DEPARTMENT OF ENERGY
FY 1997 CONGRESSIONAL BUDGET REQUEST
GENERAL SCIENCE AND RESEARCH
(Tabular dollars in thousands, Narrative in whole dollars)

NUCLEAR PHYSICS

PROGRAM MISSION

The Nuclear Physics program of the Department of Energy (DOE) has the lead responsibility for Federal support of nuclear physics research and supports fundamental research activities under the mandate provided in Public Law 95-91 which established the Department. The primary Mission of the program is to develop and support the basic research scientists and facilities, and to foster the technical and scientific activities needed to understand the structure and interactions of atomic nuclei, and to understand the fundamental forces and particles of nature as manifested in extended nuclear matter. Atomic nuclei are approximately described as a collection of nucleons (protons and neutrons), bound together by the mechanism of exchange of pions (pi mesons). The research forefront in nuclear physics now requires incorporation of the quark substructure of the nucleon into the understanding of nuclear structure. Quarks, which are the most elemental building blocks of matter, are bound together in groups of three by the exchange of gluons to form the nucleons. Attendant upon this core mission are responsibilities to enlarge and diversify the Nation's pool of technically trained talent, to facilitate transfer of technology and knowledge acquired to support the Nation's economic base, and to provide leadership in the world's cooperative efforts in the peaceful development of science. 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 to assist in setting scientific priorities. The programs intent is to be closely aligned with the Administration's science policies as put forward in "Science in the National Interest."

The GOAL of the Nuclear Physics program is to understand the structure of atomic nuclei and the fundamental forces required to hold their constituents in place by a series of systematic scientific investigations.

The OBJECTIVES related to the goal are to:

o Conduct a program of maximum effectiveness to provide new insights into the nature of energy and matter, based on evaluation by rigorous peer review.

PROGRAM MISSION - NUCLEAR PHYSICS (Cont'd)

- o Conceive, develop, construct, and operate world class scientific accelerator facilities in a timely, and effective manner. In the execution of this responsibility together with other Energy Research projects, act as the Nation's leader in developing standards and management techniques to optimize construction and operations of facilities in a cost effective, safe, and environmentally benign way.

- o Leverage United States objectives by means of International cooperation through exchanges of scientists and participation in internationally cooperative projects.

- o Continue the advanced education and training activities of young scientists to maintain the skills and conceptual underpinning of the Nation's broad array of nuclear based technologies.

PERFORMANCE MEASURES:

1. Ascertain the appropriateness and quality of the entire research program by rigorous peer reviews conducted by internationally recognized scientific experts. Maintain the highest quality research by taking appropriate corrective management actions based on results of the reviews.

2. Use the assistance of technical experts to monitor the performance in scope, costs, and schedule of construction projects. Measure construction project performance against cost and schedule milestones contained in the project plans.

3. Use peer reviews and user feedback to monitor the effectiveness of facility operations. Evaluate facility performance against objectives set in program guidance letters based on funding availability. Measure beam hour availability and user support against guidelines developed for the Scientific Facility User Initiative.

4. Compare overall progress of the field against the scientific priorities recommended in the long range plans that are regularly provided by the DOE/NSF Nuclear Science Advisory Committee (NSAC).

SIGNIFICANT ACCOMPLISHMENTS AND PROGRAM SHIFTS:

- o CEBAF construction has been completed and the experimental program has begun.

PROGRAM MISSION - NUCLEAR PHYSICS (Cont'd)

- o Relativistic Heavy Ion Collider (RHIC) construction at Brookhaven National Laboratory (BNL) has been rebaselined to account for funding reduction in FY 1996. The rebaselining increased the TEC from $475,250,000 to $486,870,000, increased the TPC from $595,250,000 to $616,530,000 and delays completion of the project by 3 months from 2nd Quarter FY 1999 to 3rd Quarter FY 1999. All of the quadrupole and sextupole, and over 70% of the dipole superconducting magnets produced by industry have been delivered, every one delivered to date has substantially exceeded specifications and over one-half of them have been installed in the accelerator tunnel. Progress according to schedule has occurred in the fabrication of RHIC detectors, including the additional experimental equipment recommended by NSAC.

- o Completion of the Radioactive Ion Beam (RIB) facility at Oak Ridge National Laboratory (ORNL) permits initiation of the experimental program in astrophysics and unstable nuclei in the summer of 1996.

- o The joint US/Canadian Sudbury Neutrino Observatory (SNO) project will be completed in January 1997 to initiate investigation of the solar burning process.

- o With transferral of operation of the Clinton P. Anderson Meson Physics Facility (LAMPF) at Los Alamos National Laboratory (LANL) to Defense Programs and termination of the research program in the main experimental area, research efforts have been refocused on thermal and ultra-cold neutron experiments at the Los Alamos Neutron Scattering Center (LANSCE) facility and other experiments on an as-available basis.

- o Utilization of the new Gammasphere detector at Lawrence Berkeley National Laboratory (LBNL) has led to the possible discovery of ultra-deformed nuclear states, whose lengths are 3 times as big as their widths.

- o Having completed the investigation of anomalous electron-positron pair creation reported by foreign scientists, the APEX detector at Argonne National Laboratory (ANL) will be phased out. Gammasphere will be temporarily relocated to ANL and coupled with the existing mass spectrometer there to take advantage of a timely opportunity for innovative research.

- o The Nuclear Physics request includes $140,078,000 to maintain support of the Department's scientific user facilities. Approximately 16% of this amount is associated with the continuation of the science user facilities initiative contained in the FY 1996 budget request. This funding will significantly provide research time for thousands of scientists in universities, Federal agencies, and U.S. companies. It will also leverage both Federally and privately sponsored research consistent with the Administration's strategy for enhancing the U.S. National science investment.

NUCLEAR PHYSICS

PROGRAM FUNDING PROFILE

(Dollars in thousands)

	FY 1995 Comparable Appropriation	FY 1996 Original Appropriation	FY 1996 Real & Comp Adjustments	FY 1996 Comparable Adjusted	FY 1997 Budget Request
Research					
Nuclear Physics..................................	$0	$236,925	-$236,925 a/	$0	$0
Medium Energy Nuclear Physics............	122,924	0	97,055	97,055 b/	104,375
Heavy Ion Nuclear Physics...................	59,764	0	66,630	66,630	70,200
Low Energy Nuclear Physics.................	23,338	0	26,070	26,070	27,800
Nuclear Theory....................................	14,650	0	14,820	14,820	15,350
Related Capital Funding.......................	35,100	0	32,350	32,350	35,700
Subtotal Research.............................	255,776	236,925	0	236,925	253,425
Construction..	71,000	67,575	0	67,575 b/	65,000
Subtotal, Nuclear Physics......................	326,776	304,500	0	304,500	318,425
Adjustment..	-7 c/	0	0	0	0
Total Nuclear Physics............................	$326,769 d/	$304,500	$0	$304,500	$318,425

a/ Comparability transfers to Medium Energy Nuclear Physics ($97,055,000), Heavy Ion Nuclear Physics ($66,630,000), Low Energy Nuclear Physics ($26,070,000), Nuclear Theory ($14,820,000) and Related Capital Funding ($32,350,000).

b/ In FY 1996 a request will be made to reprogram $2,575,000 from AIP construction to Medium Energy Facility operations ($2,200,000) and AIP operating ($375,000).

c/ Share of General Science and Research general reduction for use of prior year balances assigned to this program on a non-comparable basis.

d/ Excludes $4,508,000 which has been transferred to the SBIR program and $225,000 which has been transferred to the STTR program.

Public Law Authorization:
Pub. Law 95-91, DOE Organization Act (1977)

NUCLEAR PHYSICS
(Dollars in thousands)

PROGRAM FUNDING BY SITE

Field Offices/Sites	FY 1995 Comparable Appropriation	FY 1996 Original Appropriation	FY 1996 Real & Comp Adjustments	FY 1996 Comparable Appropriation	FY 1997 Budget Request
Albuquerque Operations Office					
Los Alamos National Laboratory	$39,514	$11,747	$0	$11,747	$10,460
Chicago Operations Office					
Argonne National Laboratory	15,623	15,491	0	15,491	16,220
Brookhaven National Laboratory	99,655	99,320	0	99,320	105,875
Idaho Operations Office					
Idaho National Engineering Laboratory	0	0	0	0	100
Oakland Operations Office					
Lawrence Berkeley National Laboratory	25,685	23,760	0	23,760	24,445
Lawrence Livermore National Laboratory	812	640	0	640	720
Oak Ridge Operations Office					
Continuous Electron Beam Accelerator Facility	69,103	67,375	0	67,375	69,000
Oak Ridge National Laboratory	12,384	13,585	0	13,585	14,385
All Other Sites a/	64,000	72,582	0	72,582	77,220
Subtotal	326,776	304,500	0	304,500	318,425
Adjustment	-7 b/	0	0	0	0
TOTAL	$326,769	$304,500	$0	$304,500	$318,425

a/ Funding provided to universities, industry, other federal agencies and other miscellaneous contractors.

b/ Share of General Science and Research general reduction for use of prior year balances assigned to this program.

NUCLEAR PHYSICS
PROGRAM OBJECT CLASS SUMMARY
(Dollars in thousands)

		FY 1995 Comparable	FY 1995 Non-Comp	FY 1996 Comparable	FY 1996 Non-Comp	FY 1997
	Direct Funding:					
	Personnel compensation:					
11.1	Full-time permanent					
11.3	Other than full-time permanent					
11.5	Other personnel compensation					
11.8	Special personal services payments					
11.9	Total personnel compensation	0	0	0	0	0
12.1	Civilian personnel benefits					
13.0	Benefits for former personnel					
21.0	Travel and transportation of persons					
22.0	Transportation of things					
23.1	Rental payments to GSA					
23.2	Rental payments to others					
23.3	Communications, utilities, and miscellaneous charges					
24.0	Printing and reproduction					
25.1	Advisory and assistance services					
25.2	Other services					
25.3	Purchases of goods and services from Government accounts	270	270	195	195	165
25.4	Operation and maintenance of facilities	163,588	163,588	138,788	138,788	149,542
25.5	Research and development contracts	16,967	16,967	25,009	25,009	28,778
25.7	Operation and maintenance of equipment					
26.0	Supplies and materials					
31.0	Equipment	28,020	28,020	26,250	26,250	26,500
32.0	Land and structures	78,092	78,092	73,688	73,688	74,200
41.0	Grants, subsidies and contributions	40,092	40,092	40,592	40,592	39,240
99.0	Subtotal, obligations	327,029	327,029	304,522	304,522	318,425
	Reimbursable Obligations	-	-	-	-	
99.9	Total Obligations	327,029	327,029	304,522	304,522	318,425
	Recovery of prior year obligations	-97	-97			
	Unobligated balance avail, start of year	-185	-185	-22	-22	0
	Unobligated balance avail, end of year	22	22			
	Budget Authority	$326,769	$326,769	$304,500	$304,500	$318,425

NUCLEAR PHYSICS

MEDIUM ENERGY NUCLEAR PHYSICS
(Tabular dollars in thousands, Narrative in whole dollars)

I. 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 academic fundamental research, and facility operations and research at electron and proton accelerator facilities at the energies of interest to nuclear physics. In addition, the subprogram supports research at accelerators operated by other Department of Energy programs (e.g., High Energy Physics and Basic Energy Sciences) and at other unique domestic or foreign facilities. Two national accelerator facilities are operated entirely under the Medium Energy subprogram - the Continuous Electron Beam Accelerator Facility (CEBAF) in Newport News, Virginia, operated by the Southeastern Universities Research Association, and the Bates Linear Accelerator Center in Middleton, Massachusetts, operated by the Massachusetts Institute of Technology. These accelerator facilities serve a nationwide community of Department of Energy- and National Science Foundation-supported scientists from over 100 American institutions, of which over 90% are universities. Both facilities provide major contributions to American education at all levels and new technical and innovative discoveries which result in important Technology Transfer and services to American industry and medicine. At both CEBAF and Bates, the National Science Foundation has made a major contribution to a new experimental apparatus. A significant number of foreign scientists collaborate in the research programs of both facilities. The planned research program at the new Continuous Electron Beam Accelerator Facility Laboratory, for example, involves 540 scientists from 17 foreign countries; 81 of these scientists are from Conseil Europeen pour la Recherche Nucleaire (CERN) member states. At CEBAF, foreign collaborators have also made major investments in experimental equipment.

The research programs supported at these facilities are ultimately aimed at achieving an understanding of the structure of the atomic nucleus in terms of the quarks and gluons, the objects which apparently combine in different ways to make all the other sub-atomic particles. Just as important is the achievement of an understanding of the "strong force", one of only four forces in nature, which 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, investigations of how the properties of protons and neutrons change when imbedded in the nuclear medium, measurements with beams of electrons or protons whose "spins" have all been lined up in the same direction (polarizing the beams) to determine unique "structure functions" which pin down particular models of nuclear structure, and studies of how particles interact with each other inside the nucleus.

I. **Mission Supporting Goals and Objectives: MEDIUM ENERGY NUCLEAR PHYSICS** (Cont'd)

Beginning, in FY 1996, operation of the Clinton P. Anderson Meson Physics Facility (LAMPF) has been supported by DOE Defense Programs.

II. Funding Schedule:

Program Activity	FY 1995	FY 1996	FY 1997	$ Change	% Change
Medium Energy Research	$ 41,017	$ 49,755	$ 52,775	$ + 3,020	+ 6.1%
Facility Operations					
Los Alamos Meson Physics Facility	$ 23,450	$ 200	$ 200	0	0.0%
Bates Linear Accelerator Center	9,857	10,200	10,900	+ 700	+ 6.9%
CEBAF	48,600	36,900*	40,500	+ 3,600	+ 9.8%
Total, Medium Energy Nuclear Physics .	$ 122,924	$ 97,055*	$ 104,375	$ + 7,320	+ 7.5%

* In FY 1996 a request will be made to reprogram $2,575,000 from AIP construction to Medium Energy Facility Operations ($2,200,000), and AIP operating ($375,000).

III. Performance Summary:

FY 1995 Accomplishments:

MEDIUM ENERGY RESEARCH:

- o At the CEBAF laboratory, scientists completed preparations for the Hall C experimental research program. The Hall B CLAS detector magnet has been installed and has been operated at superconducting temperatures.

- o At the Bates Laboratory, MIT scientists and collaborators carried out new measurements in the South Experimental Hall using a new polarimeter. Scientists also carried out measurements on the new "SAMPLE" experiment in the North Hall which uses "symmetry violation" to examine specific quark components (strange quarks) in the proton.

- At MIT, scientists are completing detectors for use in Hall A at CEBAF. MIT scientists and collaborators carried out measurements with pion beams at the Clinton P. Anderson Meson Physics Facility at Los Alamos National Laboratory, and at the Paul Scherrer Institute in Switzerland.

- MIT scientists have successfully led the U.S. collaboration of university and National Laboratory scientists in the development and construction of a new detector and target system for the HERMES experiment which commenced at the DESY laboratory in Hamburg, Germany. This experiment is measuring where the "spin" of the proton comes from.

- At Brookhaven National Laboratory, scientists and collaborators have carried out measurements on the shape of the proton using the Laser Electron Gamma Source facility. Results show that the proton is deformed and looks somewhat like a pancake.

- Brookhaven scientists and collaborators at the Alternating Gradient Synchrotron have completed analysis of an effort to search for a predicted particle consisting of six quarks.

- Argonne National Laboratory scientists have completed development of a target system for Hall C experiments at CEBAF; Argonne also has a major collaborative role in the HERMES experiment in Germany. Argonne scientists have completed a major study of the structure of the deuteron at the accelerator in Novosibirsk, Russia.

- At the Clinton P. Anderson Meson Physics Facility at Los Alamos National Laboratory, scientists and collaborators carried out high priority measurements in search of neutrino oscillations. If oscillations are found, then neutrinos would have mass, in disagreement with our present understanding of physics!

- Los Alamos scientists and collaborators prepared to carry out measurements at Fermilab to examine structure in the neutron and proton. Los Alamos scientists and collaborators are planning for a major future program using polarized protons at the Relativistic Heavy Ion Collider which is presently under construction at Brookhaven.

- The university program continued to support a broad program of research in Medium Energy Nuclear Physics utilizing not only all of the accelerator facilities supported under the Medium Energy Program, but also using other U.S. and international accelerator laboratories. Also supported was non-accelerator based research at a number of international sites.

- Funding in the amount of $1,833,000 and $225,000 has been transferred to the SBIR and STTR program, respectively.

III. **Performance Summary: MEDIUM ENERGY NUCLEAR PHYSICS** (Cont'd)

FACILITY OPERATIONS:

- CEBAF was completed and work continued on preparations for the experimental program in Hall C. The accelerator operated about 2500 hours for commissioning.

- The Bates accelerator operated 2310 hours for research. Continuous beam (not pulsed) extraction studies from the new South Hall ring were carried out.

- The Clinton P. Anderson Meson Physics Facility operated for approximately 2550 hours for research. This was the last year of support for accelerator operations by the Nuclear Physics Program. Future operation of the accelerator will be supported by Defense Programs.

FY 1996 Accomplishments (to date and planned):

MEDIUM ENERGY RESEARCH:

- At CEBAF, the Hall C experimental research program is underway. Hall A experimental equipment will be complete and the research program begun. The Hall B CLAS detector will be completed and calibration activities will be initiated.

- At the Bates accelerator, scientists and collaborators will carry out new measurements in the South Experimental Hall using the new polarimeter and newly installed detectors which make measurements outside the scattering plane. Scientists will continue measurements on the "SAMPLE" experiment in the North Hall which uses "symmetry violation" to examine the possibility of specific quark components (strange quarks) in the proton.

- MIT scientists will complete installation of detectors in the new Hall A twin spectrometers at CEBAF.

- MIT scientists and collaborators will carry out the HERMES experiment in Hamburg, Germany. This experiment is measuring what components of the proton or neutron determine the "spin" of these particles, an important scientific issue in our present understanding.

- At Brookhaven National Laboratory, Laser Electron Gamma Source scientists will begin work on detector modifications and a unique hydrogen-ice target which will allow alignment of the "spins" of the proton and the deuteron in the target independently. This will enable a new program to look more deeply into the structure of the proton and neutron.

III. Performance Summary: MEDIUM ENERGY NUCLEAR PHYSICS (Cont'd)

- Brookhaven scientists and collaborators at the Alternating Gradient Synchrotron are pursuing new experiments to look at the behavior of a strange quark in nuclei and to do spectroscopy of other particles. A major part of these efforts involves the installation of large detectors from Los Alamos and Stanford.

- Argonne National Laboratory scientists are beginning a major series of experimental efforts at CEBAF and will continue the HERMES experiment in Germany.

- At the Clinton P. Anderson Meson Physics Facility at Los Alamos National Laboratory, scientists and collaborators may continue the high priority measurements in search of neutrino oscillations if DOE Defense Program operations of LAMPF allows the high intensity proton beam into Area A. If oscillations are found, then neutrinos would have mass, in disagreement with our present understanding of the laws of physics!

- Los Alamos scientists and collaborators will carry out measurements at Fermilab to examine structure in the proton and neutron. Planning is also underway for a major future program using polarized protons at the Relativistic Heavy Ion Collider (RHIC) which is presently under construction at BNL.

- The university program will continue to support a broad program of research in Medium Energy Nuclear Physics utilizing not only all of the accelerator facilities supported under the Medium Energy Program, but also using other U.S. and international accelerator laboratories. Also supported will be non-accelerator based research at a number of international sites.

- Funding in the amount of $1,965,000 and $308,000 has been budgeted for the SBIR and STTR program, respectively.

FACILITY OPERATIONS:

- CEBAF will be operational for research into Hall C. The Hall B and Hall A detectors are still being completed. Accelerator time for research is 3000 hours, but will increase to 4500 hours if proposed reprogramming is approved.

- The MIT/Bates accelerator will operate 2000 hours for research. Both research operations and continuing upgrading of the accelerator complex will be underway.

- The Clinton P. Anderson Meson Physics Facility is no longer operated by the Nuclear Physics Program. Operations will be supported by DOE Defense Programs.

III. Performance Summary: MEDIUM ENERGY NUCLEAR PHYSICS (Cont'd)

FY 1997 Planned Accomplishments:

MEDIUM ENERGY RESEARCH:

- At CEBAF, the experimental research program will be fully underway. CEBAF and collaborating scientists will carry out the approved research program, as determined by the CEBAF Program Advisory Committee. Important experiments will include studies of the charge structure of the neutron in Hall C, measurements of the electric form factor of the proton in Hall A, and studies of the excited states of the proton will begin in Hall B.

- At MIT/Bates, MIT scientists and collaborators will carry out new measurements in the South Experimental Hall using the new polarimeter and the new detectors. Continuous, rather than pulsed beams will be available to the South Hall. Efforts to utilize a new internal target in the South Hall ring will be underway. Important experiments will include "symmetry violation" studies on the deuteron and measurements of the transition of the proton to its excited state.

- MIT scientists and collaborators will continue to carry out the HERMES experiment in Hamburg, Germany. This experiment will measure what components of the proton or neutron determine the "spin" of these particles, an important scientific issue in our present understanding.

- At Brookhaven National Laboratory, Laser Electron Gamma Source scientists plan to build a major detector modification and a unique ice target containing polarized hydrogen which will allow polarization of the proton or the deuteron in the target independently. This will enable a new program to look more deeply into the structure of the proton and neutron.

- Brookhaven scientists and collaborators at the Alternating Gradient Synchrotron will be pursuing new experiments to look at the behavior of a strange quark in nuclei and to do spectroscopy of other particles. These efforts involved the installation of large detectors from Los Alamos and Stanford.

- Argonne National Laboratory scientists will be undertaking a major series of experiments at CEBAF and will continue the HERMES experiment in Germany.

- At the Clinton P. Anderson Meson Physics Facility, Los Alamos National Laboratory scientists and collaborators may continue to carry out high priority measurements in search of neutrino oscillations, depending on review of existing results and whether DOE Defense Program operations allows the high intensity proton beam into Area A. If oscillations are found, then neutrinos would have mass, in disagreement with our present understanding of the laws of physics!

III. Performance Summary: MEDIUM ENERGY NUCLEAR PHYSICS (Cont'd)

- o Los Alamos scientists and collaborators will carry out measurements at Fermilab to examine structure in the neutron and proton. Planning is also underway for a major program using polarized protons at the Relativistic Heavy Ion Collider which is presently under construction at Brookhaven.

- o The university program will continue to support a broad program of research in Medium Energy Nuclear Physics utilizing not only all of the accelerator facilities supported under the Medium Energy Program, but also using other U.S. and international accelerator laboratories. Also supported will be non-accelerator based research at a number of international sites.

- o Funding in the amount of $4,073,000 has been budgeted for the SBIR program.

FACILITY OPERATIONS:

- o CEBAF will be operational for research in Halls A, B, and C. Accelerator time for research is planned to be 4500 hours.

- o The MIT/Bates accelerator will operate 2500 hours for research. Both research operations and continuing upgrading of the accelerator complex will be under way.

- o The Clinton P. Anderson Meson Physics Facility (LAMPF) is no longer operated by the Nuclear Physics Program. Operations are supported by DOE Defense Programs.

Explanation of Funding Changes FY 1996 to FY 1997:

- o Funding for Bates operation is increased by $700,000 (6.9%) over FY 1996 to increase beam time for research to 2500 hours to take advantage of recently completed unique new facilities.

- o The budget request reflects a $3,600,000 increase for CEBAF operations which would increase operating hours from 3000 to 4500. However, if the requested FY 1996 reprogramming of $2,200,000 into CEBAF operations is approved, the FY 1997 CEBAF operations funding provides a cost of living increase and the same number of hours for research in both years (4500).

- o SBIR has been increased to $4,073,000 from $1,965,000 in FY 1996. The SBIR allocation is included under Medium Energy Research.

NUCLEAR PHYSICS

HEAVY ION NUCLEAR PHYSICS
(Tabular dollars in thousands, Narrative in whole dollars)

I. Mission Supporting Goals and Objectives:

The Heavy Ion Nuclear Physics subprogram supports research directed at understanding the properties and behavior of atomic nuclei and nuclear matter over a wide range of conditions. These conditions are created in nucleus-nucleus collisions using beams of heavy ions. At low bombarding energies, research is focussed on the study of nuclei which are only gently excited (cool nuclear matter), but taken to their limits of deformation and to their limits of isotopic stability by adding or subtracting protons (or neutrons) to form short-lived, proton-rich (or neutron-rich) nuclei. With higher energy heavy-ion beams very highly excited nuclei (warm nuclear matter) can be formed and studied which are believed to vaporize in a process analogous to the liquid-gas phase transition of heated water. At relativistic energies, the properties of hot dense nuclear matter are studied, with a goal of observing the deconfinement of normal matter into a new form of matter, a quark-gluon plasma. Accelerators located at two universities (Texas A&M and Yale) and three National Laboratories (Argonne, Brookhaven and Berkeley) are supported and maintained by the Heavy Ion Nuclear Physics subprogram for these studies. The National Laboratory facilities are utilized by Department of Energy (DOE), National Science Foundation (NSF) and foreign supported researchers whose experiments undergo peer review by Program Advisory Committees prior to approval for beam time. DOE Heavy Ion Nuclear Physics supported researchers, at both universities and national laboratories, also use NSF and foreign accelerator facilities for their studies.

II. Funding Schedule:

Program Activity	FY 1995	FY 1996	FY 1997	$ Change	% Change
Heavy Ion Research					
Nuclear Structure and Reaction Studies	$ 15,161	$ 15,655	$ 15,880	$+ 225	+ 1.4%
Relativistic Heavy Ion Studies	23,528	21,770	23,210	+ 1,440	+ 6.6%
Heavy Ion Facility Operations & R&D					
Low Energy (ANL, LBNL, Yale, Texas A&M)	10,675	11,770	12,005	+ 235	+ 2.0%
BNL Tandem/AGS and RHIC Operations	8,690	15,900	17,550	+ 1,650	+ 10.4%
Accelerator R&D	1,710	1,535	1,555	+ 20	+ 1.3%
Total, Heavy Ion Nuclear Physics	$ 59,764	$ 66,630	$ 70,200	$+ 3,570	+ 5.4%

III. Performance Summary:

FY 1995 Accomplishments:

Nuclear Structure and Reaction Studies

- o The Gammasphere detector under construction at the Lawrence Berkeley National Laboratory (LBNL) 88-inch Cyclotron initiated experiments with over half its final configuration of gamma-ray detectors and found possible evidence of a previously unobserved nuclear shape.

- o Scientists at the LBNL 88-inch Cyclotron demonstrated that short-lived radioactive atoms can be trapped with laser light and initiated experiments studying the fundamental weak interaction.

- o At the Argonne Tandem-Linac Accelerator System (ATLAS) facility researchers observed the three heaviest nuclei, thus far known, exhibiting radioactive proton emission and used the APEX detector to measure the production of electron-positron pairs in heavy ion collisions to investigate suggestions of unexpected physics raised in previous measurements in Germany.

III. Performance Summary: HEAVY ION NUCLEAR PHYSICS (Cont'd)

Relativistic Heavy Ion Studies

- Researchers successfully initiated major experiments and performed measurements with relativistic heavy ions at the Alternating Gradient Synchrotron (AGS) at Brookhaven National Laboratory (BNL) and at the Super Proton Synchrotron (SPS) at CERN studying nuclear matter at high temperatures and densities.

- Approximately 250 scientists and students contributed to design and construction efforts on the approved detectors planned for the RHIC facility.

- Funding in the amount of $1,410,000 has been transferred to the SBIR program.

Heavy Ion Facility Operations and R&D

- The ANL ATLAS facility provided 4589 hours of heavy ion beams for experiments involving over 150 scientists and students focussed on nuclear structure and reaction mechanism studies.

- The LBNL 88-inch Cyclotron provided 4665 hours of heavy ion beams for a research program focussed on utilizing Gammasphere for nuclear structure studies and involving over 250 scientists and students. In addition over 400 hours of beam were utilized by over 50 scientists and engineers in an independently supported program to improve the radiation hardness of integrated circuits to be used for space applications.

- The tandem accelerator at Yale University and the superconducting cyclotron at Texas A&M University each provided over 2500 hours of beam for nuclear physics research involving primarily on-campus researchers and students.

- The Tandem/Booster/AGS accelerator complex at BNL provided 595 hours of relativistic energy gold (Au) beams for research and continued activities needed to prepare the facility as an injector for RHIC. The tandem facility, when not being used as an injector for the AGS, was utilized for an independently supported program studying the effects of radiation on integrated circuits in measurements involving over 45 institutions.

- RHIC start-up and inventory funds were used to start liquid helium plant operations, prepare for injection beam line tests, and procure special process, accelerator-component spares. Detector R&D funds were used to develop techniques and prototype units for RHIC detectors.

III. Performance Summary: HEAVY ION NUCLEAR PHYSICS *(Cont'd)*

FY 1996 Accomplishments (to date and planned):

Nuclear Structure and Reaction Studies

- o The Gammasphere detector at the 88-inch Cyclotron at LBNL will be used to make significant advancements in our understanding of the structure of nuclei under conditions of extreme deformation and large angular momentum.

- o LBNL scientists at the 88-inch Cyclotron will further develop capabilities for trapping polarized radioactive atoms for experimental tests of the fundamental weak interaction.

- o At the ANL ATLAS facility, the structure of short-lived, proton-rich nuclei will be studied and the puzzle of anomalous electron-positron pair production in heavy ion collisions, studied with the APEX detector, is expected to be resolved.

- o At the Texas A&M cyclotron measurements studying the compressibility of nuclear matter and at the Yale tandem facility cross section measurements important for astrophysics processes will be carried out by scientists and students.

Relativistic Heavy Ion Studies

- o Data obtained from the relativistic heavy ion experiments at the AGS at BNL and SPS at CERN will provide the most severe tests to date of theoretical model calculations of the properties of hot dense nuclear matter.

- o An increasing number of scientists and students from universities and national laboratories will be involved in the design and construction of the approved detectors planned for RHIC.

- o Funding in the amount of $945,000 has been budgeted for the SBIR program.

Heavy Ion Facility Operations & R&D

- o The ANL ATLAS facility will provide 5000 hours of beam for a research program focussed on studies of nuclear structure and reactions.

- o The LBNL 88-inch Cyclotron will provide 5000 hours of beam for a research focussed on studies of nuclear structure with Gammasphere. In addition approximately 400 hours of beam time will be utilized for radiation hardening research activities.

III. **Performance Summary: HEAVY ION NUCLEAR PHYSICS** (Cont'd)

- The tandem accelerator at Yale and the superconducting cyclotron at Texas A&M will each provide 2500 hours of beam for research involving primarily on-campus researchers and students.

- The Tandem/Booster/AGS accelerator complex at BNL will provide 1000 hours of relativistic heavy ion beams for experiments studying the properties of nuclear matter at high temperatures and densities, and continue its preparations to act as the injector for RHIC. The tandem injector will also support an independently funded program on susceptibility of space-based electronic circuits to cosmic ray damage and for production of "micro-pore" filters.

- RHIC start-up and inventory funds will be used to conduct first beam tests of the RHIC injection line, commission the beam distribution system and procure special process spares. The first completed sextant of the collider ring will complete cooldown tests. Commissioning of the cryogenic refrigeration will be completed.

- Accelerator physicists at ANL and LBNL will perform R&D on improving ion source, extraction and transport systems for radioactive ion beams.

FY 1997 Planned Accomplishments:

Nuclear Structure and Reaction Studies

- Gammasphere will continue its nuclear structure research program at the LBNL 88-inch cyclotron for three Quarters. In the 4th Quarter of FY 1997 Gammasphere will be moved for approximately a year to the ANL ATLAS facility for research coupled with existing experimental equipment there.

- The APEX detector at ATLAS will have accumulated sufficient data to have resolved the puzzle of anomalous of electron-positron pair production in heavy ion collisions. Unless unexpected physics appears, APEX operations will be phased out.

- LBNL scientists at the 88-inch Cyclotron will continue studies of the fundamental weak interaction with trapped polarized radioactive atoms and initiate studies focussed on producing and observing "superheavy" nuclei ($A \geq 112$).

- At the Texas A&M cyclotron measurements of the compressibility of nuclear matter and element formation processes relevant to astrophysics, and at the Yale tandem accelerator facility cross section measurements important for nuclear astrophysics will be performed.

III. Performance Summary: HEAVY ION NUCLEAR PHYSICS (Cont'd)

Relativistic Heavy Ion Studies

- o At the AGS at BNL and the SPS at CERN several major relativistic heavy ion experiments will continue investigations of the behavior of hot dense nuclear matter and searches for exotic particles.

- o An increased number of scientists and students will be involved in the assembly of detectors in the RHIC experimental halls.

- o Funding in the amount of $520,000 has been budgeted for the SBIR program.

Heavy Ion Facility Operations & R&D

- o The ANL ATLAS facility will provide 4600 hours of beam for an experimental program focussed on nuclear structure and reaction studies.

- o The LBNL 88-inch Cyclotron will provide 4700 hours of beam for a research program focussed on the use of Gammasphere for nuclear structure studies. In addition approximately 400 hours of beam time will be utilized for radiation hardening research for space-based electronics packages.

- o The tandem accelerator at Yale and the superconducting cyclotron at Texas A&M will each provide 2500 hours of beam for research involving primarily on-campus researchers and students.

- o The Tandem/Booster/AGS Accelerator complex at BNL will provide 1000 hours of relativistic gold (Au) beams for experiments studying the properties of nuclear matter at high temperatures and densities and continue its preparations to act as the injector for RHIC. The tandem injector will also support an independently funded program on susceptibility of space-based electronic circuits to cosmic ray damage and for production of "micro-pore" filters.

- o RHIC start-up funds will be used to inject beams into a fully instrumented sextant of the RHIC collider ring, a major milestone of the RHIC project. RHIC inventory funds will be used to procure special process spares.

- o Accelerator physicists at ANL and LBNL will continue R&D on improving ion source, extraction and transport systems for radioactive ion beams.

III. Performance Summary: HEAVY ION NUCLEAR PHYSICS (Cont'd)

Explanation of Funding Changes FY 1996 to FY 1997:

- o FY 1997 funding for Heavy Ion Research has been increased by about 4.4% compared to FY 1996.
  - Nuclear Structure and Reaction Studies will get a 1.6% increase over FY 1996.
  - In Relativistic Heavy Ion Studies, $750,000 will be added to BNL for needed buildup of the research program associated with RHIC, and the remaining program will get a roughly cost of living increase (3.2%).
- o FY 1997 funding for Heavy Ion Facility Operations has been increased by about 6.5% compared with FY 1996 levels.
  - The increase of $1,650,000 for BNL Tandem/AGS and RHIC Operations reflects a $150,000 (2%) increase for Tandem/AGS operations and $1,500,000 is the planned increase of pre-operations and inventory funding for the RHIC Project from $8,500,000 in FY 1996 to $10,000,000 in FY 1997.
  - Other facility operations will have a 2.0% increase over FY 1996. Research time available at the 88-inch cyclotron and Atlas accelerator facilities has been somewhat reduced to accommodate the transfer of Gammasphere.

NUCLEAR PHYSICS

LOW ENERGY NUCLEAR PHYSICS
(Tabular dollars in thousands, Narrative in whole dollars)

I. Mission Supporting Goals and Objectives:

The Low Energy Nuclear Physics subprogram supports research directed at addressing issues in nuclear astrophysics, the understanding of the behavior of nucleons at the surface of the nucleus as well as the collective behavior of the entire ensemble of nucleons acting in concert; nuclear reaction mechanisms; and experimental tests of fundamental symmetries. The last of these categories can often be accomplished without the use of accelerators. The study of neutrinos from the sun, whose rate of production is not understood, is an example. University-based research is an important feature of the Low Energy Program. Since most of the required facilities are relatively small, they are appropriate for sitting on university campuses, where they provide unique opportunities for hands-on training of nuclear experimentalists who are so important to the future of this field. Many of these scientists after obtaining their Ph.D.'s, contribute to a wide variety of nuclear technology programs of interest to the DOE. Two such facilities located at two universities (Duke University and the University of Washington) are supported and maintained by the Low Energy Nuclear Physics Program and a Radioactive Ion Beams facility for producing beams of unstable nuclei is being developed at Oak Ridge National Laboratory (ORNL). Included in this sub-program are 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. The activities in this sub-program are conducted in three specific areas: Astrophysics and Fundamental Interactions, Structure of Nuclei, and Facility Operations (Facilities at ORNL, Duke University and the University of Washington as well as the National Nuclear Data Center at Brookhaven National Laboratory (BNL).

II. Funding Schedule:

Program Activity	FY 1995	FY 1996	FY 1997	$ Change	% Change
Astrophysics and Fundamental Interactions	$ 6,720	$ 8,587	$ 9,140	$+ 553	+ 6.4%
Structure of Nuclei	8,423	8,362	8,430	+ 68	+ 0.8%
Facility Operations	8,195	9,121	10,230	+ 1,109	+ 12.2%
Total, Low Energy Nuclear Physics	$ 23,338	$ 26,070	$ 27,800	$+ 1,730	+ 6.6%

III. Performance Summary:

FY 1995 Accomplishments:

Astrophysics and Fundamental Interactions

- o New reaction measurements using the low beam energies at the Duke University accelerator have led to a sensitive diagnostic tool for probing the mixing of material in the interior of giant stars.

- o The international collaboration to measure the solar neutrino flux using the GALLEX facility in Italy has completed a calibration of its system using an intense radioactive source, and has solidly established that there is a 40% deficit of solar neutrinos.

- o The joint US-Russian solar neutrino detection project, the Soviet-American Gallium Experiment (SAGE), has also completed a calibration of the detectors using a radioactive source. The final results also showed a deficit of solar neutrinos and agree with the GALLEX results.

- o The underlying origin of the solar neutrino deficit will be investigated by a joint US-Canadian project: the Sudbury Neutrino Observatory (SNO). This observatory is in a cavity 70 feet in diameter and 110 feet in height excavated 6,800 feet below the earth's surface. This year the SNO cavity was completed and scrupulously cleaned of residual dust. The major detector at SNO will consist of 11,000 light sensors that are used to detect signals from 1,000 tons of heavy water. The upper portion of the support structure has been completed and 5,500 light sensors have been installed.

- o University based measurements of the rate of capture of protons by light nuclei have established a key astrophysical process for the creation of chemical elements process in blue stars.

- o Precision measurements of radioactive decay of lithium and boron nuclei provided the most stringent test yet of the theory of this class of nuclear disintegration.

- o A new probe of stellar nucleosynthesis has been established with the discovery of new low energy resonances in neutron capture on Barium isotopes at the Oak Ridge Electron Accelerator (ORELA).

- o In an effort to resolve discrepancies in the elemental composition of stars in globular clusters that are used to determine the age of the galaxy, measurements have been started on the reaction rates of helium and sodium isotopes.

III. Performance Summary: LOW ENERGY NUCLEAR PHYSICS (Cont'd)

Structure of Nuclei

- o Using special detectors, proton radioactivity has been discovered in some of the heavy elements, including bismuth.
- o Cold neutrons of extremely low energy provide a unique probe for the investigation of the origin of symmetry in nature. Present research at the National Institutes of Science and Technology's cold-neutron facility has made the most accurate measurements of the fundamental radioactive decay of the neutron, to shed light on the "arrow of time."
- o At San Jose State University, a personal computer-based program for interactively accessing nuclear structure data has been developed and issued for general use.
- o Funding in the amount of $1,265,000 has been transferred to the SBIR program.

Facility Operations

- o The Radioactive Ion Beam facility at ORNL has had its injector installed, tested, and commissioned, and low-intensity commissioning of the facility has been started.
- o ORNL's Radioactive Ion Beam facility personnel have completed transfer of ownership, shipment, and initial stages of installation of the $3,000,000 Daresbury Recoil Separator (DRS) that has been donated by the United Kingdom.
- o The National Nuclear Data Center at Brookhaven, which manages the U.S. part of the international data base, has serviced 81,000 retrievals. The level of services has increased 60% over the average yearly service rate in the past decade.

FY 1996 Accomplishments (to date and planned):

Astrophysics and Fundamental Interactions

- o A new determination of the up-quark and the down-quark mass difference will be done at the Duke University accelerator laboratory using new neutron-neutron scattering measurements.
- o The lower portion of the Sudbury Neutrino Observatory photomultiplier structure will be completed.

III. Performance Summary: LOW ENERGY NUCLEAR PHYSICS (Cont'd)

- Production will start on a special array of ^{3}He detectors that will provide an improved neutral current measurement capability at the Sudbury Neutrino Observatory.

- Construction will be complete for the cold neutron experiment located at the National Institute for Standards and Technology.

- Theories of the creation of the elements in the Big Bang will be tested by reaction rate measurements on light nuclei using specially built small apparatus at the Colorado School of Mines.

Structure of Nuclei

- Chaotic effects in the excitation of nuclei will be investigated with definitive experiments.

- Approaches will be developed for studying nuclei with neutrons to complement data from heavy ion reactions.

- The nuclear force will be studied in nuclei with abnormally high ratios of protons to neutrons at the ORNL Radioactive Ion Beam Recoil Mass Separator.

- An updated personal computer data base developed at San Jose State University will allow scientists and engineers to incorporate this program into their own data processing and modelling programs.

- Funding in the amount of $1,200,000 has been budgeted for the SBIR program.

Facility Operations

- The ORNL Radioactive Ion Beam facility will go into routine operation as a national user facility with peer reviewed and approved experiments. The facility will operate 1800 hours with an expected 1200 hours of beam on target.

- The National Nuclear Data Center will implement a major upgrade of its on-line data access system that serves as the USA's commitment to international participation.

- The National Nuclear Data Center will begin a pilot project to link its Nuclear Science References data base to the American Physical Society's journal so that users can progress from the bibliographic database to full articles and experimental data bases.

III. Performance Summary: LOW ENERGY NUCLEAR PHYSICS (Cont'd)

FY 1997 Planned Accomplishments:

Astrophysics and Fundamental Interactions

- o Newly developed neutral current detectors will be installed at the Sudbury Neutrino Observatory.

- o One of the most important reactions in present day nuclear astrophysics, that is crucial to calculations of elemental abundances and energy release in supernova explosions, will be remeasured in order to resolve a long standing discrepancy in existing measurements.

- o A new fundamental test of time reversal invariance in nuclei will be made at the National Institute for Standards and Technology using a new innovative technique.

Structure of Nuclei

- o Using the high flux of gamma rays from the free election laser at Duke University, a determination will be made of the internal quark and gluon structure of nucleons and pions.

- o By combining the use of special detectors and beams at the ORNL Radioactive Ion Beam facility, unique properties of unstable nuclei will be investigated.

- o Funding in the amount of $850,000 has been budgeted for the SBIR program.

Facility Operations

- o The ORNL Radioactive Ion Beam facility will deliver 2400 hours of radioactive beam for an experimental program and an actinide target will be developed in order to provide neutron rich Radioactive Ion Beams.

- o Using newly developed beams at the ORNL Radioactive Ion Beam facility, crucial information about the nuclear force in special nuclei will become available.

Explanation of Funding Changes FY 1996 to FY 1997:

- o The increase of $553,000 in the Astrophysics and Fundamental Interactions activities is due to a new program at Lawrence Livermore National Laboratory that utilizes the HERA array at LANSCE and new astrophysics research at ORNL's Radioactive Ion Beam facility and universities.

III. **Performance Summary: LOW ENERGY NUCLEAR PHYSICS** (Cont'd)

- The increase of $68,000 in the Structure of Nuclei activity is the result of an increase in RIB related research and a decrease due to the mothballing of the TRISTAN project at the High Flux Beam Reactor at BNL.

- The increase of $1,109,000 in the Facility Operations area includes increased costs for the full time operation of the ORNL Radioactive Ion Beam facility and increased responsibilities assigned to the National Nuclear Data Center at BNL.

- Overall FY 1997 funding for research and operation of university facilities supports an approximately continuing level of effort.

NUCLEAR PHYSICS

NUCLEAR THEORY
(Tabular dollars in thousands, Narrative in whole dollars)

I. Mission Supporting Goals and Objectives:

Theoretical Nuclear Physics is a program of fundamental science research to provide new insight into the observed behavior of atomic nuclei. The understanding of nuclear phenomena is prerequisite to understanding the material foundations of the world around us and in our universe. The research ranges from relating the description of elementary constituent particles and the fundamental forces connecting them, to descriptions of the nucleus as a whole. Theoretical models of the nucleus range from those that treat nucleons as maintaining their identities in orbits within the nucleus (shell models) to those that treat the nucleus as a coherent drop of nuclear fluid (collective models). The long-range objective of the Nuclear Theory subprogram is to obtain a comprehensive understanding of the character and structure of nuclear matter at the most fundamental level in terms of quarks and gluons. This objective is approached by interpreting results from nuclear physics experiments and by predicting new phenomena and relationships amenable to experimental tests. Nuclear theory research at universities and national laboratories entails individual efforts that transcend subcategories of nuclear physics. The selection of the elements of the nuclear theory program is based on the results of anonymous peer reviews by recognized experts in the international nuclear physics community. Much of nuclear theory requires extensive use of supercomputer capabilities and the development of innovative algorithms to use this advanced technology. The graduate students and post-docs supported in the Theoretical Nuclear Physics program are highly trained in technical problem solving techniques and have the flexibility to broadly enhance the nation's scientific and technical literacy. The strength of the nuclear theory effort is enhanced by strong interactions with the international nuclear physics community as well as by nuclear theory efforts supported by other agencies, such as the National Science Foundation. This is particularly true at the National Institute for Nuclear Physics in Seattle, increasingly recognized as a center of world leadership in nuclear theory. In many cases, directors of programs at the Institute come from outside the United States.

II. Funding Schedule:

Program Activity	FY 1995	FY 1996	FY 1997	$ Change	% Change
Nuclear Theory	$ 14,650	$ 14,820	$ 15,350	$+ 530	+ 3.6%
Total, Nuclear Theory	$ 14,650	$ 14,820	$ 15,350	$+ 530	+ 3.6%

III. Performance Summary:

FY 1995 Accomplishments:

- In FY 1995 theorists found a new way to apply the traditional nuclear shell model can be applied to a significantly expanded range of problems by using a Monte Carlo sampling technique.

- Significant progress was made this year towards the goal of understanding the structure of nucleons with the confirmation by computer studies that much of the character of the forces between quarks can be explained by special configurations of gluons.

- Theories have now been developed for describing collisions of heavy ions at all energies presently being studied experimentally, or that are planned for the future. The theories have been tested by comparison to experiment and found to agree well. The theories applicable to RHIC have now overcome initial conceptual difficulties and are ready to be applied.

- The Institute for Nuclear Theory at the University of Washington was fully staffed and conducted a successful program, acting as a focus center for the development of forefront research concepts.

- A higher quality theory program, better focused on the high priority areas of nuclear physics research, has resulted from the utilization of the findings of the panel review of the entire DOE Nuclear Physics research program conducted in FY 1994.

FY 1996 Accomplishments (to date and planned):

- Significant progress will be made in extending the nuclear shell model to deal with nuclei under extreme conditions, such as those with large excesses of protons or neutrons. This is important for understanding nucleosynthesis, and will be the subject of experimental studies using radioactive beams at the Radioactive Ion Beam facility.

- Programs appropriate to ultrarelativistic collisions will be developed to predict the behavior of collisions between nuclei at the Relativistic Heavy Ion Collider.

- The Institute for Nuclear Theory at the University of Washington will conduct programs focussed on: Nuclear Structure Under Extreme Conditions, Quark and Gluon Structure of Nucleons and Nuclei, and Nucleosynthesis in the Big Bang, Stars and Supernovae.

III. Performance Summary: NUCLEAR THEORY (Cont'd)

FY 1997 Planned Accomplishments:

- o The extension of the nuclear shell model to deal with nuclei under extreme conditions will be complete, and its predictions will be tested by results obtained in experiments using radioactive beams.

- o The application of quark models to nucleons will yield accurate values for nuclear sizes and the strengths of their interactions.

- o Theories appropriate to ultrarelativistic collisions will give detailed predictions of the results of collisions between nuclei at RHIC. These predictions will allow experiments to be refined to optimize the information that one can obtain about high density matter and the quark gluon plasma.

- o The Institute for Nuclear Theory at the University of Washington will conduct programs focussed on: Ultrarelativistic Nuclei; From Nuclear Structure to the Quark-Gluon Plasma, and two on topics which have not yet been announced.

Explanation of Funding Changes FY 1996 to FY 1997:

- o Overall FY 1997 funding for research and facility operations has increased by (3.6%), roughly the cost-of-living.

- o $50,000 is provided for theoretical support of the MIT Bates facility.

NUCLEAR PHYSICS

RELATED CAPITAL FUNDING
(Tabular dollars in thousands, Narrative in whole dollars)

I. Mission Supporting Goals and Objectives:

The Related Capital Funding subprogram provides the necessary equipment that enables the Nuclear Physics program to maintain its vigorous pursuit of scientific opportunities. A major thrust of this subprogram is to provide large experimental devices which complement construction activities at the RHIC facility nearing completion at Brookhaven National Laboratory.

Capital Equipment funds provide for particle detection systems, for data acquisition and analysis systems, and for instrumentation to improve performance of Nuclear Physics accelerators. These funds are essential for effective utilization of the national accelerator facilities operated by the Nuclear Physics program. In addition, the program has landlord responsibility for providing general purpose capital equipment at the Lawrence Berkeley National Laboratory.

General Plant Projects (GPP) provides for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. The Nuclear Physics program provides GPP funds for the Lawrence Berkeley National Laboratory as part of Nuclear Physics' landlord responsibilities for this laboratory.

Accelerator Improvement Projects (AIP) provide for additions, modifications, and improvements to major research accelerators and ancillary experimental facilities. These projects are necessary to maintain and improve the reliability and efficiency of operations, and to provide new experimental capabilities.

II. Funding Schedule:

Program Activity	FY 1995	FY 1996	FY 1997	$ Change	% Change
Capital Equipment	$ 28,000	$ 26,250	$ 26,500	$+ 250	+ 1.0%
General Plant Project	3,900	3,900	3,800	- 100	- 2.6%
Accelerator Improvement Projects	3,200	2,200*	5,400	+ 3,200	+ 145.5%
Total, Related Capital Funding	$ 35,100	$ 32,350	$ 35,700	$+ 3,350	+ 10.4%

* In FY 1996 a request will be made to reprogram $2,575,000 from AIP construction to Medium Energy Facility Operations ($2,200,000), and AIP operating ($375,000).

III. Performance Summary:

FY 1995 Accomplishments:

- o At CEBAF, the very large superconducting toroidal magnet for the CEBAF Large Angle Spectrometer (CLAS) in Hall B was assembled and tested. Some detector components have been installed. A detector package for the High Resolution Spectrometer in Hall A was completed.

- o AT BNL's Relativistic Heavy Ion Collider (RHIC), construction continued of the STAR detector's Silicon Vertex Tracker (SVT). This device adds unique capability for the study of strange particle production to the STAR detector. The Nuclear Science Advisory Committee (NSAC) viewed implementing the STAR SVT as having one of the highest priorities. The SVT has a Total Estimated Cost of $6.0 million in actual year dollars and was funded in FY 1995 at $350,000.

- o At BNL's RHIC facility, instrumenting of the PHENIX detector's North muon arm continued. This device adds unique measurement capability for muon pair production over a wide kinematic range. NSAC judged that the muon arm was an essential part of PHENIX and thus should be built. The completion of the instrumentation package for the muon arm has a Total Estimated Cost of $11.4 million dollars and was funded in FY 1995 at $350,000.

- o At BNL's AGS facility, experimental equipment needed to search for strange quark matter was assembled and the construction of a gold beam dibaryon search experiment was started.

III. Performance Summary: RELATED CAPITAL FUNDING (Cont'd)

- At LBNL, Gammasphere was mounted in its final configuration, and approximately one-half of its 110 detectors were installed and brought into operation. Gammasphere is a world-class, high-resolution, high-granularity, high-efficiency array of gamma-ray detectors that is especially useful for studying nuclear structure at high angular momentum.

- At MIT/Bates, complete a variety of accelerator upgrade activities that improve beam availability.

- At ORNL, the target/ion source on the Radioactive Ion Beam (RIB) injector was completed and was used to accelerate ions through the tandem accelerator.

- In the 6800 ft. deep underground site of the Sudbury (Ontario) Neutrino Observatory, the upper half of the 55-ft. diameter photomultiplier (PMT) support frame was assembled, and 4700 10-inch diameter PMTs were mounted on the frame. Performance of the prototype neutron counters built from extremely low-radioactivity material was demonstrated and approved for fabrication.

- GPP funding was provided for minor new construction, other capital alterations and addition, and for buildings and utility systems. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. Since it is difficult to detail this type of project in advance, a continuing evaluation of requirements and priorities may result in additions, deletions, and changes in the currently planned projects. The total estimated cost of each project will not exceed $2,000,000.

- AIP funding supported additions and modifications to accelerator facilities that are supported by the Nuclear Physics research program.

<u>FY 1996 Accomplishments (to date and planned)</u>:

- At CEBAF complete installation of all detector subsystems on the CLAS detector in Hall B. Complete detector installation and begin tune-up runs with the High Resolution Spectrometers in Hall A. Fabricate liquid hydrogen-deuterium target system for Hall A experiments. Begin major upgrade of the data reduction system to handle massive amounts of raw data.

- At BNL, continue constructing the STAR Silicon Vertex Traker detector with $1,100,000 provided in FY 1996. Final design and prototype tests of silicon drift wafers; begin fabrication of electronics.

III. Performance Summary: RELATED CAPITAL FUNDING (Cont'd)

- At BNL, continue instrumenting the PHENIX North muon arm with $400,000 provided in FY 1996. Complete design and begin fabricating mechanical components of the muon identifier detectors; fabricate muon arm magnet coil.

- At BNL's National Synchrotron Light Source, begin mounting a program of experiments at the LEGS facility that will use a target of frozen heavy and light water.

- At LBNL, complete installation of the remaining detectors for Gammasphere and begin its full experimental program.

- At BNL, provide $1,000,000 to the RHIC construction project to acquire equipment that serves project operations and the experimental programs as part of the rebaselined profile.

- At MIT/Bates, continue installation of the Out-of-Plane Spectrometer (OOPS) and make improvements to the polarized injector.

- At ORNL's Radioactive Ion Beam facility, complete low-intensity commissioning studies and begin the research program. Two large experimental devices, the Recoil Mass Spectrometer and the Daresbury Recoil Separator will be ready for use.

- At the Sudbury Neutrino Observatory, complete assembly of the photomultiplier support frame and install the remaining 4700 photomultiplier tubes. Begin commissioning the data acquisition and analysis system. Complete fabrication of the neutron counters (800 m total length) and transport the counters underground for storage in the non-radioactive environment of the mine.

- GPP funding will be provided for minor new construction, other capital alterations and addition, and for buildings and utility systems. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. Since it is difficult to detail this type of project in advance, a continuing evaluation of requirements and priorities may result in additions, deletions, and changes in the currently planned projects. The total estimated cost of each project will not exceed $2,000,000.

- AIP funding supported additions and modifications to accelerator facilities that are supported by the Nuclear Physics research program.

III. Performance Summary: RELATED CAPITAL FUNDING (Cont'd)

FY 1997 Planned Accomplishments:

- o At CEBAF install ancillary equipment items, such as polarized targets, in experimental Hall A and C spectrometer systems. Continue major upgrade of data reduction system to handle massive amounts of raw data. Begin construction of second generation experiments such as spectrometer that is designed to investigate the strange quark content of the proton.

- o At CEBAF, carry out improvements in accelerator, injector and cryogenic systems that allow simultaneous three hall operation.

- o At BNL, continue constructing the Silicon Vertex Tracker with $2,000,000 planned in FY 1997. Continue fabrication of silicon drift wafers and electronics; begin mechanical assembly.

- o At BNL, begin fabricating an electromagnetic calorimeter for the STAR detector. This device adds to the precision of measuring the particles emitted at large angles and thus provides unique information for the study of short-lived neutral reaction products.

- o At BNL, continue instrumenting the PHENIX north muon arm at RHIC with $2,650,000 planned in FY 1997. Complete design and begin fabrication of wire-chamber tracking detectors for the muon arm.

- o At BNL, provide $1,000,000 to the RHIC construction project to acquire equipment that serves project operations and the experimental programs.

- o At ORNL's Radioactive Ion Beam facility, the research program will begin using the Recoil Mass Spectrometer (RMS) and the Daresbury Recoil Separator. A large, high-efficiency gamma-ray detector array for use in conjunction with the RMS will be completed.

- o At ANL preparations will be made to install Gammasphere for an experimental program that uses the special properties of the ATLAS beam and the FMA recoil spectrometer.

- o At MIT/Bates, upon review begin construction of apparatus needed to conduct a physics program using polarized internal targets in the South Hall Ring.

- o At the Sudbury Neutrino Observatory, fill the detector with 1000 tons of heavy water and begin the research program of studying solar neutrinos. Test neutron counters and measure their internal background prior to deployment in the SNO detector.

III. Performance Summary: RELATED CAPITAL FUNDING (Cont'd)

- GPP funding will be provided for minor new construction, other capital alterations and addition, and for buildings and utility systems. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and in meeting its requirement for safe and reliable facilities operation. Since it is difficult to detail this type of project in advance, a continuing evaluation of requirements and priorities may result in additions, deletions, and changes in the currently planned projects. The total estimated cost of each project will not exceed $2,000,000.

- AIP funding will support additions and modifications to accelerator facilities that are supported by the Nuclear Physics research program.

Explanation of Funding Changes FY 1996 to FY 1997:

- An increase of $1,900,000 in AIP funds at CEBAF provides accelerator improvements that allow simultaneous three hall operation. An increase of $800,000 in AIP funds at MIT/Bates enables an upgrade of the linac RF transmitters. An increase of $400,000 allows construction of advanced ion sources at ANL and LBNL. An increase of $100,000 in AIP funding at other sites results from changes in programmatic priorities.

- The small changes in Capital Equipment funding (+$250,000) and GPP funding (-$100,000) result from adjustments in these activities.

NUCLEAR PHYSICS

CONSTRUCTION
(Tabular dollars in thousands, Narrative in whole dollars)

I. Mission Supporting Goals and Objectives:

The Construction subprogram funds the necessary activities that enable the Nuclear Physics program to maintain a set of world-leading accelerator facilities that are essential for forefront scientific investigation. The major thrust is completion of the Relativistic Heavy Ion Collider (RHIC) facility and the start of its research program in FY 1999.

II. Funding Schedule:

Program Activity	FY 1995	FY 1996	FY 1997	$ Change	% Change
Construction					
CEBAF	$ 1,000	$ 0	$ 0	$ 0	0.0%
RHIC	70,000	65,000	65,000	0	0.0%
AIP	0	2,575*	0	- 2,575	- 100.0%
Total, Construction	$ 71,000	$ 67,575	$ 65,000	$- 2,575	- 3.8%

* In FY 1996 a request will be made to reprogram $2,575,000 from AIP construction to Medium Energy Facility Operations ($2,200,000), and AIP operating ($375,000).

III. Performance Summary:

FY 1995 Accomplishments:

Construction

- o CEBAF construction was completed and accepted by DOE. The accelerator was commissioned, delivering the first five-pass 4 GeV beam in May 1995. Two large spectrometers and their detector systems are ready for experiments in Hall C. All eight very large (up to 500 ton) magnets for the High Resolution Spectrometers in Hall A have been mounted on their carriages.

- o RHIC collider construction continued with about 200 out of 360 large industrially produced superconducting dipole magnets now mounted on their stands in the ring tunnel. Final design of most other collider systems have been completed.

- o Construction of the RHIC STAR detector started with commercial fabrication of the coils and steel structure of the solenoidal magnet, construction of the STAR Assembly Building at the RHIC site, and production of Time Projection Chamber (TPC) components at LBNL.

- o Construction of the RHIC PHENIX detector started with fabrication of steel components nearly complete, and prototyping of detector subsystems taking place at 10 institutions.

FY 1996 Accomplishments (to date and planned):

Construction

- o RHIC collider construction continues with all large dipole magnets for the arcs of the machine being mounted in the ring tunnel and interconnections begun. Beam tests of the injection beam line will be completed. Begin cooldown of ring in preparation for First Sextant Cooldown Test. Begin construction of long lead-time components of other collider systems.

- o Construction of the RHIC STAR detector continues with occupancy of the STAR Assembly Building, and Counting House. Continue production and assembly of detector subsystems and electronics.

- o Construction of RHIC PHENIX detector continues with installation of magnet components, and fabrication of detector subsystems and electronics.

III. **Performance Summary: CONSTRUCTION** (Cont'd)

- AT CEBAF provide a redundant cold compressor to the central cryogenic facility in order to improve the reliability of accelerator operations.

FY 1997 Planned Accomplishments:

Construction

- RHIC collider construction continues with the finish of all magnet production, with the mounting of magnets in ring tunnel, and with the completion of final design and construction of remaining collider systems.

- Construction of RHIC STAR detector continues with testing of subsystems at LBNL, completion of assembly of all magnet and support structure, and completion of fabrication of electronics.

- Construction of RHIC PHENIX detector continues with installation, testing and mapping of magnets. Start installation of detectors in central arm.

Explanation of Funding Changes FY 1996 to FY 1997:

- No change in construction funding for RHIC.

- The decrease of $2,575,000 is associated with no request of funds for AIP construction projects with TEC's in excess of $2,000,000.

NUCLEAR PHYSICS

CAPITAL OPERATING EXPENSE & CONSTRUCTION SUMMARY
(Dollars in thousands)

Capital Operating Expenses	FY 1995	FY 1996	FY 1997	$ Change	% Change
General Plant Projects (Total)	$ 3,900	$ 3,900	$ 3,800	$ - 100	- 2.6%
Capital Equipment (Total)	28,000	26,250	26,500	+ 250	+ 1.0%
Accelerator Improvement Projects (Total)	3,200	2,200	5,400	+ 3,200	+ 145.5%

Construction Project Summary (both Operating and Construction Funded)

Project Number	Project Title	TEC	Previous Approp.	FY 1995 Approp.	FY 1996 Approp.	FY 1997 Request	Unapprop. Balance
87-R-203	Continuous Electron Beam Accelerator Facility, CEBAF	$313,200	$312,200	$ 1,000	$ 0	$ 0	$ 0
91-G-300	Relativistic Heavy Ion Collider, BNL	486,870	210,850	70,000	65,000	65,000	76,020
96-G-302	Accelerator Improvements and Modifications various locations	2,575	0	0	2,575*	0	0
	Total Nuclear Physics	--	$523,050	$71,000	$67,575	$65,000	$76,020

Major Items of Equipment (CE $2 Million and Above)

	TEC	Previous Approp.	FY 1995 Approp.	FY 1996 Approp.	FY 1997 Request	Acceptance Date
1. Silicon Vertex Tracker	$ 6,000	$ 100	$ 350	$ 1,100	$ 2,000	FY 1999
2. Muon Arm Instrumentation	11,400	50	350	400	2,650	TBD

* In FY 1996 a request will be made to reprogram $2,575,000 from AIP construction to Medium Energy Facility Operations ($2,200,000) and AIP operating ($375,000).

DEPARTMENT OF ENERGY
FY 1997 CONGRESSIONAL BUDGET REQUEST
(Changes from FY 1996 Congressional Budget Request are denoted with a vertical line in left margin.)

GENERAL SCIENCE AND RESEARCH - PLANT AND CAPITAL EQUIPMENT
(Tabular dollars in thousands. Narrative material in whole dollars.)

NUCLEAR PHYSICS

1. Title and location of project: Relativistic Heavy Ion Collider
Brookhaven National Laboratory
Upton, New York

2a. Project No. 91-G-300
2b. Construction Funded

SIGNIFICANT CHANGES

- TEC increased from $475,250,000 to $486,870,000 because of a directed change reducing FY 1996 Construction funding.

- TPC increased from $595,250,000 to $616,530,000 because of a directed change reducing FY 1996 Construction funding.

- Completion date of 2nd quarter FY 1999 changed to 3rd quarter FY 1999 because of a directed change reducing FY 1996 Construction funding.

- Funding Change:

  FY 1996 Construction funding was reduced from $70,000,000 to $65,000,000.

- Project Scope has not changed.

DEPARTMENT OF ENERGY
FY 1997 CONGRESSIONAL BUDGET REQUEST
(Changes from FY 1996 Congressional Budget Request are denoted with a vertical line in left margin.)

GENERAL SCIENCE AND RESEARCH - PLANT AND CAPITAL EQUIPMENT
(Tabular dollars in thousands. Narrative material in whole dollars.)

NUCLEAR PHYSICS

1. Title and location of project: Relativistic Heavy Ion Collider
Brookhaven National Laboratory
Upton, New York

2a. Project No. 91-G-300
2b. Construction Funded

3a. Date A-E Work Initiated: 1st Qtr. FY 1991

3b. A-E Work (Title I & II) Duration: 6 months

5. Previous Cost Estimate:
Total Estimated Cost (TEC) -- $475,250
Total Project Cost (TPC) -- $595,250

4a. Date Physical Construction Starts: 2nd Qtr. FY 1991

4b. Date Construction Ends: 3rd Qtr. FY 1999

6. Current Cost Estimate:
TEC -- $486,870
TPC -- $616,530

7. Financial Schedule (Federal Funds):

Fiscal Year	Appropriations	Adjustments	Obligations	Costs
FY 1991	$ 15,000	- 1,500 a/	$ 13,500	$ 6,000
FY 1992	49,350		49,350	23,265
FY 1993	71,400	- 1,400 b/	70,000	60,839
FY 1994	78,000		78,000	82,244
FY 1995	70,000		70,000	86,600
FY 1996	65,000		65,000	77,000
FY 1997	65,000		65,000	68,000
FY 1998	59,400		59,400	64,400
FY 1999	16,620		16,620	18,522

a/ Reflects the reduction of funds resulting from the FY 1991 sequester and general reduction.
b/ Application of a portion of the FY 1993 General Science and Research general reduction of $30,000,000 for use of prior year balances.

1.	Title and location of project: Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a.	Project No. 91-G-300
		2b.	Construction Funded

8. Project Description, Justification and Scope

The FY 1996 Congressional Appropriation reduced construction funding from $70 million to $65 million. This reduction was partially offset by an additional $2.5 million in operating and $1 million in capital equipment funding. These funding actions result in a 3 month delay in the project completion date from the second quarter of FY 1999 to the third quarter of FY 1999 and increase the TEC and TPC. The TEC has increased from $475,250,000 to $486,870,000. The TPC has increased from $595,250,000 to $616,530,000. The increase in cost covers the support of core personnel essential for subsequent operations, stretch-out costs associated with revised work schedules to accommodate the funding profile, and escalation on the FY 1996 reduction, which is to be restored in FY 1999.

The Relativistic Heavy Ion Collider (RHIC) facility will be a unique, world-class research facility with opposing colliding beams that provides collision energies of 100 GeV/AMU per beam for heavy ions as massive as gold. RHIC will use the existing Alternating Gradient Synchrotron (AGS) and Tandem Van de Graaff complex as an injector. The new accelerator will be built in the existing Colliding Beam Accelerator (CBA) tunnel (3.8 km circumference), and will utilize the experimental halls, support building and liquid helium refrigerator from the partially completed CBA project.

The collider consists of two rings of superconducting magnets for accelerating and storing beams at variable energies up to 100 GeV/AMU for the heaviest ions. The collider will have the flexibility of using the full range of ion species from protons to gold which will be available from the AGS. With protons, energies of up to 250 GeV in each beam are expected. The capability for collisions between different masses in each ring will be provided. The collider is expected to have an average luminosity (a measure of the collision rate) of about 10^{26} cm^{-2} sec^{-1} for gold-on-gold collisions at full energy.

Most of the conventional construction for the collider exists, including a ring tunnel and an operating helium refrigeration system. The existing Collider Center (50,000 sq. ft. of usable area) will contain the accelerator control center, offices, technical shops, and refrigeration plant.

The existing tunnel configuration provides for six experimental areas where the circulating beams cross. Three of the experimental areas presently have completed experimental halls and support buildings for utilities. Another experimental area is an "open area" complete with support buildings and is suitable for experiments that use internal stationary targets. New construction is needed at two areas to close gaps in the ring. The standard tunnel cross section and support buildings will be constructed. Some general site work such as the paving of roads and the stabilization of the berm will also be provided.

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300	2b. Construction Funded

8. Project Decscribtion, Justification and Scope (Continued)

The funds requested will provide an initial complement of research detectors at beam intersection regions necessary for the first-round research program with the high-energy heavy-ion collider.

RHIC is a two-ring colliding beam accelerator dedicated to the study of nuclear matter at very high temperatures and densities where the *quark-gluon degrees of freedom* are expected to be directly revealed. The purpose of RHIC is to accelerate, store, and bring into collision two circular beams of very high energy heavy ions. For the heaviest ions (e.g., nuclei of gold atoms) the energies will range up to 100 GeV/AMU in each of the two colliding beams, providing a total collision energy which exceeds by more than an order of magnitude the capability of any other existing or proposed accelerator of heavy nuclear beams.

In such collisions experimenters will be able to study extended volumes of nuclear matter with energy densities greater than 10 times that of the nuclear ground state, achieving conditions of temperature and density at which this matter loses its identity as a collection of neutrons and protons and is predicted to undergo a phase transition to a plasma of quarks and gluons. This state of matter has not yet been observed. Its existence and properties are predicted by the theory of Quantum Chromodynamics (QCD), the theory of the strong interaction which has been developed over the past two decades of progress and discovery in high energy and nuclear physics.

At present the highest energy man-made heavy ion collisions are achieved with nuclear beams impinging on stationary targets, utilizing the Brookhaven AGS and CERN Super Proton Synchrotron accelerators. Recent experiments at these facilities have confirmed expectations that very energetic collisions produce increased densities and temperatures in nuclear matter. These experiments support the predictions that at much higher energies, which can be achieved only with the colliding beams of heavy ions at the RHIC facility, the most extreme temperatures and energy densities are produced in bursts of particles formed purely from the energy in the collision. These are the sought-for thermodynamic conditions which can be directly compared with QCD calculations, and which approximate the conditions that existed before the universe condensed from a plasma of quarks and gluons to a gas of hadrons.

RHIC is designed to meet the requirements for carrying out a wide-ranging program of experiments which will open up the heretofore unexplored physics of hot dense nuclear matter and to isolate and study the new states of matter thus created. These requirements are not met by any other existing or proposed high energy colliding beams facility, all of which are designed for the acceleration of light, singly-charged particles such as protons, antiprotons, or electrons.

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300 2b. Construction Funded	

9. Details of Cost Estimate		Item Cost	Total Cost
a. Engineering design inspection and administration of item b			$ 83,982
1. Engineering, design and inspection at 18% of construction costs		$ 50,172	
2. Construction management at 12% of construction costs, item b		33,810	
b. Construction Costs			279,920
1. Conventional Construction		9,640	
a. Site Improvement	1,160		
b. Tunnels and Buildings	6,260		
c. Utilities	2,220		
2. Technical Components - Collider		270,280	
a. Collider Installation	31,120		
b. Magnet System	141,240		
c. Magnet Electrical System	11,640		
d. Cryogenic System	20,390		
e. Vacuum System	10,750		
f. Injection System	11,370		
g. Beam Dump System	6,030		
h. RF System	12,140		
i. Beam Instrumentation	11,080		
j. Control System	12,260		
k. Safety System	2,260		
c. Contingencies on Collider at approximately 2.2 percent of above costs			7,968
Subtotal			$371,870
d. Research Detectors (including EDIA and Contingency)			115,000
Total line item costs			$486,870

1. Title and location of project:	Relativistic Heavy Ion Collider Brookhaven National Laboratory Upton, New York	2a. Project No. 91-G-300 2b. Construction Funded	

10. Method of Performance

This type of construction project is a unique facility and therefore the design, assembly and testing will be done by the staff of the Brookhaven National Laboratory (with the assistance of an architectural-engineering (A-E) firm). Component parts, wherever possible, will be fabricated by industry under fixed-priced, competitively obtained, procurement actions. Some components may be fabricated in the existing shops at BNL. Building design will be on the basis of a negotiated A-E contract, and its construction will be by a competitively obtained lump-sum contract.

11. Schedule of Project Funding and Other Related Funding Requirements

a. Total project costs	Prior Years	FY 1991	FY 1992	FY 1993	FY 1994	FY 1995
1. Total Facility Cost						
Construction line item	$ 0	$ 6,000	$23,265	$60,839	$ 82,244	$86,600
Total facility cost	$ 0	$ 6,000	$23,265	$60,839	$ 82,244	$86,600
2. Other project costs						
a. R&D necessary to complete construction	$21,450	$ 6,614	$ 7,000	$ 7,200	$ 5,880	$ 3,620
b. Start-up, Invent. & Equip.	0	0	0	0	0	2,200
Total other project costs	$21,450	$ 6,614	$ 7,000	$ 7,200	$ 5,880	$ 5,820
Total project cost	$21,450	$12,614	$30,265	$68,039	$ 88,124	$92,420

a. Total project costs	FY 1996	FY 1997	FY 1998	FY 1999	Total
1. Total Facility Cost					
Construction line item	$77,000	$68,000	$64,400	$18,522	$486,870
Total facility cost	$77,000	$68,000	$64,400	$18,522	$486,870
2. Other project costs					
a. R&D necessary to complete construction	$ 0	$ 0	$ 0	$ 0	$ 51,764
b. Start-up, Invent. & Equip.	9,500	11,000	19,000	36,196	77,896
Total other project costs	9,500	11,000	19,000	36,196	129,660
Total project cost	$86,500	$79,000	$83,400	$54,718	$616,530

11. Schedule of Project Funding and Other Related Funding Requirements (Continued)

b. Related annual funding requirements (FY 1999 dollars)

1. Annual RHIC Facility Operating Costs	$49,400
2. Annual Injector Operating Costs	
AGS	19,300
Booster	3,200
Tandem	2,300
Total facility operating costs	$74,200
3. Annual plant and capital equipment costs related to facility operations	4,700
Total related annual funding *	$78,900

* Not all of these costs are incremental.

12. Narrative Explanation of Total Project Funding and Other Related Funding Requirements

a. Total project funding

1. Total facility costs

Explained in items 8, 9 and 10.

2. Other project costs

a. R&D necessary to complete construction

This included supporting R&D work on critical accelerator components before and during the construction phase. The funds covered the development of full-length (9.7 m) dipole magnets, quadrupole magnets, insertion magnets, and trim/correction spool pieces.

This also included R&D necessary for research detectors. Tests were needed to determine detailed parameters required for large-scale detectors for the heavy-ion experimental facilities, and a continued effort to develop new techniques of detection and read-out for improved utilization of the collider facility.

12. Narrative Explanation of Total Project Funding and Other Related Funding Requirements (Continued)

b. Related annual funding requirements (FY 1999 dollars)

These funds are needed for operation training of crew, early testing and check-out of various systems, as well as to establish a special process spares inventory as their construction is completed. Capital equipment is identified within other project costs for acquiring equipment to serve project operations and the experimental program. Portions of the cryogenic system and the beam injection system reached operational status in FY 1996.

b. Related annual costs (Estimated life of the facility: 20 years)

1. RHIC facility operating costs assume 38 weeks of operation with appropriate manpower, material, and support services associated with the research program. For this estimate, four experimental areas are assumed in use.

2. Injector operating costs assume that the Tandem/AGS injector complex is not being used for any function other than as the RHIC injector.

3. This item includes plant and capital equipment needed to maintain the research capability of the facility to evolving research requirements as well as funds for accelerator improvement projects and minor general plant projects required to ensure its continued high performance.