Nuclear Physics

Program Mission

The mission of the Nuclear Physics program is to advance our knowledge of the properties and interactions of atomic nuclei and nuclear matter in terms of the fundamental forces and particles of nature. To accomplish this mission, the program supports the research of scientists, the operations of facilities and the development of forefront facilities and technology. These activities are carried out under the mandate provided in Public Law 95-91 that established the Department of Energy, and assigns the Nuclear Physics program the lead responsibility for Federal support of fundamental research in nuclear physics.

Since early in the twentieth century, the study of nuclear physics has made important contributions to our knowledge about the natural universe and has had great impact on human life. Nuclear fusion powers our sun and provides the energy that supports life on earth. Fusion processes that occurred in the early universe and later in stars formed the nuclei of all the types of atoms we find on earth. Accelerators were developed in the 1920's and 1930's to study the nucleus and are today the primary tool for nuclear physics research. As accelerators evolved and became increasingly more powerful, a new field of science called high energy physics emerged from nuclear research in the 1940's and 50's to pursue the mysterious array of unexpected particles discovered in nuclear physics research. Both fields are still closely related in physics and technology; however, their focus is quite different. High energy physics focuses on understanding the interactions and properties of the elementary particles, while the focus of nuclear physics is on understanding the structure and properties of nuclei and nuclear matter in terms of their constituents. For example, based on high energy physics studies, it is now understood that the most elementary building blocks of matter are particles, called quarks, which interact by the exchange of gluons. Nuclear Physics attempts to understand how quarks bind together in groups of three to form the nucleons (protons and neutrons) and then, in turn, how these nucleons become the basic building blocks to produce the nuclei we observe in nature.

Attendant upon this core mission are responsibilities to educate and enlarge the nation's pool of technically trained talent, primarily at the graduate student and postdoctoral levels, and to facilitate transfer of knowledge and technology acquired to support the nation's needs. Knowledge and techniques developed in pursuit of fundamental nuclear physics research are extensively utilized in our society today. The understanding of nuclear spin enabled the development of magnetic resonance imaging for medical use. Particle beams are used for cancer therapy and in a broad range of materials science studies, and synchrotron light from electron accelerators is used for a wide variety of research studies, including biochemical and materials science. Nuclear physics techniques continue to develop and provide new capabilities for use in these applied areas. Highly trained manpower with knowledge of fundamental nuclear physics continues to be essential to progress in many of these areas.

The program works in close coordination with the nuclear physics program at the National Science Foundation (NSF) and, jointly with the NSF, charters the Nuclear Science Advisory Committee (NSAC) to provide advice on scientific opportunities and priorities for the nation's Nuclear Physics program. During 2001, NSAC will prepare, with community input, a new Long Range Plan for Nuclear Science, building on the previous plan submitted in 1996. The quality of the research and effectiveness of facility operations in this program are continuously evaluated through the use of merit based peer review and scientific advisory committees.

Program Goal

The goal of the Nuclear Physics program is to maintain U.S. world leadership or be among the world leaders in the major scientific thrusts of fundamental nuclear physics research. These scientific thrusts, as identified in the 1996 NSAC Long Range Plans for Nuclear Science, seek to understand:

- the properties of nuclei at their limits of stability
- the structure of nucleons and nuclei in terms of their quark substructure
- the properties and behavior of nuclear matter under conditions of extreme pressure and temperature
- fundamental symmetries and astrophysical phenomena using nuclear physics techniques

Nuclear physics research is poised to make important new discoveries, as major facilities have come on-line to address physics in two of the major thrusts of the field. High intensity electron beams from the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) now allow detailed studies of how quarks and gluons bind together to make protons and neutrons. The Relativistic Heavy Ion Collider (RHIC), now beginning operations at Brookhaven National Laboratory (BNL), will instantaneously form submicroscopic specimens of quark-gluon plasma by colliding gold nuclei, thus allowing a study of the primordial soup of quarks and gluons thought to have existed at an early stage of the universe. The Sudbury Neutrino Observatory (SNO), constructed by a collaboration of Canadian, English and U.S. supported scientists, is now taking data on solar neutrino fluxes, and will provide the first results on the “appearance” of oscillations of electron neutrinos into another neutrino type. Evidence of such oscillation would confirm indications that neutrinos have mass, an observation that would force a re-evaluation of the existing Standard Model of particle physics.

In the 1996 NSAC Long Range Plan a Rare Isotope Accelerator (RIA) facility was identified as needed to maintain a leadership role. By producing and studying highly unstable nuclei that are now formed only in stars, scientists would use exotic isotope beams produced by RIA to explore the limits of nuclear existence and to better understand stellar evolution and the origin of the elements. R&D and preconceptual activities are being supported for this proposed facility.

Program Objectives

The management objectives of the Nuclear Physics program are to:

- Conduct a research program of maximum effectiveness, at the cutting edge of all major scientific areas in nuclear physics, that will lead to new knowledge and insights on the nature of energy and subatomic matter.
- Conceive, develop, construct, and operate the scientific accelerator, detector and computing facilities that are needed to address forefront science in a timely and effective manner. In the execution of this responsibility, together with other Office of Science organizations, act as the nation's leader in developing management techniques to optimize construction and operation of facilities in a cost effective, safe, and environmentally responsible manner.
- Leverage United States effort by means of international cooperation through the exchange of scientists and financial and technical contributions to cooperative projects.
- Continue the advanced education and training activities of young scientists to develop the new skills and concepts that will become the underpinnings of the nation's broad array of nuclear related sciences and technologies in the future.

- Manage the operations of the Nuclear Physics program to high standards, by ensuring that the processes of planning, reviewing, selecting and managing science projects and programs are sound and based on peer review and merit evaluation, and reflect input from the NSAC advisory group in coordinating DOE and NSF activities in nuclear physics.

To meet these objectives, the Nuclear Physics program is organized into four subprograms:

- The **Medium Energy Nuclear Physics** subprogram supports research and facility operations that are directed towards understanding the quark structure of matter. Two national user facilities, the Bates Linear Accelerator Center at MIT and CEBAF at TJNAF, are supported by this subprogram.
- The **Heavy Ion Nuclear Physics** subprogram supports research and the operations of RHIC at BNL that are directed towards understanding the properties and behavior of hot, dense nuclear matter, and in particular, the predicted quark-gluon plasma. This subprogram also has stewardship responsibilities for BNL.
- The **Low Energy Nuclear Physics** subprogram supports research and facility operations that are directed towards understanding the properties of nuclei at their limits of stability and the fundamental properties of nucleons and neutrinos. The operations of three national user facilities, the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL), the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL) and the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL), and the operations of accelerators for in-house research programs at four universities (Yale University, Washington University, Texas A&M University, and Triangle Universities Nuclear Laboratory at Duke University) are supported by this subprogram. This subprogram also supports non-accelerator experiments, such as the SNO facility which is jointly operated by Canada, England and the U.S.
- The **Nuclear Theory** subprogram supports all nuclear physics theoretical research. The subprogram also provides support for the U.S. Nuclear Data program which has archival responsibilities for information generated in low- and intermediate-energy nuclear physics research worldwide.

All subprograms support researchers and graduate students at both universities and national laboratories and operations of facilities, and are responsible for achieving the program's objectives. Funding for the Small Business Innovation Research (SBIR) program is in the three experimental subprograms. Funding for the Small Business Technology Transfer (STTR) program is in the Medium Energy subprogram.

Evaluation of Objectives

The Nuclear Physics program evaluates the progress being made towards achieving its scientific and management objectives in a variety of ways. Regular peer review and merit evaluation is conducted for all activities, except those Congressionally mandated, based on procedures set down in 10 CFR 605 for the extramural grant program and under a similar modified process for the laboratory programs and scientific user facilities. All new projects are selected by peer review and merit evaluation for their scientific excellence. The program regularly conducts external reviews of its construction management programs to ensure they are on schedule and on budget. All experimental proposals at the national user facilities operated by the Nuclear Physics program are reviewed and evaluated for their merit and priority by Program Advisory Committees (PACs) prior to getting approval for beam time. Specific performance measures are included within the detailed program justification as appropriate.

The overall quality of the research in the Nuclear Physics (NP) Program will be judged excellent and relevant by external evaluation by peers, and through various forms of external recognition.

Leadership in key NP disciplines that are critical to DOE's mission and the Nation will be measured through external review and other mechanisms.

At least 80% of all new research projects supported by NP will be peer reviewed and competitively selected, and will undergo regular peer review merit evaluation.

Upgrades and construction of NP scientific facilities will be managed to keep within 10 percent of schedule and cost milestones.

NP will ensure that operational downtime of the facilities it manages will be, on average, less than 10 percent of scheduled operating days, barring unforeseen circumstances.

NP will ensure the safety and health of the workforce and members of the public and the protection of the environment in all its program activities.

Significant Accomplishments and Program Shifts

In FY 2000, the DOE Nuclear Physics (NP) program was the major sponsor of fundamental nuclear physics research in the nation, providing about 85% of the federal support, with the National Science Foundation (NSF) providing most of the remaining support.

Over one-third of the program's funding was provided to scientists at universities and laboratories to conceive and carry out the research. The DOE NP program involves over 1900 researchers and students at over 100 U.S. academic, federal and private sector institutions. The program funds research activities at over 85 academic institutions located in 35 states and at 7 DOE laboratories in 6 states. University researchers play a critical role in the nation's research effort and in the training of graduate students. About two-thirds of the nation's university researchers and graduate students doing fundamental nuclear physics research in FY 2000 were supported by the DOE Nuclear Physics program. Typically ~ 95 Ph.D. degrees are granted annually to students for research supported by the program. State-of-the-art facilities to address forefront physics are essential for the U.S. to maintain its world leadership role in nuclear physics research. They are necessary not only to make progress in our understanding of fundamental nuclear physics, but also to provide scientific opportunities for discovery that generate sufficient interest and excitement to attract the brightest students.

SCIENCE ACCOMPLISMENTS

Medium Energy Nuclear Physics

- *Role of the strange quark in the structure of the proton:* The SAMPLE experiment at Bates provided data that represents the first direct information on how different quark flavors contribute to the proton's magnetic moment. It was found that the strange quarks play a surprisingly small role.
- *Development of a new technique with potential for important applications:* A new precision technique for Atom Trap Trace Analysis to study rare isotopes has been developed at Argonne National Laboratory. This technique also has broad new applications, such as dating ground water, polar ice, and bones, measuring the charge radius of some ions for the first time, measuring the integrated solar neutrino flux over several million years, and tracking bone loss in humans.

Heavy Ion Nuclear Physics

- *First Relativistic Heavy Ion Collider results:* First RHIC measurements indicate that the energy density – a measure of the energy deposited in the collision region by the colliding nuclei – is the highest ever achieved in a laboratory, at least 70% higher than in similar experiments at CERN, and sufficient to create the long sought quark-gluon plasma, believed to be the state of matter of the universe shortly after the "Big Bang." Two papers reporting results have already been published and several others are expected to follow shortly.

- *Possible evidence of the observation of a quark-gluon plasma:* The WA98 collaboration, that includes several U.S. groups, reported the first measurement of direct photon emission from the initial stages of relativistic lead-lead collisions, using beams from the SPS accelerator at CERN. This measurement suggests evidence for the possible formation of a quark-gluon plasma.

Low Energy Nuclear Physics

- *Unexpected behavior in the structure of heavy nuclei:* The Gammasphere detector, coupled with the Fragment Mass Separator at the ANL ATLAS facility, provided results on the structure of the Nobelium isotope ^{254}No, showing that nuclear shell structures, entirely responsible for the stability of nuclei with charges greater than 100, persist to higher angular momentum than had been expected.

- *Discovery of a new state in ^{18}Ne changes predicted rates of nucleosynthesis:* A series of experiments with short-lived beams of fluorine at HRIBF at Oak Ridge National Laboratory discovered a new quantum state in the neon isotope, ^{18}Ne. The inclusion of this missing state in the fusion chain changes the predicted nucleosynthesis of certain elements in stellar explosions by a factor of 1000. An expanded series of measurements will be carried out in FY 2000-2001 as new neutron rich beam species are developed and beam intensities increase.

Nuclear Theory

- *Advances in microscopic calculations:* A collaboration of DOE national laboratory theorists and an NSF supported university theorist reported the successful description of nuclear structure properties in *ab initio* calculations of nuclei with up to ten interacting protons and neutrons. This work has demonstrated that properties of light nuclei can be described to high precision only by including three-body forces. Previous calculations had been limited to three interacting particles; a theoretical and technical breakthrough was achieved, permitting these studies to be extended to much larger systems.

- *Supernovae explosions* are now being simulated in spherically symmetric computer models, after decades of theoretical and computational effort by a number of leading nuclear astrophysicists.

- *New calculations of the production of neutrinos in the sun* by proton capture on helium-3 predict a rate five times larger than used in the previous standard solar model. The improved calculations still indicate that there is a deficit in the observed flux of solar neutrinos. Such specific nuclear structure calculations are beginning to be utilized, with increased frequency, in models of astrophysical processes to improve the reliability of the predicted behaviors.

- *Previously unexplored fundamental properties of Quantum Chromodynamics (QCD) in two new phases of quark matter* - a color superconducting phase and a color-flavor locked phase – have been discovered by theorists. Unlike the quark-gluon plasma, which is a high temperature phase, these phases are found at low temperature and high matter density, and may exist in the core of a neutron star.

FACILITY ACCOMPLISHMENTS

Medium Energy Nuclear Physics

- In FY 2000, the *Continuous Electron Beam Accelerator Facility at the Thomas Jefferson National Accelerator Facility provided beams up to 5.7 GeV* (42% greater than the design energy of 4 GeV) to all three experimental halls for research with polarized and unpolarized beams. Further improvements in accelerator cavity performance are expected to increase the maximum energy to 6 GeV by FY 2002.
- In FY 2000, the *MIT/Bates facility* completed its beam development program and delivered a 1 GeV beam from the linear accelerator. In addition, the Siberian Snake solenoid system was successfully operated in the South Hall Ring. These are significant milestones in the development of capabilities for the planned Bates Large Acceptance Spectrometer Toroid (BLAST) research program using the new BLAST detector.
- The *BLAST detector* at the MIT/Bates facility will be completed in FY 2001, and in FY 2002 a research program will be initiated to study the structure of the nucleon and few-body nuclei. Upon completion of the BLAST research program in FY 2004, the Bates facility will begin a 2-year phaseout.
- *Fabrication of the G0 detector* at the Thomas Jefferson National Accelerator Facility (TJNAF) will be completed in FY 2002 and commissioning will begin. It will provide the capability of mapping out the strange quark contribution to nucleon structure over a wide range of momentum transfer.

Heavy Ion Nuclear Physics

- *Construction of the Relativistic Heavy Ion Collider (RHIC)* at Brookhaven National Laboratory was completed in FY 1999 on cost and schedule. Commissioning started in FY 1999 and data taking started in FY 2000, as scheduled. The first collisions between gold ions occurred in June 2000. It is planned that RHIC will approach full luminosity (collision rate) by the end of FY 2001.
- *All four RHIC detectors (BRAHMS, PHENIX, PHOBOS and STAR) completed their planned fabrication on schedule in FY 2000*; the detectors were commissioned and took first data. These experimental collaborations include 1000 researchers and students from 90 institutions and 19 countries.
- *RHIC detector enhancements* remain on schedule. The STAR Silicon Vertex Tracker (SVT), a high-resolution, high-granularity, particle tracking system very close to the collision region, and the RHIC Detector Analysis System were completed in FY 2000. One PHENIX muon arm will be completed in FY 2001; the second arm (funded substantially by Japan) will be completed in FY 2002. The Electromagnetic Calorimeter (EMCal) for STAR began production fabrication of modules in FY 2000.
- *Computing capabilities for STAR simulations and data analysis* is being developed at LBNL, in alliance with the National Energy Research Scientific Computing Center (NERSC). Funding in FY 2000-2002 will provide a system that will assist the STAR collaboration to effectively analyze RHIC events, of which each one requires track reconstruction of thousands of particles.
- In FY 2000, BNL announced *receipt of the International Standards Organization (ISO) 14001 registration for its RHIC project*, certifying the quality of the project's environmental management system. ISO 14001 enables an organization to define potential environmental impacts and establish controls needed to prevent any impact, to monitor and communicate environmental performance, and to establish a framework for continual improvement of the system. The RHIC project is the first

DOE Office of Science and first Long Island-based organization to obtain third-party registration to the ISO 14001 standard.

Low Energy Nuclear Physics

- *US/Canadian Sudbury Neutrino Observatory (SNO)* detector began the first full year of data taking in FY 2000. Initial physics results, on the measurement of solar neutrino fluxes relevant to the question of whether neutrinos have mass, are anticipated in FY 2001. The determination that neutrinos have mass would necessitate a revision of our present understanding of the "standard model" of matter and of the dynamics of the expanding universe.
- A three-year *R&D plan for the proposed Rare Isotope Accelerator (RIA) was developed* and initiated in FY 2000. RIA has been identified by the NSAC Isotope Separation On-Line (ISOL) Task Force as the optimal configuration for a next-generation world-class facility for low energy, nuclear astrophysics and nuclear structure research.
- Assembly of the *Japanese/US Kamioka Large Anti-Neutrino Detector (KamLAND)* began in FY 2000 and will continue in FY 2001. The experimental program for the detection of anti-neutrinos from Japanese nuclear power plants will be underway in FY 2002 with measurements that will provide information regarding whether neutrinos have mass. Eleven U.S. universities participate in KamLAND. U.S. participation in KamLAND is supported jointly with the High Energy Physics program.
- Fabrication of a *novel experiment with ultra-cold neutrons* began at the Los Alamos National Laboratory in FY 2000. Measurements from this experiment at the LANSCE facility will test theories of the weak coupling of quarks. First data are expected in FY 2002.

Nuclear Theory

In FY 2000, the *Institute for Nuclear Theory (INT)* at the University of Washington continued its activities as a premier international center for new initiatives and collaborations in nuclear theory research. Started in 1990, the INT has conducted three programs each year on topics identified by an international advisory committee. U.S. and foreign researchers spend varying lengths of time at the Institute during the 2-3 month period of the program to establish collaborations and carry out projects.

PROGRAM SHIFTS

- In the FY 2002 budget request the scope of the program is maintained, pending guidance from the community. A priority in the FY 2002 budget request is to maintain utilization of its major user facilities. The research programs at these major user facilities are integrated partnerships between DOE scientific laboratories and the university community. In FY 2002, the proposed experimental research activities are considered essential for effective utilization of the facilities. Within each of the subprograms, funding for university and national laboratory research is kept constant compared to FY 2001, and lower priority activities will be phased out in order to maintain manpower and focus efforts on the higher priority activities at these facilities. In the FY 2002 budget request, funding for capital equipment is reduced compared to FY 2001 to provide a ~1% increase for facility operations to mitigate the loss of critical personnel. There will be reductions in the number of Ph.D. researchers, technical staff and graduate students in the research program as well as at the facilities. Input and guidance from the community will be sought regarding the scientific opportunities to pursue for an optimal national program within the context of available funding and to maintain the nation's leadership role in fundamental nuclear physics research.
- In FY 2001, the Office of Science assumed from the Office of Environmental Management management and budget responsibilities for activities related to packaging, shipping, disposing of,

and reducing the volume of hazardous, radioactive or mixed waste generated in the course of normal operations at Brookhaven National Laboratory.

- In FY 2000, responsibilities in the Nuclear Physics program were reassigned to better manage the activities. The low energy heavy ion component of the Heavy Ion subprogram was moved to the Low Energy subprogram to bring those scientists who are focussed on nuclear structure, reactions, and nuclear astrophysics together into one subprogram. The Nuclear Data program, which had previously been managed by the Low Energy subprogram, was moved into the Nuclear Theory subprogram.

Scientific Facilities Utilization

The Nuclear Physics request includes $240,870,000 to maintain support of the Department's scientific user facilities. This investment will provide research time for several thousand scientists in universities and other Federal laboratories. It will also leverage both Federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. National science investment.

The proposed funding will support operations at the six National User Facilities supported by the Nuclear Physics program: the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL), the Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF), the Bates Linear Accelerator Center at Massachusetts Institute of Technology (MIT), the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL), the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory (ANL), and the 88 Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL). The Alternating Gradient Synchrotron (AGS) at BNL, which is part of the RHIC complex, is also operated by the program for a limited research program. Further information on these facilities can be found in the Site Description and Detailed Justifications under the subprogram in which they are funded.

These facilities have provided over 20,000 hours of beams annually for a research community of about 3000 scientists. The FY 2002 level of operations is below the FY 2001 level. Programmatic decisions will be made, with input and guidance from the community, to reduce the program's scope with a focus on the highest priority program elements. This reduction in scope will also result in a somewhat smaller research community, particularly postdoctoral assistants and graduate students.

Workforce Development

The Nuclear Physics program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. It also provides talent for a wide variety of technical, medical, and industrial areas that require the finely honed thinking and problem solving abilities, and the computing and technical skills developed through an education and experience in a fundamental research field. Scientists trained as Nuclear Physicists can be found in such diverse areas as nuclear medicine, medical physics, space exploration, national security and the stock market.

About 800 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2000 were involved in a large variety of experimental and theoretical research projects. Nearly one quarter of these researchers are involved in theoretical research. Those involved in experimental research utilize a number of scientific facilities supported by the DOE, NSF, and foreign countries. The majority of the experimental postdoctoral associates and graduate students (~80%) conducted their research at the six Nuclear Physics User Facilities. In FY 2002, emphasis is placed on national facility operations at the expense of basic research and hardware investments until the program can be restructured based on guidance from NSAC and the community. The number of postdoctoral research associates and graduate students that can be supported in the current FY 2002 levels will decrease approximately 10% in comparison to FY 2000 numbers.

Funding Profile

(dollars in thousands)

	FY 2000 Comparable Appropriation	FY 2001 Original Appropriation	FY 2001 Adjustments	FY 2001 Comparable Appropriation	FY 2002 Request
Nuclear Physics					
Medium Energy Nuclear Physics ..	108,752	120,910	-2,289	118,621	118,020
Heavy Ion Nuclear Physics..........	150,696	160,875	-5,058	155,817	156,295
Low Energy Nuclear Physics	60,448	64,175	-1,482	62,693	62,690
Nuclear Theory	20,973	23,930	-553	23,377	23,505
Subtotal, Nuclear Physics..................	340,869	369,890	-9,382	360,508	360,510
Construction	0	0	0	0	0
Subtotal, Nuclear Physics..................	340,869 [a]	369,890	-9,382	360,508	360,510
General Reduction	0	-3,766	3,766	0	0
General Reduction for Safeguards and Security	0	-4,821	4,821	0	0
Omnibus Rescission	0	-795	795	0	0
Total, Nuclear Physics.....................	340,869 [b] [c]	360,508	0	360,508	360,510

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act"

Public Law 103-62, "Government Performance and Results Act of 1993"

[a] Excludes $7,670,000 which has been transferred to the SBIR program and $460,000 which has been transferred to the STTR program.

[b] Includes $6,363,000 for Waste Management activities at Brookhaven National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $5,078,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Funding by Site

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Albuquerque Operations Office					
Los Alamos National Laboratory	10,714	9,479	9,798	+319	+3.4%
Sandia National Laboratory	0	4	0	-4	-100.0%
Total, Albuquerque Operations Office	10,714	9,483	9,798	+315	+3.3%
Chicago Operations Office					
Argonne National Laboratory	17,912	17,782	16,568	-1,214	-6.8%
Brookhaven National Laboratory	136,462	139,450	140,429	+979	+0.7%
Fermi National Accelerator Laboratory	50	0	0	0	0.0%
Chicago Operations Office	50,018	52,548	50,113	-2,435	-4.6%
Total, Chicago Operations Office	204,442	209,780	207,110	-2,670	-1.3%
Oakland Operations Office					
Lawrence Berkeley National Laboratory	18,060	18,213	17,899	-314	-1.7%
Lawrence Livermore National Laboratory	792	732	672	-60	-8.2%
Oakland Operations Office	17,194	16,830	16,131	-699	-4.2%
Total, Oakland Operations Office	36,046	35,775	34,702	-1,073	-3.0%
Oak Ridge Operations Office					
Oak Ridge Institute for Science & Education	611	670	674	+4	+0.6%
Oak Ridge National Laboratory	15,910	15,720	15,376	-344	-2.2%
Thomas Jefferson National Accelerator Facility	72,779	73,336	73,830	+494	+0.7%
Oak Ridge Operations Office	72	0	0	0	0.0%
Total, Oak Ridge Operations Office	89,372	89,726	89,880	+154	+0.2%
Washington Headquarters	295	15,744	19,020	+3,276	+20.8%
Total, Nuclear Physics	340,869 [abc]	360,508	360,510	+2	+0.0%

[a] Excludes $7,670,000 which has been transferred to the SBIR program and $460,000 which has been transferred to the STTR program.

[b] Includes $6,363,000 for Waste Management activities at Brookhaven National Laboratory that were transferred from the Office of Environmental Management in FY 2001.

[c] Excludes $5,078,000 for Safeguards and Security activities transferred to consolidated Safeguards and Security program in FY 2001.

Site Description

Argonne National Laboratory

Argonne National Laboratory (ANL) in Argonne, Illinois, is a Multiprogram Laboratory located on a 1,700 acre site in suburban Chicago. ANL has a satellite site located in Idaho Falls, Idaho. The major Nuclear Physics program activity at ANL supported by the Low Energy subprogram is the operation and research program at the ATLAS national user facility. Other activities include: (1) a Medium Energy group which carries out a program of research at TJNAF, Fermilab, RHIC and DESY in Germany; (2) R&D directed towards the proposed Rare Isotope Accelerator (RIA) facility; (3) a Nuclear Theory group, which carries out theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy and Low Energy physics; and (4) data compilation and evaluation activities as part of the National Data Program.

The **Argonne Tandem Linac Accelerator System (ATLAS)** facility provides variable energy, precision beams of stable ions from protons through uranium, at energies near the Coulomb barrier (up to 10 MeV per nucleon) using a superconducting linear accelerator. Most work is performed with stable heavy-ion beams, however, about 6% of the beams are exotic (radioactive) beams. The ATLAS facility features a wide array of experimental instrumentation, including a world-leading atom trap apparatus. The Gammasphere detector, which ATLAS shares on a rotating basis with the LBNL 88-Inch Cyclotron, coupled with the Fragment Mass Analyzer is a unique world facility for measurement of nuclei at limits of angular momentum (high-spin states). ATLAS is a world leader in superconducting linear accelerator technology, with particular application to the proposed Rare Isotope Accelerator (RIA) facility. The combination of versatile beams and powerful instruments enables the ~240 users at ATLAS to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies.

Brookhaven National Laboratory (BNL)

Brookhaven National Laboratory is a Multiprogram Laboratory located on a 5,200 acre site in Upton, New York. The major Nuclear Physics program effort at BNL, supported by the Heavy Ion subprogram, is the operation and research program of the new Relativistic Heavy Ion Collider (RHIC). Other activities include (1) a Medium Energy group that will use polarized protons in RHIC to understand the internal "spin" structure of the protons and pursue a limited program of fixed target experiments at the AGS, (2) the Laser Electron Gamma Source (LEGS) group, supported by the Medium Energy subprogram, that uses a unique polarized photon beam to carry out a program of photonuclear spin physics at the National Synchrotron Light Source (NSLS), (3) a Nuclear Theory group that provides theoretical support and investigations primarily in the area of relativistic heavy ion physics, (4) a Low Energy group that plays an important role in the research program at the Sudbury Neutrino Observatory (SNO) that is measuring the solar neutrino flux, and (5) the DOE managed National Nuclear Data Center (NNDC) that is the central U.S. site for national and international nuclear data and compilation efforts.

The Relativistic Heavy Ion Collider (RHIC) Facility, completed in 1999, is a major new and unique international facility used by about 1050 scientists from 19 countries. RHIC uses the Tandem, Booster, and Alternating Gradient Synchrotron (AGS) accelerators in combination to inject beams into two rings of superconducting magnets of almost 4 km circumference with 6 intersection regions where the beams collide. It can accelerate and collide a variety of heavy ions, including gold beams, up to an energy of 100 GeV per nucleon. RHIC will search for the predicted "quark-gluon plasma," a form of nuclear matter thought to have existed microseconds after the "Big Bang." Operations began in FY 2000 and first results have already been published. RHIC can also accelerate and collide polarized protons at energies up to 250 GeV for a research program directed at understanding the quark structure of the proton.

The **Alternate Gradient Synchrotron (AGS)** provides high intensity pulsed proton beams up to 33 GeV on fixed targets and secondary beams of kaons, muons, pions, and anti-protons. Experiments explore the quark constituents of light nuclei, and test the theories of quantum chromo-dynamics and electro-weak forces. The AGS is the injector of (polarized) proton and heavy-ion beams into RHIC, and its operations are supported by the Heavy Ion subprogram as part of the RHIC facility. Limited operations are supported by the Medium Energy subprogram for fixed-target experiments which utilize high intensity secondary kaon and pion beams.

The **National Nuclear Data Center** (NNDC) is the central U.S. site for national and international nuclear data and compilation efforts. The U.S. Nuclear Data program is the United States repository for information generated in low- and intermediate-energy nuclear physics research worldwide. This information consists of both bibliographic and numeric data. The NNDC is a resource that maintains the U.S. expertise in low- and intermediate-energy nuclear physics by providing evaluated nuclear data for the user community. The NNDC is assisted in carrying out this responsibility by other Nuclear Data program funded scientists at U.S. National Laboratories and universities.

Lawrence Berkeley National Laboratory (LBNL)

Lawrence Berkeley National Laboratory is a Multiprogram Laboratory located in Berkeley, California. The laboratory is on a 200 acre site adjacent to the Berkeley campus of the University of California. A major Nuclear Physics effort at LBNL, supported by the Low Energy subprogram, is the operations and the research program of the 88-inch Cyclotron, a national user facility. Other activities include (1) a Relativistic Nuclear Collisions group, with activities primarily at RHIC, where the group has been a major player in the development of the STAR detector; (2) a Low Energy group which has a major role in the implementation and operation of the Sudbury Neutrino Observatory (SNO) detector in Canada, and provides the project management of the U.S. collaboration in the KamLAND detector in Japan which is looking for evidence of neutrino mass; (3) a Nuclear Theory group, that carries out a program with emphasis on the theory of relativistic heavy ion physics; (4) a Nuclear Data group whose activities support the National Nuclear Data Center at BNL; and (5) a technical effort involved in RIA R&D.

The **88-Inch Cyclotron** facility provides high intensity stable beams from protons to bismuth at energies above the Coulomb barrier (up to 15 MeV per nucleon). The electron-cyclotron resonance (ECR) ion sources at the facility are state-of-the-art and copied around the world. The Gammasphere array, widely regarded as the world's most powerful gamma-ray detector, is used to study nuclei at the extremes of angular momentum and excitation energy. The Berkeley Gas-filled Separator, a world-class instrument, is used for discovery experiments in superheavy elements. The 88" Cyclotron is used by a community of about 230 scientists.

Lawrence Livermore National Laboratory (LLNL)

Lawrence Livermore National Laboratory is a Multiprogram Laboratory located on an 821 acre site in Livermore, California. Nuclear Physics supports research in nuclear structure studies carried out with the GENIE detector that was installed and is maintained by the LLNL group at the LANSCE facility at Los Alamos National Laboratory, as well as for nuclear data and compilation activities, and a technical effort involved in RIA R&D.

Los Alamos National Laboratory (LANL)

Los Alamos National Laboratory is a Multiprogram Laboratory located on a 27,000 acre site in Los Alamos, New Mexico. Nuclear Physics supports a broad program of research including: (1) a program of neutron beam research that utilizes beams from the LANSCE facility; (2) a relativistic heavy ion effort using the PHENIX detector at the new Relativistic Heavy Ion Collider (RHIC); (3) research directed at the study of the quark substructure of the nucleon in experiments at Fermilab, and at the "spin" structure of nucleons at RHIC using polarized proton beams; (4) the development of the Sudbury Neutrino Observatory (SNO) detector as well as involvement in the planned research program; (5) a broad program of theoretical research into a number of topics in nuclear physics; (6) nuclear data and compilation activities as part of the national nuclear data program; and (7) a technical effort involved in RIA R&D.

Oak Ridge Institute for Science and Education (ORISE)

Oak Ridge Institute for Science and Education is located on a 150 acre site in Oak Ridge, Tennessee. Nuclear Physics support is provided through ORISE for activities in support of the Holifield Radioactive Ion Beam Facility (HRIBF) and its research program.

Oak Ridge National Laboratory (ORNL)

Oak Ridge National Laboratory is a Multiprogram Laboratory located on a 24,000 acre site in Oak Ridge, Tennessee. The major effort at ORNL is the Low Energy program support for research and operations of the Holifield Radioactive Ion Beam Facility (HRIBF), that is run as a national user facility. Also supported is (1) a relativistic heavy ion group, that is involved in a research program using the PHENIX detector at RHIC; (2) a theoretical nuclear physics effort at ORNL that emphasizes investigations of nuclear structure and astrophysics; (3) nuclear data and compilation activities that support the national nuclear data effort; and (4) a technical effort involved in RIA R&D.

The **Holifield Radioactive Ion Beam Facility (HRIBF)** is the only radioactive nuclear beam facility in the U.S. to use the isotope separator on-line (ISOL) method and is used by about 200 scientists. It provides a wide range of both proton-rich and neutron-rich nuclei to a suite of instruments designed for studies in nuclear structure, dynamics and astrophysics using radioactive beams. The HRIBF accelerates secondary radioactive beams to higher energies (up to 10 MeV per nucleon) than any other facility in the world with such a broad selection of ions. The HRIBF conducts R&D on ion sources and low energy ion transport for radioactive beams.

Thomas Jefferson National Accelerator Facility (TJNAF)

Thomas Jefferson National Accelerator Facility (TJNAF) is a laboratory operated by the Nuclear Physics program located on 273 acres in Newport News, Virginia. Medium Energy subprogram support is provided for the operation and research program of the **Continuous Electron Beam Accelerator Facility (CEBAF)**, a unique international electron-beam user facility for the investigation of nuclear and nucleon structure based on the underlying quark substructure, used by over 1100 scientists. CEBAF consists of two multi-pass parallel continuous beam superconducting linear accelerators connected by recirculating magnetic arcs. Polarized and unpolarized electron beams up to 200 microamperes at up to 5.7 GeV are available that can be simultaneously distributed to three target halls. A large variety of major instruments are available for studying the scattering and particle production of the electron with fixed gas and solid targets. Fabrication of the G0 detector, a joint NSF-DOE project, that will allow a detailed mapping out of the strange quark contribution to nucleon structure, will be completed during FY 2002. Support is provided for a nuclear theory group whose program of investigations supports the experimental program of the laboratory. An accelerator R&D group is supported for projects important to the Nuclear Physics program, such as the proposed 12 GeV upgrade of CEBAF and R&D for RIA.

All Other Sites

The Nuclear Physics program funds 180 research grants at 85 colleges/universities located in 35 states. Among these is a grant with the Massachusetts Institute of Technology (MIT) for the operation of the **Bates Linear Accelerator Center** as a national user facility used by about 250 scientists. The Bates facility, with electron beams up to 1 GeV, conducts experiments to study the properties and constituents of protons and light nuclei at energies below those of CEBAF. The research program probes the properties of the proton such as its shape and polarizability, and the charge distribution and magnetism of the deuteron. A major instrument for making these measurements will be the Bates Large Acceptance Spectrometer Torroid (BLAST) detector, whose fabrication will be completed in FY 2002. BLAST will observe collisions of polarized electrons in thin polarized gas targets located in the South Hall Pulse Stretcher Ring. Additional unique experiments are performed with the Out-Of Plane Spectrometer (OOPS). The Bates experimental program is scheduled to be concluded in 2004 and phased out in FY 2005-2006.

Grants for the operation of accelerator facilities at four university laboratories are supported by the Low Energy subprogram for research in selected and specialized areas conducted primarily by the in-house faculty members and students. The **Triangle Universities Nuclear Laboratory (TUNL)** utilizes a tandem Van de Graaff and polarized beams and targets to test and refine the theory of the nuclear force and its currents. A suite of instrumentation has been built up to take advantage of this unique combination of capabilities and to study fundamental symmetries and reactions important to nuclear astrophysics. **The Texas A&M Cyclotron Institute (TAMU)** operates a modern superconducting cyclotron to deliver a wide range of stable and selected radioactive beams for medium energy heavy-ion reaction studies, tests of fundamental constants of the standard model, and nuclear astrophysics. Modern instrumentation takes advantage of the heavy-ion beams, and a number of foreign collaborators use the facility. **The Yale Tandem Van de Graaff** provides a variety of stable beams for an extensive suite of instruments that, along with the opportunity for extended running times, provides the capability for detailed experiments on symmetry, collective structures, and evolution of properties in nuclei and nuclear astrophysics. The **University of Washington Tandem Van de Graaff** provides precisely characterized proton beams for extended running periods for research in fundamental nuclear interactions and nuclear astrophysics. These four accelerator facilities offer niche capabilities and opportunities not available at the national user facilities, or many foreign low-energy laboratories, such as specialized sources and targets, opportunities for extended experiments, and specialized instrumentation. These facilities operate in a university environment and thus provide a unique setting for the training and education of graduate students in the U.S., where they have the opportunity to be involved in all aspects of low energy nuclear research. These centers of excellence have in the past and continue today to produce the next generation of national leaders in nuclear science research.

Medium Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Nuclear Physics program supports the basic research necessary to identify and understand the fundamental features of atomic nuclei and their interactions. The Medium Energy Nuclear Physics subprogram supports fundamental research that is ultimately aimed at achieving a quantitative understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects that are believed to combine in different ways to make all the other sub-atomic particles. Equally important is the achievement of an understanding of the "strong force," one of only four forces in nature, and the force that holds the nucleus of the atom together. Research efforts include studies of the role of excited states of protons and neutrons in nuclear structure, investigations of the role of specific quarks in the structure of protons and neutrons, studies of the symmetries in the behavior of the laws of physics, and investigations of how the properties of protons and neutrons change when embedded in the nuclear medium. Measurements are often carried out with beams of electrons or protons whose "spins" have all been lined up in the same direction (polarizing the beams) to determine what role the intrinsic spins of the quarks and gluons play in the structure of the nucleon.

This research is generally carried out using electron and proton beams provided by accelerator facilities operated by this subprogram, other Department of Energy programs (e.g., High Energy Physics and Basic Energy Sciences), and at other unique domestic or foreign facilities. These facilities produce beams of sufficient energy (small enough wavelength) that they can probe at a scale within the size of a proton or neutron. The Medium Energy Nuclear Physics subprogram supports the operations of two national user facilities - the Thomas Jefferson National Accelerator Facility (TJNAF) and the Bates Linear Accelerator Center operated by the Massachusetts Institute of Technology. These accelerator facilities serve a nationwide community of over 500 Department of Energy and National Science Foundation supported scientists and students from over 140 American institutions, of which over 80% are colleges and universities. Both facilities provide major contributions to education at all levels. At both TJNAF and Bates, the National Science Foundation (NSF) has made a major contribution to new experimental apparatus in support of the large number of NSF users. A significant number of foreign scientists collaborate in the research programs of both facilities. The research program at the TJNAF, for example, involves over 250 scientists from 19 foreign countries; many of these scientists are from Conseil Europeen pour la Recherche Nucleaire (CERN) member states. At TJNAF, foreign collaborators have also made major investments in experimental equipment.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Research					
University Research	16,654	16,498	15,295	-1,203	-7.3%
National Laboratory Research	14,523	16,162	16,345	+183	+1.1%
Other Research	360	5,221	5,415	+194	+3.7%
Subtotal, Research	31,537	37,881	37,055	-826	-2.2%
Operations					
TJNAF Operations	66,330	66,666	67,515	+849	+1.3%
Bates Operations	10,885	12,623	12,000	-623	-4.9%
Other Operations	0	1,451	1,450	-1	-0.1%
Subtotal, Operations	77,215	80,740	80,965	+225	+0.3%
Total, Medium Energy Nuclear Physics	108,752	118,621	118,020	-601	-0.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Research	**31,537**	**37,881**	**37,055**
▪ **University Research**	**16,654**	**16,498**	**15,295**

These activities comprise a broad program of research, and include 40 grants at 35 universities in 17 states and the District of Columbia. These research efforts utilize not only each of the accelerator facilities supported under the Medium Energy program, but also use other U.S. and international accelerator laboratories. Included in University Research is Bates Research, the effort performed at the MIT/Bates Linear Accelerator Center by MIT scientists. Other University Research includes all other university-based efforts using many research facilities, including activities by MIT scientists that are not carried out at Bates. **Performance will be measured by** triannual peer review.

	FY 2000	FY 2001	FY 2002
Bates Research	**4,617**	**4,145**	**2,945**

MIT scientists along with other university researchers have completed "symmetry violation" studies on the proton and deuteron in the North Experimental Hall. The experiment (SAMPLE) provided important information on the quark flavor contribution to the proton's spin magnetism. "Out-of-Plane" measurements are being carried out using the new spectrometers (OOPS) in the South Experimental Hall on the proton, deuteron, and complex nuclei including measurements of the transition of the proton to its excited state.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Preparations are being made for a new program of research to study the structure of the nucleon and the nature of the nucleon-nucleon force, utilizing the new Bates Large Acceptance Spectrometer Toroid (BLAST) detector. The decrease in funding in the request for FY 2002 reflects the completion of the funding for BLAST fabrication in FY 2001. **Performance will be measured by** the initiation of measurements with BLAST on schedule in FY 2002 using thin gas targets and the high current circulating electron beam in the South Hall Pulse Stretcher Ring.

Other University Research...	**12,037**	**12,353**	**12,350**

In FY 2002 university researchers are supported at the same funding level as FY 2001 to address forefront science at accelerator and non-accelerator facilities. Activities include:

University scientists are collaborating on important ongoing and future experiments at TJNAF. FY 2001-2002 activities include the completion of studies of the charge structure of the neutron in Hall C. Planned measurements in Hall A include the electric form factor of the proton. A series of studies of the excited states of the proton will continue in Hall B. First parity-violation measurements to look for the "strange quark" content of the proton in Hall A have been completed. Scientists are participating in major new detector fabrication to be completed in FY 2002 for the "G0" experiment in cooperation with the National Science Foundation. "G0" will allow a "complete mapping" of the strange quark content of the nucleon using parity violation techniques. An important experiment in hypernuclear spectroscopy has just completed data taking in Hall C. Plans are also underway to carry out a program of higher resolution hypernuclear spectroscopy in Hall A.

A number of university groups are collaborating in experiments using the new Out-of-Plane Spectrometers in the South Experimental Hall at the MIT/Bates Linear Accelerator Center to probe nucleon and few-body nuclear structure. BLAST will be completed in FY2001 and university research support will be provided in FY 2002 for use of this new detector.

University scientists and National Laboratory collaborators will continue to carry out the HERMES (HERa MEasurements with Spin) experiment at the DESY laboratory in Hamburg, Germany. This experiment is measuring which components of the proton or neutron determine the "spin" of these particles, an important and timely scientific issue which will be explored in the planned program at RHIC starting in FY 2003. In FY 2002, HERMES will utilize a new Ring Imaging Cerenkov counter for identification of quark flavor contributions to the spin of the nucleon.

Polarization experiments are being conducted at the SLAC (Stanford Linear Accelerator) facility. One parity violation experiment aims to make a precise determination of the weak mixing angle, an important fundamental parameter of the Standard Model of Particle Physics.

▪ **National Laboratory Research**	**14,523**	**16,162**	**16,345**

Included is: (1) the research supported at the Thomas Jefferson National Accelerator Facility (TJNAF), that houses the nation's and world's unique high intensity continuous wave electron accelerator and (2) research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories. The National Laboratory groups carry out research at various world facilities as well as at their home institutions**. Performance is measured by** peer review and merit evaluation.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
TJNAF Research	**5,700**	**5,741**	**5,770**

Scientists at TJNAF, with support of the user community, assembled the large and complex new experimental apparatus for Halls A, B, and C. All three experimental Halls are operational. TJNAF scientists provide experimental support and operate the apparatus for safe and effective utilization by the user community. TJNAF scientists participate in the laboratory's research program, and collaborate in research at other facilities.

As of FY 2001, both Hall A and Hall C will have completed fifteen experiments each. The complex large-acceptance spectrometer in Hall B is complete and the research program has completed over 50% of the data taking for 41 experiments. TJNAF researchers participate in all of these experiments.

TJNAF scientists are participating in the assembly of a new detector for the "G0" experiment, in cooperation with the National Science Foundation. The G0 detector will be completed in FY 2002.

Other National Laboratory Research	**8,823**	**10,421**	**10,575**

Researchers at National Laboratories are supported at about the same level as FY 2001 to address forefront science at accelerator and non-accelerator facilities. These activities include:

Argonne National Laboratory scientists are pursuing research programs at TJNAF, at the DESY Laboratory in Germany, and have proposed measurements of the quark structure of the nucleon at the new Main Injector at Fermilab. The theme running through this entire effort is the search for a detailed understanding of the internal quark-gluon structure of the nucleon. They have also made important advances in the technique of Atom Trap Trace Analysis to be used in measurements of rare isotopes for precision studies of nuclear structure.

At Brookhaven National Laboratory, the Medium Energy Research group, which in previous years has concentrated on hadron beam experiments at the AGS, will change its major emphasis. Since the AGS will now serve as a heavy ion and proton injector for the new RHIC accelerator, the group's scientific emphasis will shift to "RHIC Spin". This is the set of experiments planned for RHIC that will use colliding polarized proton beams to investigate the spin content of the nucleon and, in particular, what role gluons play. In FY2001-2002, additional funding is being provided to this group to assure that appropriate scientific effort has been assembled in support of the RHIC Spin effort. A limited program of fixed target experiments will continue at the AGS, including an important study of hypernuclei for which the Japanese have made significant investments and are major collaborators.

Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists will be utilizing a new spectrometer and a recently developed polarized ice target for a program of spin physics at low energies. This unique facility produces its polarized "gammas" by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source (NSLS). In FY 2002, the research program utilizing the new equipment will commence.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

At Los Alamos National Laboratory, scientists and collaborators will be preparing to carry out a next generation neutrino oscillation experiment which builds on the experience of the Liquid Scintillator Neutrino Detector (LSND) experiment at Los Alamos, that detected a signal of neutrino oscillations. If oscillations are proven, then neutrinos would have mass, requiring changes in our present understanding of the laws of physics. The Booster Neutrino Experiment (BooNE) will use neutrinos generated from the Fermi National Accelerator Laboratory Booster proton beam; data collection is planned to commence in FY 2002.

Los Alamos scientists also are involved in experiments at Fermilab and at RHIC (RHIC Spin) that continue to try to unravel the mysteries of the internal components and spin of the nucleon. The Los Alamos group has also been instrumental in providing major components of the PHENIX detector at RHIC that are crucial in carrying out the RHIC-Spin Program of research.

▪ **Other Research**	**360**	**5,221**	**5,415**

Amounts include funds for the SBIR and STTR programs and other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

Amounts include the estimated requirements for the FY 2001 and FY 2002 SBIR programs and other established obligations.

Operations	**77,215**	**80,740**	**80,965**
▪ **TJNAF Operations**	**66,330**	**66,666**	**67,515**

Included is the funding that supports: (1) operation of the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF), and (2) major manpower, equipment, and staging support for the assembly and dismantling of complex experiments.

TJNAF Accelerator Operations	**42,126**	**42,436**	**42,910**

Funding for accelerator operations in FY 2002 supports a 3,900 hour (26-week) running schedule. In a constrained budget, TJNAF is able to almost maintain the same level of operations as in FY 2001, with a smaller staff. The accelerator now routinely delivers beams of differing energies and currents simultaneously to the three experimental halls. A maximum beam energy of 5.7 GeV has been delivered to experiments. High current, high polarization beam capability is now also available and is being used for experiments.

	(hours of beam for research)		
	FY 2000	FY 2001	FY 2002
TJNAF	4500	4050	3900

Funding is provided for AIP projects for the polarized injector and beam handling components as well as other additions and modifications to the accelerator facilities. GPP funding is provided for minor new construction and utility systems.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
TJNAF Experimental Support	**24,204**	**24,230**	**24,605**

Operating and equipment funding is provided for the experimental support needed to effectively carry out the TJNAF experimental program.

Support is increased (1% or $181,000) for the scientific and technical manpower, materials, and services needed to integrate rapid assembly, modification, and disassembly of large and complex experiments for optimization of schedules. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment for specific experiments. Efforts in FY 2002 will be focused on effectively carrying out two-Hall simultaneous operation as opposed to three.

The G0 detector, a major item of equipment with a Total Estimated Cost of $7,570,000 is being assembled. DOE's contribution is $3,965,000 and the National Science Foundation is contributing $3,605,000 to this detector. As G0 construction is completed in FY 2002 (-$957,000), TJNAF is shifting their base capital equipment and AIP emphasis (including an increase of $194,000 in capital funds) towards assembly and installation of polarized electron injector improvements for the accelerator, ancillary equipment items such as polarized targets for experimental Halls A, B, C, spectrometer systems, the completion of a major upgrade of the data reduction system to handle massive amounts of raw data, and the continuation of the fabrication of second generation experiments. **Performance will be measured by** the completion of fabrication, commissioning and initiation of measurements with the G0 detector in FY 2002.

▪ **Bates Operations**	**10,885**	**12,623**	**12,000**

Funding is provided to support accelerator operations at the MIT/Bates Linear Accelerator Center.

Bates will operate in FY 2002, to carry out a program focused primarily on commissioning activities for the BLAST detector. The new BLAST detector will observe collisions in thin gas targets located on the South Hall Pulse Stretcher Ring. **Performance will be measured by** the commissioning of the BLAST detector and the initiation of its research program in FY 2002. When the scientific program of BLAST commences in FY 2002, the Bates research effort will concentrate on this new experimental facility. Upon completion of the BLAST research program in FY 2004, it is now planned that the Bates facility will begin a 2-year phaseout. Starting in FY 2005, Decontaminating and Decommissioning (D&D) activities will be initiated. The D&D cost and schedule will be determined at that time.

	(hours of beam for research)		
	FY 2000	FY 2001	FY 2002
Bates	2000	2000	2100

Accelerator operations in FY 2001 are providing beams for research programs in the South Hall utilizing the OOPS spectrometers, for testing of internal, polarized, continuous beams in the South Hall Ring, and for development of extracted continuous beams for delivery to the existing South Hall spectrometers.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

AIP funding supports additions and modifications to the accelerator facilities; GPP funding supports minor new construction and utility systems. The decrease in FY 2002 funding reflects a decrease in the investments in AIP and capital equipment in anticipation of the phase out of the Bates facility.

▪ **Other Operations**	**0**	**1,451**	**1,450**

Funding is provided to support accelerator operations at other facilities.

Funding is provided for 600 hours (6 weeks) of beam, to carry out a limited program of high priority experiments at the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory including an important study of hypernuclei for which the Japanese made an investment in detector fabrication.

Total, Medium Energy Nuclear Physics	**108,752**	**118,621**	**118,020**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Research	
▪ **University Research**	
The MIT/Bates research activity decrease reflects the completion of funding of the BLAST detector system ($1.2 million in FY 2001). Research support is provided to carry out BLAST commissioning and its research program.	-1,200
Research support at other universities is at the same level as FY 2001. Lower priority activities will be phased out in order to maintain manpower and focus efforts on the high priority activities at TJNAF.	-3
▪ **National Laboratory Research**	
Funding for TJNAF and other National Laboratory groups is increased by about 1% to help maintain efforts. Lower priority activities will be phased out in order to maintain manpower and focus efforts on the high priority activities at TJNAF. ..	+183
▪ **Other Research**	
Estimated SBIR/STTR and other obligations increase.	+194
Total Research..	-826

	FY 2002 vs. FY 2001 ($000)
Operations	
▪ **TJNAF Operations**	
TJNAF Accelerator Operations: Funding for accelerator operations is increased by about $410,000 (+1%) in order to carry out a 26 week running schedule. In FY 2001, TJNAF is expected to operate 27 weeks. Funding (about +$63,000) for general plant and accelerator improvements projects is provided. In a constrained budget, TJNAF is able to almost maintain the same level of operations as in FY 2001, with a smaller staff.	+474
TJNAF Experimental Support: Support is increased by about 1.0% (+$181,000) in order to help maintain the needed manpower and equipment required for carrying out the highest priority experimental programs. Effort will be focused on carrying out two-Hall simultaneous operation as opposed to three. Overall capital equipment funding is increased $194,000 with additional funds provided for the planned experimental program as funding for the G0 detector is decreased.	+375
▪ **Bates Operations**	
The reduction in Bates operations reflects the planned funding profile for Bates, in which operations concentrates on research with the new BLAST detector. Bates, with a smaller operating staff, will provide 2100 beam hours for the commissioning of the BLAST detector and the initiation of its research program. Funding for Capital equipment and AIP is reduced by about $500,000.	-623
▪ **Other Operations**	
Funding of the operation of the AGS at BNL is constant compared to FY 2001 and provides 600 hours (6 weeks) of beam time to complete high priority experiments.	-1
Total Operations	+225
Total Funding Change, Medium Energy Nuclear Physics	-601

Heavy Ion Nuclear Physics

Mission Supporting Goals and Objectives

The Heavy Ion Nuclear Physics subprogram supports research directed at understanding the properties of nuclear matter over the wide range of conditions created in nucleus-nucleus collisions, particularly the predicted phase changes from the liquid to gas state and from normal to quark matter. Using beams of accelerated heavy ions at intermediate bombarding energies, research is focused on the study of the fragmentation of nuclei in highly violent collisions and the flow of nuclear matter in less violent collisions. From such studies of the flow of nuclear matter, one can obtain information regarding the equation of state of nuclear matter; such information is important in understanding the dynamics of supernova explosions. At much higher relativistic bombarding energies, collisions producing hot, dense nuclear matter are studied with the goal of observing the deconfinement of normal matter into the quark-gluon plasma. This form of matter is predicted to have been the early phase of the universe, a millionth of a second after the Big Bang. Scientists and students at universities and national laboratories are funded to carry out this research at the DOE supported Relativistic Heavy Ion Collider (RHIC) facility, as well as at the National Science Foundation (NSF) and foreign supported accelerator facilities.

The Heavy Ion Nuclear Physics subprogram supports operation of RHIC at Brookhaven National Laboratory (BNL). This is a unique world-class facility that addresses fundamental questions about the nature of nuclear matter. With it one can study collisions of heavy nuclei at energies over 10 times of that previously available at any other facility in the world, namely at CERN. The RHIC is also the only accelerator facility in the world that provides collisions of polarized protons with polarized protons. From these collisions, important and unique information can be obtained regarding the composition of the gluons that provide the binding of the quarks to make the nucleons, the protons and neutrons that make up the nucleus. The construction of RHIC was completed in August 1999, and first collisions were observed in June 2000. The RHIC facility is utilized by over 1,050 DOE, NSF, and foreign supported researchers. The RHIC experimental program is determined with the guidance of a Program Advisory Committee, consisting of distinguished scientists, that reviews and evaluates proposed experiments and advises the BNL Associate Director for Nuclear and High Energy Physics regarding their merit and scientific priority. Capital Equipment and Accelerator Improvement Project (AIP) funds are provided for additions, modifications, and improvements to the research accelerators and ancillary experimental facilities to maintain and improve the reliability and efficiency of operations, and to provide new experimental capabilities. An annual peer review of the effectiveness of RHIC operations and its research program is conducted by the program. **Performance will be measured by** completing the first round of experiments at RHIC to see possible evidence of the predicted quark-gluon plasma: a high-temperature, high-density state of nuclear matter that may have existed a millionth of a second after the big bang.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

The Heavy Ion Nuclear Physics subprogram also provides General Purpose Equipment (GPE), General Plant Project (GPP), and waste management funds to BNL as part of Nuclear Physics' landlord responsibilities for this laboratory. These funds are for general purpose equipment, minor new capital construction, alterations and additions, improvements to land, buildings, and utility systems, and the processing of hazardous, radioactive or mixed-waste generated during normal operations.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Research					
University Research	11,511	12,004	11,495	-509	-4.2%
National Laboratory Research	22,995	21,689	20,860	-829	-3.8%
Other Research	0	2,848	2,850	+2	+0.1%
Subtotal, Research	34,506	36,541	35,205	-1,336	-3.7%
Operations					
RHIC Operations	99,767	102,691	104,505	+1,814	+1.8%
Other Operations	10,060	10,641	10,640	-1	0.0%
BNL Waste Management	6,363	5,944	5,945	+1	0.0%
Subtotal, Operations	116,190	119,276	121,090	+1,814	+1.5%
Total, Heavy Ion Nuclear Physics	150,696	155,817	156,295	+478	+0.3%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Research	**34,506**	**36,541**	**35,205**
▪ **University Research**	**11,511**	**12,004**	**11,495**

Support is provided for the research of scientists and students at 27 universities in 18 states. **Performance will be measured** for all these research activities by peer review triannually.

- Researchers using primarily the NSF supported National Superconducting Cyclotron Laboratory at Michigan State University, at Texas A&M University, and at foreign facilities in France, Germany, and Italy, investigate nuclear reactions at intermediate energies, with the aim of studying the fragmentation of nuclei and the flow of nuclear matter in violent collisions.
- Research using relativistic heavy ion beams is focused on the study of the production and properties of hot, dense nuclear matter at initial experiments at RHIC, where an entirely new regime of nuclear matter now becomes available to study for the first time. The university groups provide core manpower for the operation of and data analysis from the four RHIC detectors. The ~$500,000 decrease reflects the completion of capital equipment projects in FY 2001 and no new projects in FY 2002.

	FY 2000	FY 2001	FY 2002
▪ **National Laboratory Research**	**22,995**	**21,689**	**20,860**

Support is provided for the research programs of scientists at four National Laboratories (BNL, LBNL, LANL and ORNL) that play critical roles especially in the instrumentation. **Performance is measured by** peer review and merit review.

(dollars in thousands)

	FY 2000	FY 2001	FY 2002
BNL RHIC Research	**13,192**	**10,888**	**10,065**

BNL scientists play a major role in planning and carrying out research with the four detectors (STAR, PHENIX, BRAHMS and PHOBOS) at RHIC and have major responsibilities for maintaining, improving and developing this instrumentation for use by the user community. The planned running periods in FY 2001 and FY 2002 will be critical for this new research program as RHIC approaches its design luminosity (collision rate) and all four RHIC detectors reach their full potential for studies of the expected new forms of nuclear matter that will be created in the heavy ion collisions. In FY 2002 funding is increased by about 0.5% for research, but funding for capital equipment is decreased by about $856,000 with the completion of the PHENIX muon instrumentation. Funding continues for production of modules for the Electromagnetic Calorimeter enhancement for STAR.

- The muon instrumentation for PHENIX allows measurement of the yields of muons ("heavy electrons") that probe the early stages of quark-gluon plasma formation. The Japanese are contributing substantial support for the two PHENIX muon arms, which are also critical components of the detection systems for measurements in the PHENIX RHIC Spin Program.
- The Electromagnetic Calorimeter for STAR provides capability to distinguish electrons from photons, and extends the measurement of particle energy to high energies. The detector system is also a critical component for the RHIC Spin Program for STAR. Production of calorimeter modules began in FY 2000 and will continue through FY 2003.

Other National Laboratory Research	**9,803**	**10,801**	**10,795**

Researchers at LANL, LBNL, and ORNL provide leadership in the commissioning of the PHENIX muon arm and the STAR electromagnetic calorimeter, as well as play leadership roles in carrying out the research utilizing these detectors. At LBNL development of the analysis system for RHIC data, in alliance with the National Energy Research Scientific Computing Center (NERSC), will be completed.

▪ **Other Research**...	**0**	**2,848**	**2,850**

Amounts include the estimated requirements for the continuation of the FY 2001 and FY 2002 SBIR programs and other established obligations. ....

Operations	**116,190**	**119,276**	**121,090**
▪ **RHIC Operations**	**99,767**	**102,691**	**104,505**

The Relativistic Heavy Ion Collider (RHIC) is anticipated to reach nearly full data production capabilities by the end of the planned running period in FY 2002. RHIC is a unique facility whose colliding relativistic heavy ion beams will permit exploration of hot, dense nuclear matter and recreate the transition from quarks to nucleons that characterized the early evolution of the universe. Studies with colliding heavy ion beams will provide researchers with an opportunity to explore a new regime of nuclear matter and nuclear interactions that up to now has only been characterized theoretically.

During the FY 2001-FY 2002 running periods, preparations of RHIC for its spin physics program will continue, with the anticipation that the spin physics experimental program will begin in FY 2003. The RHIC spin program accelerates polarized protons to study the internal structure of the

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

protons, in particular the role of the gluons whose interaction with the quarks binds the quarks together to make the protons and neutrons. Understanding the role of the gluons is important for understanding the properties of the quark-gluon plasma.

RHIC Accelerator Operations	**73,525**	**74,975**	**76,345**

Support is provided for the operation, maintenance, improvement and enhancement of the RHIC accelerator complex. This includes the Tandem, Booster and AGS accelerators that together serve as the injector for RHIC. RHIC came into operations in FY 2000 with a total of 4,030 hour (27-week) operations schedule that was focused on commissioning the new accelerator and detector systems. Beam time for research is expected to increase significantly in FY 2001 with a similar total operating schedule. FY 2002 funding supports a 3,000 hour (20-week) RHIC total operating schedule. The schedule provides 1,650 hours of beam for research with the remainder of the schedule (1,350 hours) for beam studies, commissioning operations with polarized protons and cryogenic warm up. With a limited budget, NP has chosen to retain personnel and run as much as possible. The planned increase in luminosity will allow more data to be acquired within a given running period, as compared to previous experimental runs. **Performance will be measured by** achieving the design luminosity (collision rate) of RHIC for heavy ions in FY 2002. Capital equipment funding is provided for normal maintenance projects and AIP funding is provided for needed improvement projects. A 1% increase in RHIC operation funding supports a 3,000 hour (20-week) running schedule. As construction of major detector projects are completed, $651,000 of capital equipment funds are shifted from BNL RHIC Research to BNL Accelerator Operations in order to optimize and maintain these large detectors, as well as start AIP initiatives that will lead to more efficient operations.

RHIC Operations

	(hours of beam for research)		
	FY 2000	FY 2001	FY 2002
RHIC	380	1900	1650

RHIC Experimental Support	**26,242**	**27,716**	**28,160**

Support is provided for the operation, maintenance, improvement and enhancement of the RHIC experimental complex, including detectors, experimental halls, computing center and support for users. RHIC detectors (STAR, PHENIX, BRAHMS and PHOBOS) will reach their initial planned potential by FY 2002. Over 1050 scientists and students from 90 institutions and 19 countries will participate in the research programs of these four detectors. Funding is increased by 1% compared to FY 2001 for experimental support.

▪ **Other Operations**	**10,060**	**10,641**	**10,640**

As steward for Brookhaven National Laboratory (BNL), the Nuclear Physics program provides GPP funding for minor new construction, other capital alterations and additions, and for buildings and utility systems. Funding of this type is essential for maintaining the productivity and usefulness of

	FY 2000	FY 2001	FY 2002
	(dollars in thousands)		

Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. The total estimated cost of each project will not exceed $5,000,000. In addition, the program has landlord responsibility for providing General Purpose Equipment (GPE) at BNL.

	FY 2000	FY 2001	FY 2002
▪ **BNL Waste Management**	**6,363**	**5,944**	**5,945**

Provides funding for the activities related to packaging, shipping, and disposing of, and reducing the volume of, hazardous, radioactive or mixed waste generated in the course of normal operations at Brookhaven National Laboratory.

	FY 2000	FY 2001	FY 2002
Total, Heavy Ion Nuclear Physics	**150,696**	**155,817**	**156,295**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Research	
▪ **University Research**	
FY 2002 funding for University Research is maintained at a constant level compared to FY 2001. Equipment funding in FY 2002 is decreased by about $500,000 as projects are completed. Lower priority activities will be reduced in order to focus efforts on those activities at RHIC identified as providing the most promising physics opportunities.	-509
▪ **National Laboratory Research**	
BNL RHIC Research: Research support is increased by about 0.5% to effectively carry out research with the enhanced detectors at full luminosity at RHIC. Capital equipment is decreased by about $850,000 as projects are being completed. Lower priority activities will be reduced in order to focus efforts on those activities at RHIC identified as providing the most promising physics opportunities.	-823
Other National Laboratory Research: Research support is maintained at a constant level compared to FY 2001. Lower priority activities will be reduced in order to focus efforts on those activities at RHIC identified as providing the most promising physics opportunities. .	-6
▪ **Other Research:**	
Estimated SBIR and other obligations remain about the same.	+2
Total, Research	-1,336

	FY 2002 vs. FY 2001 ($000)
Operations	
▪ **RHIC Operations**	
Accelerator Operations: An increase of $719,000 (+1%) in operating funds provides an estimated 20-week running schedule, compared with 27 weeks in FY 2001. An increase of $651,000 is provided to bring Capital equipment and Accelerator Improvement Project funding (to a total of $3,600,000) to a level that will sustain operations. A revised physics program will be developed which will optimize the physics output with the proposed running schedule.	+1,370
Experimental Support: An increase of $240,000 (+1%) is provided to enhance support of manpower and services to effectively carry out research measurements. An additional $204,000 is provided for experimental equipment to enhance detector and computing capabilities that will be needed for full luminosity running.	+444
▪ **Other Operations**	
FY 2002 funding for General Plant Projects and General Purpose Equipment to Brookhaven National Laboratory is constant compared to FY 2001.	-1
▪ **BNL Waste Management**	
FY 2002 funding for Waste Management is provided at the same level as FY 2001 to maintain activities.	+1
Total, Operations	+1,814
Total Funding Change, Heavy Ion Nuclear Physics	+478

Low Energy Nuclear Physics

Mission Supporting Goals and Objectives

The Low Energy Nuclear Physics subprogram supports research directed at understanding the structure of nuclei, nuclear reaction mechanisms, and experimental tests of fundamental symmetries. At the present time, emphasis is placed on addressing issues in nuclear astrophysics, and the structure of nuclei at the limits of energy, deformation, angular momentum, and isotopic stability. This research is generally conducted using beams provided by accelerator facilities operated by this subprogram, other Department of Energy programs, or at other domestic or foreign facilities.

The Low Energy Nuclear Physics subprogram supports the operation of the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory, the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory, and the 88-Inch Cyclotron facility at the Lawrence Berkeley National Laboratory. Research and development and preconceptual design activities at these facilities are in support of a next generation low-energy facility, the Rare Isotope Accelerator (RIA). All the National Laboratory facilities are utilized by DOE, NSF, and foreign-supported researchers whose experiments undergo peer review prior to approval for beam time. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems, and for accelerator instrumentation for effective utilization of all the national accelerator facilities operated by this subprogram. Accelerator Improvement Project (AIP) funds are provided for additions, modifications, and improvements to the research accelerators and ancillary equipment facilities to maintain and improve the reliability and efficiency of operations, and to provide new experimental capabilities.

University-based research is an important feature of the Low Energy subprogram. Accelerator operations are supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL), University of Washington, and Yale University. These university centers of excellence each have a critical mass of nuclear physics faculty involved in research that is conducted both on and off campus, have about 15-25 graduate students at different stages of their education, and historically have produced a large fraction of the leaders in the field. The accelerator facilities are relatively small and appropriate for siting on university campuses, where they provide unique opportunities for hands-on training of nuclear experimentalists that complement the experience that can be obtained at the national user facilities. Many of these scientists, after obtaining their PhDs, contribute to a wide variety of nuclear technology programs of interest to the DOE.

Some experiments use accelerators in conjunction with special apparatus to study fundamental nuclear and nucleon properties, for example the ultra-cold neutron trap at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory. Other experiments in low-energy nuclear physics do not require the use of accelerators. The study of neutrinos from the sun is an example. The Sudbury Neutrino Observatory (SNO) detector is designed to study the production rate and properties of solar neutrinos. The Kamioka Large Anti-Neutrino Detector (KamLAND) will study the properties of anti-neutrinos produced by reactors. Both of these experiments address the important and interesting question of whether neutrinos have a mass. The answer to this very fundamental question has profound implications for our understanding of the basic building blocks of matter and the evolution of the universe.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Research					
University Research	16,778	17,395	16,965	-430	-2.5%
National Laboratory Research	19,508	19,747	19,835	+88	+0.4%
Other Research	2,000	3,808	4,030	+222	+5.8%
Subtotal Research	38,286	40,950	40,830	-120	-0.3%
Operations					
HRIBF Operations	8,847	8,837	8,925	+88	+1.0%
ATLAS Operations	7,601	6,992	7,060	+68	+1.0%
88-Inch Operations	5,714	5,914	5,875	-39	-0.7%
Subtotal Operations	22,162	21,743	21,860	+117	+0.5%
Total, Low Energy Nuclear Physics	60,448	62,693	62,690	-3	0.0%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Research	**38,286**	**40,950**	**40,830**
▪ **University Research**	**16,778**	**17,395**	**16,965**

Support is provided for the research of scientists and students at 26 universities in 17 states. Nuclear Physics university scientists perform research as user groups at National Laboratory facilities, at on-site facilities and at other specifically fabricated experiments. These activities address a broad range of fundamental issues as diverse as the properties of nuclei, the nature of the weak-interaction and the production mechanisms of chemical elements in stars and supernovae. **Performance will be measured by** triannual peer-review. FY 2002 funding for researchers and students is the same as FY 2001. The reduction reflects the completion of experimental equipment projects.

The major component of the research, involving that of about two-thirds of the university scientists, is conducted using the low energy heavy ion beams and specialized instrumentation at the three national laboratory user facilities supported by this subprogram (i.e., the ANL-ATLAS, LBNL – 88-Inch Cyclotron and ORNL – HRIBF facilities).

Accelerator operations are supported at four universities: the University of Washington, the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University, Texas A&M University (TAMU) and at Yale University. Each of these small university facilities has a well-defined and unique physics program, providing light and heavy ion beams, specialized instrumentation and opportunities for long-term measurements which complement the capabilities of the National Laboratory user facilities. Equipment funds are provided for new instruments and capabilities, such as the intensity and energy upgrade of the TAMU cyclotron, and the gas-filled spectrometer at Yale.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

Support is provided for involvement in other accelerator and non-accelerator experiments directed at fundamental measurements, such as measurements of solar neutrino rates and the neutrino mass at the Sudbury Neutrino Observatory (SNO) in Canada and with the Kamioka Large Anti-Neutrino Detector (KamLAND) in Japan. Equipment funding for KamLAND was completed in FY 2001.

▪ **National Laboratory Research**	**19,508**	**19,747**	**19,835**

Support is provided for the research programs of scientists at six National Laboratories (ANL, BNL, LBNL, LANL, LLNL and ORNL). **Performance is measured by** peer review and merit evaluation.

National Laboratory User Facility Research............	**14,035**	**13,995**	**14,065**

Scientists at ANL (ATLAS), LBNL (88-Inch Cyclotron) and ORNL (HRIBF) have major responsibilities for maintaining, improving and developing instrumentation for use by the user communities at their facilities, as well as playing important roles in carrying out research that addresses the program's priorities.

- At ORNL the research focuses on the use of radioactive beams from the HRIBF and specialized spectrometers to study nuclear astrophysics and nuclear structure of nuclei far from stability. Measurements are made of reaction cross sections and nuclear properties, such as half-lives, which are crucial input to detailed astrophysics models that calculate the production of the elements in stars. Specialized equipment, such as HYBALL for charged-particle detection and the high-pressure gas target, are being designed, built and commissioned.
- At ANL the research focuses on the use of stable and selected radioactive beams from ATLAS, coupled to ion traps and the Fragment Mass Analyzer to study fundamental processes and properties of nuclei, and to study nuclei at the extremes of isotope stability. Studies are undertaken with traps to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model. The Advanced Penning Trap is being constructed and commissioned.
- At LBNL the research focuses on the use of stable beams from the 88-Inch Cyclotron coupled with Gammasphere and the Berkeley Gas-filled Spectrometer (BGS) to study nuclei at high angular momentum and deformation, and the heaviest of elements. The world-leading effort to search for and characterize new very heavy elements and isotopes will continue. The Gamma-Ray Energy and Tracking Array (GRETA) is being designed, with test modules undergoing development.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Other National Laboratory Research	**5,473**	**5,752**	**5,770**

Scientists at BNL, LBNL, LLNL and LANL play important roles in a number of high-priority accelerator- and non-accelerator-based experiments directed towards fundamental questions. These include:

- The Sudbury Neutrino Observatory (SNO) experiment in Canada. The SNO detector addresses the question of whether the observed reduced rate of solar neutrinos reaching the earth results from unexpected properties of the sun, or whether it results from a fundamental property of neutrinos–namely that neutrinos produced in the sun change their nature during the time it takes them to reach the earth. This latter explanation would imply that the neutrinos have mass. Results from the first measurements are expected in FY 2001. **Performance will be measured by** completing a preliminary analysis of the first data from neutral current interactions from SNO. These data will provide the first information regarding possible neutrino appearance due to neutrino oscillations. All previous measurements have measured neutrino deficits.
- The KamLAND experiment in Japan will measure the rate and properties of anti-neutrinos produced by several nuclear power reactors in an attempt to establish and measure the mass of the neutrino. Although KamLAND is less sensitive than SNO to the variety of neutrino oscillations it has the advantage of comparing the measured fluxes to a known source.
- Neutron beams at the LANSCE facility at LANL are "cooled" to very low energies for new cold and ultra-cold neutron experiments, which will make very precise measurements of fundamental neutron properties.

▪ **Other Research**	**2,000**	**3,808**	**4,030**
RIA R&D Activities	**2,000**	**2,794**	**3,000**

Funds are provided for R&D and pre-conceptual design activities directed at the development of an advanced Rare Isotope Accelerator (RIA) facility. A next-generation facility for beams of short-lived, radioactive nuclei for nuclear structure, reaction and astrophysics studies was identified in the 1996 Nuclear Science Advisory Committee (NSAC) Long Range Plan as a compelling scientific opportunity and as the highest priority for new construction. The proposed RIA facility is a new paradigm for producing intense beams of very short-lived nuclei that emerged from the 1998 NSAC Taskforce study involving international experts. This facility would position the U.S. to play a leadership role in an area of study with the potential for new discoveries about basic properties of nuclei and to significantly advance our understanding of astrophysical phenomena. The increased funding for FY 2002 supports needed R&D activities in both critical accelerator components and detector development.

SBIR and Other	**0**	**1,014**	**1,030**

The FY 2001 and FY 2002 amounts include the estimated requirement for the continuation of the SBIR and STTR programs and other established obligations. The Lawrence and Fermi Awards, funded under this line, provide annual monetary awards to honorees selected by the Department of Energy for their outstanding contributions to science.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Operations	**22,162**	**21,743**	**21,860**

Support is provided for the operation of three National User Facilities, the Argonne Tandem-Linac Accelerator System (ATLAS) at ANL, the 88-Inch Cyclotron facility at LBNL and the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL, for studies of nuclear reactions, structure and fundamental interactions. Requests for beam time at these facilities exceed available beam time by 50-75%. Program Advisory Committees are utilized by all three of these facilities to evaluate proposed experiments and provide recommendations on merit and priority prior to approval for beam time.

	FY 2000	FY 2001	FY 2002
▪ **HRIBF Operations**	**8,847**	**8,837**	**8,925**

HRIBF has coupled the existing cyclotron and tandem accelerator to develop a focused radioactive ion beam program. Both proton-rich and neutron-rich beams are provided to spectrometer systems such as CHARMS, designed for nuclear structure studies with accelerated radioactive beams, and the Daresbury Recoil Separator and the Silicon Detector Array for nuclear astrophysics studies.

	FY 2000	FY 2001	FY 2002
▪ **ATLAS Operations**	**7,601**	**6,992**	**7,060**

ATLAS provides stable heavy ion beams and selected radioactive ion beams for research. Experiments utilize ion traps, the Fragment Mass Analyzer, and advanced detectors to study the structure of nuclei at the limits of stability, and fundamental and decay properties of nuclei.

	FY 2000	FY 2001	FY 2002
▪ **88-Inch Cyclotron Operations**	**5,714**	**5,914**	**5,875**

The 88-Inch Cyclotron facility provides primarily stable heavy ion beams for research. Gammasphere and the Berkeley Gas-filled Spectrometer provide world-class instruments to study rapidly spinning nuclei, and search for and characterize the heaviest of elements and isotopes. An innovative BEARS (Berkeley Experiments with Accelerated Radioactive Species) system has been developed to provide selected light radioactive beams for experiments.

Included in the funding shown are Capital Equipment and Accelerator Improvement Project (AIP) funds provided to each of the facilities for the enhancement of the accelerator systems and experimental equipment.

In FY 2002 these low energy facilities will carry out about 100 experiments involving over 500 U.S. and foreign researchers. Planned beam hours for research are indicated below:

	(hours of beam for research)		
	FY 2000	FY 2001	FY 2002
HRIBF	2130	2100	2000
ATLAS	5385	5100	3500
88-Inch Cyclotron	4335	4950	4000
Total beam hours for research	11850	12150	9500

	FY 2000	FY 2001	FY 2002
Total, Low Energy Nuclear Physics	**60,448**	**62,693**	**62,690**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2002 vs. FY 2001 ($000)
Research	
▪ **University Research**	
FY 2002 funding for researcher and students is constant from FY 2001. Lower priority activities will be phased out in order to maintain manpower in the high priority activities at the low energy facilities and SNO. Funding for equipment decreases by $430,000 compared to FY 2001, as projects are completed. New experiments will not be started at this time.	-430
▪ **National Laboratory Research**	
National User Facilities Research: FY 2002 funding provides an increase of about 0.5% to try to maintain efforts. Activities will be phased out in order to focus efforts on the high priority activities at these facilities.	+70
Other National Laboratory Research: Research funding for the other groups is the same as FY 2001. Equipment funds will be used to complete projects underway with no new starts. Activities will be phased out in order to maintain manpower and focus efforts on the high priority activities at the national user facilities and SNO.	+18
▪ **Other Research**	
RIA R&D: In FY 2002 $3,000,000 is provided for R&D activities directed at the development of an advanced Rare Isotope Accelerator (RIA) facility. The R&D funding is directed at projects identified in a 3-year R&D plan that has been developed for work that will be performed at ANL, LANL, LBNL, LLNL, ORNL, TJNAF and Michigan State University.	+206
SBIR and Other: Estimated SBIR and other obligations increase slightly.	+16
Total Research	-120
Operations	
▪ HRIBF Operations: FY 2002 funding is increased by 1% to carry out the highest priority research; it will operate with a smaller staff than in FY 2001.	+88
▪ ATLAS Operations: FY 2002 funding is increased by 1% to to carry out the highest priority research. ATLAS will go to 5-day operations with a smaller staff.	+68
▪ 88-Inch Operations: FY 2002 funding is increased by 3.3% (+$142,000) to carry out the highest priority research. This includes $100,000 for increased power costs. The 88 Inch Cyclotron will go to 5-day operations with a smaller staff. Funding for Accelerator Improvement and Capital equipment projects will be reduced by $181,000.	-39
Total Operations	+117
Total Funding Change, Low Energy Nuclear Physics	-3

Nuclear Theory

Mission Supporting Goals and Objectives

Theoretical Nuclear Physics is a program of fundamental scientific research that provides new insight into the observed behavior of atomic nuclei. With the establishment of quantum chromodynamics as the fundamental theory of the strong nuclear interaction, the ultimate goal of nuclear theory is to understand nuclei and the nucleon in terms of their constituent quarks and gluons. It is at the highest energy scales that the nuclear quark and gluon aspects manifest themselves, and it is precisely these high energy nuclear scales that are probed by the two nuclear physics flagship facilities, the Thomas Jefferson National Accelerator Facility (TJNAF) and the Relativistic Heavy Ion Collider (RHIC). More traditionally, nuclear theorists have understood the structure of the atomic nucleus most fundamentally in terms of interacting protons and neutrons. In certain regimes of energy and momentum transfer this approach is not only valid, but has been very successful, in understanding nuclei of ordinary matter where advancing computational power has allowed much more detailed descriptions of nuclei on this microscopic level. Collective models, in which the nucleus is treated as a drop of fluid or in which pairs of neutrons or protons are treated as single particles, have achieved great success in describing many aspects of nuclear behavior too complicated to treat with protons and neutrons. The various approaches of nuclear theory have recently been applied to nuclear astrophysics topics such as supernova explosions, nucleosyntheses of the elements, and properties of neutrinos from the sun.

The Nuclear Theory subprogram supports all areas of nuclear physics, and is carried out at universities and National Laboratories. Some of the investigations depend crucially on access to forefront computing, and to the development of efficient algorithms to use these forefront devices. Components of the program are selected primarily on the basis of peer review by internationally recognized experts. A very significant component of the program is the Institute for Nuclear Theory (INT), where there is an ongoing series of special topic programs and workshops that includes experimentalists. The Institute is a seedbed for new collaborations, ideas, and directions in nuclear physics.

The program is greatly enhanced through interactions with complementary programs overseas, with those supported by the National Science Foundation, with programs supported by the High Energy Physics Program and with the Japanese supported theoretical efforts related to RHIC at Brookhaven National Laboratory. Many foreign theorists participate on advisory groups as peer reviewers. There is large participation in the INT by researchers from Europe and Japan and by researchers in overlapping fields such as astrophysics, atomic and molecular physics and particle physics.

Included in this subprogram are the activities that are aimed at providing information services on critical nuclear data and have as a goal the compilation and dissemination of an accurate and complete nuclear data information base that is readily accessible and user oriented.

Performance will be measured by reporting accomplishments on the common performance measures on leadership, excellence and relevance; quality; and safety and health.

Funding Schedule

	(dollars in thousands)				
	FY 2000	FY 2001	FY 2002	$ Change	% Change
Theory Research					
University Research	10,415	10,465	10,475	+10	+0.1%
National Laboratory Research	5,793	6,039	6,120	+81	+1.3%
Other Research	0	1,996	2,000	+4	+0.2%
Subtotal Theory Research	16,208	18,500	18,595	+95	+0.5%
Nuclear Data Activities	4,765	4,877	4,910	+33	+0.7%
Total, Nuclear Theory	20,973	23,377	23,505	+128	+0.5%

Detailed Program Justification

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002
Theory Research	**16,208**	**18,500**	**18,595**
▪ **University Research**	**10,415**	**10,465**	**10,475**

Research of university scientists and graduate students is supported through 47 grants at 37 universities in 22 States and the District of Columbia.

The range of topics studied is broad, constantly evolving, and each active area of experimental nuclear physics is supported by nuclear theory activities. Graduate student and postdoc support is a major element of this program. **Performance is measured by** triannual peer-review.

The Institute for Nuclear Theory (INT) at the University of Washington hosts three programs a year where researchers from around the world attend to focus on specific topics or questions. These programs result in new ideas and approaches, the formation of collaborations to attack specific problems and the opportunity for interactions of researchers from different fields of study. Recent programs have resulted in a new set of solar "standard model" cross sections, the generation of interest in and motivation for making more precise electric dipole measurements and the formation of a collaboration among theorists to revisit numerical methods for strongly interacting quantum systems.

▪ **National Laboratory Research**	**5,793**	**6,039**	**6,120**

Research programs are supported at six National Laboratories (ANL, BNL, LANL, LBNL, ORNL and TJNAF). **Performance is measured by** peer-review and merit evaluation.

The range of topics in these programs is broad, and each of the active areas of experimental nuclear physics is supported by at least some of these nuclear theory activities.

	(dollars in thousands)		
	FY 2000	FY 2001	FY 2002

In all cases, the nuclear theory research at a given laboratory provides support to the experimental programs at that laboratory, or takes advantage of some unique facilities or programs at that laboratory.

The larger size and diversity of the National Laboratory groups make them particularly good sites for the training of nuclear theory postdocs.

▪ **Other Research**..	**0**	**1,996**	**2,000**

Funding provides for new activities to model and calculate complex astrophysical nuclear processes, for example, in stellar supernovae explosions, and the quark/gluon-based structure of nuclei using "lattice gauge" techniques. Both efforts require investments in new computational modeling and simulation research and show great promise in pushing our understanding of the physics of these processes to new levels.

Nuclear Data Activities...	**4,765**	**4,877**	**4,910**

The Nuclear Data Program collects, evaluates, stores, and disseminates information on nuclear properties and reaction processes for the community and the nation. The focal point for its national and international activities is at the DOE managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory.

The NNDC relies on the U.S. Nuclear Data Network (USNDN), a network of DOE supported individual nuclear data professionals located in universities and at other National Laboratories who assist in assessing data as well as developing new novel, user friendly electronic network capabilities.

The NNDC participates in the International Data Committee of the International Atomic Energy Agency (IAEA).

Total, Nuclear Theory	**20,973**	**23,377**	**23,505**

Explanation of Funding Changes from FY 2001 to FY 2002

	FY 2001 vs. FY 2000 ($000)
▪ **University Research**	
FY 2002 funding level is essentially constant compared to FY 2001. Lower priority activities will be phased out in order to maintain manpower in the higher priority activities.	+10
▪ **National Laboratory Research**	
FY 2002 funding level is increased by about 1.3% compared to FY 2001. Lower priority activities will be phased out in order to maintain manpower in the higher priority activities.	+81
▪ **Other Research**	
FY 2002 funding for computational modeling and simulation research is maintained at the same level as FY 2001.	+4
▪ **Nuclear Data Program**	
FY 2002 funding level is about the same as FY 2001. Lower priority activities will be phased out in order to maintain manpower in the higher priority activities.	+33
Total Funding Change, Nuclear Theory	+128

Capital Operating Expenses & Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2000	FY 2001	FY 2002	$ Change	% Change
General Plant Projects	6,785	6,420	6,470	+50	+0.8%
Accelerator Improvement Projects	4,341	5,119	5,450	+331	+6.5%
Capital Equipment	29,394	33,026	30,300	-2,726	-8.3%
Total, Capital Operating Expenses	40,520	44,565	42,220	-2,345	-5.3%

Major Items of Equipment (TEC $2 million or greater)

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Approp-riations	FY 2000	FY 2001	FY 2002	Accept-ance Date
STAR Silicon Vertex Tracker	7,000	6,250	750	0	0	FY 2000
PHENIX Muon Arm Instrumentation	12,897	8,610	2,925	1,362	0	FY 2002
Analysis System for RHIC Detectors	7,900	6,375	1,525	0	0	FY 2000
BLAST Large Acceptance Detector	5,200	2,500	1,500	1,200	0	FY 2001
STAR EM Calorimeter	8,600	0	2,100	2,694	3,000	FY 2003
G0 Experiment Detector[a]	3,965	1,757	1,133	1,016	59	FY 2002
Total, Major Items of Equipment		25,492	9,933	6,272	3,059	

[a] The G0 Experiment Detector at TJNAF began as an NSF project with a small contribution of DOE funds (below MIE threshold). Subsequently, the cost estimate for the detector increased, leading to increased DOE and NSF contributions. The DOE contribution was raised above the MIE threshold. Therefore, a MIE was identified in the FY 2001 budget. The TEC ($3,965,000) and funding profile for G0 has been changed from that ($3,387,000) indicated in FY 2001 to correctly include TJNAF overhead and does not represent any cost growth. The NSF contribution to this effort in actual year dollars is $3,605,000.