Science Advisory Committee (NSAC) was charged in August 2008 to develop a prioritized list of research topics using isotopes, and to develop a long-range strategic plan for stable and radioactive isotope production. The first NSAC report, released in April 2009, includes federal, commercial, and community input and establishes priorities for the production of research isotopes. Following release of the report, NP issued a broad call to university, laboratory, and commercial facilities, inviting them to submit proposals describing their capabilities for producing these high priority research isotopes. These proposals were reviewed and selections were made based on cost and products in short supply; the result is that the Isotope Program is establishing new production capabilities at other laboratory sites and university facilities to optimize its ability to supply reliable sources of research isotopes at more affordable prices. An announcement through the National Isotope Development Center is now planned to notify the broad research community of the isotopes that can be produced at the increased suite of facilities and to solicit interest in the demand for these isotopes so that production schedules can be developed and coordinated. The second NSAC report on a long-range strategic plan was released in November 2009.[a]

NP continues to work in close collaboration with other federal agencies to develop strategic plans for isotope production. A goal of the program is to establish effective communication with federal agencies to better forecast isotope needs and leverage resources. For example, NP continues to work with the National Institutes of Health (NIH) on a federal working group NP assembled to address the

[a] http://www.sc.doe.gov/np/nsac/nsac.html

recommendations of the recent National Academies report, *Advancing Nuclear Medicine through Innovation*, which identified several areas in isotope production warranting attention. A five-year production strategy has been generated which identifies the isotopes and projected quantities needed by the medical community in the context of the Isotope Program capabilities. While the Isotope Program is not responsible for the production of molybedenum-99 (Mo-99), it recognizes the importance of this isotope for the Nation and is working closely with NNSA, the lead entity responsible for domestic Mo-99 production, by participating in the OSTP working group and offering technical and management support. SC is also participating in the international High-Level Group on the Security of Supply of Medical Isotopes lead by the Organisation for Economic Co-operation and Development (OECD) on Radioisotopes.

NP has also facilitated the formation of a federal working group on the He-3 supply issue involving staff from NP, NNSA, the Department of Homeland Security, and the Department of Defense. The Isotope Program's role in helium-3 (He-3) is limited to packaging and distribution of the isotope. However, the objective of this working group is to ensure that the limited supply of He-3 will be distributed to the highest priority applications and basic research.

The program is extending its community outreach with the creation of the National Isotope Development Center. The program will be organizing its first annual meeting of federal stakeholders in FY 2011 to discuss isotope needs and strategic planning.

The Isotope Development and Production for Research and Applications subprogram, which operates under a revolving fund as established by the FY 1990 Energy and Water Development Appropriations Act (Public Law 101–101) as modified by Public Law 103–316, maintains its financial viability by utilizing a combination of Congressional appropriations and revenues from the sale of isotopes and services. These resources are used to maintain the staff, facilities, and capabilities at user-ready levels and to support peer-reviewed research and development activities related to the production of isotopes. Commercial isotopes are priced at full cost. Research isotopes are priced at lower rates to allow scientific advances and are sold at a unit price, as opposed to a batch price. Investments in new capabilities are made to meet the growing demands of the Nation and foster research in the applications that will support the health and welfare of the public.

In FY 2012, efforts continue on supporting and organizing a stable and efficient workforce for the production of isotopes and R&D efforts. The suite of isotope production facilities is increasing to include other capabilities at national laboratories and university accelerator and reactor facilities which can provide cost-effective and unique capabilities; these include the Washington University, the University of California at Davis, and the Missouri University Research Reactor. Partnerships with industrial counterparts are pursued to leverage resources.

Selected FY 2010 Accomplishments

- Silicon-32 is a long-lived radioisotope with significant application in oceanographic research associated with the biogeochemical silicon cycle. The research supplies data important to climate modeling. The production of this isotope ended when the capability to do high energy proton spallation production was halted at Los Alamos in the mid-1990s. A collaborative project with the TRIUMF irradiation facility in Canada has been implemented to once again produce and supply this important research radionuclide. The target material for producing the isotope is being irradiated in the 500 MeV facility at TRIUMF, and will then be transported to the processing facility at Los Alamos where the silicon-32 will be recovered and purified using patented technology developed at Los Alamos. Silicon-32 from this process should be available by mid-calendar year 2011.

- Alpha emitting isotopes have shown strong potential in medical cancer therapy research. However, the current supply of alpha emitting isotopes is limited. Several R&D projects were initiated in 2010 to increase the supply. LANL scientists are exploring the accelerator production of actinium-225 from a thorium-232 target at LANL's Isotope Production Facility (IPF) at 100 MeV and the Brookhaven Linac Isotope Producer at 200 MeV. ORNL scientists are studying the accelerator production of thorium-229, a long half-life radioisotope that can be used as a source of actinium-225, one of its radioactive decay products. Both ORNL and PNNL are recovering and purifying actinium-227 from surplus actinium-beryllium neutron sources. The actinium-227 can be used as a source for the decay production of very high purity thorium-227 and radium-223, another medically important alpha-emitting isotope.
- Researchers at Oak Ridge National Laboratory completed the engineering design and begun procurement of components for the fabrication of a state-of-the-art research-scale prototype electromagnetic separator for stable isotope enrichment. This separator will use modern ion source and collector technologies that could lead to production scale separators for efficient, cost effective production of a portfolio of enriched essential enriched isotopes.
- Stable isotopes were purchased from Russian production facilities to partially replenish the Isotope Program inventory for both research and commercial applications. For example the stable isotope nickel-62 is used as target material for nickel-63. Nickel-63 is a reactor-produced isotope and is used for detection of explosives and as a power source for remote instrumentation. The stable isotopes acquired will help fill a gap in the existing stable isotope inventory, especially for research applications utilizing these isotopes.

Detailed Justification

(dollars in thousands)

	FY 2010 Current Appropriation	FY 2012 Request
Research	**3,000**	**4,339**

Research is supported to identify, design, and optimize production targets and separation methods. Examples for planned research include the need for positron-emitting radionuclides to support the rapidly growing area of medical imaging using PET, the development of isotopes that support medical research to be used to diagnose and treat diseases spread through acts of bioterrorism, the development of production methods for alpha-emitting radionuclides that exhibit great potential in disease treatment, the development and use of research isotopes for various biomedical applications, the development of stable isotope enrichment technologies, and the need for alternative isotope supplies for national security applications and advanced power sources. Priorities in research isotope production are informed by guidance from NSAC. All R&D activities are peer reviewed. Starting in FY 2012 funding reflects a redistribution of funds from Operations to Research efforts at the National Laboratories to more accurately capture the nature of the activities.

▪ **National Laboratory Research**	**650**	**2,594**

Support is provided for scientists at BNL, LANL, ORNL, INL, PNNL, and ANL to perform peer-reviewed experimental research on targets, separation technology maturation and development of isotope production techniques, and for the production of research isotopes at more affordable rates to the researcher. R&D activities also utilize the reactors at INL and ORNL and the accelerators at

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

LANL and BNL. Researchers provide unique expertise and facilities for data analysis. Funding reflects estimated amounts for the selection of national laboratory proposals following peer review, as well as the staff at the laboratories devoted to isotope R&D activities.

▪ **University Research**	**2,350**	**1,648**

Support is provided for scientists at universities and with industry to perform peer-reviewed experimental research on targets, separation technology maturation and development of isotope production techniques, and for the production of research isotopes at more affordable rates. Funding reflects estimated amounts for the selection of university and industry proposals.

▪ **Other Research**	**0**	**97**

In FY 2010, $75,000 was transferred to the Small Business Innovation Research (SBIR) program and $9,000 was transferred to the Small Business Technology Transfer (STTR) program. This activity includes $86,000 for SBIR and $11,000 for STTR in FY 2012.

Operations	**16,116**	**15,895**

Operations funding is provided to support the core facility scientists and engineers needed to effectively operate the Isotope Development and Production for Research and Applications facilities, and includes facility maintenance and investments in new facility capabilities. Starting in FY 2012, funding reflects a redistribution of some activities previously categorized as Operations at the National Laboratories to National Laboratory Research, as well as some internal realignments within Operations.

▪ **University Operations**	**250**	**208**

Funding is provided to academic institutions with reactors and cyclotrons for providing capabilities in the production and processing of isotopes to complement or increase the subprogram's isotope portfolio. Research isotope production at universities and national laboratories is supported under the research category above. Funding is reduced in FY 2012 as efforts with universities are also funded under Research and through collaborative work with the national laboratories.

▪ **Isotope Production Facility (IPF) Operations**	**1,068**	**1,072**

The IPF operates in a parallel-mode with the Los Alamos Neutron Science Center (LANSCE) operations of about 22 weeks in FY 2012 and is completely dependent upon the operations of LANSCE. The IPF produces isotopes such as germanium-68, strontium-82, and arsenic-73. Support is provided for the operation, maintenance, and improvement of the IPF, including radiological monitoring, facility inspections, and records management. FY 2012 funding maintains a constant effort, and reflects a realignment of some activities to Research.

Recent major isotope processing equipment purchases at LANL will greatly enhance accelerator-based isotope production. The LANL Hot Cell Chemical Processing Facility is in the midst of multiple facility upgrades including projects to refurbish hot cell windows, replace aging manipulators, upgrade a critical control panel, improve facility ventilation, replace critical cranes, and upgrade the facility train system. The LANL IPF is in the final stages of replacing the beam window that defines the boundary between the vacuum and the facility target cooling water system. Notably the demand for strontium-82 and germanium-68, used in the clinical imaging modality of

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

positron emission tomography, has grown dramatically. NP is a primary supplier of both of these nuclides, and with the investments in upgrades in processing capability, NP has been able to reliably meet the increased demand.

▪ **Brookhaven Linac Isotope Producer (BLIP) Operations**	**500**	**536**

BLIP operates in parallel mode with the RHIC operating schedule and additionally in dedicated mode to meet customer needs. BLIP produces isotopes such as copper-67, germanium-68, and strontium-82. Support is provided in FY 2012 for the operation, maintenance, and improvement of BLIP, including radiological monitoring, facility inspections, and records management.

Recent major isotope processing equipment purchases at BNL will greatly enhance accelerator-based isotope production. BNL facility projects include purchase and installation of a portal contamination monitor, germanium gamma ray spectrometer, and a lifting device to assist with the manipulator replacement. This equipment will enhance isotope production and processing capabilities and ensure reliable operation of facilities to enable the program to better meet the need for isotopes in short supply. These investments have increased the capacity to produce accelerator-produced nuclides important to both commercial and research applications, including strontium-82 and germanium-68, used in the clinical imaging modality of positron emission tomography.

▪ **National Isotope Development Center (NIDC)**	**1,915**	**2,227**

The National Isotope Development Center (NIDC) is a recently created management information center for all national laboratories and universities in the subprogram's portfolio producing and distributing isotopes. The NIDC coordinates and integrates multi-laboratory isotope production schedules and isotope inventory balances, maintains transportation container inventory and certifications, and conducts various outreach and societal activities. The business office within the NIDC is located at ORNL and coordinates all customer data such as official quotations, account balances, shipping schedules and delivery tracking, and other pertinent information. Funding reflects a realignment of some efforts from Other National Laboratory Operations in FY 2012.

▪ **Other National Laboratory Operations**	**12,383**	**11,852**

The Isotope program makes intensive use of hot cell facilities at the three main isotope production sites: BNL, LANL, and ORNL. Funding is provided to each of these facilities for the technical expertise and hot cell facilities in order to support the handling and processing of radioactive materials. Support is provided for the Chemical and Material Laboratories at ORNL that are used for processing stable isotopes, as well as activities including radiological monitoring, facility inspections, records management, the certification of isotope shipping casks, and other related expenses. FY 2012 funding reflects a shift of some efforts to the NIDC in FY 2012.

Total, Isotope Development and Production for Research and Applications	**19,116**	**20,234**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
Research	
▪ **National Laboratory Research**	
The majority of the increase reflects a shift of laboratory personnel involved in R&D efforts from Operations to Research and the initiation of a research program at BNL in conjunction with operation of BLIP. In addition, there is a redistribution of the funds anticipated to be awarded to National Laboratories following a competitive solicitation and review, as explained under University Research below.	+1,944
▪ **University Research**	
Funding for research and development is guided by priorities in research isotope production developed by NSAC. FY 2010 funding for universities reflected a disproportionate share of the total Isotope Research funding because Recovery Act funds had been used to support research at the National Laboratories. Funding in FY 2012 represents an estimate of the funds anticipated to be awarded to universities following a competitive solicitation and review.	-702
▪ **Other Research**	
• **SBIR and Other**	
Funding increases relative to FY 2010 because the mandated SBIR set-aside has been transferred out of the program in FY 2010 while those funds are included in the FY 2012 request.	+97
Total, Research	**+1,339**
Operations	
▪ **University Operations**	
Funding decreases slightly relative to FY 2010 as most university activities currently supported are funded under Research.	-42
▪ **Isotope Production Facility (IPF) Operations**	
Increased funding is provided to maintain staff, materials, and required supplies to operate the facility.	+4
▪ **Brookhaven Linac Isotope Producer (BLIP) Operations**	
Increased funding is provided to maintain staff, materials, and required supplies to operate the facility.	+36

	FY 2012 vs. FY 2010 Current Approp. ($000)
▪ **National Isotope Development Center (NIDC)**	
The increase relative to FY 2010 reflects the realignment of support from within Other National Laboratory Operations for the NIDC mission to coordinate isotope activities and customer data.	+312
▪ **Other National Laboratory Operations**	
The decrease relative to FY 2010 reflects a shift of laboratory personnel involved in R&D efforts from Operations to Research in FY 2012, as well as a realignment of some funding to NIDC. Funding is provided to maintain support for staff, materials, and required supplies to operate the facilities.	-531
Total, Operations	**-221**
Total Funding Change, Isotope Development and Production for Research and Applications	**+1,118**

Construction

Funding Schedule by Activity

	(dollars in thousands)	
	FY 2010 Current Appropriation	FY 2012 Request
Construction		
06-SC-01, 12 GeV CEBAF Upgrade (PED/ Construction), TJNAF	20,000	66,000

Description

This subprogram provides for Project Engineering and Design (PED) and Construction needed to meet overall objectives of the Nuclear Physics program.

Detailed Justification

	(dollars in thousands)	
	FY 2010 Crrent Appropriation	FY 2012 Request
06-SC-01, 12 GeV CEBAF Upgrade (PED/Construction), TJNAF	**20,000**	**66,000**

In FY 2012, funding is requested to continue construction of the 12 GeV CEBAF Upgrade. The upgrade was identified in the 2007 NSAC Long-Range Plan as the highest priority for the U.S. Nuclear Physics program. The upgrade will enable scientists to address one of the mysteries of modern physics—the mechanism of quark confinement.

FY 2012 is the peak funding year for this project and is consistent with the baselined profile. The original profile was reduced in FY 2010 and FY 2011 to account for the $65,000,000 received under the Recovery Act in FY 2009.

Total, Construction	**20,000**	**66,000**

Explanation of Funding Changes

	FY 2012 vs. FY 2010 Current Approp. ($000)
06-SC-01, 12 GeV CEBAF Upgrade (PED/Construction), TJNAF	
Increased support is provided to continue construction of the 12 GeV CEBAF Upgrade according to the planned project profile.	+46,000

Supporting Information

Operating Expenses, Capital Equipment and Construction Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Operating Expenses	454,344	502,571
Capital Equipment	39,638	30,235
General Plant Projects	2,000	2,000
Accelerator Improvement Projects	6,478	4,494
Construction (12 GeV Upgrade)	20,000	66,000
Total, Nuclear Physics	522,460	605,300

Funding Summary

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
Research	175,365	198,101
Scientific User Facilities Operations	273,818	272,123
Other Facility Operations	20,369	25,390
Projects		
Major Items of Equipment	15,998	8,686
Facility for Rare Isotope Beams[a]	12,000	30,000
Construction Projects (12 GeV Upgrade)	20,000	66,000
Total Projects	47,998	104,686
Other	4,910	5,000
Total Nuclear Physics	522,460	605,300

Scientific User Facilities Operations and Research

(dollars in thousands)

	FY 2010 Current Approp.	FY 2012 Request
CEBAF (TJNAF)		
Operations	83,327	83,930
Facility Research/MIEs	10,537	10,440
Total CEBAF	93,864	94,370

[a] FRIB is being funded with operating expense dollars through a Cooperative Agreement with Michigan State University (MSU).

	(dollars in thousands)	
	FY 2010 Current Approp.	FY 2012 Request
RHIC (BNL)		
Operations	157,195	164,610
Facility Research/MIEs	10,032	12,185
Total RHIC	167,227	176,795
HRIBF (ORNL)		
Operations	17,080	6,821
Facility Research/MIEs	4,271	4,271
Total HRIBF	21,351	11,092
ATLAS (ANL)		
Operations	16,216	16,762
Facility Research/MIEs	4,865	4,865
Total ATLAS	21,081	21,627
Scientific User Facilities		
Operations	273,818	272,123
Facility Research/MIEs	29,705	31,761
Total Scientific User Facilities	303,523	303,884

Total Facility Hours and Users

	FY 2010 Current Appropriaton	FY 2012 Request
Hours of Operation with Beam		
CEBAF (TJNAF)		
Achieved Operating Hours	5,280	N/A
Planned Operating Hours	5,110	3,870
Optimal Hours	5,980	3,940
Percent of Optimal Hours	88%	98%
Unscheduled Downtime	9%	N/A
Number of Users	1,260	1,300

	FY 2010 Current Appropriaton	FY 2012 Request
RHIC (BNL)		
Achieved Operating Hours	3,580	N/A
Planned Operating Hours	3,350	3,040
Optimal Hours	4,100	4,100
Percent of Optimal Hours	87%	74%
Unscheduled Downtime	17%	N/A
Number of Users	1,200	1,200
HRIBF (ORNL)		
Achieved Operating Hours	5,270	N/A
Planned Operating Hours	5,200	0
Optimal Hours	6,100	0
Percent of Optimal Hours	86%	N/A
Unscheduled Downtime	13%	N/A
Number of Users	260	0
ATLAS (ANL)		
Achieved Operating Hours	5,940	N/A
Planned Operating Hours	5,900	5,900
Optimal Hours	6,600	6,200[a]
Percent of Optimal Hours	90%	95%
Unscheduled Downtime	8%	N/A
Number of Users	410	430
Total Facilities		
Achieved Operating Hours	20,070	N/A
Planned Operating Hours	19,560	12,810
Optimal Hours	22,780	14,170
Percent of Optimal Hours	88%	90%
Unscheduled Downtime	11%	N/A
Total Number of Users	3,130	2,930

[a] Based on the most recent review of operations at ATLAS, the quality and quantity of the scientific output is best optimized with 6,200 operating hours.

Major Items of Equipment

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Heavy Ion Nuclear Physics						
Heavy Ion LHC Experiments, LBNL						
TEC	7,000	5,000	1,205	0	0	13,205
OPC	295	0	0	0	0	295
TPC	7,295	5,000	1,205	0	0	13,500
STAR Heavy Flavor Tracker, BNL						
TEC	0	2,400	2,900	4,550	5,350	15,200
OPC	0	280	0	0	0	280
TPC	0	2,680	2,900	4,550	5,350	16,500–17,800[a]
Low Energy Nuclear Physics						
GRETINA, Gamma-Ray Detector, LBNL						
TEC	16,570	430	0	0	0	17,000
OPC	1,500	300	0	0	0	1,800
TPC	18,070	730	0	0	0	18,800
Neutron Electric Dipole Moment (nEDM), ORNL						
TEC	4,047	4,500	2,900	1,100	TBD	TBD
OPC	933	0	0	0	TBD	TBD
TPC	4,980	4,500	2,900	1,100	TBD	17,600-40,000
Cryogenic Underground Observatory for Rare Events (CUORE), LBNL						
TEC	3,512	3,088	800	186	0	7,586
OPC	764	0	0	350	0	1,114
TPC	4,276	3,088	800	536	0	8,700
Rare Isotope Beam Science Initiatives[b]						
TEC	0	0	0	0	0	0
OPC	0	0	0	0	0	0
TPC	0	0	0	0	0	0

[a] This project received CD-1 approval in August 2010; the CD-1 TPC range is reflected, and includes $2,320,000 of additional funding that has been redirected within the RHIC research program.
[b] The first peer-reviewed awards were made under this initiative in FY 2010. The four university awards and two laboratory awards totaling $4,200,000 were all under the MIE threshold and, therefore, are not reflected in the MIE table.

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011 CR	FY 2012 Request	Outyears	Total
Total MIEs						
TEC		15,418	7,805	5,836		
OPC		580	0	350		
TPC		15,998	7,805	6,186		

Heavy Ion Nuclear Physics MIEs

Heavy Ion LHC Experiment (ALICE EMCal), LBNL: This MIE fabricates a large electromagnetic calorimeter (EMCal) for the ALICE experiment at the LHC, and is a joint project with France and Italy. It received CD-2/3 approval in February 2008 and is scheduled to finish in FY 2011.

STAR Heavy Flavor Tracker (HFT), BNL: This MIE will fabricate a high-precision tracking and vertexing device based on ultra-thin silicon pixel and pad detectors in the STAR detector. It received CD-1 approval in August 2010 and is scheduled for completion in FY 2015.

Low Energy Nuclear Physics MIEs

GRETINA Gamma-Ray Detector, LBNL: This MIE fabricates an array of highly-segmented germanium crystals for gamma ray detection. It received CD-2/3 approval in October 2007 and is scheduled to finish in FY 2011. This detector will be shared by the Nation's low-energy accelerator facilities operated by both DOE and NSF.

Neutron Electric Dipole Moment (nEDM), ORNL: This MIE fabricates a cryogenic apparatus to measure the neutron electric dipole moment using ultra-cold neutrons from the FNPB. It received CD-1 approval in February 2007 with an estimated cost range of $17,600,000-$19,000,000. The profile is slowed and high priority R&D will continue in FY 2012 for this R&D intensive and technically challenging discovery experiment. The DOE total project cost (TPC) range has been refined to reflect current estimates for this joint DOE/NSF project with NSF contributing additional funds.

Cryogenic Underground Observatory for Rare Events (CUORE), LBNL: This MIE fabricates the U.S. contribution to the Italian-led CUORE experiment to measure fundamental neutrino properties. It received CD-2/3 approval in December 2009 and is scheduled to finish in FY 2015. This is a joint DOE/NSF project with NSF contributing additional funds.

Rare Isotope Beam Science Initiatives: Competitive awards were selected in FY 2010 following peer review. There were four university and two laboratory projects awarded totaling $4,200,000, all of which were under the MIE threshold; as a result, the FY 2010 funding is included in the appropriate categories under Low Energy Research and is no longer included as part of the MIE table. The individual initiatives selected will fabricate instrumentation creating forefront science opportunities at leading rare isotope beam facilities around the world. NP terminates support for this initiative in FY 2012 in order to support higher priority activities. A limited number of the smaller international research efforts, among those selected following peer review in FY 2010, will be completed, while the larger projects will not be pursued.

Construction Projects

(dollars in thousands)

	Prior Years	FY 2010 Current Approp.	FY 2011	FY 2012 Request	Outyears	Total
12 GeV CEBAF Upgrade, TJNAF						
TEC	114,500	20,000	36,000	66,000	51,000	287,500
OPC	10,500	0	0	0	12,000	22,500
TPC	125,000	20,000	36,000	66,000	63,000	310,000

Scientific Employment

(estimated)

	FY 2010 Actual[a]	FY 2012 Request[b]
# University Grants	200	200
Average Size per year	$345,000	$345,000
# Laboratory Projects	33	34
# Permanent Ph.Ds	839	825
# Postdoctoral Associates	410	395
# Graduate Students	546	535
# Ph.D.s awarded	93	80

Facility for Rare Isotope Beams, Michigan State University, East Lansing, Michigan

1. Introduction

On February 9, 2004, the Nuclear Physics program received Critical Decision 0 (CD-0), Approve Mission Need, for construction of a Rare Isotope Accelerator Project with a preliminary cost estimate range of $900,000,000 to $1,100,000,000. As part of a subsequent alternatives analysis, the technical scope was reduced and the upper limit of the preliminary cost estimate to the federal government was revised to $550,000,000.

In June 2009, Michigan State University (MSU) was awarded a cooperative agreement to design and establish the Facility for Rare Isotope Beams (FRIB). The cooperative agreement between DOE and MSU identifies MSU providing $94,500,000 in cost share, and the preliminary cost estimate range to the federal government is $500,000,000 to $550,000,000. The final DOE federal investment will be determined when the project is more mature and ready to be baselined at CD-2. Critical Decision 1, Approve Alternative Selection and Cost Range, was approved in September 2010.

The National Environmental Policy Act (NEPA) requirements addressing the construction and operations of FRIB were satisfied in September 2010 with the approval of the Environmental Assessment and Finding of No Significant Impact (FONSI).

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[a] FY 2010 is the first year that the Isotope Program is included in the Nuclear Physics Workforce Survey. An additional 69 Ph.Ds, 24 postdoctoral associates, and 8 graduate students were supported during FY 2010 with Recovery Act funding.
[b] This table does not reflect an additional reduction of an estimated 30 technicians and operations staff that will result from the closure of HRIBF.

FRIB is not a DOE line item construction project or capital asset and is being funded with operating expense dollars through a cooperative agreement with MSU. Although cooperative agreements are excluded under DOE O 413.3A, the management principles of DOE O 413.3A will be followed, including the approval of Critical Decisions. When completed, FRIB will be operated as a DOE national user facility. Consistent with 10 CFR 600, real property and equipment acquired with Federal funds shall be vested with MSU. However, such items will not be encumbered by MSU for as long as the Federal government retains an interest. When the property and equipment are no longer of interest to the government, MSU will be responsible for decontamination and decommissioning.

The FY 2012 request continues engineering and design activities in support of achieving CD-2 approval by the fourth quarter of FY 2012 and allows the pursuit of long-lead procurements that reduce the project's cost and schedule risks. Depending on advancement of the design and technical requirements, a phased construction start may begin in FY 2012. Provided sufficient funds are available, this effort would reduce project risk.

2. Design and Construction Schedule[a]

	CD-0	CD-1	Design Complete	CD-2	CD-3	CD-4
FY 2011	02/09/2004	4Q FY 2010	TBD	TBD	TBD	FY 2017–FY 2019
FY 2012	02/09/2004	9/1/2010	TBD	4Q FY 2012	TBD	FY 2018–FY 2020

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

3. Baseline and Validation Status (DOE only)[b]

(dollars in thousands)

	TEC, Engineering and Design	TEC, Construction	TEC, Total	OPC	TPC
FY 2011	58,000	TBD	TBD	19,000	TBD
FY 2012	54,300	TBD	TBD	19,000	TBD[c]

4. Project Description, Justification, and Scope

FRIB is based on a heavy-ion linac with a minimum energy of 200 MeV per nucleon for all ions at beam power of 400 kW. The proposed facility will have a production area, three-stage fragment separator, three ion stopping stations, and post accelerator capabilities.

This proposed facility is to provide intense beams of rare isotopes for a wide variety of studies in nuclear structure, nuclear astrophysics, and fundamental symmetries. This facility will impact the study of the origin of the elements and the evolution of the cosmos, and offers a laboratory for exploring the limits of nuclear existence and identifying new phenomena, with the possibility that a more broadly applicable

[a] This project does not have a performance baseline. The CD-4 schedule range is a preliminary estimate.
[b] This project does not have a performance baseline. The amounts shown reflect the requested DOE appropriations only and do not include the planned cost share from MSU.
[c] The preliminary DOE total project cost (TPC) range is $500,000,000 to $550,000,000 not including the MSU cost share of $94,500,000.

theory of nuclei will emerge. The facility will offer new glimpses into the origin of the elements by leading to a better understanding of key issues by creating exotic nuclei that, until now, have existed only in nature's most spectacular explosion, the supernova. Experiments addressing questions of the fundamental symmetries of nature will similarly be conducted through the creation and study of certain exotic isotopes.

5. Financial Schedule (DOE only)

(dollars in thousands)

	Appropriations	Obligations	Costs
Total Estimated Cost (TEC)			
FY 2011[a]	10,000	10,000	8,157
FY 2012	30,000	30,000	30,000
FY 2013[b]	14,300	14,300	13,300
FY 2014	TBD	TBD	2,843
Outyears	TBD	TBD	TBD
Total, TEC[c]	54,300	54,300	54,300
Other Project Cost (OPC)			
FY 2009	7,000	7,000	1,874
FY 2010	12,000	12,000	13,283
FY 2011[a]	0	0	3,843
Total, OPC[d]	19,000	19,000	19,000
Total Project Cost			
FY 2009	7,000	7,000	1,874
FY 2010	12,000	12,000	13,283
FY 2011 [a]	10,000	10,000	12,000
FY 2012	30,000	30,000	30,000
FY 2013 [b]	14,300	14,300	13,300
FY 2014	TBD	TBD	2,843
Outyears	TBD	TBD	TBD
Total, TPC[e]	TBD	TBD	TBD

[a] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).
[b] The TEC funding of $14,300,000 reflects engineering and design effort only in FY 2013. The FY 2013 budget request will identify additional funding for long-lead procurement and construction activities.
[c] The funding reflected in the operating funded TEC profile is for DOE's share only of engineering and design activities, and long-lead procurements and possibly phased construction start in FY 2012 that reduce project risks. The FY 2013 budget request will identify additional funding for long-lead procurements and construction activities.
[d] The funding reflected in the OPC profile is for DOE's share of R&D, conceptual design, and NEPA activities only. Future budget requests will identify additional funding for pre-operational activities.
[e] The preliminary DOE total project cost (TPC) range is $500,000,000 to $550,000,000, not including the MSU cost share of $94,500,000.

6. Details of Cost Estimate (DOE only)

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Estimate
Total Estimated Cost (TEC)[a]			
Design and engineering	45,900	42,500	N/A
Construction	TBD	TBD	N/A
Contingency	8,400	15,500	N/A
Total, Total Estimated Cost	54,300	58,000	N/A
Other Project Cost (OPC)			
Conceptual Design/NEPA	6,500	6,500	N/A
R&D	12,500	12,500	N/A
Contingency	0	0	N/A
Total, OPC[b]	19,000	19,000	N/A
Total, TPC[c]	TBD	TBD	N/A
Total, Contingency	TBD	TBD	N/A

[a] The TEC funding is for DOE's share only of engineering and design activities only, and long-lead procurements and possibly phased construction start in FY 2012 that reduce project risks. The FY 2013 budget request will identify additional funding for long-lead procurements and construction activities.
[b] The OPC funding is for DOE's share of R&D, conceptual design, and NEPA activities only. Future budget requests will identify additional funding for pre-operational activities.
[c] The preliminary DOE total project cost (TPC) range is $500,000,000 to $550,000,000, not including the MSU cost share of $94,500,000.

7. Funding Profile History (DOE Only)

(dollars in thousands)

Request Year		FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	Outyears	Total
FY 2010	TEC[a]	0	0	10,000	33,000	18,000[b]	TBD	TBD
	OPC[c]	7,000	9,000	0	0	0	TBD	TBD
	TPC[d]	7,000	9,000	10,000	33,000	18,000	TBD	TBD
FY 2011	TEC[a]	0	0	10,000	30,000	18,000[b]	TBD	TBD
	OPC[c]	7,000	12,000	0	0	0	TBD	TBD
	TPC[d]	7,000	12,000	10,000	30,000	18,000	TBD	TBD
FY 2012	TEC[a]	0	0	10,000[e]	30,000	14,300[b]	TBD	TBD
	OPC[c]	7,000	12,000	0	0	0	TBD	TBD
	TPC[d]	7,000	12,000	10,000	30,000	14,300	TBD	TBD

[a] The TEC funding is for DOE's share only of engineering and design activities, long-lead procurements and possibly phased construction start in FY 2012 that reduce project risks.
[b] The FY 2013 budget request will identify additional funding for long-lead procurements and construction activities.
[c] The OPC funding is for DOE's share of R&D, conceptual design, and NEPA activities only.
[d] The preliminary DOE total project cost (TPC) range is $500,000,000 to $550,000,000, not including the MSU cost share. The amounts shown reflect the requested DOE appropriations only and do not include the planned cost share of $94,500,000.
[e] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

06-SC-01, 12 GeV CEBAF Upgrade, Thomas Jefferson National Accelerator Facility
Newport News, Virginia
Project Data Sheet is for PED/Construction

1. Significant Changes

This Project Data Sheet (PDS) is an update of the FY 2011 PDS.

The most recent DOE O 413.3A approved Critical Decision (CD) is CD-3, Approve Start of Construction, which was signed on September 15, 2008, with a Total Project Cost (TPC) of $310,000,000 and a planned CD-4 in FY 2015. There have been no changes in project scope, cost, or schedule since the project was baselined. The project continues to manage all identified low, moderate, and high risks. Risks can change from month to month, and include issues with the procurement and installation of components, overall staffing levels and schedule, impacts of continuing resolutions, and claims from subcontractors. For each moderate and high risk a mitigation plan is developed in order to assure successful project completion. One particular high risk is associated with the Hall D Solenoid. A spare solenoid has been strongly recommended by various review panels external to the project. Costs and schedules for this solenoid are currently being determined but preliminary estimates indicate the cost at approximately $10 million, for which project contingency would be used.

A Federal Project Director at the appropriate level is assigned to this project.

2. Design, Construction, and D&D Schedule

(fiscal quarter or date)

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

CD-0 – Approve Mission Need
CD-1 – Approve Alternative Selection and Cost Range
CD-2 – Approve Performance Baseline
CD-3 – Approve Start of Construction
CD-4 – Approve Start of Operations or Project Closeout D&D Start – Start of Demolition & Decontamination (D&D) work
D&D Complete –Completion of D&D work

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

3. Baseline and Validation Status

(dollars in thousands)

	TEC, PED	TEC, Construction	TEC, Total	OPC Except D&D	OPC, D&D	OPC, Total	TPC
FY 2007	21,000	TBD	TBD	11,000	TBD	TBD	TBD
FY 2008	21,000	TBD	TBD	10,500	TBD	TBD	TBD
FY 2009	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2010	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2011	21,000	266,500	287,500	22,500	N/A	22,500	310,000
FY 2012	21,000	266,500	287,500	22,500	N/A	22,500	310,000[a]

4. Project Description, Justification, and Scope

The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility is the world-leading facility in the experimental study of hadronic matter. An energy upgrade of CEBAF has been identified by the nuclear science community as a compelling scientific opportunity that should be pursued. In particular, the Nuclear Science Advisory Committee (NSAC) stated in the 1996 Long Range Plan that "…the community looks forward to future increases in CEBAF's energy, and to the scientific opportunities that would bring." In the 2007 Long Range Plan, NSAC concluded that completion of the 12 GeV CEBAF Upgrade project was the highest priority for the Nation's nuclear science program.

- The 12 GeV CEBAF Upgrade directly supports the Nuclear Physics mission and addresses the objective to measure properties of the proton, neutron, and simple nuclei for comparison with theoretical calculations to provide an improved quantitative understanding of their quark substructure.
- The scope of the project includes upgrading the electron energy capability of the main accelerator from 6 GeV to 12 GeV, building a new experimental hall (Hall D) and associated beam-line, and enhancing the capabilities of the existing experimental halls to support the most compelling nuclear physics research.

Key Performance Parameters to achieve CD-4, *Approve Start of Operations or Project Closeout*, are phased around the accelerator and conventional facilities (CD-4A) and the experimental equipment in Halls B, C, and D (CD-4B). The deliverables defining completion are identified in the Project Execution Plan and have not changed since CD-2. Mitigation plans exist to help ensure that the one high risk and three moderate risks will not impact the planned completion dates.

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

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[a] The Commonwealth of Virginia provided $9,000,000 to Jefferson Science Associates, LLC to leverage the federal investment of $310 million for an upgrade of the Jefferson Lab's research facilities. The $9,000,000 received reduces project risks associated with cost and schedule and helps ensure timely completion of the project. Any adjustments to the federal government's share of the TPC as a result of the funding from the Commonwealth of Virginia will be evaluated by the SC Office of Project Assessment during one of the project's future annual reviews. The timing of any possible adjustment to the TPC will be considered after the project has progressed further, the majority of the risks have been minimized or retired, and with input and advice from the SC Office of Project Assessment. The 12 GeV Upgrade project is about 42% complete as of the beginning of January 2011.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total Estimated Cost (TEC)				
PED				
FY 2006	500	500	0	88
FY 2007	7,000	7,000	0	6,162
FY 2008	13,377[a]	13,377	0	9,108
FY 2009	123[a]	123	0	5,370
FY 2010	0	0	0	265
FY 2011[b]	0	0	0	7
Total, PED	21,000	21,000	0	21,000
Construction				
FY 2009	28,500	28,500	0	5,249
FY 2009 Recovery Act	65,000	65,000	2,738	0
FY 2010	20,000	20,000	29,621	18,642
FY 2011[b]	36,000	36,000	24,800	43,750
FY 2012	66,000	66,000	7,841	58,300
FY 2013	40,500	40,500	0	55,000
FY 2014	10,500	10,500	0	17,500
FY 2015	0	0	0	3,059
Total, Construction	266,500	266,500	65,000	201,500
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 [b]	36,000	36,000	24,800	43,757
FY 2012	66,000	66,000	7,841	58,300
FY 2013	40,500	40,500	0	55,000
FY 2014	10,500	10,500	0	17,500
FY 2015	0	0	0	3,059

[a] The baseline FY 2008 PED funding was reduced by $123,000 as a result of the FY 2008 rescission. This reduction was restored in FY 2009 to maintain the TEC and project scope.
[b] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

(dollars in thousands)

	Appropriations	Obligations	Recovery Act Costs	Costs
Total, TEC	287,500	287,500	65,000	222,500
Other Project Cost (OPC)				
OPC except D&D				
FY 2004	700	700	0	77
FY 2005	2,300	2,300	0	2,142
FY 2006	4,000	4,000	0	3,508
FY 2007	2,500	2,500	0	2,751
FY 2008	1,000	1,000	0	1,802
FY 2009	0	0	0	155
FY 2010	0	0	0	62
FY 2013	2,500	2,500	0	2,403
FY 2014	7,500	7,500	0	7,000
FY 2015	2,000	2,000	0	2,600
Total, OPC	22,500	22,500	0	22,500
Total Project Cost				
FY 2004	700	700	0	77
FY 2005	2,300	2,300	0	2,142
FY 2006	4,500	4,500	0	3,596
FY 2007	9,500	9,500	0	8,913
FY 2008	14,377	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[a]	36,000	36,000	24,800	43,757
FY 2012	66,000	66,000	7,841	58,300
FY 2013	43,000	43,000	0	57,403
FY 2014	18,000	18,000	0	24,500
FY 2015	2,000	2,000	0	5,659
Total, TPC	310,000	310,000	65,000	245,000

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

6. Details of Project Cost Estimate

(dollars in thousands)

	Current Total Estimate	Previous Total Estimate	Original Validated Estimate
Total Estimated Cost (TEC)			
Design (PED)			
Design	21,000	21,000	19,200
Contingency	0	0	1,800
Total, PED (PED no. 06-SC-01)	21,000	21,000	21,000
Construction Phase			
Civil Construction	31,880	29,400	27,450
Accelerator/ Experimental Equipment/Management	191,463	175,200	174,150
Contingency	43,157	61,900	64,900
Total, Construction	266,500	266,500	266,500
Total, TEC	287,500	287,500	287,500
Contingency, TEC	43,157	61,900	66,700
Other Project Cost (OPC)			
OPC except D&D			
Conceptual Design	3,445	3,445	3,500
R&D	7,052	7,020	6,400
Start-up	8,195	7,635	7,450
Contingency	3,808	4,400	5,150
Total, OPC	22,500	22,500	22,500
Contingency, OPC	3,808	4,400	5,150
Total, TPC	310,000	310,000	310,000
Total, Contingency	46,965	66,300	71,850

7. Funding Profile History

(dollars in thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2007 PED only	TEC	19,000	2,000	0	0	0	0	0	0	0	21,000
	OPC	11,000	0	0	0	0	0	0	0	0	11,000
	TPC	30,000	2,000	0	0	0	0	0	0	0	32,000
FY 2008 PED 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

(dollars in thousands)

Request Year		Prior Years	FY 2009	FY 2009 Recovery Act	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	Total
FY 2009[a] Performance Baseline	TEC	20,877	28,623	0	59,000	62,000	66,000	40,500	10,500	0	287,500
	OPC	10,500	0	0	0	0	0	2,500	7,500	2,000	22,500
	TPC	31,377	28,623	0	59,000	62,000	66,000	43,000	18,000	2,000	310,000
FY 2010[b]	TEC	20,877	28,623	65,000	22,000	34,000	66,000	40,500	10,500	0	287,500
	OPC	10,500	0	0	0	0	0	2,500	7,500	2,000	22,500
	TPC	31,377	28,623	65,000	22,000	34,000	66,000	43,000	18,000	2,000	310,000
FY 2011	TEC	20,877	28,623	65,000	20,000	36,000	66,000	40,500	10,500	0	287,500
	OPC	10,500	0	0	0	0	0	2,500	7,500	2,000	22,500
	TPC	31,377	28,623	65,000	20,000	36,000	66,000	43,000	18,000	2,000	310,000
FY 2012	TEC	20,877	28,623	65,000	20,000	36,000[c]	66,000	40,500	10,500	0	287,500
	OPC	10,500	0	0	0	0	0	2,500	7,500	2,000	22,500
	TPC	31,377	28,623	65,000	20,000	36,000	66,000	43,000	18,000	2,000	310,000

8. Related Operation and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter or date)	3Q FY 2015
Expected Useful Life (number of years)	15
Expected Future start of D&D for new construction (fiscal quarter)	N/A

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life cycle costs	
	Current Total Estimate	Previous Total Estimate	Current Total Estimate	Previous Total Estimate
Total Project Costs	N/A	N/A	310,000	310,000
Operations	150,000	150,000	2,250,000[d]	2,250,000[c]
Maintenance	Included above	Included above	Included above	Included above
Total, Operations & Maintenance	150,000	150,000	2,560,000	2,560,000

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

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

[c] The FY 2011 amounts reflect the FY 2011 funding under the FY 2011 Continuing Resolution (CR).

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

9. Required D&D Information

	Square Feet
Area of new construction	31,500
Area of existing facility(ies) being replaced	N/A
Area of any additional D&D space to meet the “one-for-one” requirement	31,500

The “one-for-one” requirement is met by offsetting 31,500 square feet of the 80,000 square feet of banked space that was granted to Jefferson Laboratory in a Secretarial waiver.

10. Acquisition Approach

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