Brookhaven National Laboratory

BNL-67879
Informal Report

managed by Brookhaven Science Associates for the US Department of Energy

Institutional Plan

FY 2001 -- FY 2005

October 2000

Brookhaven Science Associates, LLC
Upton, New York 11973

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Disclaimer

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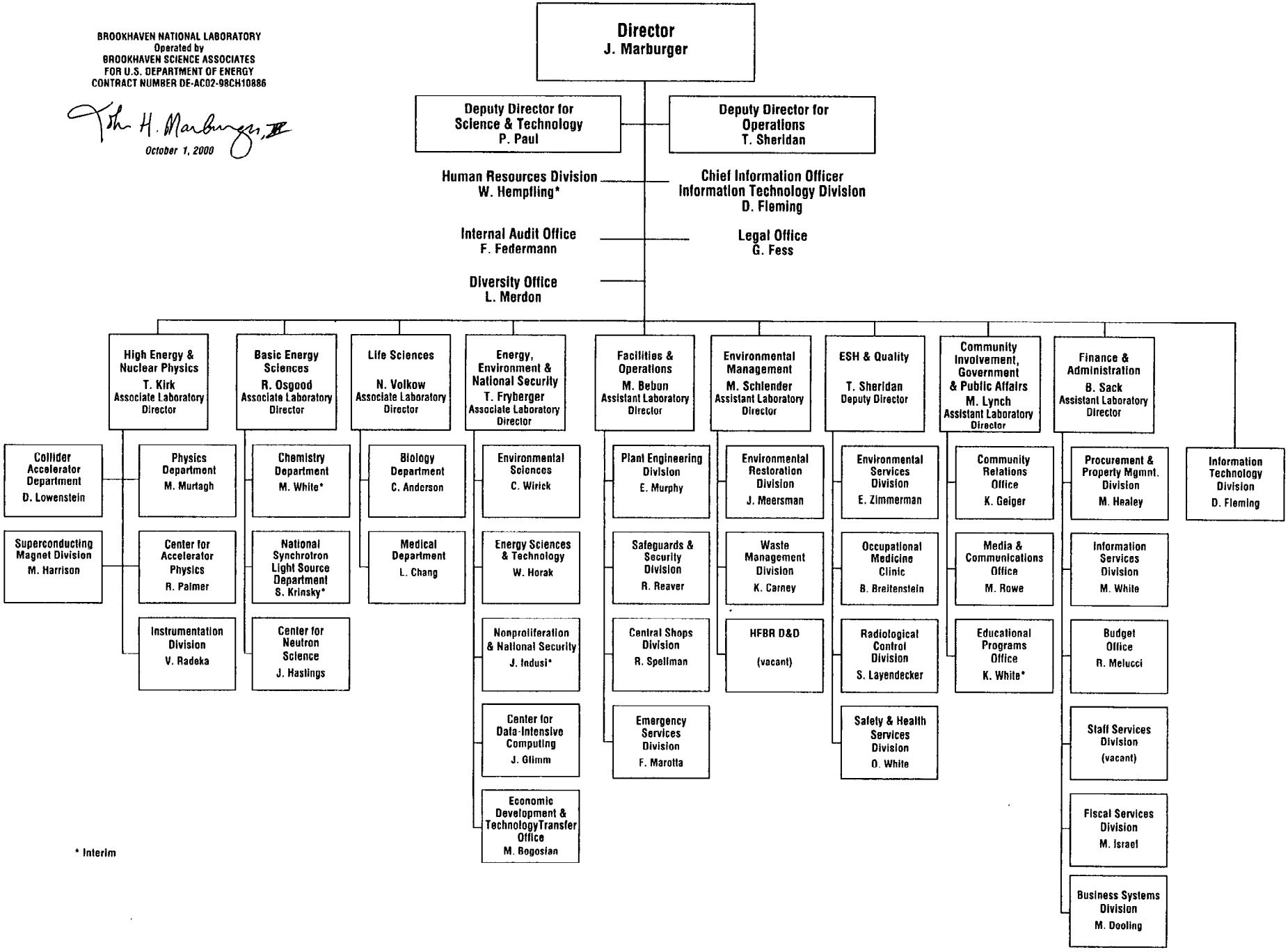
Operated by
BROOKHAVEN SCIENCE ASSOCIATES
FOR U.S. DEPARTMENT OF ENERGY
CONTRACT NUMBER DE-AC02-98CH10886

John H. Marburger, III
October 1, 2000



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Executive Summary

Brookhaven National Laboratory is a multidisciplinary laboratory in the Department of Energy national laboratory system and plays a lead role in the DOE Science and Technology mission. The Laboratory also contributes to the DOE missions in Energy Resources, Environmental Quality, and National Security. Brookhaven strives for excellence in its science research and in facility operations and manages its activities with particular sensitivity to environmental and community issues. The Laboratory's programs are aligned continuously with the goals and objectives of the DOE through an Integrated Planning Process. This Institutional Plan summarizes the portfolio of research and capabilities that will assure success in the Laboratory's mission in the future. It also sets forth BNL strategies for our programs and for management of the Laboratory.

The Department of Energy national laboratory system provides extensive capabilities in both world class research expertise and unique facilities that cannot exist without federal support. Through these national resources, which are available to researchers from industry, universities, other government agencies and other nations, the Department advances the energy, environmental, economic and national security well being of the United States, provides for the international advancement of science, and educates future scientists and engineers. Recently, the Department of Energy developed strategic plans (e.g., *The US Department of Energy Strategic Plan, 2000 (*http://www.cfo.doe.gov/stratmgt/plan/doesplan.htm) and *The US Department of Energy Comprehensive National Energy Strategy)* to assure that it meets the challenges facing the US in the 21st century. It also defined goals, objectives and the portfolio of programs and activities that support these strategies.

The Department is the third largest government sponsor in the US for science and technology, and the Office of Science within DOE establishes the goals for basic science and technology. These goals are "to advance basic research and the instruments of science that are the foundations for DOE's applied missions, a base for US technology innovation, and a source of remarkable insights into our physical and biological world, and the nature of matter and energy" (*DOE Office of Science Strategic Plan, 2000 at* http://www.osti.gov/portfolio/science.htm).

1.0 Introduction

Brookhaven National Laboratory (http://www.bnl.gov/) is a large research institution on Long Island, New York, operated by Brookhaven Science Associates (BSA) under contract with the US Department of Energy. With over 3,000 employees and an annual budget of more than $400 million, the Laboratory is the largest employer in Eastern Long Island. Its 350 buildings occupy almost 5,300-acres on the western edge of Suffolk County's environmentally important Pine Barrens.

Since its founding in 1947, the Laboratory's primary mission has been scientific research in fields requiring unique and complex, often large, facilities, and the design, construction and operation of those facilities for external users as well as for its own scientists. BNL research departments are organized in four directorates (Nuclear and High-Energy Physics, Basic Energy Sciences, Life Sciences, and Energy/Environment/National Security). Other departments are devoted to future and ongoing scientific facilities. The largest of these facilities are particle accelerators and synchrotron light sources. More than 4000 scientists from the United States and abroad come to the Laboratory each year to use BNL's facilities and to participate in joint scientific ventures with its staff.

The following recent successes highlight work performed at the Laboratory in 2000:

- Completed construction and initiated the research mission of the Relativistic Heavy Ion Collider (RHIC). The rapid ramp-up of the performance of the accelerator and the four detectors exceeded expectations. Detector commissioning, data acquisition, and data analysis activities of the new Phobos, STAR, and PHENIX experiments were performed superbly, and there was strong performance by BRAHMS. The crucial RHIC Computing Facility was able to accept flawlessly the huge data flow from the detectors and then store and make the data available for rapid analysis. At the end of the scheduled first run period in Sept. 2000, 10% of the design luminosity had been reached.

- The first gold ion collisions at RHIC were reported in June. RHIC heavy ion research produced the first results on the research of the Quark Gluon Plasma.

- A second major RHIC programmatic achievement was the acceleration and storage of polarized protons and the demonstration that the proton spin polarization could be preserved through the acceleration process, and then rotated at will by use of the Siberian Snakes. This sets the stage for the beginning of the RHIC Spin Physics program.

- Researchers in a Brookhaven/Argonne team made significant advances in the demonstration of the High Gain Harmonic Generation Free Electron Laser (HGHG FEL) using the Accelerator Test Facility (ATF) at BNL. This leading edge technology provides an important step beyond any FEL principles presently in use. It could be the basis for a very powerful new tool to generate extremely intense, short (femtosecond) coherent pulses of light. It will open up new research opportunities in chemistry, biology and material science.

- For the first time anywhere research at the ATF successfully demonstrated 2 stage laser acceleration of electron bunches. This Staged ELectron Laser Acceleration (STELLA) is an essential 1st step for acceleration by a train of lasers which could provide very high electric field gradients for acceleration.

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- Significant progress has been made on improving the performance and associated experimental capabilities of the new Laser Electron Accelerator Facility (LEAF), including shortening the pulse to 7 picoseconds which offers new opportunities for capturing transient phenomena.

- In the area of gas-phase molecular dynamics, transient FM Doppler spectroscopy has been extended to prototype studies of non-adiabatic interactions in the branching of chemical reactions which are a key element in predictive codes for modeling combustion.

- For the first time laser spectroscopy has been successfully used to study the reaction dynamics of oxygen adsorption on an important catalytic metal surface for the measurement of state and energy resolved product distributions.

- A new process for synthesizing monodispersive cubic powders of pure and doped MgO and nanowhiskers of pure and doped ZnO has been used to produce materials to study the adsorption and decomposition of sulfur and nitrogen based oxides (SO_x and NO_x) using X-ray, neutron, thermodynamic and flow reactivity measurements.

- Recent measurements have shown that electron bombardment of an oxidized metal complex produces chemically-active excited states via electron capture. This has implications for the design of transition-metal-based solar energy conversion systems and suggests new photolytic pathways for the synthesis of certain coordination complexes.

- High-resolution photoemission studies at the NSLS indicate that molybdenum carbide is more active towards C-S bond breaking than other frequently used hydrodesulfurization catalysts.

- At the NSLS the total operational hours exceeded the initial schedule delivering X-ray, UV and IR beams for about 5,500 hours for the largest user community of any synchrotron facility. Significant facility upgrades include: beam line upgrades at X1B, X6A, X-17, and U5UA. A digital feedback system was installed to provide increased transverse stability of beam position in the VUV ring; and design and procurement have been completed for the insertion device exit chambers at X9, X13, and X29. the

- A novel, quantitative, and highly sensitive method, using Transmission Electron Microscopy (TEM), has been developed to image and measure the distribution of valence electrons in solids. This method is based on the acute sensitivity of electron beams to scattering at very small angles by valence electrons in crystals.

- PET imaging of the anti-estrogen drug tamoxifen (labeled with C-11) revealed rapid and high binding in the brain. Tamoxifen is used as an adjuvant therapy for breast cancer.

- A new approach to imaging the enzyme monoamine oxidase (MOA) in peripheral organs in humans has been developed for assessing whether peripheral MOA is inhibited by tobacco smoke thereby potentially contributing to smoke toxicity.

- BNL research has provided new insight into the biochemistry of the reward circuits in the brain that are related to drug addiction. Researchers have determined that dopamine, a chemical associated with pleasure and reward, surges in certain areas of the brain when a subject experiences a "high" from an injected dose of Ritalin.

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- A team of scientists determined the atomic structure of a key enzyme that performs several important chemical jobs in the body, including synthesizing estrogen and detoxifying chemicals as they enter the body. In addition, the enzyme may have medical and commercial applications in cancer therapy, in reducing pollution in industrial waste streams, and in manufacturing epoxies.

- Research conducted at the NSLS has enabled the discovery of how one form of cold virus binds to human cells. The discovery could lead to the development of drugs that block infection. Similar research at the NSLS has enabled scientists to characterize how the immunodeficiency virus (HIV, the virus that causes AIDS) binds to its cell surface receptor.

- The Free-Air Carbon Dioxide Enrichment (FACE) array has enabled a greater understanding of large-scale field experiments which is critical to evaluating the role of ecosystems in regulating global carbon dioxide concentrations in a warmer, CO_2 enriched world.

- The atmospheric sciences programs continue to make significant contributions to several aerosol and pollutant studies across the US For example, research identified that emissions of biogenic hydrocarbons are so large in southeastern US that any ozone control strategy based upon further reduction in anthropogenic hydrocarbons will fail. Additionally, it was demonstrated that ozone production efficiency per unit NOx emitted, is smaller in large fossil fueled power plants than it is in small power plants which has profound policy implications with respect to electrical power production.

- Scientists found a molecular "weak link" that may limit the productivity of some of the world's most commercially important strains of rice. Understanding this mechanism could lead to ways to improve the production of rice, the most important food source for more than half the world's population.

The Brookhaven Science Associates contract, which began March 1, 1998, challenges management to produce outstanding science and operate forefront facilities in a safe, environmentally responsible manner in harmony with the surrounding community. During the past year, management successfully met these challenge. The Science and Technology programs have achieved outstanding performance. The Laboratory instituted several efforts to strengthen research management, increase the number of post doctoral staff and recruit new scientific staff in critical areas. BNL installed the Standards Based Management System (SBMS) and implemented Integrated Safety Management (ISM). In May 2000, the DOE verified the Laboratory's Integrated Safety Management System without finding significant deficiencies. Eight organizations were registered as ISO 14000 compliant.

2.0 Director's Statement

From its beginning in 1947 as the nation's first peacetime federal laboratory, Brookhaven National Laboratory has served the large and demanding science community in the Northeastern United States with a combination of "big science" facilities and a cluster of basic science departments that ensure the relevance of the facilities to the needs of the scientific community and the missions of the Department of Energy. One of these missions is to provide "extraordinary facilities for extraordinary science", and most of DOE's investment in the Laboratory is directed through the Office of Science to this end. Today Brookhaven National Laboratory is a world leader in accelerator-based science and technology.

The Laboratory operates the world's frontier facility for a new area of nuclear science already known as "RHIC physics". And it operates what by some measures are the world's most productive sources of coherent short wavelength light at the National Synchrotron Light Source. Both facilities rely on a focussed set of departments that combine technology and basic science to ensure continuing leadership in the conception, design, construction, and operation of high quality accelerator-based beams of light and matter for scientific purposes. Still other departments lead in the utilization of the facilities to advance knowledge, and also take scientific advantage of the Laboratory's base of talent and capabilities for discovery and for issue-oriented research.

These are the fundamental components that make Brookhaven essential to the nation's science effort: large scale or complex facilities plus supporting technology plus science departments that link to a broader community of mostly university based users. The Laboratory's twin large user facilities, RHIC and NSLS, are based on technology for accelerating and for detecting the scattering products (including light) of ions and electrons, respectively. Together they probe nearly the entire range of scales -- from human-sized to elementary particles -- of interest to most areas of physical and biological science.

The research departments that link RHIC, NSLS, and smaller facilities to users and to DOE missions are challenged to meet the evolving needs of science and society. Accelerator-based beams are universal probes, useful to far more areas of science than any one department can encompass. Choosing disciplinary capabilities must therefore be done carefully in partnership with the Department of Energy and its advisory committees. Research in the Laboratory's departments falls broadly in the categories of "discovery- oriented" and "issue-oriented" programs, corresponding roughly to basic science, and applied science and technology. Most discovery-oriented research at Brookhaven is linked in some way to the facilities and is carried out in collaboration with users who are supported by a wide range of sponsors. Most issue-oriented work addresses a specific Department of Energy mission. Exceptions to these rules occur in areas such as the life sciences where the Laboratory's capabilities provide unique opportunities for another agency's mission, in this case the National Institutes of Health.

Since accelerator-based science has a huge compass, research at Brookhaven can be focussed at only a few points within a broad spectrum of science and technology. As the titles suggest, the Laboratory's traditional departments of physics, chemistry, and biology continue to be appropriate homes for much discovery-oriented work. Similarly, the newly created departments of Energy Science, Environmental Science, and National Security, and the traditional Medical Department, host much issue-oriented work. Departments such as Instrumentation, the Magnet Division, and the Accelerator Test Facility support the accelerator-based facilities and their detectors, but also produce technology of great value for unrelated areas such as medical imaging or nanotechnology.

Much of the work performed at the Laboratory is interdisciplinary, and traditional departmental titles do not adequately convey the evolving priorities of discovery- or issue-oriented research. Therefore theme areas have been identified to render these priorities more explicit. The themes have been

introduced to provide a more focussed framework for departmental activity, including planning, staff recruitment and proposal preparation. They label the "bright spots" of laboratory research activity within a potentially broad spectrum.

This emphasis on interdisciplinary themes and their relation to DOE missions, user needs, and core capabilities is part of a renewed effort within the Laboratory to establish priorities, focus resources, and make a strong case for each of the areas in which we propose to work. Brookhaven is also identifying areas of weakness that threaten the quality of its research, and repairing them or reallocating resources to create critical new capabilities. One of these is computing. Another is the general management of the Laboratory, including mandated areas within environmental, safety, and quality management. The Laboratory is taking rapid strides in these areas, and will take full advantage of newly available web-based and hypertext tools to maintain currency in management technology. Workforce issues such as diversity, recruitment, recognition, and career paths are receiving new attention and will continue to require investment in the future.

Brookhaven shares with its sister laboratories created more than fifty years ago an aging physical infrastructure inappropriate for the key role it plays in the national science mission. Here too the Laboratory is focussing its effort and working with the Department of Energy to create a better environment for employees and users. The Laboratory is similarly repairing the infrastructure of community support, recently stressed by environmental concerns.

The success of Brookhaven National Laboratory depends singularly upon the quality of its people. Only by maintaining the highest standards of excellence in each of the talents, skills and crafts needed to produce the whole will the Laboratory secure and maintain the position of world leadership to which it aspires. The Laboratory engages in rigorous and candid self-assessment, accepts responsibility for its actions and commitments, vigorously recruits and retains new talent from diverse populations, and encourages continual training and self-renewal.

3.0 Laboratory Profile

The four key missions of the Department of Energy are Energy Resources, Science and Technology, Environmental Quality and National Security. Since its inception more than 50 years ago, Brookhaven National Laboratory has been a leader in DOE's mission in Science and Technology with important contributions to the other mission objectives. Brookhaven strives to maintain a balance between scientific research, the development of new facilities, and operation of existing facilities. BNL's continuing success depends on our ability to maintain alignment of our mission, goals and objectives with those of the DOE. BNL engages in extensive collaborations with other laboratories, federal agencies, universities and industries providing expertise and its facilities for the solution of scientific and technical challenges at the international, national, and the regional level.

3.1 Mission

Brookhaven National Laboratory's role within the DOE laboratory system is to produce excellent science and advanced technology in a safe, environmentally responsible manner with the cooperation, support, and appropriate involvement of our scientific and local communities. The elements of the Laboratory's mission, which support the four DOE strategic missions, are the following:

- To conceive, design, construct, and operate complex, leading edge, user-oriented facilities in a safe, environmentally benign manner that is responsive to the DOE and the needs of the international community of users.
- To carry out basic and applied research in long-term programs at the frontier of physical, chemical, life, and environmental sciences in support of DOE's missions.
- To develop advanced technologies that address national needs and to transfer them to other organizations and to the commercial sector.
- To disseminate technical knowledge, to educate new generations of scientists and engineers, to maintain technical capabilities in the nation's workforce, and to encourage scientific awareness in the general public.

3.2 Core Competencies

Brookhaven National Laboratory is recognized for fundamental discoveries about the structure of matter and energy, the development and implementation of new accelerator concepts, the linking of this knowledge to practical technologies, and the transferring of those technologies to address society's most challenging problems. The Laboratory's success is based on the high quality of its scientific and technical staff, the technologies and facilities available to staff and users in a broad range of scientific fields, and the integration of research disciplines.

The Laboratory's breadth of expertise provides the basis for its contributions to the DOE's missions and focuses on providing extraordinary tools for the pursuit of basic science and technology. In facilities design, construction and operations, our core competencies are in the design, engineering, and operation of accelerators and detectors, and in the technology of superconducting magnets for accelerators. In basic science and technology, our core competencies are in the physics of energy and matter, the chemistry and physics of materials and condensed matter, chemical energy sciences, biological sciences, environmental sciences and technology, imaging, systems analysis and modeling, and energy science and technology.

Within these core capabilities Brookhaven hosts an impressive array of facilities:

- For High Energy and Nuclear Physics: The Relativistic Heavy Ion Collider (RHIC), the Alternating Gradient Synchrotron (AGS), Accelerator Test Facility (ATF), Superconducting Magnet Development and Construction Facility.
- For Physical and Life Sciences: The National Synchrotron Light Source (NSLS), Scanning Transmission Electron Microscope (STEM), Transmission Electron Microscope (TEM), Magnetic Resonance Imager (MRI), Positron Emission Tomography (PET), Laser Electron Accelerator Facility (LEAF), Booster Applications Facility (BAF).
- For Data and Computation: RHIC Computing Facility (RCF), RIKEN teraflop computer, National Nuclear Data Center (NNDC), Visualization Center, Atmospheric Radiation Measurement (ARM) External Data Center.
- For Medical Treatment: Radiation Therapy Facility (RTF), Whole Body Composition Facility.
- For Production: Brookhaven Linac Isotope Producer (BLIP), PET Isotope Production Cyclotrons, and Tandem Van de Graaff Facility.

3.3 FY01 R&D Resource Profile

In FY 2001, the Laboratory expects to receive about $450 M from DOE, other DOE laboratories, and other federal, state, local and private entities (Work For Others.) The DOE Office of Science (OS) provides the major funding for BNL. Figure 1 illustrates the FY 01 projected distribution, based on the Presidential Budget, of funds from DOE, those from other DOE laboratories and operations offices, and those from other non-DOE sources. Figures 2 and 3 illustrate the distribution of projected DOE funds among the DOE four missions and the Science and Technology goals, respectively.

BNL's primary mission for the DOE is Science and Technology. More than 80% of our funding is provided directly by the DOE Office of Science to support the operations of our unique user facilities and research programs in high energy and nuclear physics, basic energy sciences, and biomedical and environmental sciences. BNL contributes to the DOE mission in Energy Resources, and National Security. In FY 2001 DOE will fund approximately $4M of R&D in geothermal energy and natural gas storage systems, practical conductors for electric power systems using high Tc oxides, research on battery materials, and studies on efficient and affordable building and power plant plumes.

We expect $25 M from DOE in FY 2001 to support work in nuclear non-proliferation through the US-Russian Nuclear Security Programs and the Safeguards Science and Technology Development and the Advanced Systems programs. Thirty-three percent of the FY 2001 funds will support our programs in countering nuclear and biological/chemical terrorism, and in protecting critical infrastructure. The majority of these funds will support work in the Initiative for Proliferation Prevention that engages weapons scientist of the Former Soviet Union in non-weapons related research and commerce.

Our role in the DOE Environmental Quality mission is focussed primarily on activities to restore the BNL site and to manage radioactive and hazardous wastes. We expect about $28 M from the DOE Office of Environmental Management for the remedial action programs including work to decontaminate/ decommission the Brookhaven Graphite Research Reactor. In FY 01 the DOE Office of Science will assume responsibility for the ongoing waste management operations and will provide about $5M to support those activities.

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The programs at BNL contribute significantly to programs at other DOE laboratories, federal agencies, institutions and industry. The work done for other agencies derives from our unique facilities and our core competencies. In FY 01 we are projecting a total income of about $93M from Work For Others (WFO), which includes about $36M from other DOE Laboratories.

The total projected budget in WFO consistent with the DOE Science and Technology mission is approximately $70M. Two major activities dominate this profile, funding from Oak Ridge National Laboratory to support our participation in the Spallation Neutron Source, and funding from NASA to support construction of the Booster Application Facility. Other significant activities include NIH support for a crystallography beamline and work at the NSLS, support for the Neuroimaging Center, and for the operations of the Scanning Transmission Electron Microscope. BNL projects a significant amount of funding from NIH for biomedical research and from NASA for radiobiological research in support of manned space missions.

Figure 1 - FY01 Funding Profile

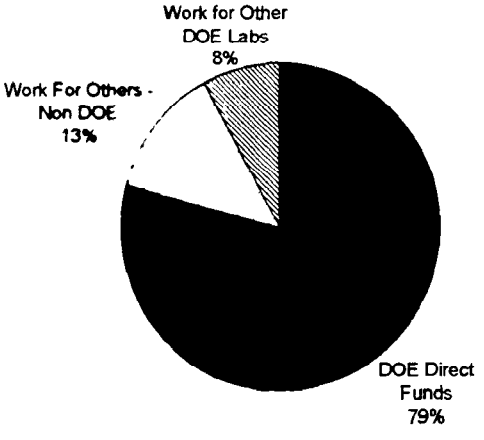


Figure 2 - DOE Funding Profile

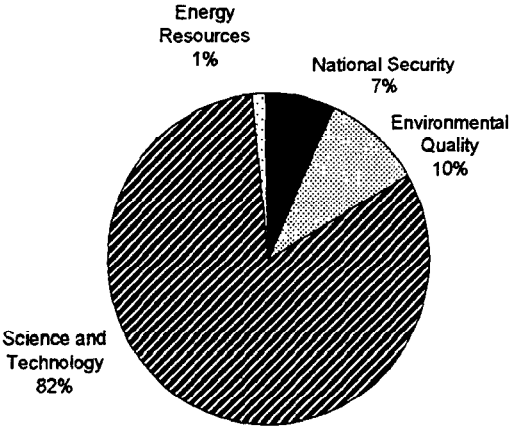
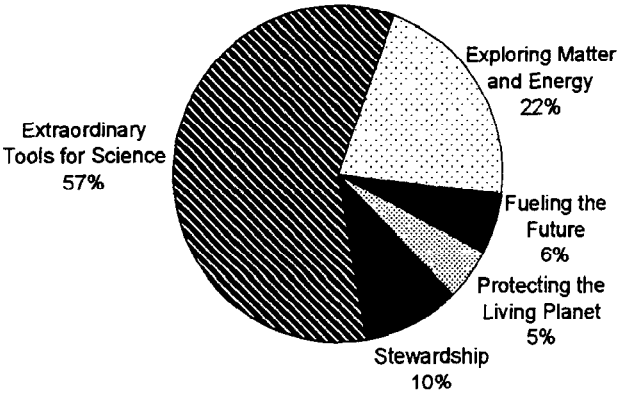


Figure 3 - DOE Science and Technology Mission Goals



In Energy Resources, funding from others is expected to exceed that provided directly by the DOE. The Nuclear Regulatory Commission provides more than $8M for work on reactor safety, technical support to the Commission, and support for work on Russian and Ukraine reactors. The Department of State (DOS) provides the most support in National Security to the program office for the IAEA on international safeguards, representing more than 80% of the total WFO budget in National Security.

3.3.1 DOE Science and Technology Mission

The DOE Office of Science, which funds the Laboratory's Science and Technology programs, has defined goals for the Science and Technology mission (http://www.er.doe.gov/sidebar/stratpln.pdf). These goals are the basis of BNL's planning and are reflected in the Laboratory's Critical Outcomes.

DOE will provide almost $200M to support the "Extraordinary Tools for Science" at BNL. We provide cutting edge "Instruments for the Frontiers of Science," including operations of major user facilities, the experimental stations within those facilities, advanced R&D on new accelerator concepts, participation in the several major collaborations, and operation of our Imaging Center. In FY 2001 over $100 M will support the operation of the Relativistic Heavy Ion Collider, the nation's newest major science facility for nuclear physics. RHIC is unique in the world for its ability to explore the "quark gluon plasma." This facility will have its first full year of operation for research, with all four dedicated detector systems operational in FY 2001.

The National Synchrotron Light Source (NSLS) is one of the principal DOE synchrotron sources. The user community continues to expand in number and discipline. The Laboratory is committed to enhancing the role of the NSLS as a national resource for materials, chemical and biological research. The NSLS continues to participate in the national R&D program for the next evolution in light sources.

The Laboratory initiatives, RHIC II, e-RHIC, Laser Seeded Free Electron Laser, Cyclotron Isotope Research Center, and Center for Structural Biology of Membrane Proteins build on the Laboratory's core competencies for providing these extraordinary tools for science.

With the permanent shutdown of the High Flux Beam Reactor, BNL is working with other neutron sources in the US to provide expertise in neutron scattering and instrument development. The FY01 Presidential budget terminated support for the HFBR Structural Biology Facilities. We have proposed a program funding transfer to support neutron scientists who over the last two years, have shifted their efforts to build a highly productive crystallography consortium involving additional beam lines at the NSLS. Neutron scientists at BNL have engaged in the development of neutron sources and instrumentation for other facilities such as the SNS and HFIR. BNL also has proposed a Center for Neutron Science to support the unique capabilities that reside at BNL and to lead the development of applications of the SNS to a variety of scientific problems.

Starting in FY01, BNL has proposed that the DOE Office of Science provide programmatic funding for R&D in BNL's Instrumentation Division to foster the development of novel detector concepts and to push the state of the art for extending the technical performance of existing detector technologies.

A challenge for BNL is to advance computation and simulation as a critical tool in gathering and interpreting complex data streams for scientific discovery. The Laboratory has committed to increasing its role by building up the Center for Data Intensive Computing in collaboration with the University of Stony Brook. This Center already has an active program of simulations that assist research in the hydrodynamics of muon collider targets, accelerator design, brain imaging, and cancer treatment plans. Eventually this investment will increase BNL's role in the DOE advanced computation programs. We propose that this center receive program funding from the DOE starting in FY02.

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Our R&D portfolio in "Exploring Matter and Energy" includes large high energy and nuclear physics experimental and theoretical research programs, basic studies in X-ray and neutron scattering, heavy ion research, support for research at the Laser Electron Gamma Source, condensed matter research, structural biology, and genome sequencing and analysis.

A number of programs at BNL study the emergence of new phenomena as a function of length scale in 1 nanometer to 1000 nanometer range; such as the current carrying capacity of high Tc superconducting tape or the electron transfer crucial to artificial photosynthesis that depends on molecular length. A continuous upgrading of the NSLS beam capabilities and a strong program in neutron science are crucial for this effort that is a national priority. BNL's Nanoscience Initiative builds on these core capabilities and is based on a multi-institutional multi-disciplinary collaboration. BNL also submitted new proposals in response to the DOE Complexity Initiative, which focus on the evaluation of material properties as a function of size.

BNL's cross-cutting biomedical initiatives would expand the DOE's role in biomedical research by supporting the basic tools and facilities needed to advance current state of knowledge about cancer, aging, substance abuse, and even the effects of space radiation during deep space travel.

The DOE Office of Science support for the Structural Biology Experimental Research Program is being redirected in FY 2001. All currently funded projects will terminate on September 30, 2000. Future funding will depend on the successful competition for new funds as part of the Structural Biology program solicitation issued in November 1999. In response to the program solicitation, pre-proposals were submitted to DOE for review, and BNL was encouraged to submit six formal proposals for merit review and consideration for funding in FY 2000 and FY 2001.

The Human Proteome Project is a proposed large-scale, multi-disciplinary, cooperative effort involving national laboratories, universities, and industry. Along with several other centers, BNL has been piloting procedures for cost-effective large-scale determination of protein structures by X-ray crystallography, starting from known coding sequences. Procedures were implemented for rapid cloning, expression, purification, and crystallization. Unfortunately, DOE support for this pilot program will terminate September 30, 2000. However, in partnership with Rockefeller University, the Albert Einstein College of Medicine, Cornell Medical School, and Mt. Sinai School of Medicine, we recently applied to NIH for a grant to support further development of structural genomics technologies and establish a pilot structure-production center.

Fueling the Future is a "critical goal" for the DOE where the S&T mission includes basic research that will lead to cleaner, safer, more efficient energy systems. In FY 2001 DOE will provide approximately $16 M to support basic research that includes work on thermal-, photo- and radiation-induced reactions in condensed media, structure-function designs of photosynthetic and catalytic porphyrins, and synthesis and structure of conducting polymers.

At BNL basic research in "Efficient Energy Use" includes research on photo-induced molecular dynamics in gas and condensed phase, gas phase molecular dynamics, and catalysis. Our basic research to address the challenge of "Clean and Affordable Power" includes research on superconducting materials, metal-environment interactions, and basic studies of materials by neutron scattering, X-ray scattering, electron spectroscopy, and powder diffraction.

The DOE will fund over $14M of R&D, to address the challenges related to "Protecting the Living Planet." In the biomedical area this supports research in radiotracer chemistry and neuroimaging, high-field magnetic resonance imaging and radioisotope production. Our program initiatives in

Biomedical Sciences would enhance our capabilities in cellular biology, functional genomics, cancer research and imaging.

During the past several years, the Office of Science has supported both clinical and pre-clinical studies of Boron Neutron Capture Therapy (BNCT). At this time, the dose escalation trials for the malignant brain tumor, glioblastoma multiforme, achieved the primary clinical objective of determining the tolerance of the normal brain to BNCT and are now closed to patients. Future funding will depend on the successful competition for new funds as part of a radiation therapy and radiobiology program solicitation expected to be issued in mid 2000.

The DOE also supports BNL programs related to defining the "Impacts of Energy Related By-Products on People and the Environment." These funds support R&D in the Chemistry and Microphysics of the Troposphere, the Free Air Carbon Transfer and Storage experiment, and research on aerosols.

A continuing challenge also is to strengthen the nation's institutional assets for basic science and multidisciplinary research. In FY 2001 DOE will provide over $17M in both programmatic and non-programmatic construction to enhance the science facilities and improve the infrastructure at the Brookhaven site. However, the Laboratory is over 50 years old, and needs a significant and sustained increase in infrastructure funds to improve aging facilities, provide adequate services and utilities and adequate space for staff and visitors.

Finally, DOE will provide $27M in FY01 to meet the challenges of managing the site. These funds will assure that the High Flux Beam Reactor is in safe shutdown and transferable to the DOE Office of Environmental Management for decontamination and decommissioning. BNL also is requesting funds from the Office of Security and Emergency management to support site-wide and cyber security programs.

3.4 BNL Planning Assumptions

The Laboratory's planning basis includes the strategic requirements of the Department of Energy, considers input from the scientific community in the Laboratory and at large and our surrounding communities, and maximizes use of the capabilities of the Laboratory. The Laboratory's internal planning principles are the following:

- We will fully align our missions, goals, objectives and expectations with those of our customer, the DOE and other sponsors, and our stakeholders.
- We will build on the strengths at the Laboratory in accelerator-based sciences and technologies, detector and imaging technology and research expertise in a broad array of scientific disciplines.
- We will add critical competencies needed to strengthen our overall strategic position and support the advancement of our programs.
- We will form strong partnerships with other laboratories within the DOE system to perform the research needed to address the challenges of the 21st century.
- We will strive to transfer needed technologies to industry and contribute to the education of the future generations of scientist and engineers.
- We will plan and implement improvements to our infrastructure, both the management systems and processes and the physical plant.

- We will develop our human resources through training, recruitment, incentives and a focus on diversity.
- We will fully integrate the expectations of our many communities into the day to day operations of the Laboratory.

In addition there are overarching assumptions that are summarized below.

- We will assure the quality and alignment of our science and technology programs through a robust peer review program.
- We will meet BNL's assigned goals for the Spallation Neutron Source, the Large Hadron Collider and the ATLAS detector.
- We will strive to increase BNL support from other federal agencies to assure the availability of our facilities throughout the government.
- We will make the attraction and retention of high-quality scientific staff a Laboratory priority.
- We will position BNL as a leader in computational science through the Center for Data Intensive Computing.
- We will re-engineer BNL's computational and information capabilities to support and enhance our progress in other research areas.
- We will foster more and larger collaborative efforts in the next three to five years, particularly in the High Energy/Nuclear Physics, Basic Energy Sciences and Biological and Environmental programs.
- BNL will strive to expand its contribution to DOE's missions in Energy Resources, Environmental Quality, and National Security by leveraging our unique assets in user facilities, instrumentation, and basic science.

These principles and assumptions guide the development of our program directions and new initiatives.

4.0 Laboratory Strategic Plan

4.1 The BNL Planning Environment

Science-based multi-disciplinary strategic planning at Brookhaven National Laboratory is of great importance and involves difficult choices among a broad range of opportunities. The basic planning units at BNL are the Science and Facility departments. Input for setting priorities starts with the departmental planning committees that are advisory to the department chairs, developing a strategic plan for the department. These plans and the DOE planning initiatives and priorities form the visions of the four Science and Technology Directorates for their three-year and ten-year planning horizons. These visions are presented as a group at the major Strategic Planning Meeting. This one-day retreat involves all Level 1 and 2 science managers, augmented by selected science and technology group leaders. The product of this planning meeting are programmatic initiatives (which extend and/or amplify existing programs) and a list of high-priority Laboratory Initiatives that will extend or create new capabilities and/or research directions.

Both the programmatic initiatives and the Laboratory Initiatives are updated and validated at a second planning meeting that takes place at the beginning of the following February. The Level 1 and 2 managers and all the chairs of the departmental planning committees attend this meeting.

Laboratory Initiatives are long-term priorities and centers of investment. They are updated every year, but are not expected to change rapidly. Initiatives are provided for consideration by the Department of Energy. Their inclusion in this plan does not imply the DOE's approval of or intent to implement an initiative

4.2 Laboratory Priorities

4.2.1 Introduction

Through its 50 years of existence BNL scientists have played a role of innovation in many scientific areas, but especially in accelerator physics and accelerator-related science. The selection of key Laboratory initiatives is based on those innovations where BNL can make substantial contributions to the long-term priorities of the DOE. Accordingly, some initiatives that had scientific merit in the absolute but were not supportive of present DOE planning have been replaced. The time scale of the chosen initiatives ranges from three years to ten years.

4.2.2 Next Generation RHIC

The Relativistic Heavy Ion Collider is an international flagship facility for Nuclear Physics and the major new capability in the BNL Nuclear Physics program. RHIC will let scientists explore Quantum Chromodynamics (QCD), the exact theory of the strong interaction, in the nuclear environment. In the first phase of the program emphasis is on the study of the quark-gluon plasma using relativistic heavy ions and on spin physics at the quark level using energetic polarized protons. For the next five years these capabilities are unique worldwide. It is the responsibility of the Laboratory to plan for assuring the cutting edge capability of this facility for these two core science programs. Because the planning, R&D and design phases of major improvement to RHIC class facilities typically require years to accomplish, the planning for such upgrades starts when the facility begins operation and continues from that time. The first improvement cycle for RHIC is called "RHIC II".

The Laboratory is also initiating plans for the next scientific frontier in nuclear physics. RHIC offers exciting possibilities for addressing new QCD physics with the addition of an electron beam. This "e-RHIC" facility is in the early planning phase.

4.2.2.1 RHIC II

Because the cross sections for heavy-ion collisions are geometric, the basic collision rates, even for central ion-ion collisions, are large and the initial collider luminosity for RHIC gold ion collisions is modest ($2 \times 10^{26} cm^{-2} sec^{-1}$) at the collision points. This is because RHIC is the first heavy ion collider in this energy regime and all the phenomena are of interest to investigate and measure. The initial research program began in FY 2000 with the four original RHIC detectors, BRAHMS, PHENIX, Phobos, and STAR. Since RHIC is a new facility, a year or more is required to bring the machine up to its initial design luminosity. In the following years we will realize small improvements in the machine and detectors, setting the stage for a major upgrade, RHIC II.

The goal of the RHIC II Initiative is a 40-fold increase in the luminosity of the machine with necessary improvements of the existing RHIC detectors to exploit the luminosity increase and to pursue the new research paths opened up by analysis of the first exploratory round of experiments. The budget estimate for the RHIC II Project is $130M and is distributed as shown below:

Table 1 - Cost Elements for RHIC II Initiative

RHIC II Elements	
Accelerator Upgrades	
Electron beam cooling	$60M
Beam optics and controls	$20M
Detectors	
Electronic Upgrades	$40M
Additional upgrades	$10M
Total Estimated Costs:	**$130M**

The cost estimates are schematic because RHIC II planning is just beginning and few of the technical and cost specifics for detector elements are known. However, in the case of the accelerator complex, the general improvement path is known. To achieve a 40 fold increase in luminosity, we must double the bunches in RHIC, decrease beta functions at the intersection points by a factor of 2, and increase the electron cooling of the ion beam by a factor of 10.

The first two improvements are straightforward and achievable. Electron cooling of the ion beam currently is under consideration and could result in even larger gains in luminosity. We are confident that we can achieve a factor of 4 increase in luminosity without beam cooling. A factor of 10 is conservatively achievable with electron and/or stochastic beam cooling, and the full factor of 40 should be achievable with vigorous R&D. This means that a year of data acquisition at the original design luminosity of RHIC (30 weeks at $2x10^{26}$ $cm^{-2}sec^{-1}$) could be done in less than a week with RHIC II. An R&D effort on electron cooling is underway, with an initial report due by the end of 2000.

The scientific motivation for increased luminosity is to assure scientific productivity and discoveries, and to pursue research results that require more data (rare processes). To do this, the detectors must be improved in step with the accelerators. In the case of the first generation RHIC detectors, the

improvements are of two types, electronic rate capability and new instrumental capability. The first type of improvement is necessary to handle the increased data rates, and is included explicitly as part of the RHIC II initiative. The second type of improvement changes the detector capabilities in qualitative ways (hadron-blind detector, nanosecond resolution time-of-flight, high granularity calorimetry, etc.) and enables investigation of new phenomena not accessible by the initial instrumentation. These will be pursued with planned capital improvement funds included in the RHIC operations budget. The radical form of the second type of upgrade is an entirely new detector (or detectors). Such improvements may be deemed appropriate after the first round of experiments in the new energy regime of RHIC have been carried out. They would be driven by proposals from the scientific user community. Funding for major new detectors is not included in the cost estimate for the RHIC II initiative.

The main elements of RHIC II would become operational soon after the Large Hadron Collider (LHC) collider begins operating in 2005, with its single detector, ALICE, dedicated to heavy ion physics. The advent of the ALICE physics program will complement the mission of RHIC. The two facilities are in very different energy regimes (100 GeV/amu for RHIC vs. 2.8 TeV/amu for ALICE). The RHIC regime is ideal for studying the hadron-plasma phase transition in nuclear matter; the LHC regime will provide data in the very high temperature, pure plasma regime. Furthermore RHIC II will be the center of a dedicated facility with 4 (or more) detectors, improved capability and experienced scientists. The two facilities, RHIC II and ALICE, will provide very complementary physics programs. The RHIC II scientific objectives will become clarified over the next two years as RHIC data become available.

4.2.2.2 e-RHIC

The RHIC Collider lattice is specially designed to hold a very large number of heavy ions in each bunch. Therefore, when multi-GeV electron beams are made to collide with the circulating heavy ion beam, unique experiments probing QCD in the nuclear medium at normal nuclear temperatures can be done with unparalleled luminosity. In addition to performing fundamental measurements on parton distributions and QCD sum rules in semi-inclusive electron-proton collisions, electron-heavy ion collisions offer particular advantages for studying hadronic matter at very high (saturation) parton densities. For example, for the same electron energy, electron-Au collisions at RHIC energies produce about the same parton densities as electron-proton collisions at Large Hadron Collider energies. It is predicted that in the saturation region, gluons will form a "color glass condensate," another form of QCD matter. Many experiments are possible with a specially designed detector that could be installed at the 12 o'clock position of the RHIC ring. The electron-Au and electron/proton operation could be implemented in such a way that it would be transparent to the regular RHIC heavy ion program.

With international collaboration BNL presently is exploring the design characteristics of a reference 10 GeV electron beam intersecting in one interaction region with 100 MeV/A gold ions, or 250 GeV polarized protons. It is feasible to achieve luminosities of 5 $x10^{30}$ $cm^{-1}s^{-1}$ for e-Au collisions, and 2x 10^{32} $cm^{-1}s^{-1}$ for electron-proton. The electrons would be accelerated in a superconducting linear accelerator and either inserted into a fixed-magnet warm ring or alternatively intersect directly with the ion bunches. The latter scheme would involve complete recovery of the linac beam energy. Table 2 provides a preliminary cost estimate, based on estimates from the TESLA project. The scientific merits of this initiative and the timetable for possible implementation will be subject to the discussions for the next Long Range Plan for Nuclear Science.

It should be pointed out that a low-emittance 10 GeV electron beam followed by the appropriate wigglers would be a very powerful source of synchrotron X-ray radiation even without free-electron lasing. In addition, we estimate that with laser seeding and high-gain harmonic generation, a 10 GeV electron beam could reach about 1.5 Angstroms in FEL mode, with many additional orders of magnitude increase in intensity.

Table 2 - Cost Elements for e-RHIC Initiative

e-RHIC Elements	
10 GeV superconducting LINAC	$200M
Detector for e-p/A collisions	$85M
Intersection region	$10M
Total Estimated Costs:	**$295M**

4.2.3 Laser Seeded Free Electron Laser

This Laboratory initiative is BNL's plan to contribute to the national effort towards X-ray Free Electron Lasers (FELs) and to support the Linear Coherent Light Source (LCLS) project. It is a coordinated program using BNL's expertise to develop key elements of X-ray FEL sources and to define the science. It includes a plan to establish the BNL Center for Laser Physics in recognition of the symbiotic relationship of lasers and accelerator technology, widely held to be a critical aspect of the next advance in sources. The program exploits the advanced accelerator technologies developed at BNL's Accelerator Test Facility (ATF), including its pioneering high brightness electron gun and includes BNL's resource for testing advanced gun concepts and developing new X-ray detectors. This initiative also uses the Deep Ultra Violet Free Electron Laser (DUV-FEL) as a dedicated test-bed for electron beam and photon research critical to the development of short wavelength FELs. A unique aspect of the BNL program is the development of the High-Gain Harmonic Generation (HGHG) FEL that can provide excellent temporal coherence and ultra-short femtosecond output pulse duration using chirped pulse amplification. The theoretical foundation of the HGHG approach was verified by the first successful demonstration of an HGHG FEL in the infrared at the ATF. Finally, the NSLS plays a key role as a resource for developing and testing novel science and the experimental apparatus to pursue research at an Advanced X-ray Source (AXS). The integration of all of these elements is a unique opportunity at BNL that takes advantage of largely existing programs and personnel, and allows the DOE to rapidly address the key questions posed by the Leone panel.

The Accelerator Test Facility has a preeminent position in the development of RF photocathode electron gun technology, and has impacted significantly the pursuit of electron beam development for advanced accelerator concepts, including FELs. The ATF provides the electron beam and infrastructure for supporting many experiments as well as continuous development of tools to characterize and manipulate electron beams.

The ATF is hosting two important proof-of-principle FEL experiments, the BNL-NSLS High Gain Harmonic- Generation experiment in collaboration with ANL-APS, and the VISA experiment which is part of the pre-construction R&D for the LCLS. The VISA experiment is designed to test and characterize SASE FEL operation in the visible, where high quality optical diagnostics are readily available. It is a collaboration involving SLAC, BNL, LBNL, LLNL, and UCLA.

The Leone panel recommended integrating conventional laser technology with accelerator technology to optimize performance of the next light sources. In response to the current needs and future challenges in light sources BNL proposes the establishment of the BNL Center for Laser Physics.

The common challenges of accelerator and optical science research include:

- advances in high brightness electron beams, electron-beam diagnostics,

- photon sources for high temporal coherence FELs,
- synchronization of light sources for "coherent" multicolor experiments, and
- advanced ultra-fast optical metrology.

Progress in optical technology needed in Atomic and Molecular Orbital physics for dynamic control at the quantum level with sculpted light fields will benefit from advances in low-emittance rf-guns. The practical advances in high harmonic sources derived from fundamental strong field physics can provide a viable source for seeded-FEL sources in the hard X-ray regime, as well as define a roadmap towards light pulses on the atomic time-scale.

The DUV-FEL is a dedicated experiment for development of advanced FEL sources and science. The accelerator consists of an ATF developed photocathode gun driven by a solid-state laser system scaled from the LEAF gun driver. A four-tank S-band SLAC linac has been fitted with an electron bunch compression chicane developed by BNL in collaboration with scientists from LANL and SLAC. The accelerator can provide beam at energies above 200 MeV, with pulses potentially as short as 100 femtoseconds and charge on the order of 1 NC. The long NISUS undulator will be used for the FEL experiments. The plan for the facility includes a series of experiments and upgrades of the machine that will lead to operation in the deep ultra-violet region (100 nm).

The parameters of the facility and the technological developments required to achieve them are relevant to the development path for an Advanced X-ray Source (AXS). With the DUV-FEL gun system and laser, we will explore techniques that use short pulses and laser shaping. We will develop methods for stabilizing the phase of the laser and accelerator that will be important for pump-probe type experiments with AXS facilities. The DUV-FEL bunch compression system will be studied as a way to produce the extremely short high-current pulses required for short wavelength FELs, and also as a way to examine problems in preserving emittance for bright beams. Studies on CSR induced emittance dilution are planned for the DUV-FEL in collaboration with scientists from TJNAF. Ultra-short bunch diagnostics based on cross-correlation of laser and electron beam or radiation emitted by the electron beam will be developed as part of the DUV-FEL program. This type of metrology is required to determine the stability and reproducibility of the short bunch beam.

The FEL development program will start with SASE experiments at visible wavelengths because of the excellent optical diagnostics available in this spectral region and then be extended into the deep UV. Seeded beam FELs offer the possibility of extending the seed laser properties (coherence, bandwidth, wavelength stability, pulse length) to much shorter wavelengths than the seed laser can itself produce. Studies will be done on chirped pulse amplification of the HGHG FEL output. We will explore the relative tradeoffs of high harmonic generation in the laser seeding as compared with very high order harmonic generation in the FEL to study the extension of the HGHG approach down to shorter wavelengths. The combination of these processes may be an attractive avenue for AXS development.

Generation of the high brightness electron beam needed for an X-ray FEL is of paramount importance. Looking beyond the LCLS toward the AXS it is important to investigate possible sources that can give higher performance than the existing photocathode RF guns. A current line of investigation is a new type of high gradient electron gun based on a compact high voltage pulser. It is believed that fields up to 1 GV/m can be supported without breaking down and that normalized rms emittances of 0.3mm-mrad at a charge of 1 nC may be possible.

The second focus is the development of detector systems that would be suitable for use at an AXS. These new detectors must register 10^{12} photons in 100 femtoseconds, probably with 10 micrometers spatial resolution over an area of 1 m^2. This technology does not exist at the moment, at least not in the

same device. All current electronic detectors rely on the photoeffect for their operation, either in the gaseous state, or in the solid state. There is ample room for improvement in both performance and scale in both types of detector. The specific detectors targeted for development will depend upon extensive interaction with the potential users, and will require testing at sources available at the NSLS, ATF, and DUV-FEL.

The NSLS will take an active roll in developing the scientific applications for AXS facilities, and providing proof of principle experiments. Under this initiative, several facilities will be made available for prototype experiments. For example, the soft X-ray undulator beamline, Xl B on the X-ray ring, will be used to develop detectors and methods associated with photon correlation spectroscopy (speckle) in the soft X-ray range. The low energy undulator, U5, on the VUV ring will be used to develop magnetic imaging techniques that should provide a basis for instrumentation for an AXS based program for the study of magnetic structures on the submicron length scale.

4.2.4 Nanoscale Science

Many of the physical and chemical properties of a material object change dramatically as the object reaches a scale-size on the order of 30 nanometers (nm) in length or less. Similarly, structural or compositional features of similar dimensions often determine the unique properties of certain classes of materials; an excellent example is the pattern of atomic dimensional stripes in many functional metal oxides. These important physical phenomena along with the emerging technological interest in ultrasmall devices has resulted in a major national and DOE program in nanoscience and technology. Within the last year, BNL has worked to develop a strongly interdisciplinary plan in nanoscience that is aligned with the DOE nanoscience program. The BNL planning has involved collaboration among six internal departments or divisions and capitalizes on our strengths in chemistry and condensed matter physics. The program also makes use of our very diverse synchrotron user facility, the NSLS, as well as our emerging strength in advanced, ultrahigh resolution TEM. In addition, the program expands on our materials programs via collaborations with nearby university partners, Columbia, Stony Brook, and Princeton. The plan includes steps to enhance our capabilities through significant internal investment. The elements of this plan our discussed in more detail below.

BNL possess a number of important experimental and theoretical capabilities for participation in a wide range of nanoscience research. These include:

- the use of the NSLS as a probe of the structural, electronic, and dynamic of nanoclusters and assemblies,
- the ultrahigh resolution TEM facility at BNL, which has been used for imagining of the structure of clusters and the fields of magnetic assemblies,
- the investigation of new methods of synthesis and fabrication of nanoscale materials, such as the formation of monodispersed nanoparticles of transition metal oxides or the use of hydrogen-based reactions to produce nanocomposite materials,
- the use of the BNL Center for Data Intensive Computing for work on ab initio computation of solid-state materials, and
- ultrafast laser methods and scanning microscopy for probing electron and atomic dynamics of single-nanoparticles.

BNL scientists in collaboration with our Stony Brook partners have pioneered the use of soft X-ray holography for imaging of assemblies of submicrometer objects and used zone plates for soft X-ray microscopy at dimensions of ~30nm. We have investigated new methods of synthesis and fabrication of transition metal oxides in connection with SUNY-Stony Brook and used of STM, to expand our capability in the area of nanocatalytic materials.

These assets and activities have positioned BNL to participate in the Presidential Interagency National Research Initiative entitled "National Nanotechnology Initiative - Leading to the Next Industrial Revolution." The Laboratory's response to this initiative is facilitated by a BNL Task Force on Nanoscale Science, Engineering, and Technology (NSET Task Force), which includes members from the Biology, Chemistry, Physics, NSLS, Energy Sciences and Technology, and Environmental Sciences Departments and the Instrumentation Division. This NSET Task Force organized a coherent portfolio of LDRD projects, which has focused the BNL effort into three specific area of research on nanomaterials. This Laboratory-wide investment has enabled us to expand the scientific manpower in the area of nanoscience, both through postdocs and through new staff in specific areas such as nanotube imaging.

The three LDRD areas are as follows:

- nanomagnetism.
- charge transfer in molecular materials, and
- catalytic materials.

This "superproposal" approach to LDRD research has also promoted collaborations with various universities and national laboratories relevant to the major thrust areas. In addition, other BNL funds have been invested to enhance the instrumentation capability in the nanoscience areas of fabrication and materials synthesis.

Finally BNL is participating in the DOE proposal for a DOE Laboratory-wide set of Nanocenters. Our response to this call has been to build on our strengths in the fields listed above, as well as in the area of metal-oxides and soft-materials, to develop a center based on Functional Materials at the Nanoscale. The Center will include work on catalytic materials, soft materials, and metal-oxide materials, which exhibit superconductivity, ferroelectricity, and other correlated-electron phenomena such as magnetostriction or 'colossal' magnetoresistance. In addition, the Center includes research on the development of new nanoprobing techniques and instruments. The work and capabilities in the Center are complementary to those at other national laboratories such as Argonne and Oak Ridge. Finally a major goal of the Center is to expand significantly our interactions and collaborations with our university partners. This goal includes the establishment of more user facilities, the expansion of joint appointments, and the expansion of graduate students working at BNL.

4.2.5 Cyclotron Isotope Research Center

BNL is committed to advancing medical radioisotope production and to the development of a facility to serve as a reliable year-round domestic source of medical isotopes for nuclear medicine, for R&D, and for training. This facility would be used to develop and produce new medical radioisotopes for diagnostic and therapeutic applications, and to develop high-power targets for producing larger quantities of both Positron Emission Tomography (PET) and non-PET radioisotopes. It would be available year-round for medical radioisotope research and production, and for training. It would enable the development of new and more effective radiopharmaceuticals for diagnostic PET and Single Photon

Computed Tomography (SPECT) imaging, and also catalyze and advance the relatively new but very promising field of radionuclide therapy for cancer and other diseases. It also will serve as a much-needed national resource for the education and training of future radiochemists and radiopharmaceuticals scientists.

Protons at energies of up to 70 MeV and continuous beam currents of up to 2 mA will produce an uninterrupted supply of radioisotopes, in sufficient quantity to support research investigations as well as multi-center clinical trials in human subjects. Up to four beam lines will allow simultaneous multiple user capability for research, production and, if necessary, for outside commercial use.

The versatility and reliability of this machine combined with its inherent safety and flexibility of operation will reposition the US as a premier and meaningful contributor to future clinical research into diagnosis and treatment of medical conditions, including heart disease and cancer. These missions are consistent with BNL's role as a provider of unique and sophisticated user facilities that serve as research tools to advance scientific knowledge for the benefit of mankind. The 70 MeV cyclotron will complement major existing facilities at BNL such as the AGS, RHIC, NSLS, and BAF among others.

4.2.6 Center for Structure of Complex Membrane Proteins

Membrane proteins are critical elements of biological process and are directly related to DOE missions in the environmental consequences of energy generation and use and human health. Membrane proteins and protein complexes are critical targets in bioremediation, cell signaling, and human function; they function in microbes as transporters and in the brain as receptors for neurotransmitters. Approximately 30% of the genes in a typical bacterium code for membrane proteins and this fraction is larger for eukaryotic systems. However, as a class, these proteins are difficult to analyze, and therefore, membrane proteins account for less that 1% of know protein structures. To understand how a "Microbial Cell" functions, we need to know how membrane proteins function and to develop new technologies for analyzing the complex structures they form in their native cellular environments.

The same technologies can be applied to human brain receptors. The dopamine receptor, with and without bound ligands is representative of a class of proteins that are key components to understanding substance abuse, aging and other neuro-related issues. Its expression and function in the human brain is being studied using sophisticated Positron Emission Tomography technology; therefore, it is a prime candidate for structural analysis to advance our understanding of how to facilitate crystallization of membrane proteins.

To attack the difficult problem of membrane protein structures, strengths in molecular biology and biochemistry need to be brought together with the appropriate analytical tools in a critical mass. The Biology Department has strengths in protein expression and protein engineering. These need to be coupled with new, high-throughput methods for sample handling to develop and validate approaches and techniques that are applicable to membrane proteins and complex protein structures. To accomplish this task we propose to partner with the State University of New York to develop a center of excellence that will coordinate the talents and resources of both institutions and facilitate acquiring the additional resources that will be needed.

A component of our proposed center will be a new Cryo-EM facility for the analysis of two-dimensional arrays of membrane proteins, isolated complex particles and frozen tissue sections. Examples include heavy metal antiporters and membrane bound oxido-reductases of relevance to the DOE bioremediation effort. This endeavor would be funded in part by Laboratory Directed Research and Development, would include collaboration with the University of Stony Brook, and would be built and operated with funding from both the DOE and the NIH. During the first year, we will firmly establish the

objectives and a roadmap for the program including components in structural biology, biochemistry and genetics, and begin to develop the specifications for and conceptual design of the Cryo-EM to support diffraction analysis. In the second and third years we would simultaneously build the center and ramp up to full research capacity.

4.2.7 Environmental Facilities Initiative

Carbon is perhaps one of the most significant environmental problems of the 21st century. Innovative methods for reducing carbon generation, for sequestering carbon, and for evaluating the effects of carbon dioxide on terrestrial ecosystems are needed to solve this problem. The terrestrial biosphere can become either an increasing source or a sink for CO_2 as climate and atmospheric chemistry change. Quantifying biological exchange and understanding processes regulating it are critical to assessing the potential for future anthropogenic climate changes.

BNL's Environmental Facilities Initiative (EFI) focuses on how to effectively use facilities to address a specific global change question. Specifically, the DOE funds facilities where researchers can study the effects of enhanced carbon dioxide on ecosystems (FACE Facilities) and which can measure the flux of carbon dioxide at fixed locations using eddy flux covariance techniques (Ameriflux). The EFI is developing the capability to couple measurements from FACE and Ameriflux sites to guarantee that the effects of artificially enhanced carbon dioxide can be compared directly with natural fluxes at the same site. Since the terrestrial biosphere is the primary driver for the annual variability of carbon dioxide in the atmosphere, this will provide critically important input to models that can be extrapolated to larger scales and to the hotter, wetter climate that is likely in the next century. A network of coupled facilities would be required to adequately represent the global set of terrestrial ecosystems.

The ability to acquire and manage large data flows, in near-real time, from widely distributed facilities is crucial to EFI. In FY 2000, BNL increased its new research capabilities by supporting innovative ideas to effectively participate in this initiative. As DOE/OBER clarified its objectives over the past six months, BNL has oriented its capabilities toward the emerging EFI concept. We have built specific tools such as the Research Platform software and developed Internet-based data communications tools. We have made continued improvements to our on-line data server and software systems and these now are being accessed by a wide user community.

In FY 2001, we will continue to build research capabilities at BNL to strengthen our ability to play a leading role in global change science. In particular, we will develop on-line data streaming capabilities and develop the capability to make eddy-covariance measurements of carbon flux from ecosystems.

DOE/OBER is exploring the possibility of a Terrestrial Ecosystem Research Facility (TERF). In FY 01 BNL will participate in efforts to define the concept and develop a plan for such a facility. This facility will be a test bed of unprecedented scope for monitoring, probing and understanding how terrestrial ecosystems respond to rapid environmental change and human caused perturbations. Our overall goal is to provide capabilities to DOE to help shape the overall focus and roadmap for such a facility or facilities and to position the Laboratory as a significant partner as the facility and programs are further defined and matured.

4.2.8 Center for Data Intensive Computing

Computational science is a critical factor for the success of DOE's science programs. Advances in hardware have made the acquisition of adequate computational resources within the reach of most laboratories. There is a need for an intellectual atmosphere and culture of scientific computing in which new algorithms and new techniques in applied mathematics are brought to bear on scientific problems. Brookhaven has established the Center for Data Intensive Computing, directed by the Chair of Applied Mathematics and Statistics at SUNY Stony Brook. The mission of the Center includes the following:

- data mining,
- visualization and graphics,
- parallel and distributed computing and networking, and
- modeling and simulation.

Current efforts are in accelerator science, medical imaging, materials and chemical science, and climate change. We are starting research efforts in data distribution via the Internet for RHIC and in Monte Carlo simulations of oxides.

The work in accelerator science includes the development of parallel codes for particle and spin coupling, and the study of magnetohydrodynamic effects in targets for the Spallation Neutron Source and a future muon collider. In medical imaging our efforts include new algorithms for the extraction of regions of interest from PET scan images of the human brain of normal and addicted subjects, the development of new parallel algorithms for treatment planning in boron neutron capture therapy, and the development of automated systems for the analysis of images of individual neurons. In materials and chemical science we have developed a new parallel code for the study of photon localization in semiconductor lasers and contributed to the development of algorithms for the simulation of combustion. In climate change we developed new parallel codes for aerosol transport in the troposphere. In the near future, we are planning efforts using quantum Monte Carlo simulation of high temperature (oxide) superconductors and work with an interlaboratory group on the distribution and access of RHIC data. We are also building a Beowulf type cluster of more than 100 Intel processors running UNIX.

The aim of the CDIC is to build up a portfolio of programmatically supported research activities that will provide full support for the Center. This would include the addition of up to 10 FTE by 2004 and the purchase of hardware. This Center will enable BNL to fully support the emerging high-priority scientific programs with advanced computing modalities and will assure our competitiveness into the future.

Table 3 - Resource Projections for Laboratory Initiatives

Resource Projections for Laboratory Initiative (FY 00 $ in million)						
	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05
RHIC II			5.0	50.0	50.0	25.0
e-RHIC[a]		0.1	0.2	0.2	0.5	
Laser Seeded FEL[b][c]	1.2	3.2	3.1	TBD	TBD	TBD
70 MeV Cyclotron			17.8	10.2	3.2	1.4
Nanoscience Initiative[b][c]		1.6	1.7	2.0		
Center for Structural Biology and Membrane Proteins		0.5	0.8	1.1	2.0	1.8
Environmental Facilities Initiative[b][c]	0.3	(d)	(d)	(d)	(d)	(d)
Data Intensive Computing [b][c]	0.60	0.60	1.2	2.0	3.0	3.0

[a] The resource timetable has not been developed, funds in FY02-FY04 are for planning and development.
[b] Funds for FY 00 are provided through the Laboratory Directed Research and Development Program.
[c] Funds for FY 01 are provided through the Laboratory Directed Research and Development Program.
[d] BNL's role in the out years will be defined as the TERF concept matures.

5.0 Department of Energy Programs

5.1 Science and Technology Facilities

5.1.1 Relativistic Heavy Ion Collider

Present Program: The Relativistic Heavy Ion Collider (RHIC) is the largest facility for nuclear physics in the US and the most powerful source of heavy ion collisions in the world, creating conditions which occurred microseconds after the "Big Bang". Additionally, RHIC has the capability to accelerate, store and collide polarized proton beams as a result of the collaborative efforts with the RIKEN Institute of Japan. RHIC offers potential for new discoveries about the most fundamental structure of matter. Construction of RHIC was completed in FY 1999, operations as a national user facility in Nuclear Physics began in FY 2000. The rapid ramp-up of the performance of the accelerator and the four detectors exceeded expectations. The crucial RHIC Computing Facility was able to accept flawlessly the huge data flow from the detectors and to store and make date accessible for rapid analysis. At the end of the scheduled run, 10% design luminosity had been reached. There are a total of 986 users from the United States and 19 countries at the four complementary experiments. About 10% of the RHIC facility scientific users are staff members of BNL.

RHIC allows the first exploration of a form of matter, the quark gluon plasma that has not existed in the universe since it was created in the "Big Bang" about 12 billion years ago. The core of the RHIC experimental program includes the following:

- experimental discovery of the quark gluon plasma and the exploration of its properties, and
- the detailed study of the origin of nucleon spin and its connection to the gluon.

Near-term Program: For FY 01 RHIC will operate for about 35 weeks for the heavy ion program and we will initiate the polarized proton program. For the near term the heavy ion program will continue with a mix of polarized proton operation that optimizes the physics output. We will also focus efforts on improving the performance of the collider and the detectors.

Long-term Program: It will take at least 10 years to fully explore the prospective richness of RHIC phenomena and, if it turns out to be as rich in new phenomena as anticipated, the lifetime of the program could stretch beyond 20 years.

The four existing RHIC detectors (BRAHMS, PHENIX, Phobos, and STAR) for the initial experimental program represent an optimum diversity and complement each other. Like all programs in basic science. these detectors and the accelerator facilities that produce the colliding beams will evolve in time to follow the unfolding science directions. The RHIC program will accommodate this evolution through a program of systematic upgrades to detectors and accelerators that continually improves these elements and assures that RHIC science is at the frontier of discovery. This continuous evolution will be punctuated by major improvements such as the construction of major new detectors or detector modifications, significant accelerator improvements to enhance beam parameters such as luminosity, and to provide new capabilities, such as electron collisions in the RHIC ring that can expand the horizon of RHIC exploration by qualitative jumps.

All the research groups doing experiments at RHIC can access the powerful computers and data storage facilities of the RHIC Computing Facility (RCF). The RCF records, archives and serves as the computation resource for data reduction and analyses of experimental data obtained from all the detectors in the RHIC facility. The RCF operations began operations in FY 2000 and will continue to grow in

power as the RHIC needs evolve. We have developed and are implementing a detailed plan for maintaining this capability over the next decade of RHIC operations.

5.1.2 Alternating Gradient Synchrotron (AGS)

Present Program: The Alternating Gradient Synchrotron (AGS) produces the world's highest intensity, high-energy proton beam and includes the world's largest superconducting magnet at the muon g-2 experiment. Research at the AGS has lead to increased understanding of the nature of matter. The AGS is the pivotal accelerator in a complex of machines that produce particle and ion beams for many scientific users at BNL. The users represent a number of scientific communities including particle and nuclear physics, radiobiology, national defense, materials sciences and advanced accelerator science. The AGS can accelerate heavy ions up to 11 GeV/atomic-mass-unit and can produce polarized proton beams that enable a RHIC Spin Physics Program as part of the RHIC nuclear science mission. At the lower energy end, short-lived isotopes for medical research are produced using the proton linac, and various industrial items are tested with Megavolt ion beams at the Tandem van den Graaff machine.

Near-term Program: Since 1999 the prime mission of the AGS is to inject heavy ions into the RHIC machine on an as need basis (about twice a day). All experiments at the AGS must be endorsed by BNL's High Energy and Nuclear Physics Program Advisory Committee. The AGS now provides beams for experiments of exceptional scientific merit on a case-by-case basis, as proposed by the Laboratory and approved and funded by the DOE program sponsor. The AGS capabilities are available to other agencies with the condition that such work does not interfere with the prime mission as injector to RHIC. At present, NASA also supports a radiobiology research program using heavy ion beams. This compatible Work for Others (WFO) use is authorized by the DOE's Nuclear Physics Division.

Long-term Program: The AGS provides the world's best venue for the exploration of very rare phenomena in particle physics as a result of the exceptional intensity of the high-energy proton beams. In 2002 the AGS will embark on the 'Rare Symmetry Violating Processes' (RSVP) project, a plan to build and operate experiments that will investigate rare phenomena of compelling interest to particle physics. RSVP is a Work For Others Program that will probably be sponsored by the National Science Foundation. In addition several important experiments using pion, kaon and muon beams are planned at the AGS for particle and nuclear physics users. Three of these experiments have been approved and funded by DOE and others are in the approval process. NASA expects to continue it radiobiology program at the AGS and expand the program with the use of the Booster.

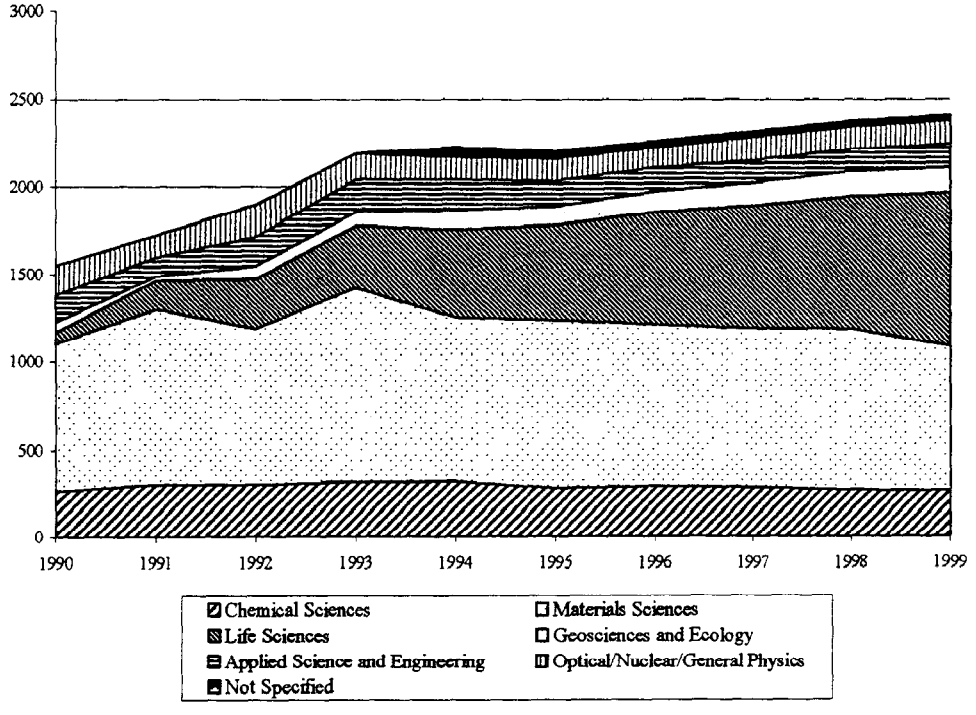
5.1.3 National Synchrotron Light Source (NSLS)

Present Program: The National Synchrotron Light Source (NSLS) is one of the principal DOE synchrotron sources. Light sources are an essential tool for research in a wide variety of disciplines. During the early years research focused on material problems and chemical processes. More recently the applications have expanded to include large biological systems. The number of users of synchrotron radiation has almost tripled over the last 10 years. The NSLS is devoted to the production and utilization of synchrotron radiation and to the development of electron based radiation sources including new applications of this radiation in the physical and biological sciences. It provides high intensity X-ray, ultraviolet and infrared light to 85 beam lines for users from over 350 national and international institutions. The distribution of the users by discipline is given in the figure 4 and table 4.

Table 4 - Distribution of NSLS Users by Discipline

Type of Science	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Chemical Sciences	264	304	303	318	321	281	292	285	268	265
Materials Sciences	837	993	882	1104	929	952	916	902	914	819
Life Sciences	62	167	286	354	503	548	642	701	761	881
Geosciences and Ecology	62	26	75	80	113	106	123	136	147	147
Applied Science and Engineering	155	106	167	186	177	147	138	126	127	134
Optical/Nuclear/General Physics	170	129	183	151	129	128	116	136	131	138
Not Specified	0	0	1	0	56	44	34	34	32	32
Total	1550	1725	1897	2193	2228	2206	2261	2320	2380	2416

Figure 4 - Distribution of NSLS Users by Discipline



During FY1999 a number of improvements were made to the facility including the following major upgrades. NSLS implemented ALARA (As Low As Reasonably Achievable) program improvements that continues to improve the radiation shielding around the VUV ring. A unique system was installed to keep the electron bunch length constant independent of the beam current. A second new improved RF cavity was installed in the X-ray ring, and the program to further reduce floor vibrations has made considerable progress. The X-ray ring now routinely operates at an energy of 2.8GeV (up from 2.5GeV) and the necessary upgrades to operate at this energy with the low emittance lattice are progressing. Two new IR beamlines were commissioned along with a new diagnostic beamline. The high-resolution low-energy undulator beamline produced a stream of forefront research in the area of high-temperature superconductivity. Lock-in detection was used on the elliptically polarized wiggler and the induced moment on Cu in a Co/Cu multilayer was observed. The production MEMS beamline was commissioned and the optics were improved on both the high and low energy X-ray absorption spectroscopy beamlines.

Near-term Program: The user community continues to expand in numbers and disciplines, and BNL is committed to enhancing the role of the NSLS as a national resource for materials, chemical and biological research. To meet this commitment several upgrades are in progress. Two new undulator beamlines are under construction that will bring the complement of insertion devices at the NSLS to 9, and a new superconducting wiggler and associated expanded beamlines for research at high pressure are nearing completion.

The NSLS will construct the remaining two new RF cavities. A new sextapole power supply system will be completed, and this will allow X-ray ring operation at an energy of 2.8 GeV in the low-emittance mode. We will also install the new superconducting wiggler. The preliminary design for the in-vacuum small gap undulator exit chamber will be completed; it will provide both the zero degree IVUN port as well as one bending magnet port. We will pursue the idea of further reducing the beta function to permit even smaller gaps along with concepts for a hybrid magnet design that would provide higher on-axis fields, thus increasing K and significantly improving the performance. Major progress will be made in the construction of a new NIH funded beamline for structural biology.

Long-term Program: Building on the success of the National Institute of Heath (NIH) funded research in macromolecular crystallography, the NIH is funding the construction of additional beamlines and purchasing new detectors. We are proposing a similar resource that will provide materials and chemical scientists access to the full range of synchrotron experimental techniques. The NSLS continues to contribute to the national R&D program leading to the next evolution in light sources. The BNL concept of High-Gain Harmonic generation coupled to the best of laser and accelerator technology was demonstrated in FY 1999, and this R&D will be extended to shorter wavelengths in FY2000. In addition, a proposal, Generation and Characterization of Attosecond Pulses was submitted to the DOE Novel Tabletop X-ray Light Source Initiative.

There are extensive development programs that will improve the stability, reliability, and lifetime of electron beams and develop new insertion devices that modulate polarization state and produce even brighter photon beams. Equally important are programs to develop new beamline instrumentation including beamline optics; monochromators and detectors that will let users take full advantage of the unique research capabilities offered by the NSLS. The Participating Research Teams continue to invest heavily in the facility, and the DOE BES program seeks to keep the facility at the forefront to justify this investment. Because of the wide array of experimental techniques available, the NSLS is able to provide a comprehensive approach to solving problems in the physical and biological sciences.

The NSLS also will take an active role in promoting the development of scientific applications for the Advanced X-ray Source facilities, and providing facilities for conducting proof of principle experiments.

5.1.4 Accelerator Test Facility

Present Program: The Accelerator Test Facility (ATF) is a user facility dedicated to long-term R&D in the Physics of Beams. ATF provides the electron beam and infrastructure for supporting many experiments as well as continuous development of electron beam characterization and manipulation tools. The core capabilities include a high-brightness photo-injector electron gun, a 70 MeV linac, high power lasers synchronized to the electron beam to a picosecond level, four beam lines (most with energy spectrometers) and a sophisticated computer control system. The ATF has a preeminent position in the development of RF photocathode electron gun technology, and made a significant impact on the pursuit of electron beam development for advanced accelerator concepts, including Free Electron Lasers.

ATF users numbered 75 in FY 00 and represented universities, national labs and industry. These researchers conduct R&D on Advanced Accelerator Physics and study the interactions of high power electromagnetic radiation and high-brightness electron beams, including laser acceleration of electrons and Free-Electron Lasers. Other areas of investigation include the development of electron beams with extremely high brightness, photo-injectors, electron beam and radiation diagnostics and computer controls. The ATF hosts two important proof of principle FEL experiments, the BNL-NSLS High Gain Harmonic Generation experiment in collaboration with ANL-Advanced Photon Source, and the VISA experiment designed to test and characterize SASE FEL operation in the visible, where high quality optical diagnostics are readily available. This is done in collaboration with SLAC, LBNL, LLNL and UCLA.

Some notable recent results are achievement of High-Gain Harmonic-Generation FEL, initiation of operations in the Visible SASE experiment, achievement of a record hard X-ray photon flux in picosecond pulses from the Compton Scattering experiment and major advances in the Staged Electron Laser Accelerator experiment. Next year we expect to enter the plasma acceleration field using the new terawatt picosecond CO_2 laser that is now being commissioned.

In the facility R&D and improvements, we measured the phase space distribution of a picosecond slice of an electron beam in transverse tomography and longitudinal tomography, improved the photo-cathode drive laser, enhanced the beam brightness of the ATF, improved the phase and amplitude stability of the beam, achieved record performance of the photocathode and improved diagnostics, power supplies and services. A major effort is underway to upgrade the computer control system to accommodate the terawatt CO_2 laser.

Near-term Program: Next year we hope to proceed with the computer control system upgrade, with electron beam brightness improvements and associated beam diagnostics, install a bunch compressor, upgrade the high-energy beam transport system, begin operations with the terawatt picosecond CO_2 laser and increase the facility's energy to 120 MeV.

Long-term Program: In the next five years we expect to construct a new Experimental Hall that will provide us with more beam lines, increase the beam energy to 200 MeV and construct a strong laser field experimental station for laser experiments that do not require the electron beam (such as generation of GeV ion beams, plasma X-rays, etc).

5.1.5 High Flux Beam Reactor

Present Program: BNL has been a leader in the development of neutron facilities for over half a century. With the permanent shutdown of the High Flux Beam Reactor (HFBR), BNL scientists are actively involved in the development of spallation neutron sources and instrumentation. BNL is leading the effort to construct a backscattering spectrometer (HERMES) for the Los Alamos Neutron Scattering Center and arranging to move a spectrometer from the HFBR to the High Flux Isotope Reactor (HFIR) at ORNL. BNL is also collaborating with ORNL to construct a new cold triple axis spectrometer at HFIR. We plan to form at least two Instrumentation Development Teams at the Spallation Neutron Source.

Future Program: Arrangements are being made for the BNL neutron scattering staff and its user community to continue their strong research programs at other facilities by providing operational and technical support. A new FWP was submitted to the DOE Office of Basic Energy Science to support these activities (See section Center for Neutron Science, Section 5.2.3.6).

5.1.6 Laser Electron Accelerator Facility (LEAF)

Present Program: The new Laser Electron Accelerator Facility (LEAF) significantly enhances Brookhaven's instrumental capability for research in both radiation chemistry and photochemistry. LEAF delivers synchronized picosecond electron and photon pulses, and provides a means to study the fundamentals of ionization in condensed media on fast time scales. This includes reactions at "extreme" temperature and pressure, supercritical fluids, geminate and spur decay, direct ionization and excitation of solutes, "dry" electrons and holes, and ionization in heterogeneous media.

Future Program: Researchers are developing a new generation of LEAF experiments using electron-pulse excitation and laser-pump-laser-probe detection schemes to probe the spectroscopy and dynamics of short-lived radicals and ions in real time. The LEAF facility also holds significant promise for new studies related to radiation-induced chemistry relevant to fundamental studies of electron transport in molecular-scale electronics and devices in support of BNL's nanoscience initiatives.

5.1.7 Transmission Electron Microscopy Facility (TEM)

Present Program: The Transmission Electron Microscopy Facility has a new, state-of-the-art, 300kV field-emission high-resolution microscope, one of the best microscopes in the US, with capabilities for high-resolution atomic imaging, magnetic imaging, nanoprobe spectroscopy, and energy filtered electron diffraction. The TEM research activities at present concentrate on the understanding of nanoscale crystal structure and structural defects and their role in determining the physical properties of advanced materials, such as high temperature superconductors, permanent magnets, and transition-metal oxides with colossal magnetoresistance effects.

In FY99, BNL developed a shadow image/diffraction technique to make accurate measurements of the distribution of valence electrons in YBCO and Bi/2212 superconductors, conducted in-situ field-dependence studies of magnetic domain structure and pinning behavior of $Nd_2Fe_{14}B$ hard magnets using magnetic imaging methods, and developed methods for induction mapping at nanoscale resolution using off-axis electron holography and Monte Carlo. We used low-temperature atomic imaging and energy-filtered electron diffraction techniques to resolve a conflict between competing structural models on charge and orbital ordering in $La_{0.33}Ca_{0.67}MnO_3$. The capability and detection limit (~0.2%) of imaging light elements, such as boron, using an energy filter system have been explored and quantitative comparison made with electron energy-loss spectroscopy.

Near-term Program: BNL is extending a shadow image/diffraction technique to measure lattice displacements associated with crystal defects. Using an image simulation method developed at BNL for a coherent electron beam, lattice displacements down to 0.001nm in Bi/2212 superconductors can now be measured. We are currently working on twist grain-boundaries (including electromagnetically characterized bi-crystals) in the system to determine potential variation and lattice displacement simultaneously to understand the interfacial structure and transport properties of the interfaces. BNL is developing in-line holography and phase amplification methods to improve spatial resolution of phase mapping for magnetic materials and to explore the possibility of boron mapping in tissue samples.

Long-term Program: Our main goal is to develop and apply advanced quantitative electron microscopy techniques to fundamental problems in materials science. The TEM facility and expertise are complimentary to those in Physics, NSLS, Chemistry and Biology. The following areas are focal points for use of this facility over the next few years:

- The study of atomic structure, bonding characteristics, and charge variation at grain boundaries and interfaces with unprecedented spatial resolution using quantitative electron diffraction, imaging, spectroscopy, Z-contrast and structural modeling techniques including those developed at BNL.
- Direct observations of charge stripe and individual superconducting vortex lines and their interaction with defects in superconductors, and charge ordering and stripe phase in transition-metal oxides.
- Nanoscience and technology related areas, including fabricating quantum-structure using electron lithography.
- In-situ experiments and dynamic observations of magnetic, ferroelectric behaviors and shape-memory effects of functional materials.
- Exploration of the 3-D structure of membrane proteins and nanoscale protein-labeling metal-particles by cryoelectron microscopy.
- Expanded collaboration with scientists from SUNY Stony Brook and two NSF Centers on semiconductors, polymers, and biomaterials.

5.2 Science and Technology Programs

5.2.1 Nuclear and High Energy Physics

Experimental and theoretical Nuclear and High Energy Physics are sponsored by the DOE Office of Science High Energy and Nuclear Physics program offices. Most of the R&D is concentrated in the Physics Department with smaller program in the Chemistry and Energy Science Departments.

5.2.1.1 Nuclear Physics - Quark Gluon Plasma and Spin Physics (KB)

Present Program: BNL is home to a large and strong research program in nuclear physics, supported by the DOE Nuclear Physics Division, that complements the user facilities operated by BNL for the benefit of the entire nuclear physics community. In the experimental areas of research, BNL is responsible for operating and maintaining the RHIC complement of four experimental detectors as fully functional forefront instruments. A second, equally important role of BNL research is a leadership program in nuclear physics covering the entire RHIC-based heavy-ion and spin physics program. For this second mission, BNL maintains four strong RHIC experimental research groups based on the RHIC detectors (BRAHMS, PHENIX, Phobos, and STAR). During FY 00 the detector groups completed construction of all four detectors and participated in the start-up of RHIC Collider operation.

The Laboratory is establishing a RHIC Spin group. Nuclear physics staff also support a limited set of fixed-target medium-energy user experiments that can be explored with secondary beams (kaons and pions) from the AGS. These experiments focus on important special topics particularly the study of hypernuclei. In FY00 BNL research in this area concentrated on the analysis of data for the existence of the H-particle (a six quark fully symmetric particle), the Double Lambda hypernuclei, and on high-resolution studies of hypernuclear gamma decays. In FY 2001 and FY02, using low energy kaon beams, two experiments will be conducted on the non-mesonic decay of lambda- He^4 and on Hypernuclear Gamma Rays.

A world class nuclear theory group is working on Quantum Chromodynamics (QCD). The active research areas include phenomenological models of matter at high energy density, the high-energy limit of hadronic interactions and nuclear structure, and hypernuclei. This work is done in close collaboration with nuclear theorists in the RIKEN BNL Research Center (RBRC) and other nuclear theory groups in the Long Island area (Columbia, SUNY Stony Brook and Yale). RIKEN BNL Research Center is located at

BNL and is a complementary theory and experimental physics institute. The RBRC is an integral part of the Nuclear Physics research at BNL and is funded primarily by the RIKEN Institute of Wako, Japan. RBRC and BNL scientists, together with outside users, form the RHIC Spin Group. In FY 00 the group formulated an experimental research program using spin-polarized protons in the RHIC Collider and established, in collaboration with the Accelerator Physics group, the capability of bringing 70% spin polarized protons through the AGS to the injection point of RHIC.

All the RHIC experiments are supported by the powerful computers and data storage facilities of the RHIC Computing Facility (RCF), which records, archives and serves as the computation resource for data reduction and analysis of experimental data from all the detectors. The RCF started operation in FY 2000 and will continue to grow in power as the RHIC needs evolve. There is a detailed plan for maintaining this capability over the next decade of RHIC operations.

Nuclear Physics research at BNL also includes the polarized-beam/polarized-target Laser Electron Gamma Source (LEGS) Experiment at the National Synchrotron Light Source (NSLS). The LEGS researchers are studying the electromagnetic structure of the nucleon, including studies of nuclear structure around the delta resonance region. These studies will provide unique new data for polarized photons interacting with polarized hydrogen and deuterium (frozen spin) targets developed by the collaboration. The LEGS data will be used to measure the spin-polarizability and Gerasimov-Drell-Hearn spin-sum rules. Future work in the LEGS will involve the study of pi ^{0} production from polarized neutrons from the same frozen spin targets. The current LEGS program has an anticipated program lifetime of about five years.

Future Program: In the future the nuclear physics research mission includes further strengthening of the RHIC-based experimental groups and the continuation of both experimental and theoretical nuclear physics in support of the evolving RHIC, AGS and LEGS programs. During the FY 2001-2002 BNL will consolidate a strong RHIC Spin experimental group in the Physics Department to provide intellectual strength to the spin physics program comparable to that already in place for the relativistic heavy-ion program. The experimental RHIC detector groups will lead the planning for detector evolution in the future as the RHIC physics program evolves and new results and research directions appear. The BNL-based research groups are expected to lead in defining and accomplishing the work, in cooperation with the entire RHIC experimental community.

5.2.1.2 High Energy Physics - Standard Model and Rare Particles and Processes (KA)

Present Program: For more than forty years, BNL has been a strong center for experimental and theoretical research in high-energy physics. Now the BNL research groups lead and support precision experiments at the AGS and participate as users in other High Energy Physics facilities such as the D0 Experiment at Fermilab and the ATLAS Experiment at CERN-LHC.

To accomplish this research mission, DOE Division of High Energy Physics supports three experimental groups (Electronic Detector, Omega, and Quark-Gluon Spectroscopy) as well as a particle theory group. These groups are expected to continue their currently defined mission at least for the next decade. BNL also supports a small experimental group in the Center for Accelerator Physics (CAP) where researchers pursue topics in advanced accelerator physics. CAP scientists are currently engaged in a program of accelerator R&D to explore the technical feasibility of muon colliders and muon storage rings.

Future Programs: The Electronic Detector Group continues a program to study rare kaon decays. Their goal is to uncover experimental manifestations of CP-violation in these decays. Rare kaon decays

represent both an important experimental window into the nature of CP-violation and a tool for exploring for physics beyond the Standard Model. Probing for physics beyond the Standard Model through rare decays will continue to be an important topic for many years and BNL's experimental group will continue to be one of the leaders in this field. The next experiment in this program, E949, will make the first precision measurement of the very rare Kaon decay, K+ → $^{8}_{2}$+ nu nubar. Indeed, the ability of the Rare Symmetry-Violating processes (RSVP) to probe mass regimes far above the energy of current or planned accelerators is likely to ensure that this approach to the energy frontier may outrun all of the planned high-energy machines in the decades to come. Through the National Science Foundation's Major Research Equipment program, BNL is working with several universities on a suite of experiments that will pursue this experimental pathway in the decade to come.

The Omega group engages in experiments outside BNL, the D0 Experiment at Fermilab and the ATLAS Experiment at CERN's Large hadron Collider (LHC). These experiments constitute the leading edge of the energy frontier in particle physics and the BNL group has contributed strong intellectual leadership as well as important hardware and software for success of the experiment. At present, BNL is the Host Laboratory for the US ATLAS Construction Project, the US ATLAS Computing Project and will provide the oversight and operations management for all US scientists participating in the ATLAS experiment once it becomes operational and serves as a source of high energy physics data. Members of the Omega Group also participate in the muon g-2 experiment at the AGS; this experiment is making a new precision measurement of g-2 that constitutes one of the best near-term probes for uncovering evidence for physics beyond the Standard Model. This experiment will conclude its data-gathering phase in 2001 and may be succeeded by a new experiment using the muon g-2 ring to provide important new upper limits on the muon neutrino mass. A second smaller effort of the Omega group is the participation in the MINOS neutrino experiment under construction at Fermilab. This experiment will confirm the neutrino oscillations observed in the Super Kamiokande experiment now underway in Japan and will provide better statistics on the $^{F}_{S_{\mu}}$ to $^{F}_{S_{\tau}}$ oscillation process. The plan for the next 10 years for the Omega Group is to pursue particle physics at the energy frontier in D0 and ATLAS, a natural role for BNL given our host Laboratory role for all US groups in ATLAS.

After identifying at least two exotic mesons, the Quark-Gluon Spectroscopy Group is in the final stages of data analysis, since its AGS-based experimental program terminated in FY 1999. This group is presently exploring new research directions.

The BNL High Energy Theory group pursues a wide range of theoretical studies in particle physics. At the present time these include; electro-weak studies; collider phenomenology, perturbative Quantum Chromodynamics (pQCD), lattice gauge theory, and field theory with emphasis on finite temperature effects. A recent example was the calculation of 2nd order weak effects contributing to the muon g-2 value, an important contribution to the theoretical understanding of this number and one that enabled the muon g-2 value to be used as a probe for physics beyond the Standard Model. The work of the Theory group is expected to continue along the same general pattern into the future.

5.2.2 Advanced Facilities - Concepts, Designs and Instrumentation

Accelerator, detector, source development and superconducting magnet R&D are essential core competencies for the Laboratory. These support the existing Science & Technology facilities at BNL and at other DOE Laboratories, and are essential for the effective development of future DOE facilities.

5.2.2.1 Accelerator Physics

Present Program: Brookhaven National Laboratory, with its suite of accelerators of diverse types (AGS, RHIC, NSLS, Tandem, ATF, etc.) has one of the largest concentrations of innovative accelerator scientists in the US. BNL staff members maintain a modest teaching program in accelerator physics at the graduate level.

In addition to improving and upgrading the accelerators at BNL, our accelerator scientists pursue a program of continuing accelerator physics research using the RHIC, AGS, NSLS and ATF. Experiments to study advanced concepts are performed in the Laboratory's unique user facility for in-house and external accelerator experiments, the Accelerator Test Facility (ATF).

BNL staff also participate in the 'Neutrino Factory and Muon Collider Collaboration', an international group of accelerator physicists that pursue R&D on the concept of capturing an intense beam of muons in an accelerator/storage ring complex. The Center for Accelerator Physics provides a focus for this work. BNL's AGS, the world's highest intensity proton synchrotron, will serve as a crucial test bed for the new approaches and technologies needed by any proton source suitable for a future muon storage ring or collider facility (Section 5.2.2.4, Muon Collider Neutrino Storage Beam). The muon collider/storage ring R&D program will require about a decade to reach its presently defined technical goals.

BNL also provides accelerator design and production of accelerator components to outside clients. This includes the complete design and construction of the Accumulator Ring and Beam Transport for the DOE's Spallation Neutron Source construction project, a collaboration that will be active throughout 2006. BNL is now constructing the new 'Booster Applications Facility' to continue and expand the current NASA-funded radiobiology program that has been active for the last three years at the AGS. Design and construction of a 70 MeV Cyclotron for research and production of special, radio-pharmaceutical isotopes and a 270 MeV Rapid Cycling Synchrotron for proton radiation cancer therapy needed by the University of Pennsylvania in Philadelphia are near-term accelerator projects for sponsors outside DOE sponsored program.

Future Program: These activities plus the exploration of concepts for the future evolution of BNL accelerator facilities rounds out the spectrum of accelerator physics activities at BNL. In the future, all of these activities are expected to continue, evolving in emphasis with the needs of the Laboratory and in response to opportunities for BNL to contribute to the national program of accelerator R&D, design, and improvement.

5.2.2.2 Superconducting Magnet Research and Development

Present Program: The ability of BNL to design, build and test substantial numbers of large, superconducting magnets, especially for accelerator applications, has been a part of the Laboratory core capabilities since the early 1980s. During the development of RHIC and SSC accelerators, this capability matured into a leading source of US expertise. During the production period for the RHIC Project, this expertise was fully institutionalized. In parallel the Laboratory began a vigorous program of high temperature superconductor and magnet design. The current R&D activities are focused on the magnet requirements of possible future accelerator facilities, in addition to producing innovative magnets for operating facilities.

Near-term Program: The present primary production mission is to build and test a limited number of superconducting dipoles for the Large Hadron Collider (LHC) Accelerator Project; test all the superconductors for the CERN-based LHC accelerators; and build spare superconducting dipoles,

quadrupoles and correction magnet modules as replacement magnets for use in RHIC as needed. In addition to the RHIC magnet baseline activity that will go forward for years into the future, BNL also is producing a small number of special purpose superconducting magnets for the Laboratory as well as for external application. Unique designs have been developed for helical dipole magnets for use in the RHIC Spin Program, as well as a direct wind technology, available only at BNL, for building interaction-region magnets for the HERA facility at DESY.

Working groups associated with both future hadron colliders and muon storage rings/colliders have been active in the past few years, and generic magnet requirements are available. For a 3rd generation hadron collider at a center-of-mass energy of 100 TeV, an interesting approach is based on 12 Tesla dipole magnets. The immediate technical challenge is to produce a dipole magnet capable of operating at this field. The standard NbTi superconductor used over the past 20 years for accelerator magnets will not reach these field levels and attention has moved to both Nb_3Sn and high temperature superconductors (HTS). While both materials are capable of operating to these fields, they are difficult materials to work with.

Muon Colliders produce a different set of challenges; the decay of the intense muon beams results in a large amount of energy deposited into the magnet. Generating fields of up to 8 Tesla require that the superconductor be shielded from this radiation in some way. High temperature superconductors that exhibit very small temperature dependence when cooled to helium temperatures, would be effective. A conceptual design of a magnet, which removes the coils from the mid-plane, is being developed as an alternative to a large bore magnet where most of the aperture is filled with shielding. A cable-in-conduit Nb_3Sn coil concept is also being pursued in an attempt to produce a more rugged coil structure.

During the past year, R&D work on both the helical dipoles and the DESY magnets has been successfully concluded and the Superconducting Magnet Division is in production on both projects. A prototype LHC magnet has been fabricated and is presently under test. BNL plans to build one more prototypes. In the area of high field magnets the Division has started to wind and measure small test coils of the new superconductors to study magnetization effects, material degradation, and 'quench' characteristics. BNL wound and measured first full-length (HTS) coils for a 1m test magnet. The engineering design of a magnet capable of withstanding the mechanical forces at 12 Tesla is progressing, as is the conceptual design of a muon collider magnet.

Long-term Program: The long-term goal in high field magnet R&D is to demonstrate an HTS dipole magnet that achieves 12 Tesla in an accelerator quality fashion. The program also will continue work on a 12 Tesla dipole based on Nb_3Sn technology as a fall back position if needed. The present goal of this program is the demonstration of a muon collider style proof-of-principle magnet.

The Laboratory also is investigating the potential application of HTS in an ultra-high field NMR solenoid. Only HTS can reach the 24 Tesla-field level needed for a next generation device but many issues related to stability and field quality need to be demonstrated. Small test coils will be used to develop power supplies capable of achieving the necessary stability levels. BNL is also considering an R&D collaboration with the GSI laboratory in Germany to look at the prospect of developing rapid-cycling superconducting magnets. While the GSI-proposed in-house program determines the initial requirements there are other potential applications of such a technology of possible interest to BNL.

The R&D and the production work in the Superconducting Magnet progress are expected to continue for many years, since both the fabrication of superconducting magnets and the magnet R&D functions are important to long-range BNL accelerator programs, including the operation and improvement of the RHIC facility. In this work, the Superconductivity Magnet Division collaborates with the

Superconducting Materials Group, in the Materials and Chemical Sciences Division of the Energy Sciences and Technology Department in the development of magnet using HTS superconductors.

5.2.2.3 Advanced Instrumentation

Present Program: BNL has strong core competencies in advanced detector, instrumentation, and source development related to our main user facilities and to other DOE facilities.

The BNL Instrumentation Division is a research division that develops state-of-the-art instrumentation for the scientific and technical organizations at BNL. The Division provides the research programs with expertise in detectors, microelectronics, micro-fabrication, lasers and optics.

The current focus is on following technical areas:

- Semiconductor detectors
- Gas and noble liquid detectors
- Lasers and optics
- Monolithic circuits
- Microfabrication

The Instrumentation Division also provides specialized shops, laboratories and development areas. In many of the technical areas, the instrumentation developed at BNL has been first-of-a kind and has enabled the Laboratory's scientific staff and users to pursue experiments that could not have been attempted without these innovative instruments. Examples include liquid argon calorimetry, silicon drift detectors, cathode pad chambers, low noise electronics and optics metrology. In the foreseeable future, the Division is anticipated to remain stable in size and mission in order to preserve and encourage the continued innovation of instrumentation concepts that look to future capabilities for BNL scientific and technology applications.

BNL also has been a leader in advanced instrumentation for Synchrotron Sources for over a quarter of a century and many of the techniques for spectroscopy, scattering and imaging have resulted from the programs both at the NSLS and in the BNL research departments. Recent examples are the applications of circular magnetic dichroism using lock-in techniques centered on an elliptically polarized wiggler which can switch the helicity of the photon beam at rates of up to 100Hz, and the application of infrared spectromicroscopy. The development of infrared spectromicroscopy led to the construction of 6 beamlines at the NSLS making the facility a leading center for the characterization of materials using infrared radiation. Currently, in collaboration with the APS and the Geophysical Laboratory, we are developing techniques for inelastic scattering at high pressure. The Physics Department is a leading member of the CMC CAT at the Advanced Photon Source where BNL staff are involved in developing and using an insertion device beam. One of the essential roles for the Electron Spectroscopy Group is developing new spectroscopic techniques, based at the NSLS, in angle resolved photoemission and infrared spectroscopy that allow detailed studies of correlated systems. .

Our current activities also include the application of transient frequency modulated spectroscopy to examine the product state distributions of benchmark unimolecular reactions, and the development of ion imaging methods to study the gas-phase products of surface reaction using coherent VUV radiation such as that available from the proposed DUV-FEL facility.

Future Program: Over the next few years, BNL's will continue to support the scientific users at the Laboratory with an emphasis on completing work for the US ATLAS Project and RHIC detectors as well as various projects for the Medical Research Program and neutron detectors related to the SNS.

Several new projects are anticipated in support of the applied science programs, and of the new fixed-target experiments, MECO and KOPIO, at the AGS. In addition, in the immediate future we intend to upgrade and enhance BNL's capability in nanoscale patterning for basic science studies and for sensor devices.

Brookhaven also will continue to make important advances in instrumentation leading to new applications of laser spectroscopy with high temporal and spectral resolution, and in support of accelerator-based BNL light sources. We will continue our current activities on the application of transient frequency modulated spectroscopy and the development of ion imaging methods to study the gas-phase products of surface reaction using coherent VUV radiation. In addition, BNL submitted a new proposal to DOE's Fourth Generation Light Source Initiative to generate and characterize attosecond pulses.

In the long term, BNL hopes to receive support for R&D in the Instrumentation Division from DOE High Energy Physics, Nuclear Physics and Basic Energy Science program offices. In FY 01 BNL submitted Field Work Proposal to DOE for direct support of these R&D activities. A major thrust will also be to obtain a more extensive nanofabrication capability and systems for thin film growth.

5.2.2.4 Muon Collider/Neutrino Storage Beams

A successful muon storage ring design could provide the means to precisely characterize neutrinos or, at a later stage, provide a basis for a muon-muon collider to extend the frontier of particle physics beyond the era of CERN's Large Hadron Collider.

Present Program: BNL is a major player in a DOE funded, multilabloratory collaboration engaged in the muon collider R&D program. The goal of the collaboration is to explore the feasibility of a multi-TeV (Trillion electron volts) collider. The national program includes computer simulation and experiments for creating intense muon beams from high-power proton accelerator beams, dampening relative motion of muons in the bunch (cooling) to reduce the emittance of the beam, and acceleration to a high energy for injection into a storage ring. In addition to simulations and other design studies, BNL has a specific mission under this collaboration to conduct experimental targeting study using the high intensity proton beams from the AGS.

These studies will resolve the most critical technical questions presently standing in the way of a research facility where muons could be stored in a race-track ring to create an intense beam of high energy neutrinos for neutrino physics, or circulated in a collider facility where muon-muon collisions could be used for the investigation of TeV scale high energy physics. BNL has a specific mission within this collaboration to conduct an experimental targeting study, E951, using high-intensity proton beams from the AGS.

Near-term Program: A short-term muon R&D objective is to develop the BNL site specific plan for a muon storage ring. This plan includes the improvements to the AGS, such as a high power proton driver, design of a detector suitable for muon identification with charge determination and design of a storage ring with neutrino energies that are consistent with the physics objectives, detector capability and distance to the detector location. The environmental impact of such a facility is a significant issue in the development of this plan. Present concepts include an AGS beam power upgrade to 1-2 MW, and a muon storage ring energy of 20 GeV or less. The neutrino beam would be directed to a point about 1500 km away from BNL. The study also includes the R&D for high-field high-T_c superconducting magnets suitable for the storage ring. Requirements include a high-field magnet design to optimize the ratio of useful straight section to total circumference and a high-T_c superconductor to cope with the heat generated by radiation from muon decays.

The BNL concept will focus on the possibility of detecting the oscillation of anti e-neutrino to anti-mu-neutrino with the appearance of muons with charge opposite to that of the stored muons.

Long-term Program: Subject to the determination that such an intense neutrino source based on a muon storage ring can be built economically and in an environmentally safe manner, BNL intends to develop a conceptual design in collaboration with the multi-laboratory/university collaboration. The goal is to build such a facility at BNL using the improved AGS as the muon driver. This facility will serve as a pilot for the TeV region collider.

5.2.3 The Physics and Chemistry of Materials and Condensed Matter (KC)

The condensed matter and materials programs at BNL have, in recent years concentrated on the study of magnetism and superconductivity and in the study of phase transitions in the bulk and at surfaces. Much of the experimental work requires instruments developed at Brookhaven's major user facilities and fosters continuing interactions of facility users and BNL staff. The research also is collaborative with other scientists at Brookhaven, at universities, at other national laboratories and in industry. Some current research themes, which cross discipline boundaries include studies of the following:

- correlated electron systems, especially transition metal oxides,
- surface and interfacial structure, and
- magnetic systems

Researchers are investigating the basic relationships between microscopic structures and macroscopic properties of advanced superconductors, providing both the basic data and understanding the fundamental materials science required for their effective practical use. Emphasis is placed upon studies of high temperature superconducting cuprates including investigations of physical properties of lattice defects, especially their role in altering superconducting properties as well as of kinetics of the formation of these oxides in practical conductors. BNL researchers extensively use transmission electron microscopy, X-ray diffraction techniques at the NSLS and neutron diffraction. Other researchers focus on developing an understanding of electroresponsive conducting polymers, and to use this information in the synthesis of improved materials. Their goal is to elucidate the microscopic origin of the electroresponsive phenomena, such as ionic conductivity, and to develop a rational approach to synthesis. The long-range goal is a polymer Li^+ cation conductor with potential application to real devices.

Recent results in material and condensed matter include the development of the stripe picture of charge ordering in cuprate superconductors, the demonstration of non-Fermi liquid behavior in BISCO, the direct observation of orbital ordering in manganates, the observation of layering in liquid metal alloy surfaces, and the discovery of cheap, cobalt-free electrode materials for Ni-metal-hydride batteries. New directions, include the following:

- development of efforts in magnetic nanostructured materials,
- soft condensed matter physics, and
- materials growth and preparation, particularly in the area of complex materials.

These initiatives involve collaborations among several departments at Brookhaven, and to augment our programs, we are aggressively strengthening our theoretical capabilities.

5.2.3.1 Neutron Scattering

Present Program: The principal objective of the neutron scattering program at BNL is the study of cooperative phenomena in complex solids by elastic and inelastic neutron scattering to gain an understanding of underlying physical principles. This includes structural and magnetic phase transformations, magnetic structure, and elementary excitations such as spin waves and phonons. A major theme of our current research concerns strongly correlated electron phenomena in transition-metal-oxide compounds such as high-temperature superconductivity in the layered cuprates and colossal magnetoresistance in manganites. The interplay between electronic, magnetic, and structural degrees of freedom in these systems, as well as in the f-electron heavy-fermion materials is of particular interest to the researchers. Other systems include S=1 linear chain antiferromagnets with quantum-disordered ground states, S=1/2 coupled chain (ladder) systems, spin glasses, and shape-memory alloys exhibiting Martensitic phase transformations. Neutron scattering is a unique tool for the studying these phenomena, and experiments are done at other neutron facilities in the US and abroad. In many cases, this work is complementary to parallel studies using X-ray scattering or electron spectroscopy available at the NSLS.

This year researchers observed stripe-rotation at the insulator-to-superconductor transition in $La_{(2-x)}Sr_{(x)}CuO_{(4)}$, a transition from a quantum-disordered to ordered magnetic state in a doped spin-Peierls system, and discovered a new structural phase associated with the ferroelectric properties of $Pb(Zr_{(1-x)}Ti_{(1-x)})$.

Future Program: Next year researchers will study further the quantum phase transitions in low dimensions and the competition among crystal field effects and spin and charge ordering in cobaltates. A major initiative involves the development of a facility for the growth and preparation of single crystal transition metal oxide samples, consistent with the DOE Complexity Initiative.

5.2.3.2 X-ray Scattering

Present Program: The central objective of this program is to study the structural, electronic and magnetic properties of condensed matter systems using synchrotron-based X-ray scattering techniques. Researchers are particularly interested in investigating surface and interfacial phenomena, magnetic structure and phase behavior, orbital and charge ordering in transition metal oxides, and electronic excitations in solids. Much of the work of the X-ray Scattering Group is collaborative with researchers at universities, at industrial and other national laboratories, and with scientists from other departments at Brookhaven. Recently researchers observed Pr ordering at the orbital wave vector in $Pr_{(1-x)}Ca_{(x)}MnO_3$, a 300-fold enhancement of the so-called 6 eV feature in resonant inelastic X-ray scattering studies of $CuGeO_3$, developed and used resonant X-ray scattering techniques to characterize phase separation at liquid metal alloy surfaces, observed lock-in behavior and island growth in thin Cu films grown on Ru(001) surfaces, and observed in-plane ordering at liquid alkane interfaces.

Future Program: Next year researchers will explore thin transition metal oxide films, reflectivity of the electrochemical double layer, and small angle scattering of clays. Longer-term initiatives include programs in soft condensed matter physics and complex magnets, consistent with the DOE initiatives in Complex Materials and in Nanoscience. In addition, the X-ray Group is exploring an internal collaboration with the Biology and Chemistry Department staff on protein adsorption at membrane surfaces.

5.2.3.3 Powder Diffraction

Present Program: The focus of this research is to increase the fundamental knowledge about structure-property relationships in inorganic materials, in particular, oxides. This focus is consistent with

the DOE initiative in Complex Materials. Researchers rely on the synchrotron X-ray powder diffraction capabilities at the NSLS and neutron powder diffraction at various national and international neutron sources. BNL researchers study rare-earth doped manganates and cobaltates, metal alloys and oxides used as battery electrodes, ferroelectric materials of the lead zirconate-titanate system, framework structures and magnetically ordered alloys and compounds. The goal is to elucidate phase transitions, in particular, charge and spin ordering, using Rietveld refinement techniques, including ab initio solution of the structure of unknown materials. The Powder Diffraction Group is the steward of the X7A beam line at the NSLS in conjunction with a Participating Research Team comprised of four industrial members, six academic institutions, and BNL.

This year researchers observed the first low-to-high spin state transition upon cooling induced by long range charge and orbital ordering in $YBaCo_2O_5$ and discovered low-cost, cobalt-free electrode materials for nickel-metal-hydride batteries.

Future Program: Next year's research program will focus on characterizing phase diagrams and phase separation in cobaltates and manganates, and in situ observation of structural changes induced in electrochemistry of nanomaterials. These research directions are consistent with the DOE Complexity and Nanoscience Initiatives, respectively.

5.2.3.4 Electron Spectroscopy

Present Program: In the Electron Spectroscopy Program researchers study the electronic and magnetic properties of surfaces and thin films and examine how such properties influence the physical behavior of materials. Research topics include: high resolution photoemission studies of complex oxides, high resolution studies of the metal/insulator transition in ultra-thin films, infrared studies of correlated metals including ultra-thin films and oxides, the use of undulator sources to perform spin-polarized valence-band and core-level, photoemission studies of magnetic films and multilayers. This research supports the objectives of the DOE Complexity and Nanoscience Initiatives.

Future Program: Next year researchers will continue studies of the insulator-to-superconductor transition and of the c-axis conductivity in "bad" metals, and establish Pulsed Laser Deposition as a means of growing in situ samples for these studies.

Photoemission is an excellent tool for extracting information on the self-energy corrections to the mass and lifetime of single particle excitations. In particular, using this method they have shown that the high T_c superconductor BISCO represents a non-Fermi liquid. These studies will be extended to all parts of the phase diagram. Other highlights include evidence for an oscillatory coupling between the quantum well electronic states and the phonons in silver films deposited on molybdenum substrates, and the discovery of deviations of the infrared conductivity from weak localization theory in thin metal films.

5.2.3.5 Condensed Matter Theory

Present Program: BNL's condensed matter theory research works in close collaboration with the neutron scattering group on magnetism and high temperature superconductivity. A program to understand charge transport in "bad metals", such as oxide and organic conductors and superconductors, is an on-going collaboration with the experimental group working on infrared and angle-resolved photoemission spectroscopies. Theoretical studies on X-ray magnetic scattering and orbital ordering impacts strongly the research of the X-ray Scattering Group. All of this research responds to the objectives of the DOE initiative in Complex Materials.

Theorists address different aspects of the electronic structure of surfaces and alloys including the prediction of meta-stable alloy phases, magnetism of adlayers and compounds, and the relationships between photoemission spectroscopy and the underlying ground state properties. During the past year researchers introduced a non BCS mechanism of high T_c superconductivity, characterized the dynamic coupling of 1-dimensional Haldane-gap excitations to local crystal field transitions of rare earth ions in the mixed spin antiferromagnet Nd_2BaNiO_5, and explained an orthorhombic thickness-induced buckling of body centered cubic Cu films on Au surfaces.

Future Program: In the future the theorists will concentrate on theoretical studies of magnetism in complex oxides, with further exploration of the experimental consequences of the stripe model of superconductivity, and with the effects of external fields on adsorbates at surfaces.

5.2.3.6 Program Initiative - Center for Neutron Science

This initiative develops a comprehensive program to provide elastic and inelastic neutron scattering techniques and to sustain the world-class neutron science capabilities that BNL has had for more than 50 years. Since its inception BNL has been a leading center for neutron science. Traditionally this research was centered at BNL's High Flux Beam Reactor (HFBR). The HFBR was permanently shut down in 1999 and the research activities of the BNL neutron scientists are now conducted at the NIST reactor and ISIS. BNL's Center for Neutron Science, formerly part of the reactor division will be expanded into a Neutron Science Division. This Division will expand research capability for BNL scientists at HIFR and prepare a research basis at the Spallation Neutron Source now under construction. The initial step are to the transfer the US Japan Instrument from the HFBR to HIFR including some improvement to the present instrument; firmly establish an operational infrastructure at HIFR, and in collaboration with the national SNS project establish the scientific basis for and develop the conceptual design for new or additional instruments at SNS.

This initiative involves several components including the following.

- Research and development in support of spallation neutron source development focused on the SNS. The AGS Spallation Target Experiment is an international collaboration using the record proton per pulse intensity from the AGS to study targetry issues for the SNS. This program will be extended to look at all aspects of neutron production and use including, for example, the possible use of slab moderators for the SNS long wavelength target station.

- Development of state-of-the-art instruments for neutron sources in the US, primarily for the SNS. These development efforts encompass all aspects including commissioning and operations. This will provide forefront experimental capabilities for the national program using neutrons from both pulsed and steady state sources. Examples of possible instruments include a high resolution backscattering crystal spectrometer for SNS and a tripe axis spectrometer optimized for cold neutrons produced at HFIR.

- Development of novel detectors for neutron applications. This is a joint effort with BNL's Instrumentation Division to provide large area, good spatial resolution and excellent temporal resolution detectors. These efforts will directly support instrument development at both BNL and in the neutron community for the SNS.

- Define and implement future research directions for neutron science. Forefront areas of research involve understanding increasingly complex systems where the variations and interplay of the electronic, magnetic, chemical and mechanical properties need to be understood and manipulated at the nanometer length scale. Such systems include sensors, tailor made catalysts, hydrogen storage and

micro- and macro- porous materials, methane clathrates and carbon nanotubes. Neutron scattering techniques are universally accepted as a critical tool for understanding the structural properties of matter on this scale and are unique in their ability to probe the dynamic response, which many believe will play a decisive role in the evolution of nanotechnology.

5.2.4 Energy Sciences (KC)

BNL's Energy Science focus area includes R&D on energy conversion, energy use and alternate energy sources. Research is coupled to our competencies in advanced experimental techniques, such as neutron and X-ray scattering, and on our unique facility capabilities. BNL concentrates on basic research on combustion, catalysis, bio-fuels, batteries, and solar energy conversion. The Basic Energy Science Program Offices sponsor this research. Other offices within the DOE programs sponsor work in the Energy Resource Mission area. These are summarized in Section 5.3.

Energy utilization includes catalysis, combustion, radiation induced chemistry for energy conversion and storage, and plant biosynthesis. The new Laser Electron Accelerator Facility (LEAF) provides a one of a kind tool for investigating the temporal properties of electron transfer associated with chemical, solar and electrochemical energy conversion. New experimental tools for investigating the rates of gas-phase radical chemical reactions, and nucleation and growth of aerosol particles help elucidate the efficiency of fossil fuel combustion. Plant sciences include mechanistic and molecular based studies of photosynthesis, lipid metabolism and genetic systems. The studies on lipid biosynthesis may lead to exciting prospects for engineering new pathways for the synthesis of alternative fuels and petroleum replacing chemicals.

5.2.4.1 Catalysis and Interfacial Chemistry

Present Program: The primary goal of the Catalysis and Interfacial Chemistry effort is a molecular-level understanding of chemical reactions that take place at the surface/interface of solids. This understanding can only be achieved by examining how chemical reactivity responds to the interplay of the physical and electronic structure, morphology, and the dynamic properties of a material. Besides providing insights into fundamental surface electrochemistry and electrocatalysis, the results of the research will have potential applicability in electrochemical energy conversion in fuel cells, and lithium batteries. BNL's current research includes the fundamental aspects of sulfur interaction with model catalysts, neutron and thermodynamic studies of molecular adsorption, synthesis and reactivity of doped metal oxide powders, selective oxidation of small hydrocarbons, and the dynamics of desorption and activated adsorption. By combining the use of spectroscopic techniques (e.g., photoemission, inelastic neutron scattering, XAS, state-resolved laser ionization) with structural tools that probe the short and long-range order, the BNL scientists can identify and characterize reactive surface species over a wide range of time and length scales and under a variety of conditions, including high pressure and temperature. Many of these measurements make extensive use of synchrotron radiation provided by the NSLS at two beam lines supported by the Chemistry Department (X7B, U7A). In addition, BNL scientists tailor the electronic properties of the catalyst to achieve a desired chemical activity by synthesis which produce MgO powders with highly uniform particle size distributions and precise transition metal doping (Zn, Cu, Fe). The goal of research in electrochemical/electrocatalysis is to understand the relationship between the structure of an electrode surface and its electrocatalytic properties, and the role of phase formation in the stability of intercalation electrodes. In addition to providing insights into fundamental surface electrochemistry and electrocatalysis, the results of the research will have potential applicability in electrochemical energy conversion in fuel cells and lithium batteries.

Recent studies using atomically resolved Scanning Tunneling Microscopy (STM) demonstrate that atomic-scale imaging will enhance significantly our understanding of metal-on-metal growth,

morphology, and reactivity in two-dimensional reactions on surfaces. Work in this area will grow over the next few years with the arrival of a new variable temperature, ultra-high vacuum STM instrument, that will be used as a nanoscale probe of the correlation between reactivity and surface structure. The new instrument will be an important part of a catalysis-related proposal for Brookhaven's Nanoscience Initiative. This work will emphasize metal-on-metal, and metal-cluster growth with the goal to control cluster dispersion and density, and understand the parameters controlling the stability of cluster morphology.

Future Program: In the future the program efforts will focus on reactivity and structure correlations on nanoscale materials, which hold considerable promise as chemical and photo-catalyst with properties that can be controlled via particle size, particle density and chemical environment. Success in this area will require new expertise in materials synthesis as well as the development of characterization tools that can index chemical activity with the spatial resolution of proximity probes

5.2.4.2 Radiation-Induced Chemistry

Present Program: The efficient capture and storage of light energy in useful chemical forms requires a fundamental understanding of the physical and chemical transformations induced by radiation and the subsequent electron transfer processes. Using the complementary techniques of excitation by photons or fast electrons, Brookhaven scientists study electron transfer reactions (theory and experiment), motions of charges in condensed media (including glasses and supercritical fluids), and the chemical and physical transformations of excited and highly reactive species. Complementary theoretical and experimental efforts elucidate the factors that control excited-state lifetimes, and investigate electron transfer rates of transition-metal complexes and other donor/acceptor systems. A major component of this research is the new Laser Electron Accelerator Facility (LEAF) that significantly enhances Brookhaven's instrumental capability for research in both radiation chemistry and photochemistry. By providing synchronized picosecond electron and photon pulses, LEAF provides a means to study the fundamentals of ionization in condensed media on fast time scales.

Long-term storage of solar energy as fuels or valuable chemicals requires efficient coupling of light absorption and chemical transformations. Mechanistic studies of systems which couple photo-induced electron transfer processes to the bond-forming reactions required in the photogeneration of molecular hydrogen and the photoreduction of carbon dioxide to carbon monoxide or methanol are a major focus. In one program the focus is to understand the structure-function relationships that determine the photophysical and chemical properties of porphyrins in living systems and in synthetic systems. Porphyrins are nature's catalysts and carry out a remarkable spectrum of bioenergetic reactions ranging from photosynthetic energy transduction to conversion of carbon dioxide into hydrocarbons. This research seeks to unveil the chemistry common to these multifaceted (photo) catalytic reactions mediated by porphyrins in vivo, and aims to develop tailored synthetic porphyrins that duplicate the selectivity and efficiency of porphyrin-based solar energy conversion and catalysis. In the past year researchers have demonstrated that changing the shape of photosynthetic and catalytic molecules can dramatically change their properties yielding new classes of molecules that duplicate natural systems and may lead to new materials for photocatalytic and molecular photonic devices.

Future Program: A new generation of experiments using electron-pulse excitation from the LEAF and laser pump-;laser probe detection schemes are in development to probe the spectroscopy and dynamics of short-lived radicals and ions in real time. The LEAF facility also holds significant promise for new studies of radiation-induced chemistry relevant to radioactive waste remediation and of charge transport in molecular-scale devices in support of BNL's nanoscience initiatives. In particular, future efforts will be aimed at fundamental aspects of charge-transfer between molecular adsorbates, and metal and semi-conductor nanoparticles that could serve in future photonic devices for solar energy conversion.

5.2.4.3 Gas-Phase Reaction Dynamics and Combustion

Present Program: Accurate models of combustion chemistry in real systems require accurate kinetic data for radical-radical reactions over a wide range of temperature and pressure. At Brookhaven, these measurements are performed by a combination of high-resolution, high-sensitivity, laser absorption methods and by high-temperature, flow-tube reaction kinetics studies with mass-spectrometric sampling. Spectroscopic measurements on radical species such as CH_2, C_2H_5 and C_2Br provide information on the energy levels and structures and, in turn, provide new tools for the study of energy flow and chemical bond cleavage in radicals involved in chemical reactions. Recent kinetic studies have focussed on the $CH_3 + O$ radical-radical reaction for which the CO product fraction was accurately determined via mass spectrometry, isotope labeling and diode-laser adsorption spectroscopy.

Future Program: These studies will be extended in the near future to other crucial radical-radical reactions such as two of the poorly understood reactions of the propargyl (C_3H_3) radical which are thought to play a crucial role in initial stages of soot formation in hydrocarbon combustion. This work bears on both the efficiency of fossil fuel combustion and the environmental impact and will form the basis of future efforts in gas-phase radical chemistry including new developments in reaction dynamics. With a highly interactive collaboration that combines experimental/theoretical or a combination of experimental techniques BNL's research will expand to include the experimental and theoretical aspects of the spectroscopy and electronic properties of radicals and metal-containing clusters, fundamental studies of the dynamics, energetics and reactivity of polyatomic radicals and highly excited molecules and the elucidation of the rate constant and product yields of the radical-radical reaction $CH_3 + OH$. The methylene generated in the reaction leads to CH radical that react with nitrogen to form nitrogen-containing combustion products. The new program focussed on experimental and theoretical studies of the electronic structure of metal-containing cluster compounds cross cuts gas phase chemical dynamics, surface chemistry and catalysis. The gas phase radical chemistry program involves a joint program between BNL and the Chemistry Department at SUNY Stony Brook to investigate the dynamics of radical reactions using novel ion-imaging and intense VUV radiation from the DUV-FEL facility at BNL.

5.2.4.4 Bioenergetic Research

Present Program: Research in bioenergetic systems includes artificial photosynthesis, plant biosynthesis, lipid metabolism and genetics. The goal of these programs is to understand how natural plant systems convert energy, regulate the energy conversion process, modify their basic biochemical processes and may be modified to produce renewable energy resources.

Plant systems are an attractive potential renewable source of industrial starting materials currently derived from petrochemicals. BNL researchers use an integrated approach, combining X-ray crystallography, spectroscopy, molecular genetics, and biochemistry to probe structure-function relationships within these lipids. Understanding the factors that control the selectivity and specificity of these processes will allow us to redesign lipid-modification enzymes with improved function or for novel uses. The long-term goal is to introduce these re-engineered enzymes into crop plants, which will result in renewable sources of industrial starting materials currently derived from petrochemicals. Researchers also are working to elucidate the molecular mechanism that protects photosynthetic tissue from stress related damage in "marginal" lands. Energy from cultivated plant biomass grown in marginal lands also is a viable option as an alternative energy source. Genetic engineering offers a powerful tool for understanding these complex systems, and determining the functional relationships of how genes and their products work together to accomplish complex tasks. Researchers are using genomic techniques to understand how genes that regulate the expression of other genes can effect a plant's traits.

In the past year, researchers in these programs have set the stage for identifying the enzymes responsible for adjusting the efficiency of photochemical reactions, and elucidating the specific details of how lipid metabolize enzymes work; a necessary step in tailoring enzymes to produce renewable oils for industrial applications.

Future Program: Over the next two to three years researchers expect to engineer soluble desaturase with predefined regiospecificity, understand how photosynthetic enzymes sense and are controlled by their redox environment, learn how plant genes function at the level of expression and how their products influence complex biological process.

Within the next five years the genomes of at least two plant species will have been sequenced, and sequencing of several other plant genomes will be underway by DOE and others. BNL will seek to expand and renew it capabilities in molecular plant genetics and research into fundamental mechanisms that will contribute to faster and better ways to engineer plants with desired properties. These programs will support national and world needs to develop renewal methods for producing raw materials and DOE goals in carbon management and bioremediation.

5.2.5 Environmental Sciences (KP and KC)

Present Program: BNL's environmental science programs are supported by the DOE Office of Biological and Environmental Research and the Office of Basic Energy Sciences. The OBER sponsored Atmospheric Science program acquires data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related chemicals and particulate matter. The emphasis is on processes and models related to new air quality standards for tropospheric ozone and particulate matter, and the relationships between air quality and climate change. Our research effort includes:

- development of methods and practical instruments for detection and real-time measurement of a variety of atmospheric constituents,
- development and application of gaseous tracers for studies of atmospheric transport and dispersion, building air infiltration and ventilation, geophysics of oil and gas recovery from production wells, and leak detection in fluid handling systems,
- theoretical, laboratory, and field studies of the formation and behavior of aerosols,
- studies of the formation, transport, mixing, and removal of gaseous and particulate pollutants in ambient air,
- modeling of the kinetics of chemical reactions of atmospheric pollutants,
- laboratory and field studies directed at the incorporation of sulfur and nitrogen oxides into cloudwater with the consequent formation of acid rain,
- theoretical and observational studies of radiative transfer and fluxes in the atmosphere,
- analysis of data and development of parameters relevant to global climate change.

BNL also is a partner in the DOE-OBER Atmospheric Radiation Measurement and also maintains the ARM External Data Center (Section 5.6, Major DOE Partnerships)

DOE-BER also supports research, at several levels, to understand and identify the sources, destinations, and impacts of carbon dioxide in our global environment. The BNL Terrestrial Carbon Cycle program investigates the natural carbon cycle, including quantifying the role of the terrestrial biosphere as a sink or source of carbon dioxide. In the Duke Forest in North Carolina, BNL established and operates

the Forest Atmosphere-Carbon Transfer and Storage Experiment (FACTS-1). FACTS-1 researchers study processes regulating forest carbon balance. A specific objective is to quantify the physiological processes controlling CO_2 fluxes in a pine forest under ambient and elevated atmospheric CO_2. BNL also supports the Free-Air CO_2 Enrichment (FACE) facility development. BNL helps re-establish operations of the trace gas delivery systems at several FACE sites at the beginning of each growing season, and also provides technical engineering support to several sites throughout the growing season. BNL provides coordination across FACE sites by maintaining collaborations, data management, visualization, integrative modeling, and by coordinating data submissions to the Carbon Dioxide Information Analysis Center (CDIAC). In order to improve predictions of future atmospheric CO_2, the coupling between photosynthetic organisms and the atmosphere must be understood. New tools in molecular biology are being applied to determine how C-uptake by plants adjusts to increases in atmospheric CO_2. A novel system to non-destructively measure soil carbon using inelastic neutron scattering is in development for field use.

The objective of the DOE-OBER Natural and Accelerated Bioremediation Research Program (NABIR) is to provide a fundamental understanding of complex phenomena to reduce or prevent pollution in order to protect human health and the environment. Knowledge gained through this research provides the fundamental scientific understanding needed to make bioremediation a viable option for dealing with DOE's most challenging clean-up problems. The goals of the Molecular Genetic Analysis program include. sequencing the ends of Clostrida genomic fragments, analyzing the nucleotide sequence sequences in detail to identify regulatory elements and completely sequencing regions of high biological relevance. A related program is exploring the transformations of heavy metal ions in anaerobic systems undergoing bacterial sulfate reduction.

The DOE Office of Basic Energy Sciences also funds basic research in the nucleation dynamics in microparticles and chemical characterization of ultrafine particles. The goal is to provide analytical tools to study the physical and chemical characteristics of microparticles that are common atmospheric aerosols The DOE- BES Geoscience program funds a research in X-ray microtomography to study the interior of geological samples, determine both fluid flow and mechanical properties in porous media, and to study the distribution of trace elements in plants and insects. In another program, researchers study the chemistry of polysulfides in rich marine sediments, the incorporation of sulfur into organic matter, and the effect of this in preserving sedimentary organic matter. These programs may aid the search for new petroleum deposits and provide a new understanding of sulfur compounds found in petroleum.

Future Program: In the Atmospheric Sciences program researchers will continue field studies of the chemical and physical properties and fate of energy related pollutants. Field studies from the Phoenix and Philadelphia area will be completed and work will be underway to study the transport of pollutant and pollutant precursors from the industrialized mid-west to the east. New and improved instruments for field studies will be deployed, depending on the needs of the field program. This includes new instrumentation for rapid in-situ aircraft measurements of ambient aerosol size distribution. Laboratory work will continue on defining the mechanistic role of multiphase chemical processes in the production of photooxidants and aerosols in the troposphere, including the development of analytical methods to characterize aerosol organic constituents, to measure gas phase nitrous acid concentration and to improve capabilities to gain sized related composition for organic and inorganic components in aerosols. Researches will develop methods to use the BNL aerosol model to provide boundary and initial conditions for higher resolution models to accurately represent the impact of exogenous aerosols to areas of interest. Researchers will continue to develop models and parameters for shortwave radiative forcing by aerosols, using ARM data to gauge the accuracy and uncertainty and develop and code a model to evaluate aerosol shortwave forcing from vertical profiles and a model for downwelling radiation. Work will continue on solutions under extreme conditions, particularly the dynamics of nucleation and researchers will develop new systems to investigate nanoparticles and initiate work on ice nucleation under upper tropospheric conditions.

Researchers in the Terrestrial Carbon Cycle Program will continue operation of the FACTS-1 facility at the Duke Forest. Canopy photosynthesis , conductance and leaf area index measurements will continue. Laboratory and field investigations to improve, refine, elucidate and validate mechanisms that control how carbon uptake by plants adjusts to increases in carbon dioxide will continue. The CanVeg model will be improved by including feedbacks between canopy processes and atmospheric carbon dioxide, including scaling and canopy integration. We will plan and build the software tools necessary to produce a computer modeling platform suitable for use by the FACE and Ameriflux communities. The FACE engineering group will improve the FACE design and control systems to improve efficiency of carbon dioxide use and control of carbon dioxide concentrations. In a separate effort we will be developing a proof-of- principal system to measure carbon in soil using inelastic neutron scattering.

We propose to continue the BER NABIR efforts and develop capabilities in a new area. BNL's accelerator physicists and environmental scientists are evaluating synchrotron-based molecular environmental science research conducted during the past few years at DOE light sources to identify research that would benefit the DOE environmental clean-up efforts and the basic research underpinning these efforts. BNL's National Synchrotron Light Source and the Environmental Science Department will partner to develop new applications that better serve the molecular environmental science user community.

For the Office of Basic Energy Science, BNL expects to develop a general picture of nucleation process far from equilibrium and to develop a new system to extend the study of phase transformations to nanoparticles. In the geoscience program BNL will expand and refine computed microtomography and work to improve the measurement and visualization technologies. Research also will continue on the transformation of organic matter during the progression from early to late diagenesis and the interaction of metals on the catalytic formation of organic matter will be investigated.

In March 2000, BNL created a new Environmental Sciences Department that includes all of BNL's environmental research and technology. This new department is structured to enhance interdisciplinary research. BNL plans to grow the environmental science staff in two areas. The NSLS accelerator physicists and environmental scientists are exploring new synchrotron applications for the molecular environmental science community. In addition BNL will connect the basic research conducted in the Biology Department with the more applied research in the Environmental Sciences Department.

5.2.6 Medical and Imaging Sciences

BNL takes advantage of the unique facilities and expertise at the Laboratory for research in medical and imaging science. Researchers use nuclear technology and radiopharmaceuticals to develop new treatments, new diagnostic tools and to study human physiology and the mechanisms of disease in the areas of oncology and neuroscience. The overall research is funded not only by the DOE, but also is supported by the National Institutes of Health (NIH), and the National Aeronautics and Space Administration (NASA).

5.2.6.1 Imaging Research

The imaging programs are a joint effort of the Chemistry and Medical Departments. The program goals are the following:

- to conduct basic research in radioisotope and radiotracer chemistry,
- to develop and apply new aspects of magnetic resonance imaging,
- to develop new imaging modalities, and

- to carry out basic and clinical studies in the neurosciences.

Present Program: The basis of the Positron Emission Tomography (PET) Program is cyclotron-based positron emitting isotope production and rapid radiotracer synthesis to provide radiotracers for imaging specific molecular targets and studying drug distribution and kinetics. Researchers conduct basic and clinical neuroscience research using PET to investigate neurotransmitters and their interactions, to characterize the molecular changes occurring in addiction, and to use new knowledge in the development of addiction treatments. BNL also has a long-standing commitment to investigate the molecular changes underlying normal aging and the relationship of those changes to neurodegenerative disease and its treatment. A second objective is to investigate the actions of therapeutic drugs in the human body to optimize their beneficial effects, minimize toxicity and expedite their introduction into the practice of health care. We also are involved in developing tracers to characterize the molecular properties of tumors and in the use of imaging to investigate different facets of radiation therapy. There are two cyclotrons (41" and 60"); 1 radio frequency quadupole (RFQ) accelerator; 2 PET scanners; 1 Single Photon Emission Computed Tomography (SPECT) scanner, and an animal PET (MicroPET).

The Magnetic Resonance Imaging (MRI) facility is equipped with a 4 Tesla instrument for human and animal studies. The integration of PET, SPECT, and MRI imaging modalities within a single center at BNL provides a unique opportunity to conduct basic research in the development, validation, and application of novel imaging methods and to investigate the synergistic uses of multiple imaging modalities to probe molecular mechanisms involved in normal brain function and disease.

The PET program will be expanded with the addition of a new PET rodent camera allowing us to explore the use of PET technology for imaging transgenic animals as well as allowing us to conduct longitudinal studies in individual animal subjects. Our current work on radioligands as targets for tobacco and marijuana receptors will be extended to human subjects. The MRI program will be expanded with the recruitment of 2 new scientists and the proposed acquisition of a 7 Tesla MRI instrument.

Future Program: In the next year we plan to commission the new animal PET scanner, pursue acquisition of a new high field animal magnetic resonance imaging instrument for functional and spectroscopic studies in animals, and continue the development of in vivo approaches to assess gene expression and gene delivery.

5.2.6.2 Isotope Research and Production Program

Present Program: The goals of the Isotope Research and Production Program are to develop, produce, evaluate, and distribute new radionuclides and radiopharmaceuticals that would lead to:

- improved diagnostic and therapeutic procedures in nuclear medicine, particularly for oncology, cardiac disease, and neurosciences and
- a better understanding of physiological processes in health and disease.

Many unique Laboratory facilities (the Brookhaven Linac Isotope Producer (BLIP), cyclotrons, high-level radiation processing facilities, radiochemical laboratories) as well as protocols for animal testing and clinical trials, are all part of this program. The BLIP is a unique national resource for the production of many isotopes crucial to nuclear medicine for both research and routine clinical use in patients, and which are generally unavailable elsewhere. The BLIP facility has supported both new radiopharmeceutical developments at BNL, and the distribution of many difficult-to-produce isotopes to industry and to research investigators.

We continue to investigate the use of radioisotopes, such as Sn-117m, for the palliation and treatment of bone metastases that are frequent in patients with advanced breast, prostate, and lung cancer. We have used isotopes produced at the BLIP for labeling monoclonal antibodies that are directed against antigens expressed in breast, colon, and other cancers. Recently, we also developed immunoconjugates labeled with certain positron emitters that may be useful in the early detection of breast and colon cancer using high resolution PET imaging. Molecular engineering could enhance the cytotoxic potential of radiolabeled antibodies, and we are working on fusing viral proteins to antibodies to increase the uptake of the labeled conjugate into tumor cells that could be used to image or destroy the tumor.

Future Program: In the future we will continue to focus on the following key research areas:

- development of new isotopes (e.g., no-carrier-added tin-117m, scandium-47 and mercury-195m), and associated radiolabeling methodology;
- radiolabeled, bio-engineered molecular constructs from single chain antibodies and viral vectors, for gene expression imaging and gene/radioisotopic therapy of cancer;
- clinical trials of tin-117m chelates for palliation of metastatic bone pain, and for the treatment of primary/metastatic bone cancer and rheumatoid arthritis;
- targeted tumor therapy using radiolabeled anti-angiogenic peptides, and STTR-binding peptides.

A major new Laboratory initiative is a new 70 MeV Cyclotron Isotope Research Center. It is described in Section 4.

5.2.6.3 Cancer Research

Our goals in cancer research are to develop new forms of radiation based treatments for cancer, including Boron Neutron Capture Therapy (BNCT) and Microbeam Radiation Treatment (MRT) using the National Synchrotron Light Source.

Present Program: The boron delivery agent in Boron Neutron Capture Therapy used in pre-clinical and clinical work on BNCT is a boronated analog of the amino acid phenylalanine, *p*-boronophenylalanine or BPA. Pre-clinical studies demonstrated the biological effectiveness of BPA-based BNCT relative to conventional photon radiation. Effective tumor control with little or no damage to adjacent normal tissue was demonstrated in animals. Based on these results, BNL initiated a dose-escalation clinical trial of BNCT for patients with the malignant brain tumor glioblastoma multiforme in 1994. The primary clinical objective was to determine the tolerance of the normal brain tissue to BNCT. This objective was achieved, and the clinical trial was closed to further patient accrual in 1999.

In conventional radiation therapy, damage to normal tissues surrounding the tumor is thought to arise largely from injury to endothelial cells. This leads to disruption of blood perfusion and eventually necrosis. Recent data indicates that Microbeam Radiation Therapy (MRT) spares normal tissue so that microvasculature in normal tissue can regenerate from endothelial cells that survive between the individual microbeam treatments, and spare the normal tissue. MRT uses arrays of parallel, microscopically thin slices of synchrotron X-rays. The tolerance of normal tissues to microbeams versus conventional broad beams, both administered in a single fraction, is 6-fold higher for the rat skin tissue, and 3-fold higher for the brain tissue of duck embryos, after the microbeam dose is adjusted for the unexposed volumes between the microbeams. In animal studies, tumors irradiated with single-fraction unidirectional microbeams invariably showed either substantial delay in the tumor growth or tumor

eradication at doses which were well tolerated by the surrounding normal tissues. MRT administered in cross-fired geometries also showed strong tumoricidal effects.

Future Program: The results of the clinical trial with BPA-based BNCT suggest that the delivery of the boron to the tumor is not optimized. Researchers will continue basic research to explore the ability of longer infusion times to improve the effectiveness of BPA-based BNCT against tumor cells in the main tumor mass and against tumor cells infiltrating the normal brain. Animal studies are planned that will improve the accuracy of the biological effectiveness factors used for dose estimation in BNCT. We are continuing data analysis and follow-up of treated patients. Basic research also is continuing in animal tumor models in order to improve the effectiveness of BNCT against malignant gliomas and to explore the possible applications of BNCT to other tumors.

BNL also will perform radiobiological and biochemical studies in animal models to address specific issues that arose during the clinical trials. These include the sensitivity of lung tissue to BNCT, the possibility of using BNCT after photon therapy and the potential usefulness of fractionated BNCT, and to determine whether biochemical manipulations can improve the accumulation of BPA in the tumor. Pilot studies in animal tumor models will determine the feasibility of BNCT for other tumor types such as lung tumors, head and neck tumors or soft tissue sarcomas.

We also are continuing the evaluation of new boron compounds that could be used alone, or in combination with BPA. The development and testing of new boron compounds will continue. The effectiveness of a boronated porphyrin in tumor therapy experiments is encouraging. Researchers are evaluating the effectiveness of newly synthesized boronated amino acids and nucleosides in cell culture and in animal tumor models either alone or in combination with BPA.

In Microbeam Radiation Therapy, we propose to extend the microbeam research to:

- understand the radiobiological bases for the MRT effects in normal and cancerous tissues,
- quantify the radiobiological effects involved, and
- optimize the parameters for unidirectional and cross-fired MRT for reaching the best therapeutic ratio, using head and neck tumor models.

The long-term goal is to extend these studies to large animals to examine the potential of MRT in clinical radiation therapy. If these studies and others indicate a clear clinical application, we estimate that relatively small, dedicated synchrotron facilities could be developed to use MRT in a clinical setting.

5.2.6.4 Medical and Imaging Science Program Initiatives

For BNL's long-term program, we are proposing five program initiatives in medical and imaging sciences, The Laboratory for Cell Biology, Behavior and Functional Genomics, an expansion of our cancer and radiobiology research programs, Imaging Instrumentation Development, and Radiotracer Applications to Environmental Studies.

Laboratory for Cell Biology, Behavior, and Functional Genomics: We propose to develop a laboratory, which will provide a mechanistic and functional framework for PET- and MRI-imaging studies including human and animal studies on addiction, aging, drug development, and cancer. This will enhance our on-going research to develop and validate new methods for assessing gene delivery and the functional activity of specific gene products (receptors, enzymes, transporters) in normal and genetically altered animals in conjunction with the new DOE-OBER funded animal PET. We will add a particularly important aspect, a strong animal behavior component to complement and enhance our current

capabilities (microdialysis, electrophysiology, and *in vitro* binding) for understanding and treating addiction. This laboratory will facilitate the integration of the imaging and NASA Space Medicine projects to investigate the behavioral, cognitive and motor consequences of increased radiation burdens in space.

Cancer Research: We will build on our current strengths in radiotracer development and nuclear imaging, radiation therapy, and the applications of the Light Source in diagnosis and treatment to consolidate and expand BNL's efforts in cancer research. PET imaging will be further developed to characterize the molecular properties of human tumors and to map drug distribution and kinetics to understand the therapeutic- and side-effects of anti-cancer drugs, different types of radiation therapy in normal tissues as well as the mechanisms accounting for its toxicity in malignant tissue, and the potential clinical applications to malignant brain tumors. Progress in the last year includes obtaining an IND from the FDA to use a new F-18 labeled radiotracer for the enzyme catechol-O-methyltransferase (COMT) to image estrogen metabolism in breast tumors with a view to enhancing understanding and early detection. We have formed a collaboration with the Department of Surgery at SUNY Stony Brook. We plan to image the first breast cancer patients in FY2000. We also will continue to investigate the use of radioisotopes, such as (Sn-117 nDTPA) and other isotopes produced on BLIP, for the palliation and treatment of bone metastases that are frequent in patients with advanced breast cancer. Our new efforts will include exploration of new BLIP-produced radioisotopes coupled to monoclonal antibodies that are directed against antigens expressed in breast cancer cells. In addition, BNL recently developed immunoconjugates labeled with certain positron emitters that may be useful in the early detection of breast cancer using high resolution PET imaging. Molecular engineering could enhance the cytotoxic potential of radiolabeled antibodies. We are working on fusing viral proteins to antibodies to increase the uptake of the labeled conjugate into tumor cells that could be used to image or destroy the tumor. An important component of the Cancer Initiative will be to continue to strengthen ties with Stony Brook scientists and the new Stony Brook Cancer Center.

Neuroscience Initiative: We plan to expand the neuroscience program to investigate the role of genes in brain function and in neuropsychiatric diseases. In order to facilitate expansion we are recruiting a leader in the field of genetic-neuroscience, who will facilitate the development of methodologies that use imaging tools to measure gene expression in vivo in the brain. This initiative involves an expansion of the collaborations between the imaging group (Chemistry and Medical Departments), the Biology Department and the Center for Data Intensive Computing. In parallel we expect this to facilitate the DOE Biomedical Engineering Initiative since it will promote development of novel imaging methodologies, instrumentation and radiotracers. It will also further Neuro-Informatic Initiative at NIH since it will require the development of new analytical tools for data analyses.

Imaging Instrumentation Development Initiative: Because of the remarkable growth of PET and BNL's leadership in developing PET radiotracers, we began a program to design and develop new specialized PET imaging instruments, based on innovative designs and special applications (e.g., positron-detector probes for freely moving animals, arterial blood detectors, and rectilinear scanner for rapid kinetics in small animals). Researchers from Medical, Chemistry, Physics, and Instrumentation have already designed, fabricated, and now are evaluating prototypes for these devices, and results are very encouraging. We have obtained DOE Bioengineering funds and a CRADA to partially fund this initiative. However, a major cost and limiting factor will be to obtain the funds for scintillation crystal detector modules and associated electronics needed to scale up the prototype devices.

Radiotracer Applications to Environmental Studies: We have a collaboration with SUNY-Stony Brook, Department of Ecology and Evolution to use short lived radiotracers to probe the mechanisms of underlying biosphere/atmosphere exchange, with special emphasis on pollutant exchange between plants and the atmosphere including nitrogen dioxide, carbon monoxide and hydrocarbons. This is in the early

stages and if funding is obtained we intend to actively pursue this important area using BNL's Cyclotrons, Radiotracer laboratory and core scientific expertise.

5.2.7 Biological Science - Molecular and Structural Biology

Present Program: The DOE Office of Biological and Environmental Research (OBER) sponsors research in molecular, cellular and structural biology in conjunction with other offices in DOE (BES, NN, and EM), other federal entities (particularly NIH), private foundations, and collaborating industries within BNL's Biology Department. These programs extend from the molecular level to that of the organism and primarily address basic questions in molecular genetics, cell biology, and structural biology that support DOE objectives and provide insights and tools relevant to areas of DOE interest. They include:

- identifying and characterizing cellular mechanisms that detect DNA damage, repair the damage, and prevent oncogenesis,
- analyzing the genomes, gene expression, and the proteomes of model organisms,
- understanding enzymes and enzyme systems that carry out fundamental processes required for life,
- the productive utilization of biology for mankind including the engineering of systems for improved bioremediation and other useful purposes, and
- developing and validating complex tools for determining protein structures for use by the worldwide research community.

The Biology Department has a long and distinguished history of research on DNA damage and repair, both defining the basic biochemistry and genetics and in developing tools for accurate and sensitive measurements. Using recently devised methods for measuring clustered DNA damage - two or more closely spaced strand breaks, abasic sites, or oxidized bases on opposing strands- researchers demonstrated that the frequency of cluster damage induced by ionizing radiation is comparable to that of frank double-strand breaks. Researchers also have shown that even low doses (0.1-1 Gy) of high linear energy transfer ionizing radiation induce clustered damage in human cells. Efforts to extend the sensitivity of the technique to ultra-low doses and to determine whether cluster damage occurs during normal metabolic processes are in progress. Our goal is to understand the effects of low dose, low LET ionizing radiation administered specifically to the cytoplasm or the nucleus, and to assess any biological effects in the unirradiated neighbors ("bystander effect").

Double-strand breaks and clustered damage are repaired in mammalian cells primarily by two mechanisms, one involves DNA end-joining by components regulated by the DNA-dependent protein kinase. Recent studies show that the large catalytic subunit of this kinase consists of domains that are stable to proteinase digestion. At least some of these domains can be expressed as recombinant proteins in eukaryotic systems, potentially paving the way for a detailed structural analysis. BNL scientists also developed methods to detect specific phosphorylation events in proteins that occur in response to ionizing radiation and other forms of DNA damage. Such reagents can be used to trace the pathways of response to DNA damage and regulate cell cycle progression, apoptosis, and DNA repair.

The Genome Sequencing Group is developing and implementing the biochemistry and vectors for sequencing difficult regions of human chromosomes by a nested-deletion strategy. Using this strategy, researchers have successfully closed gaps in the sequence of several highly repeated regions of human chromosome 19 that had proved difficult to sequence by conventional technology. Efforts to standardize protocols and to establish a robust production mode for application to finishing the sequence of the human genome are on-going. The single-copy, amplifiable vectors (pSCAN) are being modified to optimize

their usefulness for developing and sequencing libraries enriched for full-length cDNAs from organisms and tissues of interest including unicellular diatoms, mice and the human brain. We also are developing and testing the application of these vectors for profiling gene expression in organisms of interest to the DOE including specific regions of the human brain.

A pilot project in functional genomics began in FY 1998 to test the potential of high-throughput protein crystallography for obtaining structures for representatives of protein families for which no structural information is available. Genome and cDNA sequencing projects provide a rich source of information for identifying protein families and obtaining coding sequences for selected proteins. Efficient methods based on 96-well format techniques that were developed for efficient genome sequencing are being adopted for the identification and expression of selected protein domains. Recent studies of 95 yeast proteins indicate that at least half are likely to produce soluble proteins suitable for crystallization studies. However, a number of issues also were identified that need to be resolved. These include insolubility resulting from peptide tags and errors introduced during PCR amplification and cloning. The NSLS is ideal for the rapid and efficient collection of X-ray diffraction data; therefore, we believe we have the ability to make an important contribution through development of methods to an understanding of protein structure. To pursue these efforts we have partnered with our neighboring institutions, The Rockefeller University and the Albert Einstein College of Medicine, to form a Structural Genomics Research Consortium. We anticipate that this consortium will be funded primarily by sources other than the DOE; nevertheless, the expected results will directly support DOE missions in human health, bioremediation, and carbon management.

We propose to establish a group to completely re-engineer software for phasing, model building and structure refinement for protein crystallography, greatly reducing the need for human involvement. Without substantial automation, the process of converting synchrotron data to fully refined structures will become a serious bottleneck in high-throughput protein crystallography. Additional scientific staff and expanded collaborations with the University at Stony Brook for research and training in bioinformatics and computational biology are planned as part of the Center for Data Intensive Computing.

Many of our research programs use our facilities for Structural Biology to analyze structures and interactions of biologically important proteins and their complexes, including the following:

- structures of viruses, chromatin and ribosomes,
- interaction of a viral attachment protein and the receptor on the host cell,
- the outer surface proteins of pathogens (including the antigen used in the vaccine for Lyme disease), and
- toxin structures, protein chaperons, DNA repair complexes, and DNA modifying enzymes.

BNL has an extraordinary combination of strengths in molecular genetics, structural biology, genomics, and biotechnology. The Laboratory's highly interactive research environment is the ideal incubator from which complex user facilities for structural biology can be developed and optimized for the wider research community. Demand for these facilities is strong and growing. We continue to partner with outside groups who invest in upgrades or construction of new protein crystallography facilities at the NSLS, thereby increasing overall user access.

The Laboratory's Scanning Transmission Electron Microscopes (STEM I and III) are available for high-resolution measurement of shapes and masses of biological molecules and their complexes. The types of information that can be obtained include 3D location of atoms in individual molecules or complexes, the arrangement of molecules in higher-order structures, and the overall shapes and interactions of

complexes of molecules. Such information is essential for understanding how biological molecules and structures function. Recent successes include the development of new gold-labeled tags for identifying important functional sites in proteins such as ATP binding pockets. Anticipated improvements in detector technology associated with STEM III should permit locating specific atoms including phosphorous and boron.

Future Program: The Laboratory aims to align its research programs to the interests of OBER. Near-term objectives include the following:

- Institute programs to characterize and measure the effects of low dose and low-dose rate ionizing radiation on human cells and human health and to characterize the effects of genetic diversity on the responses to DNA damage.
- Sequence difficult regions of human DNA, and develop and validate vectors for improved genome sequencing.
- Develop capabilities for characterizing gene expression at the mRNA level from organisms that are important for bioremediation and carbon management as well as from specific region of the human brain; produce cDNA libraries enriched for full-length cDNAs, and assist in their analysis.
- Characterize complexes involved in signaling the presence of and repair of DNA strand breaks and complex damage in human cells, and initiate studies to determine the structures of the proteins involved.
- Continue to develop technology for efficient, high-throughput protein crystallography to demonstrate the feasibility of a structural genomics component of a Human Proteome Project in partnership with universities and in coordination with other National Laboratory Centers.
- Continue research to determine the structures and interactions of biological complexes, improving the methodology, and engineering proteins for useful purposes.
- Continue to improve our user facilities for structural biology, with emphasis on improving the efficiency of protein crystallography at the NSLS and the ease of access for all users.
- Strengthen and extend radiobiology research to investigate the cellular mechanisms involved with radiation induced cell damage; investigate the effects of heavy particle radiation that mimics radiation effects of space on cells and whole organisms, and develop an in-vitro radiobiology facility at the NSLS X15A beamline that uses precisely collimated X-ray beams to target separately the cell nucleus and the cytoplasm in tissue cultured cells.

In partnership with the State University of New York at Stony Brook and others, BNL intends to increase it capabilities for determining structures of membrane proteins and complex protein structures. These capabilities will support DOE initiatives in carbon management, bioremediation, and the Microbial Cell as well as strengthen a partnership within BNL in DNA damage signaling and brain function.

5.2.8 Technology Transfer (KT)

Present Program: A goal of the Science and Technology Program to "Add value to the US economy through the development and application of new and improved technologies." BNL's technology transfer program has two primary objectives, to complement our research mission through involvement in technology transfer projects and enhance our research capabilities on behalf of DOE, and to be a resource for US industry, enhancing competitiveness in domestic and international markets. BNL uses the following mechanisms for technology transfer:

- use by industry of Brookhaven's world-class designated user facilities,
- sponsored research,
- cost-shared research projects under Cooperative Research and Development Agreements (CRADAs), and
- intellectual property licensing.

The Laboratory's Office of Economic Development and Technology Transfer is responsible for BNL's patent prosecution and licensing program, the CRADA program, sponsored research with industry, universities, and state and local governments, facility agreements for designated user facilities, the technical assistance program for industry, and the personnel exchange and technology maturation activities.

Brookhaven Science Associates has the right to take title to the technologies invented by Brookhaven employees at the Laboratory and the patents covering them. The following are examples of promising technologies that are available for licensing:

- biological materials and processes, including gene expression systems, DNA-sequencing processes, and recombinant plasmids for encoding restriction enzymes,
- environmental remediation techniques, including materials to encapsulate contaminated wastes,
- radiolabeled monoclonal antibodies for diagnostics and therapeutics, and
- instrumentation for preparing radiotracers for medical research and clinical applications.

Inventions arising from our biotechnology research programs continue to be of special interest to industry. Our strengths in medical imaging, radiopharmaceuticals, nuclear medicine, molecular genetics, genomics, structural biology, and protein engineering continue to produce new technology that is licensed to industry. Technology based on our T-7 gene expression system continues to evolve, with new patents issued and new commercial licenses continuing to be granted. At the beginning of FY00, there are 109 technologies in BSA's Patent Licensing Portfolio; 42% of these technologies are licensed to industry, and 24% of the licensed technologies been commercialized, with new products based on these technologies now on the market. The net revenue generated by the licensing program, which is re-invested in the Laboratory's research programs, continues to increase each year. At the same time, the licensing program continues to be very cost effective, with the costs of patent prosecution, patent maintenance, and licensing being 28% of the gross revenue in FY 98 and 23% in FY 99. (Licensing Information is provided in Appendix C).

Over the past several years, CRADAs have proven to be a valuable component of BNL's research portfolio. These programs enhance BNL's research capabilities and by providing access to industrial expertise and capabilities. Cost-shared CRADAs generated several new technologies and numerous patents, created new commercial products and processes, and demonstrated the societal relevance and public benefit of DOE research.

BNL's participation in CRADAs (Appendix C) is funded primarily by the following three sources:

- DOE's Office of Science-Laboratory Technology Research (LTR) that supports most of BNL's programs,
- DOE Initiative for Proliferation Prevention (IPP) Program for the Newly Independent States of the former Soviet Union, and,

- industrial partners who jointly support BNL-patented technologies for commercialization.

The DOE Office of Science Laboratory Technology Research program supports high-risk, multidisciplinary research partnerships to investigate challenging scientific problems whose solutions have promising commercial potential. BNL's strengths in research on electronics/instrumentation, energy, the environment, and biotechnology underpin our participation in this enterprise.

Future Program: The instrumentation capabilities at BNL are used in two active CRADAs with Long Island companies funded by LTR. In the first, we are working with Symbol Technologies to design, fabricate, and test two novel devices for collecting and transmitting data, an optical photosensor array, and a 2.4 GHz, single chip, frequency agile radio transceiver. The second project with a small Long Island business, Brookhaven Technology Group, is to generate a compact, cost-effective, high-brightness 5 MeV electron gun. Such high-brightness electron beams are needed for high-luminosity electron colliders and efficient short-wavelength Free Electron Lasers.

With two other DOE-LTR-supported CRADAs. The Laboratory participates in a cooperative research program with Oxford Superconducting fabricating new superconducting materials. BNL will contribute significantly to the understanding of the interface structures between the superconducting materials, the buffer layers, and the substrates by employing transmission electron microscopy. This understanding is essential for selecting materials and establishing deposition processes in the manufacture of superconducting wire. BNL also plays an important role in developing advanced batteries. BNL and Gould Electronics are jointly exploring new electrode and cathode materials for rechargeable lithium batteries. The Laboratory established new methods of characterizing in-situ X-ray absorption and X-ray diffraction spectroscopy that are being used to study the relationship between performance and structural characteristics of new battery materials.

LTR-funded CRADAs also leverage DOE's investment in biotechnology research at BNL. BNL and Oncogene Research Products are engaged in cooperative research to develop reagents to detect specific responses to DNA damage; the work is expected to have an important impact on ongoing biomedical research in cell growth and cancer. Oncogene anticipates that this research will lead to techniques for testing the effectiveness of specific cancer therapies. BNL continues its joint research with Diatide to develop and test the application of tin-117m DTPA to treat bone cancer in humans. This CRADA will expand on a successful collaboration between BNL and Diatide that developed tin-117m to palliate pain in bone-cancer patients.

The DOE-LTR program funded several promising environmental technologies over the years. At present, BNL is conducting a research program with PhytoWorks, Inc. to study the basic mechanisms by which plants take up contaminants from sediments contaminated with toxic metals and radionuclides, and ultimately, to explore methods which enhance this update of contaminants.

BNL continues its participation in the AMTEX initiative, which is supported by DOE-BES. The Biology Department conducts research with Cotton, Inc. to understand the basic relationships of structure and function in the cotton plant. We will identify the key genes that influence cotton-fiber traits, such as its length, strength, and thickness, and will seek to modify these genes so that Cotton, Inc. can produce transgenic cotton plants and evaluate the properties of the fiber.

The Initiative for Proliferation Prevention Program for the Newly Independent States (IPP-NIS) supports research partnerships at BNL which take advantage of the research capabilities of established scientific institutions in the NIS and the commercialization expertise of industry. DOE supports the research conducted by BNL and the NIS institute, while our industrial partner supports its own work through a CRADA. BNL is a participant in one IPP-NIS CRADA and it is anticipated that BNL will

initiate five new IPP-NIS CRADAs during the upcoming year. BNL and Radkowsky Thorium Power Corp. currently work with the Kurchatov Institute to develop a new type of fuel for nuclear reactors.

The Laboratory has successfully attracted research funding from industry to support research collaborations. BNL is working with Dow Chemical Company to create environmentally beneficial agricultural plants with novel applications for human health and nutrition. It is anticipated that through this collaboration with Dow, BNL will assist in the development of genetically engineered seed crops that can produce oil to replace conventional fuels and petrochemicals.

BNL identified technology transfer as a potential growth area in the Laboratory's overall R&D portfolio. We will vigorously pursue opportunities to expand research partnerships to support the Laboratory's overall strategic plan and to build on recognized research capabilities and our unique scientific facilities.

The Laboratory's work for non-federal sponsors allows us to carry out research for industry, universities, non-profit sponsors, and state and local government. We anticipate more interactions with the medical-products-and-health community, New York State utilities, the environmental industry, and the electronics industry in our region as a result of our growing relationship with SUNY's Centers for Advanced Technology (Stony Brook biotech and sensors, Albany fuel cells), New York State's Energy Research and Development Agency (NYSERDA), and the Long Island Forum for Technology (LIFT).

The Laboratory will continue expanding the Intellectual Property Licensing Program to effectively foster the marketing of our new technologies. We will explore the possibilities that computer software, originated at BNL, may have market applications and be appropriate for copyrighting and licensing.

5.2.9 Educational Programs (KX)

The DOE Office of Science, in conjunction with other agencies, supports an educational mission at the Laboratory. The mission of the Educational Programs is:

- to enrich the training of the future scientists and engineers, and build the capacity of undergraduate institutions in support DOE's scientific mission,
- to provide educational and career pathways in mathematics, science and engineering for a diverse population of students in undergraduate and precollege institutions,
- to increase science literacy in schools and support the enhancement of teacher preparation in precollege mathematics, science and technology (MST) teaching,
- to provide resources and activities that support the Laboratory's efforts Community Involvement and Public Outreach, and contribute to the Laboratory being regarded as an educational resource and valuable asset to the local and national community.

Present Program: The *Undergraduate Internships* program aims to develop participants' skills in research through BNL staff mentors who provide a first-hand exposure to science and the scientific community. The goal of some activities such as the community college effort is to build the technical workforce and foster diversity. Each summer the Summer Academic Semester Research Appointments and the Community College Institute host over 100 and 25 undergraduates respectively.

Topical Conferences, Workshops or Summer Schools offer educational enrichment in areas where the Laboratory has unique capabilities. These include a Nuclear Chemistry Summer School, Undergradu-

ate Mini-Semesters, and two Summer Institutes for High School Students. These programs provide a foundation for building capacity in the schools through new curricula, distance learning or research collaborations. The research programs at the Laboratory are the basis for each of these activities.

Teacher Enhancement Programs either directly involve secondary teachers in the Laboratory's research program or provide opportunities for teachers to learn basic science principles and participate in activities that relate to those principles. Science enrichment activities engage primary teachers in learning scenarios simulating actual processes related to BNL's research. These are conducted in collaboration with schools of education to help focus outcomes on improved pedagogy. Once a primary DOE focus, these teacher programs are now largely supported by other agencies.

The National Science Foundation is currently sponsoring an MSTe Program in which BNL is a key contributor to an educational reform initiative that will reach over five hundred Kindergarten through sixth grade teachers. In FY 00, DOE offered summer research appointments to undergraduate science education majors through its new Pre-Service Teacher (PST) program. This is a step that BNL has long advocated as a means of adding an important dimension to teacher preparation.

BNL's Educational Outreach and Resource Programs support schools, faculty and teachers by offering student activities or opportunities based on the BNL experience. This was once a major DOE effort but programs have been severely scaled down. Nevertheless, the Laboratory maintains collaborations with more than ten local precollege educational organizations, conducts teacher workshops, offers special student events, and provides technical assistance to school districts, largely through voluntary efforts and cooperation among BNL organizations. These efforts which include the Science and Society Essay Contest, assistance for local schools participating in a national robotics contest, and accredited in-service courses for elementary teachers, reach hundreds of teachers and parents and over one thousand students annually.

5.2.9.1 Education Program Initiatives

Undergraduate Programs will remain a principal focus of DOE-supported activities. Increased funding would allow us to increase student internships during the academic year offer programs supporting student-faculty research teams at major Laboratory facilities, and establish new topical institutes in areas such as materials science to build capacity at participants' home institutions. The long term objective is to establish a Long Island Consortium for Undergraduate Research that would link programs offered by the educational community, the industrial community and the Laboratory thereby providing a research-based training to prepare and retain Long Island's top students for the local high-tech job market.

We hope to expand the Teacher Enhancement Programs with support from DOE and other agencies, and build on the success of the NSF funded MSTe Program. One of the shortages identified by the MSTe program (and confirmed by the experience of teachers at the BNL Science Museum) is a lack of basic science understanding by elementary school teachers. With additional funding, workshops and In-Service courses can be developed and implemented to meet this need, linking the basic science education principles to ongoing BNL research.

In addition to supporting undergraduate and teacher enhancement programs, the expansion of DOE programmatic support for K-12 programs for students will expand the opportunity for students to participate in science at BNL. These programs are currently funded through Laboratory overhead funds, and include programs in the BNL Science Museum, outreach programs to schools and libraries, and tours of BNL facilities for high school groups.

5.3 Energy Resource Mission - Energy Technologies

BNL performs R&D related to the DOE Energy Resource Mission to provide clean sustainable energy. The Laboratory's activities focus on basic and applied research, systems analysis, technology development, and transfer to industry of work and technologies that provide innovative solutions to some of the world's most important energy challenges. On-going projects include non-proliferative nuclear reactor designs, energy/economic modeling computing, energy infrastructure reliability, and energy transmission and storage, including fuel cells and batteries.

The Laboratory's role in the DOE Energy Resource mission is performed primarily under the auspices of DOE Offices of Energy Efficiency, Fossil Energy, and Nuclear Energy, Science and Technology, with some funding from other offices within DOE, such as the Office of Policy. In addition, much of the underlying basic research supporting the Energy Resource mission is sponsored by the DOE Basic Energy Science Program described previously.

The DOE in its April 1998 Comprehensive National Energy Strategy (CNES) outlined the Department's goals and objectives for the nation's energy future. In February 2000, the DOE R&D portfolio analysis identified three main areas that align with the CNES goals. BNL is developing initiatives in the three focus areas: Reliable and Diverse Energy Supply, Clean and Affordable Power, and Efficiency and Productive Energy use.

BNL recently restructured its organization to better support the DOE Energy Resource objectives and to increase the focus on its Energy Resource programs. These programs support three of the four DOE strategic goals, Reliable and Diverse Energy Supply, Clean and Affordable Power, and Efficient and Productive Energy Use.

BNL has several local, national, and international energy R&D partnerships that support continued US leadership in the energy field. This work supports not only the DOE, but also NRC, EPA, New York State, and private industry programs.

5.3.1 Reliable and Diverse Energy Supply (EE, FE)

Present Program: Scientists in BNL's programs on Natural Gas Storage Systems for the DOE Office of Energy Efficiency and Renewable Energy, work with US industry, to demonstrate systems that will lead to significantly reduced costs for production and storage of liquefied natural gas. This includes assessing the production of Liquid Natural Gas from landfills, developing state-of-the-art storage tanks and refueling facilities, designing novel cryogenic fuel delivery systems, and developing strategies for market end-use.

For the DOE Office of Fossil Energy we continue research on biochemical upgrading of oils and other petroleum products. Several bacteria strains have been selected for testing for desulfurization, denitrification, and hydrocarbon redistribution. Additionally, research continues on the use of ultra-low sulfur fuels in home heating.

5.3.1.1 Initiatives

The goal is to ensure reliable, clean, and diverse domestic fuels supplies. The DOE has two new initiatives in this area: the Ultra-Clean Transportation Fuels Initiative and the Bio-Based Products and Bioenergy Initiative. We propose the following initiatives in response to these DOE projects.

Natural Gas to Liquids: Vast natural gas reserves remain unrecovered due to the high cost of access to markets. Catalytic and chemical processing to convert this gas to liquid fuels offers the potential to provide a large resource of ultraclean liquid fuels for use in diesel applications. Over the last decade, BNL has built an international reputation in the area of Liquid Phase Low Temperature (LPLT) methane conversions. Our initiative focuses on developing advanced, nanosized metal catalyst systems for selective hydrocarbon production.

Oil and Gas Processing: The goal of this DOE program is to develop new processing technologies that can produce economic higher-quality end products and handle lower quality feedstocks. BNL is pursuing novel techniques for sulfur removal that builds on our on-going work in bioprocesses for upgrading crude oil.

Hydrogen Systems: Hydrogen is a clean fuel with the potential to replace fossil fuels in every sector of the economy. DOE's interest in hydrogen systems includes research on Proton Exchange Membrane (PEM) fuel cells. BNL is proposing to explore the feasibility of Nuclear Magnetic Resonance (NMR) for in-situ imaging of an operating PEM fuel cell. If successful, this would lead to a tool to aid in designing fuel cells for greater power density and improved component design.

Methane Hydrates: In FY 2000, a DOE began a new initiative to harvest the vast quantities of methane existing as hydrates on the ocean floor and in permafrost. The first phase concentrates on establishing fundamental properties of methane hydrates that will lead to safe production of methane by 2015. BNL has strong expertise in structural studies of clathrate hydrates and will team with other national laboratories to apply our expertise in this area. In addition we will pursue research in areas such as the kinetics of transformation and application of BNL tracer technologies to the safety and stability of methane hydrate production.

5.3.2 Clean and Affordable Power (EE, FE, NE):

Present Program: The Laboratory has several programs that develop next generation options for use of fossil fuels, renewable energy resources and nuclear power. Several of these projects could lead to significant reductions in greenhouse gas emissions. Key projects include fuel cells, thermophotovoltaic power generation, geothermal energy systems, distributed energy systems, and advanced proliferation resistant nuclear fuel cycles. Work includes development of advanced materials required to take advantage of domestic energy supplies, biochemical upgrading to increase available fossil fuel products, and natural gas storage systems.

Technologies for the small-scale co-production of electricity and useful heat are rapidly emerging as alternatives to large-scale central power stations. These systems offer the advantages of high overall efficiencies, reliability, and modularity; they also can be located at or near the source of demand, obviating the need for investment in transmission and distribution facilities. The two leading candidates for mass-market commercialization are fuel cells, which produce electricity and heat through the electrochemical conversion of hydrogen and oxygen to water and micro-turbines, scaled-down versions of the combustion turbines used to power aircraft and to produce peak power for utilities.

The Laboratory participates in a field test of a micro-turbine power generator with KeySpan. We are developing a program proposal to DOE to monitor power quality in the building serviced by the micro-turbine.

Thermophotovoltaics (TPV) is a technology for generating electric power from a hot surface using photocells. BNL is part of an industry team developing a 500-Watt, oil-fired portable generator for

the US Army. BNL also is working with an industry team to develop non-military applications such as hybrid solar/gas-fired TPV cogeneration and self-powered residential heating appliances.

Geothermal materials research continues on corrosion resistant materials and cements for reducing costs associated with the use of geothermal energy. Corrosion testing of NiCrMo alloys, evaluation of coatings and mortars for resistance to sulfur oxidizing bacteria, numerical modeling of remediated wells, and field testing, in collaboration with NREL, have been the focus of our programs this year, and work will continue into next fiscal year.

MARKAL-MACRO is a technology specific, data-rich optimization model that provides least-cost energy system solutions under specified constraints to support policy and planning decisions. MARKAL-MACRO and its associated databases and methods are used to evaluate energy source uses on both environmental and micro/macro economic scales. It can answer specific questions in conjunction with other models, such as air quality dispersion models, and Geographic Information Systems (GIS) representations. Major projects include work with Hong Kong, and a new initiative for the Central American States and Taiwan in which MARKAL-MACRO models for these countries will be used to evaluate Clean Development Mechanisms in support of the Kyoto Protocols. The current primary sponsors of this work are the DOE's Offices of Policy and International Affairs and Nuclear Energy and the EPA Offices of Policy, Planning and Evaluation, Air Quality, and International Activities, and EPA Region 2.

BNL has three projects to develop advanced proliferation resistant nuclear fuel cycles. The Radkowsky Thorium Fuel Project retrofits existing Pressurized Water Reactors, and the Russian variant with minimum changes to existing systems/hardware and operating cycle-lengths, making it economically competitive. Work on this technology includes US industry, major Russian institutes, MIT, and Ben Gurion University. The Laboratory is also developing two other non-proliferation reactor designs under the Nuclear Energy Research Initiative.

5.3.2.1 Initiatives

The DOE goal is to ensure that the electrical generation industry can reliably deliver adequate, affordable supplies with acceptable environmental impacts. DOE has defined two initiatives in this area; the International Clean Energy Initiative and the Energy Grid Reliability Initiative. BNL proposes the following programs in response to these new DOE Initiatives.

Micro-Grids: Distributed power (DP) has the potential for increased reliability and efficiency that result from reduced transmission power losses and the potential to use waste heat. It also offers an avenue for the practical use of renewable technologies, such as photovoltaics and geothermal. However, there are numerous research challenges that must be met before the potential can be realized. BNL is proposing four proof-of-principle innovative projects to address four of these research challenges.

- Standards for Local Interconnected Micro-Grids: BNL has a prototypic experimental facility consisting of demonstration fuel cells, a microturbine, and the local power grid. Over the next two years we will develop a power quality standard based on data collected at this facility.
- Modeling Reliability Management: BNL supports the DOE in energy/economic/environmental (E-3) analyses of technologies that meet national policy goals, such as clean development mechanisms to support the carbon mitigation goals of the Kyoto protocols. BNL currently is developing a reliability technology template that could be incorporated into an analytic tool to assist policy makers in this area.

- Probabilistic Tools to Examine Contingencies: These models can be applied to accommodate correlated failures of system elements. BNL has initiated a one year project to modify probabilistic models developed for nuclear power plants to the prototypic micro-grid that is on-site.
- Improving the Performance of Distributed Energy Technologies: PEM fuel cells are an exciting distributed energy technology. BNL proposes to establish the feasibility of NMR for in-situ imaging of an operating PEM fuel cell. This is a high-risk proposal and BNL is requesting funds in FY-01 to perform a first stage feasibility study to address such questions as the needed spatial resolution. If this analysis is satisfactory, BNL would pursue an experimental demonstration in FY 02 at the BNL NMR imaging facility.

Wind Power: BNL is beginning a new program on materials for wind power applications. Specifically BNL will apply expertise developed in support of geothermal systems to materials problems in wind technology deployment.

Integrated Energy-Economic-Environmental Assessment: BNL, a leader for over two decades in energy assessment and model development, proposes to support initiatives related to the International Clean Energy Initiative through comprehensive energy and environmental assessments related to global change. This initiative builds on work developed at BNL, combined with private-sector contributions, to create a public-private partnership that can address a wide range of analytical options and technical solutions to the issues defined by the public debate on global climate-change, carbon management, and international environmental security planning.

The primary tool is BNL's MARKAL-MACRO. Areas that can be examined include projections of greenhouse-gas emissions under CO_2 constraints, evaluation of emission-reduction options, ranking of technology portfolio options, or specification of the environmental impacts of alternative energy futures for a country or locality.

Nuclear Energy: The DOE Office of Nuclear Energy, Science and Technology (NE), has two major research initiatives that are aligned with BNL core competencies: the Nuclear Energy Research Initiative (NERI), and Nuclear Energy Plant Optimization (NEPO). Under the first NERI competition, BNL received funds for two projects on non-proliferative reactor designs.

NEPO is being developed jointly by DOE and the Electric Power Research Institute to pursue technologies that foster life-extension and optimize electrical generation from existing power plants. This could reduce global carbon emissions by enabling continued operation of existing Light Water Reactors beyond their license period. For the NEPO initiative, we will pursue programs on operational improvement, aging management, and high burn-up fuel.

The DOE Office of Nuclear Energy, Science and Technology in coordination with Office of Nonproliferation and National Security has a major new program on non-proliferative reactors. BNL is participating on an inter-laboratory team for this program, making use of our expertise in non-proliferative light water reactor design.

Secure Energy Infrastructure: BNL is developing a program with Consolidated Edison of New York to examine critical infrastructure issues in the electric grid. This program, in partnership with Sandia National Laboratory, will initially focus on the reliability of power transmission cables.

5.3.3 Efficient and Productive Energy Use (EE)

Present Program: BNL continues its programs to develop more efficient and nonpolluting heating systems as well as improve the distribution and use of energy in buildings. BNL is developing advanced oil burner technologies for home use. Flame quality indicators developed within the program have been licensed and are now available commercially. This program now is developing standards for the ultra-low sulfur fuel for home heating use. The use of ultra-low sulfur fuel will significantly reduce emissions from home heating systems and increase efficiency by reducing fouling in boilers.

BNL also licensed two technologies in this area this year, supported by DOE and developed under CRADAs: an in-situ asbestos material remediation process, and RAPTOR, an improved concrete cutting system based on high-velocity gas gun technology. The asbestos remediation system won an IR 100 award in 1999 and Raptor a Discover Award in 2000.

The Laboratory also is developing battery materials for hybrid and electric vehicles that are not constrained by the availability of advanced cost-effective materials. The emphasis is on cathodes for high-rate lithium ion batteries. The program makes use of the National Synchrotron Light Source to perform in-situ studies of battery materials

5.3.3.1 Initiatives

DOE's goal is to reduce the growth of energy use in transportation, building, and the industrial sectors BNL currently supports the DOE in all three areas, but will seek opportunities to increase our programs in these areas, especially those with a regional benefit.

Smart Cities: BNL is developing a research plan to address the problems of aging infrastructure and the impacts to the cities that rely on that infrastructure. This effort will use information processing, advanced instrumentation, and materials technology to improve safety, security, and efficiency of our cities Smart Cities will include participation by universities, local-, state-, and federal-government authorities, and businesses. We will develop early demonstration projects to establish the efficacy of "self-monitoring" structures and facilities, based on available or prototype measurement techniques and sensing systems Research will focus on development of built-in monitoring and associated intelligence capabilities State of life, need for corrective action, emergency response, preventive maintenance, and environmental threats, will be integrated into forecasting decision-tools for city managers and, eventually, for public communication.

Transportation: A joint research agreement resulted in a proposed five-year program on sustainable transportation and its impact on fuel efficiency and environmental quality. Dialogue also is under way that will lead to a new undergraduate and graduate program in human factors, led by BNL researchers. Our past effort in modeling automobile traffic will be reevaluated for potential collaboration with PNNL and Battelle to support the US Intelligent Transportation Program.

Infrastructure: Over the last decade, federal and local governments identified a growing crisis in the nation's transportation system and other infrastructure systems. The nation's intermodal transportation systems, rail, air and marine, are overused and under-maintained. The associated infrastructure, including bridges, tunnels and utilities, is reaching the end of its design life expectancy. It is in the national interest to aggressively explore new technological solutions to these old problems. In addition, experts at BNL are addressing computer security and support for emergency and first responders.

5.4 National Security Mission (NN, NNSA, EM)

BNL does not have a weapons development mission, rather, BNL scientists work on US domestic and international programs in nonproliferation and national security. The focus areas are the following:

- nuclear safeguards and chemical/biological/nuclear arms control verification and transparency;
- security-related environmental threat reduction,
- Russian fissile materials protection, control and accounting, and
- technical support to the International Atomic Energy Agency on safeguards (Work For Others).

5.4.1 Safeguards and Arms Control Verification and Transparency (NN)

Present Program: BNL perform analyses, conducts research and development, provides technical support to US programs and policymakers, and builds prototype instruments and systems (hardware and software). These activities further US interests in nuclear materials safeguards and security, verification and transparency, nonproliferation of weapons of mass destruction and nuclear security-related infrastructure protection.

Currently we support both the DOE and the IAEA in the implementation of "integrated safeguards systems". This incorporates traditional Nonproliferation Treaty safeguards activities with the new Strengthened Safeguards System, especially the provisions of the Additional Protocol. BNL provides technical input on the Fissile Material Cutoff Treaty (FMCT) to the US negotiators and a technical staff member serves as a "transparency monitor" under the US/Russian Federation Highly-Enriched Uranium Purchase Agreement.

BNL has successfully completed high-resolution gamma ray spectroscopy measurements on US nuclear weapons and components and associated data analyses, technical support to the US/Russian warhead dismantlement transparency initiatives in preparation for START-III, and "red-teaming" and design activities for information barrier concepts used in warhead and SNM transparency instrumentation and systems.

Future Program: During the next two years, BNL will play a more significant role in design, development and testing of nuclear warhead dismantlement transparency systems by collaborating with scientists from relevant Russian institutes. We also expect to participate in the development of advanced nuclear detectors and measurement systems with special capabilities for dealing with US safeguards and arms control requirements, including:

- measurement of the fissile content in spent fuel;
- γ-ray spectrometry at room temperature with resolution to distinguish between plutonium and highly-enriched uranium and other non-strategic radioactive materials, and,
- a neutron imaging system for locating and measuring Special Nuclear Material "holdup" in process lines.

We also will work to reconstitute our R&D and technical support role in US domestic safeguards, for the DOE Office of Safeguards and Security, and with the newly formed Office of Plutonium, Uranium and Special Nuclear Material Inventory.

5.4.2 Environmental Threat Reduction (NN)

Present Program: These activities incorporate environmentally oriented components into nuclear, chemical and biological safeguards, nonproliferation and dismantlement programs. We also work to ensure that the knowledge and skills possessed by former weapons scientists are refocused on civilian activities with an environmental orientation.

In FY 00 under the Arctic Military Environmental Cooperation Program (AMEC) and the Murmansk Initiative, joint funded by DOE, DOD and EPA, BNL is investigating ways to manage nuclear wastes generated by the dismantlement of Russian nuclear-powered, ballistic missile-launching submarines. In addition, we also are working to develop an environmentally oriented program within the DOE/NN Nuclear Cities Initiative, and supporting DOE/HQ-EM and their landlord facilities to ensure they are properly prepared to respond to emergency situations involving safety and safeguard-related activities.

Future Program: We expect an expansion of the Nuclear Cities concept to include regions of Russia where the Northern and Pacific nuclear naval fleets are operating and being decommissioned and dismantled. BNL funding requests start at about $650K in FY 01 for program management and expands to about $5M in FY02 for program implementation. In addition, the scope of the Nuclear Cities program will expand to three new cities and BNL hopes to play a lead role in the overall Environmental Thrust supported by DOE HQ.

5.4.3 Russian Nuclear Materials Protection, Control and Accounting (MPC&A)(NN)

Present Program: Brookhaven has been involved in non-proliferation programs at Russian facilities since 1994. This extremely important program is funded at $150M annually, and expected to increase in the next several years. BNL plays a lead role in the following areas:

- the introduction of technologies for very precise measurements of bulk nuclear materials, both in liquid and solid forms during storage and processing operations;
- the development and implementation of comprehensive physical inventory statistical sampling plans, measurement requirements and performance procedures, and;
- the use of measurement control techniques.

These activities have provided unprecedented access to the largest of the Russian production facilities, including Tomsk-7, Mayak Production Association, Krasnoyarsk-26 and Chelyabinsk-70.

Our activities involve direct interaction and collaboration with Russian technical specialists. BNL maintains a key technical role for a number of projects at Russian facilities in the framework of the MPC&A Program. A very significant recent achievement, fostered by BNL, was the comprehensive physical-inventory at the "Fast Critical Facility" at the Institute of Physics and Power Engineering in Obninsk. BNL is a principal proponent of extending this effort of accounting for weapons-useable materials to all Russian facilities.

BNL also plays a major role in the Nuclear Materials Conversion and Consolidation (MCC) project, which is an important component of the MPC&A program. Currently we have MCC activities at the Luch and Dimitrovgrad facilities. A critical goal for the MCC project is to reduce the number of sites and buildings that contain weapons-useable nuclear material, and to reduce the attractiveness of existing highly enriched uranium by down-blending to low enriched uranium.

BNL leads an evaluation effort to ensure that the most appropriate and sustainable equipment is used in the MPC&A Program in Russia. During FY 2000, BNL identified, researched, and evaluated potential Russian MPC&A equipment vendors who might help Russia sustain the MPC&A upgrades over the long term. A reference catalog of MC&A equipment was published jointly by BNL and a leading Russian institute, and is widely used for selecting destructive and non-destructive assay equipment, measurement capabilities, and methodologies.

For the past year, a BNL scientist has been a member of the "Technical Survey Team" (TST), a group of experts who provide top-level technical review, strategic and program-related advice, and recommendations to DOE/HQ on all aspects (and projects) under the MPC&A Program. In FY 00 a BNL scientist will assume leadership of the TST, which is expected to play an expanding role in influencing the future direction of the multi-year MPC&A activities in Russia.

Future Program: BNL expects to assist the Russians in conducting material balance exercises on some of their very large uranium and plutonium processing operations. This will provide a good assessment of the Materials Control &Accountability upgrades already in place and, more importantly, help the Russians establish a much better accounting and control of operations at these complex facilities.

5.5 Environmental Quality Mission (EM, NP, KP)

Present Program: The Environmental Quality Mission at BNL is dominated by the activities to remediate the site, decontamination and decommissioning of the Brookhaven Graphite Research Reactor, and Waste Management Operations. The DOE Office of Environmental Management supports the remediation programs and the Office of Science Nuclear Physics program provides support for Waste Management Operations (See Section 8).

DOE Office of Biological and Environmental Research does support research programs related to the DOE Environmental Quality Mission. Researchers strive to understand the basic biochemical mechanisms involved in the microbial transformations of organic complexing agents of radionuclides and toxic metals commonly present in DOE wastes. One goal of is to determine how microbes can be used to reduce the concentration of environmental radionuclides and heavy metals. Remediating marine sediments contaminated by radionuclides and toxic metals is a special challenge and basic research on the transformation of heavy metal contaminants in sulfate-reducing sub-surface environments also will continue.

Future Program: We envision advances leading to technologies that will aid in the environmental restoration and long-term management of DOE contaminated sites. Brookhaven has a long history in bioremediation and polymer encapsulation and holds patents in both areas. Strategic objectives include hiring staff to more effectively use BNL's unique research facilities to understand remediation processes and aligning research programs and technologies to be more consistent with sponsors' needs. BNL also has proposed one of their innovative technologies, 3D-contaminant characterization, for use in the Brookhaven Graphite Research Reactor Decommissioning Project. A technology for the in situ treatment of mercury contaminated soils is in development; this technology could effectively be used at several sites in the DOE complex.

5.6 Major DOE Partnerships

Relativistic Heavy Ion Collider (RHIC): RHIC, designed to create and explore a new state of matter, the "quark-gluon plasma" and to be world's highest energy source of polarized proton-proton collisions, represents a major collaborative effort among the US DOE Laboratories, US universities, and

worldwide scientific communities. The four RHIC detectors, BRAHMS, PHENIX, PHOBOS, and STAR, involve more that 986 scientists from five DOE National Laboratories, 40 US universities, and 50 non-US institutions from 19 different countries. Each of the collaborating DOE Labs, as well as many of the US universities and foreign institutions contributed to the design and construction of the detectors and are participating in the experimental program that begins in 2000.

Large Hadron Collider (LHC): Brookhaven plays an important role for United States in the LHC Project and the subsequent scientific program. BNL is the host laboratory for US participation in the ATLAS detector. The Laboratory manages construction of the US contributions to this detector, including the computing infrastructure. BNL will also provide operations management and oversight for all US scientists participating in the ATLAS experiment and will operate the BNL-located Teir-1 Computing Center, positioning US scientists for effective collaboration in the physics research program. BNL collaborates with two other DOE laboratories (ANL and LBNL) and with research teams from about 29 universities in the United States. BNL is also a member of a three-laboratory team (with Fermilab and LBNL) that manages the US contributions to the accelerator part of the LHC Project. BNL will test all the LHC superconducting cable and produce a set of RHIC-type superconducting magnets for the LHC machine lattice. BNL also contributes important expertise to the LHC accelerator physics effort.

Muon Collider/Storage Ring: Three potential technologies are possible successors to the LHC linear electron-positron colliders, muon colliders, and very large hadron colliders. The world's high-energy physics community will vigorously pursue R&D to refine the technical merits of these technologies and to characterize their costs and scientific applicability to the next generation of research in particle and nuclear physics. BNL is a key member of the multi-institution Muon Collider Collaboration, initiated in 1997. The goals of this collaborative effort are to explore the feasibility of a practical multi-TeV collider and a multi-GeV muon storage ring for neutrino physics. Computer calculations and experimental tests of muon collider concepts are a central component of this R&D program. BNL is consolidating the group's efforts in a directed program of exploratory R&D, employing a project management approach. Members of the Muon Collaboration include 9 national laboratories and 17 university research groups.

Spallation Neutron Source (SNS): The spallation Neutron Source is a 1 GeV, 2 MW proton facility that will be built at the Oak Ridge National Laboratory. BNL is a member of a 6 Laboratory consortium (Argonne National Laboratory, Los Alamos National Laboratory, Lawrence Berkley National Laboratory, Oak Ridge National Laboratory, Thomas Jefferson National Accelerator Facility, and Brookhaven National Laboratory) that will construct the world's most powerful accelerator-based neutron source for the DOE Basic Energy Sciences program. BNL's responsibility is the design, construction, and commissioning of the 1 GeV accumulator ring and the beam transports from the linac to the ring and from the ring to the target station.

D0 Collaboration: BNL helped design and build Fermilab's D0 detector and for many years has been part of a key user-group at D0. This very productive research effort continues. The announcement of the discovery of the top quark by the D0 Collaboration, several years ago, is evidence of this productivity; BNL's physicists played a leading role in that very important and successful search. Now BNL is providing new apparatus, the Preshower Detector, to upgrade D0. When the upgrade is complete in 2001, BNL will be a leading participant in a multi-year experimental search for the Higgs boson, and for physics beyond the Standard Model.

Other Collaborations in High Energy and Nuclear Physics: BNL's nuclear physicists are involved in several upcoming experiments at the Thomas Jefferson National Accelerator Facility (TJNAF) and will continue to do so in future years. BNL's nuclear chemists have contributed significantly to solar-neutrino experiments and will continue for the foreseeable future. The successful GALLEX Collaboration recently concluded its program with exciting results on the solar-neutrino puzzle

and BNL researchers now are turning their attention to the Solar Neutrino Observatory (SNO) in Canada where the United States has significant involvement through the DOE Nuclear Physics Division.

Global Climate Change and Carbon Management: BNL participates in the multi-laboratory and university collaborations on global climate change and carbon management protocols. BNL leads the FACE program and has a principal role in the ARM program. We are working closely with Pacific Northwest National Laboratory and Oak Ridge National Laboratory to integrate the various tasks in DOE's climate change response, and to link with the other agency participants from National Oceanographic and Atmospheric Agency, and National Space and Aeronautics Agency. National coordination and integration is essential for developing a unified climate change model as proposed as part of the Strategic Simulation Initiative.

International Nuclear Safety Program: BNL is a member of the national laboratory team headed by Pacific Northwest National Laboratory to ensure the continued safety and orderly shutdown of the Former Soviet State's reactors. The team corrects major safety deficiencies and establishes nuclear safety infrastructures that will be self-sustaining. More than 150 joint projects were initiated at nuclear installations. BNL's focus will continue to be in the areas of training, simulator development, safety system upgrades, fire hazard analysis, and technology transfer.

Initiatives for Proliferation Prevention: BNL is an active participant with the other multi-program laboratories and the Kansas City Plant in the Initiatives for Proliferation Prevention Program. This program develops partnerships with scientists in key institutes in the Newly Independent States of the Former Soviet Union to develop technologies appropriate for commercialization. The program seeks to employ former weapons scientists of the Former Soviet Union in non-weapons related research and commercial activities. BNL has initiated over fifty individual projects that reflect the overall research portfolio of the laboratory. We will expand our existing program by developing additional cooperative research and development agreements with US industry. We will make use of our interactions with LISTNET to engage local software development companies in this program. We will participate in the Nuclear Cities Initiative, which seeks to provide commercial opportunities for the former weapons scientists in the ten closed cities of the Russian Federation.

6.0 Work For Others

6.1 Federal Sponsors

Several of our biomedical programs and facilities operate through partnerships with, and funding support from, other federal agencies or non-federal funding sources. These programs/facilities include our Imaging and Neuroscience Center, the Scanning Transmission Electron Microscope, and the Structural Biology program at the NSLS. This type of partnership and distributed support is important in advancing science and technology in the national interest.

More than 600 biologists from Brookhaven, other national laboratories, universities, and pharmaceutical companies use seven of the NSLS experimental stations to study biological structures by X-ray crystallography. The National Center for Research Resources of the National Institutes of Health granted $1.6 M to help scientists improve X-ray biology facilities at BNL roughly doubling the existing support budget. The grant is the first installment of a five-year, $8.3 M investment in the project. The grant, which started on 1 October 1998, will allow Brookhaven scientists to develop new structural biology methods, equipment, and software for the NSLS. Five of the existing experimental stations are directly involved in this collaborative effort, which will also ensure standardization in approach, hardware, software, techniques, and enhancements to the benefit of all structural biology users.

The five structural biology stations are:

- X-8C - Operated by a Participating Research Team (PRT) comprised of Los Alamos National Laboratory, NRC Canada, UCLA, Hoffman-La Roche, and BNL Biology Department.
- X-12B - Operated by a BNL Biology Department PRT.
- X-12C - Operated by a BNL Biology Department PRT.
- X-25 - Operated by a BNL National Synchrotron Light Source PRT.
- X-26C - Operated by a PRT comprised of Cold Spring Harbor, SUNY Stony Brook, and the BNL Biology Department.

They will be joined by the proposed X-6 PRT which recently became available for redevelopment. It is sited in the first X-ray ring quadrant that has biological support laboratories provided by the NSLS Structural Biology Addition dedicated in April 1995. A majority of structural biology beamlines is located in that area. The intellectual environment, the existing suite of beamlines, and the geography indicate that X-6 is a prime location for another structural biology beamline. Because of the close proximity of the X-5 hutch we need to build the X-6A station first. NIH has provided a grant of $2.6 M to build and equip this station and expects to fund the operation starting in FY2000.

NIH also provides substantial support for biomedical research through grants to individual investigators. Such grants support work at the Imaging and Neuroscience Center, investigations on DNA damage and repair, protein structure and folding, viral proteases and receptors, and the Lyme disease bacterium. With support from NIH, we will collaborate with the Medical Center at the University at Stony Brook for genomic, biochemical, and protein structural analysis of the Lyme disease bacterium and emerging pathogens of regional interest.

The construction and operation of the Booster Applications Facility for NASA (http://bnlstb.bio.bnl.gov/) represents DOE's partnership with NASA to provide extraordinary facilities and capabilities for research on issues of national concern. This initiative is consistent with BNL goal to

provide innovative science and our strategic objective to apply our unique research facilities to issues of human health, and to provide our unique capabilities to assist other national programs.

The NASA and the DOE major goals are the following:

- to use BNL's unique accelerator facilities, such as the Alternating Gradient Synchrotron (AGS) and the Booster, to simulate aspects of the space radiation environment,
- to support investigations of the response of living systems to radiation exposure in space, and
- to promote developments in science and technology that meet NASA's requirements for radiation protection in space.

The Booster Applications Facility will deliver a complete range of high-atomic number, high-energy heavy ion beams with energies from 40 MeV/A to 1500 MeV/A, depending on the particular ion species. The first substantial funding was received in FY 1999 to start constructing the facility. The major emphasis during FY 1999 was directed to completing Title 1 civil construction and initiating Title 2, as well to engineer the beam equipment and the expedite the Tandem upgrade. Construction will continue in FY00.

Brookhaven's capabilities and skills also extend to international work supporting DOE and its sister agencies in transferring technology to friendly nations. Our near-term focus is the former States of the Soviet Union, specifically reactor safety, and decommissioning the nuclear navy. BNL supports the EPA's Office of International Affairs and DOD in several environmental cleanup projects in Kazakstan. Brookhaven's International Safeguards Project Office (ISPO) assists the International Atomic Energy Agency (IAEA) in developing safeguards verification approaches, new measurement and surveillance systems and integrated safeguards approaches incorporating NPT and Additional Protocol Safeguard measures. Our MARKAL-MACRO computer code is being used increasingly by developing nations to help them design energy-efficient infrastructures.

BNL designated growth in our science and technology work for other federal agencies as a goal over the next three to five years. We will accomplish this goal by increased interdisciplinary research collaborations that will expand our ability to address issues of environmental quality, national energy needs, global security, and human health.

We will continue to seek partnerships with the Division of Research Resources and the National Institute of General Medical Sciences (NIGMS) of the NIH to develop facilities for medical research at the NSLS and increase their usefulness to the wider research community. The NIH Division of Research Resources funded work at BNL to support technology development and to increase users' access to a cluster of five protein-crystallography beamlines at the NSLS. The NIGMS also is exploring ways in which their support can increase the efficiency and users' access to these protein-crystallography beamlines. BNL researchers working on these beamlines plan to search for single-nucleotide polymorphisms in human genes that are important for recognizing and repairing DNA damage, starting with the DNA-dependent protein kinase and related genes.

We also will seek increasing support from NASA, NIH, EPA, DOD, and DOT offering our unique user facilities and expertise. For the DOD, we will expand our work on chemical and biological defenses. For NIH, we expect increasing use of our cancer diagnostic and treatment facilities and expertise. For EPA, the Corps of Engineers and the Navy, we are proposing to expand our harbor sediments program in conjunction with the University at Stony Brook and Battelle-Duxbury. We intend to use our expertise in human factors and risk assessment, combustion and cable test facilities, and the Raman LIDAR system for the Department of Transportation, to address aircraft safety and airport security.

While the Nuclear Regulatory Commission (NRC) budget sharply decreased over the past three years, and support for BNL decreased accordingly, we expect funding to continue in certain areas. In the international nuclear-power community, we see potential growth in the use of our technologies, and we intend to exploit this growth area while maintaining our current multi-year programs with the NRC. We also will pursue non-nuclear markets that need the capabilities of our two test facilities, the Combustion Test Facility and the Electric Cable Test Facility (e.g., the chemical and aerospace industries).

6.2 Non-Federal Sponsors

Historically, sponsored research has been an underused component of the Laboratory's Technology Transfer Program; now it is recognized as an opportunity for future growth. BNL will seek to expand its sponsored research with non-federal entities in areas that are relevant to DOE's research missions. BNL has many unique capabilities and facilities not available in the private sector that offer opportunities for sponsored research in environmental sciences, energy technologies, transportation research, and biotechnology.

BNL's atmospheric chemistry and oceanography programs are extensively involved in sponsored research programs; several leverage DOE's investments in atmospheric chemistry. BNL's work for North Carolina State University involves data analyses with a series of diagnostic modeling exercises to understand the photochemical process forming ozone in the Nashville area. We conduct similar research for the Pennsylvania State University by investigating the relationship among conditions leading to high ozone concentrations and increased levels of particulates in the urban polluted environment. Laboratory staff participate in a program sponsored by Science Engineering Associates (SEA) to develop a unique application for a tracer technology developed by BNL for atmospheric studies; this tracer technology reveals leaks in underground containment barriers.

Our oceanography capabilities are the basis for a number of active sponsored research programs. Through the Woods Hole Oceanographic Institution (WHOI), BNL participates in the Global Ocean Ecosystem Dynamics (GLOBEC) program. We have placed moorings and collected data for GLOBEC to establish a fundamental understanding of how the abundance of key marine animal populations varies in space and time. On a local level, we participate in a program sponsored by Suffolk County, using instrumentation developed at BNL to study the relationship between dissolved organic nitrogen and the brown tide blooms in the Peconic Estuary and the Great South Bay. Brown tide has significant environmental and economic consequences on Long Island.

BNL participates in the Long Island R&D Initiative, sponsored by the local utility, KeySpan Energy, to develop new technologies with potential application in the utility industry. Staff use their experience with high-performance polymer cements to recycle boiler ash and other power-plant waste products. Waste materials incorporated into a composite cement are used for rapid-setting patch materials to repair damaged roadways.

BNL conducts important research in advanced oil heat technologies under the sponsorship of the New York State Energy Research and Development Authority (NYSERDA). NYSERDA-sponsored research at BNL includes the development of an advanced oil burner capable of operation at two firing rates, which results in improved efficiency. Another NYSERDA-funded program includes the development of oil and gas heating systems that have improved electric power consumption and that can be operated during periods of power outages. In both of these programs, BNL is working with local small businesses to commercialize these improved heating technologies.

Our biomedical research programs and capabilities are of value to several sponsors. We are conducting a study for KGL, Inc. to assess the DNA-damaging effects of agents applied topically to human

skin. Several such agents, with cosmetic or medical uses, seem to increase sensitivity to ultraviolet-induced sunburn. BNL's research in Positron Emission Tomography (PET) continues to contribute in several studies with New York University Medical Center. PET studies have been extremely effective in monitoring the brain's metabolic functions and providing new insight into treatments for schizophrenia and Alzheimer's disease.

7.0 Management and Operations Systems

Brookhaven National Laboratory is committed to full implementation of Performance Based Management to assure that we can meet the challenges of the future. Those challenges include a changing science and technology environment, increased competition for funds, and the institutionalization of modern, effective management practices and systems. These challenges are being met by a concerted and focused effort to plan our future and manage our assets. We accomplish our goals by continuous alignment of our missions with the DOE missions and national goals, by institutionalizing modern forms of management, and by setting an expectation of "excellence in performance" for every employee.

7.1 Performance Based Management

Under BSA management, the Laboratory operates in a cycle of institutional development through "Performance Based Management (PBM)." This includes is a cyclic process of performance enhancement that can be described succinctly as: "Plan, Do, Check, Change." The planning process provides a set of Critical Outcomes, Objectives, and Performance Measures for the Laboratory. These flow directly from DOE's requirements, expectations, and strategic view. Responsibility for accomplishing these is documented explicitly for each employee through a set of Roles, Responsibilities, Accountabilities, and Authorities (R2A2's), supplemented annually by individual goals. Line supervisors provide an assessment of the work that forms the basis for evaluations, planned modifications, and individual compensation decisions.

Planning: The Laboratory's integrated planning system is a key element of our Performance Based Management approach. The planning basis includes the strategic requirements of the Department of Energy, considers input from the scientific community and our surrounding communities, and maximizes use of the capabilities of the Laboratory. Those planning principles that guide the management of BNL are the following:

- We will fully align our missions, goals, objectives and expectations with those of our customer, the DOE and other sponsors, and our stakeholders.
- We will plan and implement improvements to our infrastructure, both the management systems and processes and the physical plant.
- We will develop our human resources through training, recruitment, incentives and a focus on diversity.
- We will fully integrate the expectations of our many communities into the day to day operations of the Laboratory.

These principles integrate with those used to guide the programmatic planning and are fully supportive of the Laboratory's Critical Outcomes.

At an annual Partners Retreat, BNL, in cooperation with DOE, establishes Critical Outcomes, Objectives, and Performance Measures. The Critical Outcomes and Objectives are the highest strategic results in programs and management improvements that the Laboratory will deliver to the DOE in three to five years. They are chosen to support and advance the DOE missions or to foster needed improvements in management of the Laboratory.

Critical Outcomes: Critical Outcomes and Objectives are drivers for the planning process, and are consistent with the Performance Expectations of the DOE Office of Science. Further, the Critical

Outcome for Science and Technology assures that BNL's R&D programs remain aligned with the DOE missions and goals. The Critical Outcomes and Objectives for FY 2001 are the following:

Science and Technology: BNL will deliver innovative, forefront science and technology aligned with the DOE strategic goals in a safe environmentally sound and efficient manner and will conceive, design, construct and operate world class user facilities.

Objective:

- Quality of Research
- Relevance to DOE Missions
- Facility Construction and Operation
- Research Program Management

Operational Excellence: BNL will conduct all work and operate all facilities with distinction, fully integrated with and supportive of its science, technology and cleanup missions, while being fully protective of its workers, its users, the public and the environment and fully responsive to DOE expectations for ES&H, quality, facility and information management.

Objectives:

- ESH&Q Operational Performance
- Facility Operational Performance
- ESH&Q Management Systems
- Information Infrastructure

Leadership and Management: BNL will be recognized by its users, staff, stakeholders and customers as having the highest quality leaders and staff, being a community asset, good neighbor and valued employer, being an exemplary environmental steward; and supporting its missions with the best business practices.

Objectives:

- Leadership
- Communication and Trust
- Environmental Stewardship
- Business Management

Doing: The next step in Performance Based Management is the assignment to each individual a share of the Critical Outcomes through *Roles, Responsibilities, Accountabilities, and Authorities* (R2A2) documents. The R2A2 ensures that all employees, from the Director down, comprehend all aspects of their position and how it fits into the functions of the Laboratory. The annual goals capture the elements of that employee's performance relevant to the Laboratory's current improvement agenda. Employee performance is evaluated against these goals.

BNL has implemented a Standards Based Management System (SBMS) to provide Laboratory-wide direction and to ensure that current DOE policies and regulations are applied through Laboratory

procedures. SBMS provides staff immediate access to policies, standards of performance, requirements, and procedures governing all the work done at the Laboratory. It documents the processes and systems that implement Integrated Safety Management at BNL.

Checking and Changing: The Critical Outcomes are to cover all work done at the Laboratory. Every organization's work relates to one or more Outcomes. The Performance Based Management System requires that each line organization conduct a Self-Assessment to evaluate organizational performance against relevant Outcomes and provide information to focus future efforts on strengths and opportunities for improvement.

The work of the Laboratory is defined by a series of tasks assigned to organizations within the Laboratory. Some of these tasks are components of formal projects; some are on-going programs, others are work elements such as scientific research that do not lend themselves easily to "projectization." All elements and related information about scope, schedule, and budget are captured in a Laboratory-wide Integrated Information Management System (IIMS). Using project management technology, this system provides a "work breakdown structure" for the Laboratory, and permits tracking progress as work proceeds. IIMS is accessed through the SBMS and encompasses summary activities, logic and links to other improvement activities, and detailed project plans.

Brookhaven National Laboratory is a complex facility with a challenging scientific mission. It encompasses a number of major user facilities, any one of which could stand alone as a significant research institution. Performance Based Management is a tool known to be effective for driving institutional improvement and BSA is committed to full implementation of PBM at BNL.

7.2 Environmental, Safety, Health and Quality Management

BNL has implemented an integrated set of non-overlapping BNL management systems that embody the requirements defined by DOE for Integrated Safety Management (ISM). These systems collectively form the Standards Based Management Systems (SBMS) that are BNL's highest level operating and business processes defining how work is conducted at the Laboratory. These management systems are defined via Management System Descriptions that identify the system's processes, standards of performance, external requirements, and the set of Lab-wide procedures and guidelines (subject areas and manuals) to carry-out the elements of each system. The SBMS also provides policies, standards of performance, Laboratory-wide procedures, and guidelines governing the work that staff performs. These management systems operate in an integrated fashion ensuring that work is accomplished in a safe and environmentally sound manner. These integrated processes achieve "defense in depth" by carefully applying controls tailored to the work being performed. This strategy ensures that all work processes incorporate ES&H considerations into each element of BNL's work as a natural part of conducting it. A principal operating philosophy for this system is to deliver standards and requirements to the workplace with a format and content sufficient to serve the needs of virtually all BNL work. The Laboratory has enhanced the line ownership and accountability for ES&H performance. Managers responsible for the work are expected to understand the hazards, establish appropriate controls before work is started, and ensure appropriate control of all workplace risks. Field deployed ES&H subject matter experts assist line managers in meeting these responsibilities.

7.2.1 Safety, Health and Quality Management

ES&H activities are an integral part of all work at the Laboratory. BNL continues to implement a set of unified ESH and operational Management Systems to ensure that employees work is in responsible manner by carefully applying controls tailored to the work.

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ES&H activities are integrated into work by tools that assist employees in applying the Five Core Functions of Integrated Safety Management (ISM), starting with the initial plans for the work. The Laboratory has enhanced line ownership and accountability for ES&H performance. Managers responsible for the work are expected to understand the hazards, establish appropriate controls before work is started, and ensure appropriate control of all workplace risks. Integrated Safety Management is essential for a comprehensive ES&H Program.

The following activities have been recently conducted to strengthen the application of ISM in all Laboratory work:

- An institutional program for clearly defining Roles, Responsibilities, Accountabilities, and Authorities (R2A2s) has been implemented.
- Improved line self-assessment programs for evaluating ESH, operational, and programmatic performance. The Office of Independent Assessment issued guidance more consistent with the overall principle of self-evaluation and will review the results of this improvement at the close of FY 00 to identify determine if further improvements are necessary, as well as assess the quality of the self assessments from the organizations.
- Established an Independent Oversight office, reporting directly to the Assistant Laboratory Director for ES&H and Quality, to verify that the line Self-Assessment programs meet expectations and to conduct independent studies or investigations upon request.
- Established a formal Price Anderson Amendment Act (PAAA) Program to identify and evaluate noncompliance with nuclear safety rules.
- Replaced the Corrective Action Tracking System with the Action Tracking System to assure that all external evaluations are easily tracked and closed in a timely manner The ATS system for external assessments was implemented in March, 2000.
- Improved and documented the system for prioritizing ES&H and Infrastructure needs.
- Improved work planning for scientific programs and routine work. The Subject Areas 1.3.5 and 1.3.6 covering the application of the Five Core functions to work planning and control for experimental and routine operations were implemented in the first quarter of FY 2000.
- Re-engineered the Radiological Control Program to include a new Laboratory-wide Radiation Control Program, and reorganized radiological services provided to the Laboratory.
- Developed a formal Laboratory-wide lessons-learned program to identify, analyze, and disseminate the findings across organizations.

The overall integration of ES&H into research and operational activities improved significantly under BSA's leadership. BSA has defined three basic areas to ensure the continued effectiveness, efficiency, and sustainability of the ISM.

- Timely development and implementation of priority subject areas identified on the SBMS Subject Area Development Schedule.
- Development and benchmarking of a sustainable ISMS measurement system.
- Developing and implementing cost management tools and processes.

BSA uses a measurement strategy based on management system life cycles. The life cycle of a management system can be viewed through the five fundamental transitional phases.

- Development: documentation of policies and procedures,

- Implementation: policies and procedures are put into use
- Verification: demonstrated wide-spread used and acceptance,
- Behavioral Impacts: change in culture, attitudes, and work habits, and
- Performance results: change in operational performance.

The ISMS measurement approach will be designed to observe these phases and demonstrate the causal relationships between them. The focus will be on measuring Management System performance through robust self-assessments as part of the Laboratory's Integrated Assessment program and using assessment results to continually improve ISM.

A sustainable ISM is well integrated in the business processes of the institution. Integration is strengthened by giving line managers decision authority to purchase the services of ES&H technical expertise necessary to perform organizational work in accordance with the expectations of the Laboratory Director. This will require shifting services that have been traditionally funded through G&A sources to a "purchased service" model. The purchased service model facilitates line ownership of ES&H performance. It also provides an activity- based cost accounting framework that that will help identify and manage ES&H costs.

BNL's Quality Management System established a QA Program Description that describes the way in which BNL meets the requirements of DOE O 414.1 and 10 CFR 830.120. The Quality Program is deployed through multiple Management Systems that directly relate to the topics identified, (e.g., training requirements are integrated into the Training and Qualification Management System). This integrative approach ensures the quality of activities in the everyday operations of the Laboratory, and reinforces the understanding that quality is each individual's responsibility and an essential part of all work activities.

BNL's Quality Program is not sufficiently integrated into the various Management Systems and as a result does not satisfy current requirements of DOEO 414.1 and 10CFR 830.120. A formal project has been initiated to address this. The overall scope of this project is to develop and integrate a Laboratory wide Quality Assurance Program into current management systems. The project plan is designed to achieve full conformance to DOE QA program requirements by December 30, 2000.

7.2.2 Environmental Management

BNL is committed to the prevention of environmental impacts and to the final cleanup of the Laboratory. Our approach for environmental management of Laboratory operations includes three key elements of environmental protection involving management systems, pollution prevention programs and environmental cleanup. In FY00 the Laboratory made significant progress in defining the roles and responsibilities for environmental stewardship at BNL. There were several notable accomplishments.

- Worked with DOE and EPA to fully implement an Environmental Management System that builds upon, and improves existing systems. BNL received certification for the eight organizations in August 2000, BNL will seek certification for the entire Laboratory in FY 01. Full implementation of the EMS is expected to result in significant improvements in the Laboratory's environmental performance.
- Completed environmental evaluations of 130 industrial processes and 1870 experiments, identifying all wastes, emissions and effluents, regulatory requirements and pollution prevention opportunities.
- Strengthened BNL's pollution prevention program.

- Expanded groundwater monitoring of operating facilities and integrated environmental restoration and environmental surveillance monitoring.
- Resolved environmental vulnerabilities identified during the Facility Review Project, assigning priority to those with the potential to impact groundwater quality.
- Developed and implemented an Environmental Compliance Representative Program to provide technical support that meets our commitment to EPA for rigorous review of processes generating waste, and that promotes early integration of environmental compliance and pollution prevention into projects.
- Developed an integrated environmental monitoring database to share information with internal and external stakeholders in a user-friendly, timely manner.

Environmental management at BNL is focused on preventing environmental impacts. We do this through the implementation of our ISO 14001 Environmental Management System (EMS) for all facilities and operations at BNL. Under this internationally recognized program, potential environmental aspects and impacts of Laboratory operations are examined. Specific plans are created for monitoring and mitigation of impacts. Continuous improvement is stressed to lessen or eliminate the environmental impact over time. Through the implementation of an ISO 14001 designed environmental management system, BNL will continue to see reductions in its operational discharges and potential impacts to the environment.

Another key component of environmental management systems at BNL is our multi-media environmental monitoring program. During FY 2000, this program was consolidated in the Environmental Services Division to ensure coordination among program customers and to strengthen the capabilities and comprehensiveness of the Laboratory's environmental monitoring program. The initial focus of the consolidation strategy has been to optimize and integrate the groundwater monitoring program.

Our waste minimization and pollution prevention program is strategically important. It is critical to the future financial and operating success of the Laboratory to avoid waste creation and the production of excess materials that might become waste. The Laboratory's approach is to plan for waste avoidance at the earliest planning stages of an experiment. In this manner, BNL will continuously look for opportunities to drive down the cost of managing wastes and minimize waste-related risks on the environment while continuing to support world class science programs.

Finally, BNL is committed to completing its environmental restoration mission by FY 2006 or sooner. The Laboratory's restoration program is fully engaged in several substantial cleanup projects involving contaminated soils, groundwater, facility decommissioning, and the river environment within and adjacent to the BNL property. We intend to accomplish our cleanup mission goals through the use of sound project management practice, value engineering approaches and innovative contracting strategies.

Examples of progress in the restoration program include the following:

- completed a final Record of Decision for the cleanup of soil contamination at BNL.
- completed construction and commissioning of operations for the first "off-site" treatment system for removing contamination in groundwater located south of the BNL property, which compliments 5 other groundwater treatment systems that are operational within the boundaries of BNL and have treated more than a billion gallons of groundwater to date,
- installed of the groundwater treatment system for tritium plume source control at the High Flux Beam Reactor,

- completed the final Record of Decision for the cleanup of groundwater contamination at BNL and the surrounding areas,
- completed the baseline planning for BGRR Decommissioning Project and three key removal actions leading to the decommissioning and partial dismantlement of the former Graphite Research Reactor complex,
- completed the re-design of a groundwater remedial action plan in support of final Record of Decision for Operable Unit VI,
- completed the Supplemental Sampling Report for Peconic River; an extensive field sampling survey of the Peconic River to determine the presence of plutonium isotopes and other radio-nuclides of key stakeholder interest,
- completed the draft Proposed Remedial Action Plan and Record of Decision for Operable Unit V, Peconic River Cleanup.
- deployed technology deployments for radioactive soil containment technology, groundwater treatment technology, for facility decommissioning, and for waste management and processing/minimization, and
- completed baseline cost reduction proposals forecasting $20 million for the period FY00 to FY06 for the cleanup program.

Concurrent with the environmental restoration program, BNL is actively managing an inventory of excess materials for final disposition. These materials include former experimental apparatus, shielding materials, chemicals, and recyclable metals. A Laboratory-wide inventory of these materials was completed during FY 1999. This inventory, plus other materials identified as part of this program, is being systematically characterized, packaged, and submitted for dispositioning or disposal.

In FY01 and beyond the Laboratory will focus on the following:

- improving the Environmental Management System,
- developing the next generation of Environmental Information Management System to integrate monitoring data for all media,
- improving operational and engineered controls to improve the groundwater protection program, placing emphasis on preventing further insults to groundwater quality,
- continuing to focus on reducing the total project costs for the Environmental Restoration Program,
- achieving or accelerating milestones for remediation,
- ensuring that wastes from current Laboratory activities are managed properly to ensure regulatory compliance and cost efficiency, and
- identifying excess material inventories, characterizing and developing plan for disposal/treatment options to reduce inventories.

To achieve our goal in waste management, we recognize the need to have a consistent funding source for waste management in the Office of Science. This is key to continuing the momentum of program improvements and waste elimination.

As we continually improve our environmental stewardship we will be integrating pollution prevention, waste minimization and resource conservation into all our planning and decision making. We

will adopt cost effective practices that eliminate, minimize or mitigate environmental impacts and we will maintain environmental effluents, emissions and waste as low as possible.

7.3 Communications Management

Recent years have been marked by an emphasis on communicating with the public about environmental concerns, crisis management and site remediation. Over the next three to five years, there will be a renewed importance placed on promoting the Laboratory's extraordinary research capabilities and accomplishments.

This does not signal devaluation in the importance of the Laboratory's environmental communications. Rather, it represents a shift from explaining legacy environmental concerns and proposed solutions, to reporting progress and closeout for legacy environmental issues at Brookhaven Laboratory. Our three-to-five-year goal is to augment confidence and trust in our cleanup efforts and to generate community enthusiasm for major research programs and initiatives.

The Laboratory will:

- continue to familiarize the community with the type and quality of our scientific research,
- generate local pride in Brookhaven as a community asset renowned internationally and contributing to the educational and economic benefit for Long Island,
- seek input from stakeholders on issues of importance to them,
- involve stakeholders and the general public in tours, student visits and similar activities that make Brookhaven science and Brookhaven people familiar, friendly and accessible,
- position Brookhaven as a preferred location to do science by making it attractive to both users and potential employees, and
- work with our DOE colleagues to foster multi-laboratory initiatives and promote the national laboratory system.

While there is substantial agreement that BNL has made important progress in restoring public trust and confidence, the Laboratory will remain very aggressive in its efforts to strengthen this foundation of trust and confidence. BNL will continue and enhance those community programs that have been useful and informative to the public, effective and beneficial to the Laboratory. For example, the museum, education and tour programs brought more than 25,000 students and visitors to the Laboratory in FY99. A visit to BNL increases understanding of the Laboratory's purpose and goals. We will sustain this level of students and visitors and strive to enhance their positive experience.

We also will continue to support programs that reach out to the community, including Discoveries To Go, Magnets To Go, Ambassador Program, Envoy Program, Exhibits, Fairs, Festivals, Speakers' Bureau, and Stakeholder Relations Program.

The Laboratory will place increased emphasis on reinforcing and expanding contacts with key groups and organizations on Long Island emphasizing the following message:

- The Laboratory is a rare scientific resource - an asset to Long Island for its intellectual merit, its economic contributions and its educational valuc.
- The Laboratory acknowledges its environmental problems and is working diligently, in cooperation with stakeholders, to correct them.

- The Laboratory is itself a member and a stakeholder in the community. We participate in mutual aid, blood drives, United Way, etc. We have an abiding commitment to Long Island because we live here, work here and raise our families here.
- The Laboratory is dedicated to proactive pollution prevention, waste minimization, and the reduction or elimination of hazardous waste on site.

The Community Advisory Council (CAC) is a broad-based group formed in 1998 that advises the Director on issues of importance to the community in general, and to the variety of organizations represented on the CAC. The Laboratory provides information on programs of interest, data as requested, facilitation services, administrative support and action-item coordination. The Laboratory will continue to nurture the CAC by supplying support services to the council and, its subcommittee activity.

Both the local community and the public at large have expressed interest in Brookhaven Laboratory's scientific advances and initiatives. To reinforce communications and trust, the Laboratory will continue to shape its science messages to ensure that they are understandable and relevant to the general audience. Our main messages are the following:

- The Laboratory is a unique, world-class user facility offering extraordinary tools to the world of science.
- This multi-purpose installation covers the gamut from the sublime science of quark-gluon theory to the practical technology of a quiet jackhammer.
- Brookhaven has exceptional capabilities in many areas including high-energy and nuclear physics, advanced accelerators, materials and chemical sciences, medical imaging, biotechnology, advanced computing and other important fields.
- Brookhaven's scientists, engineers and technicians are training the next generation to help keep America in the forefront of worldwide research.
- Brookhaven provides a challenging and competitive work environment for scientists, engineers, computer specialists and administrative professionals.
- The Laboratory works with other federal, state, local and private entities to keep America on the frontier of scientific knowledge.

We will prominently feature in our communications RHIC, addiction research, the SNS collaboration, the ATLAS detector, and a collaborative effort with CERN.

In FY01, RHIC will begin to produce important research results and papers. It is expected that the first wave of papers will be introduced at a worldwide conference at BNL tentatively scheduled for January 2001. That conference will generate global attention in the international science press. Preparations for the communications aspects of this event will be similar to those for the RHIC dedication.

Overall, the science news at the Laboratory is less predictable than RHIC and demands that Laboratory communicators remain prepared to deal with communication opportunities on relatively short notice. In FY99, addiction research, Chinese flutes and ribosome research are just three of dozens of science subjects about which the Laboratory has successfully communicated with the science press, the public and employees.

Communications support of lab-wide programs such as ISO certification Integrated Safety Management, Environmental Management System, other initiatives will continue to be a vital function.

7.4 Human Resources and Diversity Management

The Laboratory's Human Resources System supports Performance-Based Management and contributes to achieving the Laboratory's Critical Outcomes, by providing the tools that employees use to define their work and improve the results of their work. This includes making the web based tools more accessible to and usable by employees.

The main vehicle for these tools is the Laboratory's Standards Based Management System (SBMS), which now provides information to guide staff in developing and maintaining employee R2A2s, documents which delineate for each employee their responsibilities and authorities. We will enhance the model R2A2s, which are accessible in SBMS, to integrate more completely and succinctly the requirements of the Laboratory's management systems.

We also will provide additional instructions and guidance for conducting employee performance appraisals and setting individual goals. Laboratory management will extend efforts to improve the quality of performance appraisal and goal planning through training and quality reviews. The implementation of a new Human Resources Information System will provide enhanced capabilities for management decision-making, including the link of employee rewards to performance.

Two major themes that will continue to be emphasized in the Laboratory's critical outcomes are leadership and diversity. Recent leadership programs include the 360^{0} evaluation, succession planning, management training hierarchy and plans, and individual development plans. The programs have shown promise and will be improved to include a wider range of staff and reflect a higher level of integration and thoroughness. Two additional programs recently initiated to enhance leadership include a career development pilot and a scientific career advisory program.

The primary emphasis in diversity is on increasing the representation of women and minorities in the managerial and professional ranks. The Diversity Office reports to Laboratory Director and champions a diversity initiative to promote the hiring of women and underrepresented minorities as post-doctoral Research Associates and Scientific Staff.

We will seek to involve managers more in the Laboratory Diversity goals by assigning accountability through individual managers' goals and heightening management awareness of diversity objectives when positions are open. We also will strive to increase the recruiting sources and retain a greater pool of information on qualified minority applicants.

7.5 Information Management

7.5.1 Information Technology Management

Information Technology Management focuses on supporting the scientific research and advanced technology of the Laboratory by providing a reliable and secure network; a cost-effective, reliable and secure computing/communications infrastructure for administrative computing; and support to scientific programs for unique computing problems. Our goal is to advance Information Technology (IT) at BNL, and to direct IT resources to fully support the Laboratory's mission and goals. To accomplish this site-wide restructuring, BNL has appointed a Chief Information Officer and established an Information Technology Leadership Council (ITLC) to serve as an executive body for major Information Technology issues. The ITLC developed the IT Strategic Plan, which is driven by the goals and objectives of the scientific programs and support operations.

The major objectives for Information Technology Management are the following:

- to assess and improve site-wide computer security,
- to define and develope a scientific computing infrastructure,
- to implement a standardized administrative computing and communications infrastructure,
- to deliver site-wide knowledge management capabilities, and
- to develop and deploy an application implementation strategy for the Laboratory's business systems.

Strategies and organizational ownership for achieving the objectives are documented in the IT Strategic Plan. In FY00, priority was placed on improving the administrative computing infrastructure, in order to further the goal of site-wide standardization. Multiple e-mail servers were replaced by a central Exchange server, and a common interface (Outlook) was installed on the desktops. A remote management framework (Systems Management Server) was piloted, proving the viability of remote desktop access, efficient asset management and software deployment. This was followed by the procurement of an Enterprise Management System (HP Openview) for the site that will enhance the management of the desktop. HP Openview is being deployed via the cooperation of System Administrators across the site, and, along with the extensive re-engineering of desktop support within the Information Technology Division will achieve the *Infrastructure Standardization* objective described in the IT Strategic Plan. In support of this objective the IT Leadership Council drafted a set of guiding principles for the implementation and operation of a standard infrastructure, based on the "Eight Principles of IT" established in FY99 by the Lab Director. In FY01 BNL will continue to implement the IT Strategic Plan to fully serve the needs of the Laboratory.

7.5.2 Cyber Security

The cyber security initiative is of particular importance to the Laboratory. Based on the results of a vulnerability study conducted in 9/99 together with DOE Notice 205.1, Unclassified Cyber Security Program, BNL developed a comprehensive Cyber Security Program Plan (CSPP). This plan includes initiatives already in progress as well as those planned for the future. The CSPP is compliant with DOE requirements and acknowledges the need to provide a secure computing environment as well as ensure the collaborative atmosphere essential for scientific research. The CSPP established a Computer Security Advisory Council to recommend policy and a Computer Security Incident Response Team to deal with prompt, effective response to incidents.

In FY01 BNL will:

- complete the Perimeter Defense Network,
- implement host-based security (including clear text password guidelines, Kerberos evaluation) and authentication services,
- establish a Security Information Management System, including a Threat Assessment Subsystem, Intrusion Detection Subsystem, and a data fusion system for Monitoring Independent Trends to Enhance Network Security,
- conduct a comprehensive vulnerability assessment and analyze the results, and
- develop an application level security strategy.

Processes also were put in place to address the following:

- sustained Laboratory management attention to Cyber Security,
- clear definition of Cyber security roles, responsibilities and authorities for users and system administrations,
- training for users, system administrators and network managers,
- development of cyber security policies and procedures (as well as documentation for the latter) to be applied consistently across the site, and
- formal risk assessment, to evaluate threats that both exploit cyber security vulnerabilities and impact the mission of BNL.

7.5.3 Business Information Management

Business Information Management is vital to effective scientific performance, and to efficient, cost-effective administrative functions. Our goal is to provide state-of-the-art computational resources that meet the business information needs of the research programs including, programming, administrative architecture, process engineering, security and applications architecture, application training, and archiving for major business systems.

The Laboratory implemented several major new administrative information systems, starting with an integrated suite of financial-management software packages purchased from PeopleSoft, Inc. and modified many former business practices to match the products features. By mid FY2000, all existing applications, except Human Resources, Payroll, Labor Cost Distribution, and Travel will be moved from the existing Hewlett-Packard mini-computers to a Windows NT operating environment. By FY2001, these remaining systems will be migrated to the Windows NT platform and a new web-enabled version of PeopleSoft will be implemented. The web client of PeopleSoft will allow for the rollout of many new self-performance functions for PeopleSoft, such as Time Reporting, Benefits Selection and update of Payroll Withholding.

7.5.4 Information Services Management

The strategic goal for Information Services Management is to achieve full electronic management of documentary information, from its initial generation to archival preservation. This will increase the efficiency with which scientific, technical and administrative information is managed and maximize the ease of access and retrieval of information, throughout its life cycle. The Laboratory will be positioned to leverage its knowledge resources by using sophisticated search-engines and electronic information management systems.

Strategies include the evaluation, selection, and pilot implementation of commercial off-the-shelf software systems to deliver enterprise-wide knowledge management capabilities for document management and records management systems. The Laboratory will select and pilot key components of these systems beginning in FY 01.

By the end of FY 00, BNL's vital records program will be well established and a cost effective, offsite records storage center for storage of duplicate copies of vital records will be selected. Procedures for updating vital records will be implemented in FY 01.

7.6 Safeguards and Security Management

The role of the Safeguards and Security System is to support the basic scientific mission of DOE and the Laboratory, through the following objectives:

- to protect DOE's Special Nuclear Materials, Classified Matter and Property against theft, diversion, or destruction,
- to prevent the loss of information or sabotage of programs that could have significant financial impact, and
- to prevent radiological- or toxicological-sabotage that would endanger employees, the public, or the environment.

The Laboratory achieves these objectives through programs such as Operations Security, Technical Surveillance Countermeasures, Classified Computer Security, Communications Security, Material Control & Accountability, Property Protection and On-Site Hazardous Materials Packaging, and Transportation Safety. We also implement preventive programs, such as property-protection access controls, site surveillance, community crime prevention, and Security Education and Awareness.

BNL's Counterintelligence (CI) Program Manager is responsible for program coordination of activities through the DOE Brookhaven Group and the DOE Office of Counterintelligence, Washington, D.C. The CI Manager works closely with BNL's Safeguards and Security personnel and the Operations Security (OPSEC) Working Group, as well as other Federal agencies. The program includes protection of information, foreign travel briefings and debriefings, host debriefings, and interactions with the foreign visits and assignments office. The CI Manager leads the Laboratory's effort to expand and update the list of sensitive technologies.

Information on safeguards and security policies, such as access controls, fraud, waste, abuse, corruption and other criminal offenses, classified information and security requirements, visits and assignments of foreign nationals, computer security, and contractor and subcontractor registration are available through the Standards Based Management System (SBMS). The Security Manual, also available through SBMS, gives employees specific guidance on security matters and procedures.

Safeguards and Security staff interact with BNL's departments and employees to establish guidelines, plans, and strategies to protect sensitive or classified information, export information, Cooperative Research And Development agreements, protocol visits, and Work For Others. Vulnerability Assessments (VA) are done before a visit, such as the IAEA Inspection, where the VA will involve the Departments of Defense and Energy, as well as OPSEC and Counterintelligence personnel.

The Safeguards and Security Enhancements Plan is a long-range plan to ensure security is continuously improved efficiently and cost-effectively. Subject-matter experts annually review the Plan to ensure that the necessary protective measures are planned systematically to identify and prioritize vulnerabilities. The Visitor Reception Center is an important long-range project that would provide a centralized facility where visitors, vendors, contractors, new employees, and the public could obtain information about the Laboratory, receive safety and other training, housing assignments, badges and vehicle registration.

The DOE Brookhaven Group and the DOE Chicago Operations Office review and approve the Safeguards and Security Plan (SSP). The SSP, a classified document, provides a blueprint for a successful safeguards and security program at BNL. In conjunction with the SSP, the Safeguards and Security Management System Description documents how safeguards and security are managed at BNL.

7.7 Site and Facilities Management

The BNL site is approximately 5,320 acres, 30% of the total area is developed. There are about 400 buildings in use with a total area of 4.36 million square feet and a replacement value of approximately $4 billion. Many building date back to World War II and some are older. Most of the major permanent buildings, excluding those constructed for RHIC were constructed in the 1960s. The site is served by site wide utility systems that include electrical, steam, sanitary sewer, storm sewer, and potable water. In addition there are limited distribution systems for chilled water and compressed air. The following summarizes trends for the site and presents the overall site and facility plans. Appendix D provides a more detailed discussion and figures.

7.7.1 Trends

Building and Facilities: Approximately 78% of the buildings are at least 30 years old, 34% are over 50 years old. The cost of maintenance, repair and capital renewal are high, buildings are small, and dispersed across the site. Approximately 120 portable structures were removed over the last five years and the current inventory is 838. Since 1996 BNL has held one lease for a 1000 square foot apartment for a staff member working at a site in North Carolina. The number of contaminated facilities had not changed from 1994 until 2000. Nine buildings, part of the High Flux Beam Reactor complex, were transferred to the DOE Office of Environmental Management following the permanent shut down of the facility. This increased the number of surplus contaminated facilities from 10 to 19. The number of surplus non-contaminated buildings was decreased from 7-6 as a result of a delay in demolishing Bldg. 118 until suitable replacement space is available. There is no clear trend at this time.

Office Space Utilization: Several factors make it difficult to discern a clear trend in office space utilization. Departments and divisions are reorganizing and in the process reviewing their space charges and space utilization. This has driven consolidation. The MEL/FS program recently supported construction of a new building to consolidate applied programs. The demand for user office space is increasing with the onset of RHIC operations, the projected increase in the users at the NSLS and the continued deterioration of the older buildings. Funding in not sufficient to construct new space and demolish older areas, and the trend is renovate older, less efficient areas to provide space that meets the demands. Most support organizations are housed in World War II era buildings.

Utilities: the DOE MEL/FS program has over the years provided significant support to address the utility infrastructure. BNL also has used GPP to address smaller, more localized concerns. In general the utility systems are sound. The primary concerns are the reliability of the electrical distribution system and the need to expand and improve the reliability of the networking system.

Maintenance: Deferred maintenance increased from $50 M in FY 98, to $106 M in FY 99 as the Laboratory identified all sources of deferred maintenance. The decreasing trend in maintenance funds that began in 1995 was curtailed in FY99 as funding levels were returned to their pre-1995 levels.

Energy Management: The site building energy use per square foot for FY 99 was 28% less than the FY85 base year, and resulted in a $3 M saving over energy costs when compared to the base year (FY 85). BNL is well ahead of the DOE goal of 20% savings by FY 00.

General Purpose Facilities Funding: The current backlog of GPP projects is a total of approximately $110M, $62M for ESH projects and $48M for infrastructure projects. This represents an increase of about $70M in the backlog over the last 5 years. Each year the backlog is increased by $10M to $12M as new projects are added. The current backlog of high priority GPP projects is $29M. The backlog is expected to increase faster as BNL accelerates its CAS inspections and as existing facilities continue to

age. The anticipated MEL/FS line item requirements for FY 01 - FY 05 are about $88 M. Based on a 10 year funding level of $5 M - $6M per year, there will be a $60 M backlog by 2005.

7.7.2 Site and Facility Plans

There are many factors that contribute to our site and facilities planning. The first is a set of baseline assumptions that apply to most DOE multipurpose laboratories.

- DOE increasingly competes for program funds.
- User needs continue to grow.
- Information Technology increasingly dominates work-style.
- In-house work is increasingly interdisciplinary.
- Quality of life factors are significant in recruitment.

The second is a set of assumptions specific to the BNL site.

- Past budget constraints have created extended deferrals of capital. renewal/replacement projects and annual maintenance.
- The lack of available space requires the continued use of wood frame buildings, most of which are more than 50 years old.
- User space is inadequate.
- Departments and divisions are dispersed in several buildings lowering their operational efficiency.
- Roofing systems are failing or have failed and need replacement. It will require $1.3 M per year over 30 years to replace roofs. This funding level exceeds current and projected funds, causing backlogs to increase.
- Peak electrical demand will grow by 30% as RHIC becomes fully operational.

The Director has articulated a vision for the Laboratory that includes quality workplaces for users and employees, consolidation of science in theme or focus areas, stronger interdisciplinary interactions, a coherent user experience, modern information technology and an emphasis on openness and community orientation.

The assumptions combined with an overall vision for the Laboratory resulted in the following Site Master Plan guidelines:

- The 50s/60s vintage office/lab building will require major renovations
- Modern warehousing will be required.
- Maintenance service centers will be modernized and consolidated.
- Support groups will be consolidated in fewer (or single) facilities.
- Departments will continue to realign to accommodate DOE missions and needs.
- Additional flexible users space will be required
- Additional flexible experimental, assembly and equipment storage facilities will be required.

The new Site Master Plan which will be available this year, will lay out a plan for the site based on these and other guidelines. Increased levels of GPP and/or MEL/FS Line Items would allow new con-

struction. However, the GPP and MEL/FS levels would need to be increased significantly over a period of years to begin a renovation of the site to meet these guidelines in a reasonable time. Other options such as public-private partnerships need to be evaluated and worked with the DOE.

The proposed above target Applied Science and Technology Building would reduce at least the equivalent amount of 50-year old space, provide modern facilities and allow consolidation of staff to increase operational efficiency. Similarly the above target Research Support Center would reduce back-logs by eliminating renovation of areas with significant Life Safety Code issues, roofing, duct-work and mechanical equipment replacement needs. New larger multi-story buildings would reduce roof area and associated replacement costs, improve energy efficiency, and improve operational efficiency by co-locating staff. And finally, the above target User Science Center will provide better facilities to attract and support users. This type of facility would be more efficient and more conducive to collaborative research. BNL will continue to seek a state partnership for this facility.

The overall plan is to consolidate staff from the 50 year old wooden structures and to modernize the other "permanent" facilities. This will provide the quality of facility need to support continued world class research, at an efficiency level conducive to attracting new and sustaining existing research with facilities that are more easily maintained at an achievable maintenance funding level.

8.0 Resource Projections

The following tables provide the resource projections for the Laboratory for FY 2001 through FY 2005, and show the resources for FY 00 as of April, 2000. The FY 01 budget projection is based on the FY 01 Presidential Budget.

Table 5 - Laboratory Funding Summary
(S In Millions In Budget Authority)

	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
DOE EFFORT	296.7	294.5	302.7	352.1	352.1	352.1	352.1
WORK FOR OTHER THAN DOE	47.4	42.8	50.0	56.3	56.3	56.3	56.3
TOTAL OPERATING	344.1	337.3	352.7	408.4	408.4	408.4	408.4
CAPITAL EQUIPMENT	25.8	32.5	32.0	37.1	37.1	37.1	37.1
PROGRAM CONSTRUCTION(a)	35.8	35.3	54.3	85.3	78.3	51.6	37.6
GENERAL PURPOSE EQUIPMENT(GPE)	2.0	4.0	4.6	6.7	6.7	6.7	6.7
GENERAL PLANT PROJECTS(GPP)	7.4	5.4	6.2	12.9	12.9	12.9	12.9
TOTAL LABORATORY FUNDING	**415.1**	**414.5**	**449.8**	**550.4**	**543.4**	**516.7**	**502.7**

(a) Includes Spallation Neutron Source Construction
* Escalation Factors: FY2001 and FY2002 at 3.0% and 3.5% Respectively
** Constant FY2002 Dollars

Table 6 - Laboratory Personnel Summary
(Personnel In FTE)

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
DIRECT			72				
DOE EFFORT	1371	1219	1307	1426	1426	1426	1426
WORK FOR OTHER THAN DOE	240	264	307	330	330	330	330
TOTAL DIRECT	1611	1483	1614	1756	1756	1756	1756
TOTAL ORGANIZATIONAL BURDEN	165	196	191	190	190	190	190
LABORATORY DIRECTED R&D	26	33	22	16	16	16	16
TOTAL MATERIAL BURDEN	85	89	86	88	88	88	88
DISTRIBUTED/ALLOCATED SERVICES	597	378	76	591	591	591	591
TOTAL INDIRECT	531	799	582	590	590	590	590
TOTAL LABORATORY PERSONNEL	**3015**	**2978**	**3088**	**3231**	**3231**	**3231**	**3231**

Table 7 - Funding By Assistant Secretarial Office
(S In Millions In Budget Authority)

DEPARTMENT OF ENERGY PROGRAMS	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
OFFICE OF SCIENCE							
OPERATING	237.7	229.7	230.6	270.2	270.2	270.2	270.2
CAPITAL EQUIPMENT	25.6	32.5	32.0	37.1	37.1	37.1	37.1
GENERAL PURPOSE EQUIPMENT	2.0	4.0	4.6	6.7	6.7	6.7	6.7
GENERAL PLANT PROJECTS	7.4	5.4	6.2	12.9	12.9	12.9	12.9
CONSTRUCTION	20.7	9.5	11.1	29.7	45.5	35.7	36.0
TOTAL	**293.4**	**281.1**	**284.5**	**356.6**	**372.4**	**362.6**	**362.9**
CONSERVATION & RENEWABLE ENERGY							
TOTAL - OPERATING	**2.7**	**3.9**	**3.7**	**5.0**	**5.0**	**5.0**	**5.0**
ENVIRONMENT, SAFETY & HEALTH							
TOTAL - OPERATING	**0.7**	**0.4**	**0.3**	**0.5**	**0.5**	**0.5**	**0.5**
		72.0					
NONPROLIFERATION AND NATIONAL SECURITY							
TOTAL - OPERATING	**21.0**	**24.9**	**25.1**	**30.9**	**30.9**	**30.9**	**30.9**
DEFENSE PROGRAMS							
TOTAL - OPERATING	**1.1**	**0.4**	**0.0**	**0.4**	**0.4**	**0.4**	**0.4**
ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT							
OPERATING	29.8	30.9	28.4	27.2	27.2	27.2	27.2
CAPITAL EQUIPMENT	0.2	0.1	0.0	0.0	0.0	0.0	0.0
TOTAL	**30.0**	**31.0**	**28.4**	**27.2**	**27.2**	**27.2**	**27.2**
FOSSIL ENERGY							
TOTAL - OPERATING	**0.6**	**0.5**	**0.2**	**0.4**	**0.4**	**0.4**	**0.4**
OFFICE OF NUCLEAR ENERGY							
OPERATING	1.9	2.8	3.3	4.1	4.1	4.1	4.1
CONSTRUCTION	0.0	0.0	0.0	18.7	11.1	3.5	1.6
TOTAL	**1.9**	**2.8**	**3.3**	**22.8**	**15.2**	**7.6**	**5.7**
OFFICE OF POLICY, PLANNING, AND ANALYSIS							
TOTAL - OPERATING	**0.1**	**0.1**	**0.0**	**0.2**	**0.2**	**0.2**	**0.2**
OFFICE, SECURITY & EMERGENCY MANAGEMENT							
TOTAL - OPERATING	**0.6**	**0.6**	**10.7**	**12.8**	**12.8**	**12.8**	**12.8**
OFFICE OF CHIEF FINANCIAL OFFICER							
TOTAL - OPERATING	**0.2**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
OFFICE OF COUNTER INTELLIGENCE							
TOTAL -OPERATING	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**

Table 7 - Funding By Assistant Secretarial Office
(S In Millions In Budget Authority)

DEPARTMENT OF ENERGY PROGRAMS	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
TOTALS-DOE PROGRAMS							
OPERATING	296.7	294.5	302.7	352.1	352.1	352.1	352.1
INVENTORIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	25.8	32.5	32.0	37.1	37.1	37.1	37.1
PROGRAM CONSTRUCTION	20.7	9.5	11.1	48.4	56.6	39.2	37.6
GENERAL PURPOSE EQUIPMENT	2.0	4.0	4.6	6.7	6.7	6.7	6.7
GENERAL PLANT PROJECTS	7.4	5.4	6.2	12.9	12.9	12.9	12.9
TOTAL	**352.6**	**345.8**	**356.6**	**457.2**	**465.4**	**448.0**	**446.4**

* ESCALATION FACTORS: FY2001 AND FY2002 AT 3.0% AND 3.5% RESPECTIVELY
** CONSTANT FY2002 DOLLARS

Table 8 - Work For Other Than DOE (S In Millions In Budget Authority)	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
NUCLEAR REGULATORY COMMISSION							
TOTAL - OPERATING	**7.1**	**6.9**	**8.3**	**8.8**	**8.8**	**8.8**	**8.8**
DEPARTMENT OF DEFENSE							
TOTAL - OPERATING	**1.3**	**1.1**	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION							
OPERATING	1.4	3.8	3.0	4.1	4.1	4.1	4.1
CONSTRUCTION - BOOSTER APPL. FACILITY	3.5	8.6	12.5	5.2	0.0	0.0	0.0
TOTAL	**4.9**	**12.4**	**15.5**	**9.3**	**4.1**	**4.1**	**4.1**
DEPARTMENT OF STATE							
TOTAL - OPERATING	**5.2**	**5.0**	**6.2**	**6.3**	**6.3**	**6.3**	**6.3**
NATIONAL SCIENCE FOUNDATION							
TOTAL - OPERATING	**0.8**	**0.0**	**0.0**	**8.1**	**8.1**	**8.1**	**8.1**
DEPARTMENT OF HEALTH AND HUMAN SERVICES							
TOTAL - OPERATING	**15.6**	**8.8**	**13.1**	**9.8**	**9.8**	**9.8**	**9.8**
ENVIRONMENTAL PROTECTION AGENCY							
TOTAL - OPERATING	**3.0**	**2.3**	**3.4**	**3.2**	**3.2**	**3.2**	**3.2**
OTHER FEDERAL AGENCIES							
TOTAL - OPEARTING	**1.5**	**1.0**	**1.2**	**1.3**	**1.3**	**1.3**	**1.3**
OTHER DOE LABS							
OPERATING	7.5	5.5	5.1	4.9	4.9	4.9	4.9
CONSTRUCTION - SNS	11.6	17.2	30.7	31.7	21.7	12.4	0.0
TOTAL FUNDING	**19.1**	**22.7**	**35.8**	**36.6**	**26.6**	**17.3**	**4.9**
ALL OTHERS							
TOTAL OPERATING	**4.0**	**8.5**	**8.4**	**8.5**	**8.5**	**8.5**	**8.5**
TOTALS-WORK FOR OTHER THAN DOE							
OPERATING	47.4	42.8	50.0	56.3	56.3	56.3	56.3
CONSTRUCTION	15.1	25.8	43.2	36.9	21.7	12.4	0.0
TOTAL	**62.5**	**68.6**	**93.2**	**93.2**	**78.0**	**68.7**	**56.3**
LABORATORY TOTALS INCLUDING WORK FOR OTHERS							
OPERATING	344.1	337.3	352.7	408.4	408.4	408.4	408.4
INVENTORIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	25.8	32.5	32.0	37.1	37.1	37.1	37.1
PROGRAM CONSTRUCTION	35.8	35.3	54.3	85.3	78.3	51.6	37.6
GENERAL PURPOSE EQUIPMENT (GPE)	2.0	4.0	4.6	6.7	6.7	6.7	6.7
GENERAL PLANT PROJECTS (GPP)	7.4	5.4	6.2	12.9	12.9	12.9	12.9
TOTAL	**415.1**	**414.5**	**449.8**	**550.4**	**543.4**	**516.7**	**502.7**

* ESCALATION FACTORS: FY2001 AND FY2002 AT 3.0% AND 3.5% RESPECTIVELY ** CONSTANT FY2002 DOLLARS

Table 9 - Laboratory Personnel Summary (Personnel In FTE)	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
DEPARTMENT OF ENERGY PROGRAMS							
OFFICE OF SCIENCE	1220	1060	1100	1203	1203	1203	1203
CONSERVATION & RENEWABLE ENERGY	18	16	16	17	17	17	17
ENVIRONMENT, SAFETY & HEALTH	5	2	2	2	2	2	2
NUCLEAR ENERGY	7	11	11	11	11	11	11
NONPROLIFERATION AND NATIONAL SECURITY	35	29	35	39	39	39	39
OFFICE OF COUNTER INTELLIGENCE	1	2	3	3	3	3	3
DEFENSE PROGRAMS	4	2	0	1	1	1	1
ENVIRONMNTL RESTORATION & WASTE MGMT.	74	89	58	61	61	61	61
FOSSIL ENERGY	2	3	2	3	3	3	3
OFFICE, POLICY, PLANNING, AND ANALYSIS	1	0	0	1	1	1	1
OFFICE OF SECURITY & EMERGENCY OPERATION	2	4	80	85	85	85	85
OFFICE OF CHIEF FINANCIAL OFFICER	2	1	0	0	0	0	0
TOTAL DOE PROGRAMS	**1371**	**1219**	**1307**	**1426**	**1426**	**1426**	**1426**
WORK FOR OTHER THAN DOE							
NUCLEAR REGULATORY COMMISSION	29	31	34	35	35	35	35
DEPARTMENT OF DEFENSE	4	2	5	6	6	6	6
DEPARTMENT OF STATE	7	8	8	8	8	8	8
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	12	29	39	38	38	38	38
DEPARTMENT OF HEALTH AND HUMAN SERVICES	28	36	36	36	36	36	36
NATIONAL SCIENCE FOUNDATION	0	0	0	32	32	32	32
ENVIRONMENTAL PROTECTION AGENCY	4	4	4	4	4	4	4
OTHER FEDERAL AGENCIES	12	2	7	8	8	8	8
OTHER DOE LABS	83	105	110	109	109	109	109
ALL OTHERS	61	47	64	54	54	54	54
TOTAL WORK FOR OTHER THAN DOE	240	264	307	330	330	330	330

Table 9 - Laboratory Personnel Summary (Personnel In FTE)	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005
TOTAL LABORATORY-DIRECT	1611	1483	1614	1756	1756	1756	1756
TOTAL ORGANIZATIONAL BURDEN	165	196	191	190	190	190	190
LABORATORY DIRECTED R&D	26	33	22	16	16	16	16
TOTAL MATERIAL BURDEN	85	89	86	88	88	88	88
DISTRIBUTED/ALLOCATED SERVICES	597	378	593	591	591	591	591
TOTAL INDIRECT	531	799	582	590	590	590	590
TOTAL LABORATORY-PERSONNEL	3015	2978	3088	3231	3231	3231	3231

Table 10 - Funding By Assistant Secretarial Level Office (In Millions In Budget Authority)	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
DEPARTMENT OF ENERGY PROGRAMS							
OFFICE OF SCIENCE PROGRAMS							
KA-05 FACILITY OPERATIONS							
OPERATING	35.5	6.5	8.0	8.2	8.2	8.2	8.2
CHANGES IN INVENTORIES							
CAPITAL EQUIPMENT	10.1	15.3	13.2	11.8	11.8	11.8	11.8
GENERAL PURPOSE EQUIPMENT)	2.0						
GENERAL PLANT PROJECTS	7.4						
CONSTRUCTION (AIP)				0.6	0.6	0.6	0.6
TOTAL FUNDING	**55.0**	**21.8**	**21.2**	**20.6**	**20.6**	**20.6**	**20.6**
DIRECT PERSONNEL	**196**	**72**	**89**	**90**	**90**	**90**	**90**
KA-04 RESEARCH AND TECHNOLOGY							
OPERATING	14.5	17.5	15.5	23.0	23.0	23.0	23.0
CAPITAL EQUIPMENT	0.0	0.0	0.0	0.2	0.2	0.2	0.2
TOTAL FUNDING	**14.5**	**17.5**	**15.5**	**23.2**	**23.2**	**23.2**	**23.2**
DIRECT PERSONNEL	**71**	**76**	**79**	**98**	**98**	**98**	**98**
KA HIGH ENERGY PHYSICS							
OPERATING	50.0	24.0	23.5	31.2	31.2	31.2	31.2
CAPITAL EQUIPMENT	10.1	15.3	13.2	12.0	12.0	12.0	12.0
GENERAL PURPOSE EQUIPMENT	2.0	0.0	0.0	0.0	0.0	0.0	0.0
GENERAL PLANT PROJECTS	7.4	0.0	0.0	0.0	0.0	0.0	0.0
CONSTRUCTION (AIP)	0.0	0.0	0.0	0.6	0.6	0.6	0.6
TOTAL FUNDING	**69.5**	**39.3**	**36.7**	**43.8**	**43.8**	**43.8**	**43.8**
DIRECT PERSONNEL	**267**	**148**	**168**	**188**	**188**	**188**	**188**
KB-01 MEDIUM ENERGY PHYSICS							
OPERATING	2.8	2.6	4.8	5.6	5.6	5.6	5.6
CAPITAL EQUIPMENT	0.4	0.1	0.3	2.0	2.0	2.0	2.0
TOTAL FUNDING	**3.2**	**2.7**	**5.1**	**7.6**	**7.6**	**7.6**	**7.6**
DIRECT PERSONNEL	**16**	**15**	**23**	**26**	**26**	**26**	**26**
KB-02 HEAVY ION PHYSICS							
PHYSICS RESEARCH	6.9	6.0	6.3	8.8	8.8	8.8	8.8
FACILITY OPERATIONS							
AGS/TVDG OPERATIONS	5.8						
	24.9	74.2	81.5	88.0	88.0	88.0	88.0
RHIC PRE-OPS/ INVENTORY	35.9	40.0					
RHIC EXPERIMENTAL SUPPORT	8.1	25.2	24.5	29.7	29.7	29.7	29.7
TOTAL FACILITY OPERATIONS	74.7	99.4	106.0	117.7	117.7	117.7	117.7
TOTAL OPERATING	**81.6**	**105.4**	**112.3**	**126.5**	**126.5**	**126.5**	**126.5**

Table 10 - Funding By Assistant Secretarial Level Office (In Millions In Budget Authority)	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
OFFICE OF SCIENCE							
KB-02 HEAVY ION PHYSICS (CON'T)							
CAPITAL EQUIPMENT							
ADDITIONAL EXPERIMENTAL EQUIPMENT	10.0	7.3	6.0	1.7	1.7	1.7	1.7
RHIC OPERATIONS-EQUIPMENT		0.3					
RHIC EXPERIMENTAL SUPPORT-EQUIPMENT		2.4	4.8	9.3	9.3	9.3	9.3
GENERAL PURPOSE EQUIPMENT		4.0	4.6	6.7	6.7	6.7	6.7
OTHER PROGRAMMATIC	0.4	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL CAPITAL	**10.4**	**14.0**	**15.4**	**17.7**	**17.7**	**17.7**	**17.7**
GENERAL PLANT PROJECTS		5.4	6.2	12.9	12.9	12.9	12.9
CONSTRUCTION (AIP)	1.3	1.3	2.4	5.6	5.6	5.6	5.6
CONSTRUCTION (RHIC) (a)	16.6						
USER RESEARCH CENTER (b)				10.0	9.6		
TOTAL CONSTRUCTION	**17.9**	**6.7**	**8.6**	**28.5**	**28.1**	**18.5**	**18.5**
TOTAL FUNDING	**109.9**	**126.0**	**136.3**	**172.7**	**172.3**	**162.7**	**162.7**
DIRECT PERSONNEL	**490**	**475**	**505**	**514**	**514**	**514**	**514**
KB-03 NUCLEAR THEORY							
TOTAL OPERATING	**1.0**	**3.8**	**1.4**	**2.0**	**2.0**	**2.0**	**2.0**
DIRECT PERSONNEL	**6**	**19**	**8**	**12**	**12**	**12**	**12**
KB-04 LOW ENERGY PHYSICS							
OPERATING	3.1	0.7	3.3	3.8	3.8	3.8	3.8
CAPITAL EQUIPMENT	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL FUNDING	**3.2**	**0.8**	**3.4**	**3.9**	**3.9**	**3.9**	**3.9**
DIRECT PERSONNEL	**13**	**3**	**17**	**19**	**19**	**19**	**19**
KB NUCLEAR PHYSICS							
OPERATING	88.5	112.5	121.8	137.9	137.9	137.9	137.9
CAPITAL EQUIPMENT	10.9	14.1	15.8	19.8	19.8	19.8	19.8
CONSTRUCTION							
GENERAL PLANT PROJECTS	0.0	5.4	6.2	12.9	12.9	12.9	12.9
CONSTRUCTION (AIP)	1.3	1.3	2.4	5.6	5.6	5.6	5.6
RHIC (a)	16.6						
USER RESEARCH CENTER (b)				10.0	9.6		
TOTAL CONSTRUCTION	17.9	6.7	8.6	28.5	28.1	18.5	18.5
TOTAL FUNDING	**117.3**	**133.2**	**146.2**	**186.2**	**185.8**	**176.2**	**176.2**
DIRECT PERSONNEL	**525**	**512**	**553**	**571**	**571**	**571**	**571**

(a) FUNDED (b) PROPOSED

* ESCALATION FACTORS: FY2000 AND FY2001 AT 3.6% AND 3.0% RESPECTIVELY

** CONSTANT FY2001 DOLLARS

Table 10 - Funding By Assistant Secretarial Level Office (In Millions In Budget Authority)	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
OFFICE OF SCIENCE							
KC-02 MATERIALS SCIENCES							
OPERATING (RESEARCH)	11.2	10.8	9.6	11.1	11.1	11.1	11.1
NSLS OPERATIONS	20.5	20.4	21.6	29.7	29.7	29.7	29.7
HFBR OPERATIONS	21.9	19.4	17.5	10.9	10.9	10.9	10.9
TOTAL OPERATING	53.6	50.6	48.7	51.7	51.7	51.7	51.7
CAPITAL EQUIPMENT	3.1	3.0	5.6	6.0	6.0	6.0	6.0
CONSTRUCTION (ARAM)	1.5	1.3	2.0	2.0	2.0	2.0	2.0
TOTAL FUNDING	**58.2**	**54.9**	**56.3**	**59.7**	**59.7**	**59.7**	**59.7**
DIRECT PERSONNEL	**274**	**255**	**251**	**272**	**272**	**272**	**272**
KC-03 CHEMICAL SCIENCES							
OPERATING (RESEARCH)	9.9	9.6	9.4	12.1	12.1	12.1	12.1
NSLS OPERATIONS	7.6	7.6	7.7	8.2	8.2	8.2	8.2
TOTAL OPERATING	17.5	17.2	17.1	20.3	20.3	20.3	20.3
CAPITAL EQUIPMENT	1.8	1.5	1.5	2.8	2.8	2.8	2.8
TOTAL FUNDING	**19.3**	**18.7**	**18.6**	**23.1**	**23.1**	**23.1**	**23.1**
DIRECT PERSONNEL	**37**	**37**	**36**	**49**	**49**	**49**	**49**
KC-04 ENGINEERING AND GEOSCIENCES							
OPERATING	0.6	1.0	0.4	0.5	0.5	0.5	0.5
CAPITAL EQUIPMENT	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL FUNDING	**0.7**	**1.1**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**
DIRECT PERSONNEL	**3**	**2**	**2**	**2**	**2**	**2**	**2**
KC-06 ENERGY BIOSCIENCES							
OPERATING	1.2	1.5	1.1	1.1	1.1	1.1	1.1
CAPITAL EQUIPMENT	0.0	0.1	0.1	0.1	0.1	0.1	0.1
TOTAL FUNDING	**1.2**	**1.6**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
DIRECT PERSONNEL	**5**	**5**	**4**	**5**	**5**	**5**	**5**
KC BASIC ENERGY SCIENCES							
OPERATING (RESEARCH)	22.9	22.9	20.5	24.8	24.8	24.8	24.8
NSLS OPERATIONS	28.1	28.0	29.3	37.9	37.9	37.9	37.9
HFBR OPERATIONS	21.9	19.4	17.5	10.9	10.9	10.9	10.9
TOTAL OPERATING	72.9	70.3	67.3	73.6	73.6	73.6	73.6
CAPITAL EQUIPMENT	5.0	4.7	7.3	9.0	9.0	9.0	9.0
CONSTRUCTION (ARAM)	1.5	1.3	2.0	2.0	2.0	2.0	2.0
TOTAL FUNDING	**79.4**	**76.3**	**76.6**	**84.6**	**84.6**	**84.6**	**84.6**
DIRECT PERSONNEL	**319**	**299**	**293**	**328**	**328**	**328**	**328**

(a) FUNDED (b) PROPOSED

* ESCALATION FACTORS: FY2000 AND FY2001 AT 3.6% AND 3.0% RESPECTIVELY

** CONSTANT FY2001 DOLLARS

Table 10 - Funding By Assistant Secretarial Level Office (In Millions In Budget Authority)	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
OFFICE OF SCIENCE							
KG MULTIPROGRAM ENERGY LABS							
TOTAL CONSTRUCTION	**1.3**	**6.9**	**6.7**	**11.5**	**27.7**	**27.5**	**27.8**
TOTAL FUNDING	**1.3**	**6.9**	**6.7**	**11.5**	**27.7**	**27.5**	**27.8**
DIRECT PERSONNEL	**0**	**0**	**6**	**4**	**4**	**4**	**4**
KP BIOLOGICAL & ENVIRONMENTAL RESEARCH							
OPERATING	23.8	20.2	15.9	23.6	23.6	23.6	23.6
CAPITAL EQUIPMENT	-0.4	2.3	0.3	3.0	3.0	3.0	3.0
TOTAL FUNDING	**23.4**	**22.5**	**16.2**	**26.6**	**26.6**	**26.6**	**26.6**
DIRECT PERSONNEL	**97**	**91**	**73**	**108**	**108**	**108**	**108**
KJ COMP. AND TECH. RESEARCH							
TOTAL FUNDING	**2.1**	**2.1**	**1.5**	**3.3**	**3.3**	**3.3**	**3.3**
DIRECT PERSONNEL	**12**	**10**	**7**	**4**	**4**	**4**	**4**
KX UNIVERSITY AND SCIENCE EDUCATION							
TOTAL FUNDING	**0.4**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**	**0.6**
DIRECT PERSONNEL	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTALS-OFFICE OF SCIENCE							
TOTAL OPERATING	237.7	229.7	230.6	270.2	270.2	270.2	270.2
CAPITAL EQUIPMENT	25.6	32.5	32.0	37.1	37.1	37.1	37.1
GENERAL PURPOSE EQUIPMENT	2.0	4.0	4.6	6.7	6.7	6.7	6.7
GENERAL PLANT PROJECTS	7.4	5.4	6.2	12.9	12.9	12.9	12.9
CONSTRUCTION	20.7	9.5	11.1	29.7	45.5	35.7	36.0
TOTAL FUNDING	**293.4**	**281.2**	**284.5**	**356.6**	**372.4**	**362.6**	**362.9**
DIRECT PERSONNEL	**1220**	**1060**	**1100**	**1203**	**1203**	**1203**	**1203**

* ESCALATION FACTORS: FY2001 AND FY2002 AT 3.0% AND 3.5% RESPECTIVELY
** CONSTANT FY2002 DOLLARS

Table 10 - Funding By Assistant Secretarial Level Office
(In Millions In Budget Authority)

	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
OTHER DOE PROGRAMS							
CONSERVATION & RENEWABLE ENERGY							
EB SOLAR AND RENEWABLE RES. TECHNOLOGIES							
TOTAL OPERATING	2.2	1.7	1.7	1.8	1.8	1.8	1.8
DIRECT PERSONNEL	9	8	7	7	7	7	7
EC BUILDINGS AND COMMUNITY SYSTEMS							
TOTAL OPERATING	0.8	1.2	1.0	1.8	1.8	1.8	1.8
DIRECT PERSONNEL	5	4	5	6	6	6	6
EE TRANSPORTATION							
TOTAL OPERATING	(0.3)	1.0	1.0	1.4	1.4	1.4	1.4
DIRECT PERSONNEL	4	4	4	4	4	4	4
TOTALS-CONSERVATION & RENEWABLE ENERGY							
TOTAL OPERATING	2.7	3.9	3.7	5.0	5.0	5.0	5.0
DIRECT PERSONNEL	18	16	16	17	17	17	17
ENVIRONMENT, SAFETY & HEALTH							
HC ENVIRONMENT ,SAFETY AND HEALTH (NON-DEFENSE)							
TOTAL OPERATING	0.5	0.2	0.1	0.4	0.4	0.4	0.4
DIRECT PERSONNEL	3	1	1	1	1	1	1
HD ENVIRONMENT, SAFETY AND HEALTH (DEFENSE)							
OPERATING	0.2	0.2	0.2	0.1	0.1	0.1	0.1
DIRECT PERSONNEL	2	1	1	1	1	1	1
TOTALS-ENVIRONMENT, SAFETY, AND HEALTH							
OPERATING	0.7	0.4	0.3	0.5	0.5	0.5	0.5
DIRECT PERSONNEL	5	2	2	2	2	2	2
NONPROLIFERATION AND NATIONAL SECURITY							
GC VERIFICATION RESEARCH AND DEVELOPMENT							
OPERATING	1.0	1.0	1.0	4.6	4.6	4.6	4.6
DIRECT PERSONNEL	7	5	6	8	8	8	8

Table 10 - Funding By Assistant Secretarial Level Office (In Millions In Budget Authority)	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
OTHER DOE PROGRAM							
NON PROLIFERATION AND NATIONAL SECURITY (CON'T)							
GJ ARMS CONTROL AND NONPROLIFERATION							
OPERATING	20.0	23.8	24.1	26.2	26.2	26.2	26.2
DIRECT PERSONNEL	28	24	28	30	30	30	30
VM URANIUM TRANSPARENCY							
OPERATING	0.0	0.1	0.0	0.1	0.1	0.1	0.1
DIRECT PERSONNEL	0	0	1	1	1	1	1
TOTALS-NONPROLIFERATION AND NATIONALL SECURITY							
OPERATING	21.0	24.9	25.1	30.9	30.9	30.9	30.9
DIRECT PERSONNEL	35	29	35	39	39	39	39
OFFICE OF COUNTER INTELLIGENCE							
CN COUNTER INTELLIGENCE							
OPERATING	0.3	0.3	0.4	0.4	0.4	0.4	0.4
DIRECT PERSONNEL	1	2	3	3	3	3	3
DEFENSE PROGRAMS							
DP OTHER WEAPONS ACTIVITIES							
OPERATING	1.1	0.4	0.0	0.4	0.4	0.4	0.4
DIRECT PERSONNEL	4	2	0	1	1	1	1
ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT							
EW ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT							
OPERATING	29.8	30.9	28.4	27.2	27.2	27.2	27.2
CAPITAL EQUIPMENT	0.2	0.1					
CONSTRUCTION							
TOTAL FUNDING	30.0	31.	28.4	27.2	27.2	27.2	27.2
DIRECT PERSONNEL	74	89	58	61	61	61	61
FOSSIL ENERGY							
AA COAL							
OPERATING	0.3	0.1	0.0	0.0	0.0	0.0	0.0
DIRECT PERSONNEL	1	0	0	0	0	0	0

Table 10 - Funding By Assistant Secretarial Level Office (In Millions In Budget Authority)	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
OTHER DOE PROGRAMS							
FOSSIL ENERGY (CON'T)							
AB GAS							
OPERATING	0.0	0.1	0.0	0.0	0.0	0.0	0.0
DIRECT PERSONNEL	0	0	0	0	0	0	0
AC PETROLEUM							
OPERATING	0.3	0.3	0.2	0.4	0.4	0.4	0.4
DIRECT PERSONNEL	1	3	2	3	3	3	3
TOTALS-FOSSIL ENERGY	0.6	0.5	0.2	0.4	0.4	0.4	0.4
DIRECT PERSONNEL	2	3	2	3	3	3	3
OFFICE OF NUCLEAR ENERGY							
ST ISOTOPE PRODUCTION AND DISTRIBUTION PROGRAM							
OPERATING	1.9	2.3	3.0	3.1	3.1	3.1	3.1
CONSTRUCTION - CYCLOTRON ISOTOPE RES. CTR. (b)				18.7	11.1	3.5	1.6
TOTAL FUNDING	1.9	2.3	3.0	21.8	14.2	6.6	4.7
DIRECT PERSONNEL	7	9	10	10	10	10	10
AF NUCLEAR ENERGY RESEARCH & DEVELOPMENT							
OPERATING	0.0	0.5	0.3	1.0	1.0	1.0	1.0
DIRECT PERSONNEL	0	2	1	1	1	1	1
TOTALS-OFFICE OF NUCLEAR ENERGY							
OPERATING	1.9	2.8	3.3	4.1	4.1	4.1	4.1
CONSTRUCTION	0.0	0.0	0.0	18.7	11.1	3.5	1.6
TOTAL FUNDING	1.9	2.8	3.3	22.8	15.2	7.6	5.7
DIRECT PERSONNEL	7	11	11	11	11	11	11
OFFICE OF POLICY, PLANNING, AND ANALYSIS							
PE POLICY, ANALYSIS AND SYSTEMS STUDIES							
OPERATING	0.1	0.1	0.0	0.2	0.2	0.2	0.2
DIRECT PERSONNEL	1	0	0	1	1	1	1

Table 10 - Funding By Assistant Secretarial Level Office
(In Millions In Budget Authority)

	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
OTHER DOE PROGRAMS							
OFFICE OF SECURITY AND EMERGENCY OPERATION							
SO SECURITY AND EMERGENCY MGMT.							
OPERATING	0.0	0.3	10.1	11.4	11.4	11.4	11.4
DIRECT PERSONNEL	0	1	77	82	82	82	82
GD NUCLEAR SAFEGUARDS & SECURITY							
OPERATING	0.3	0.0	0.3	1.1	1.1	1.1	1.1
DIRECT PERSONNEL	1	1	1	1	1	1	1
ND EMERGENCY MANAGEMENT							
OPERATING	0.3	0.3	0.3	0.3	0.3	0.3	0.3
DIRECT PERSONNEL	1	2	2	2	2	2	2
TOTALS OFFICE OF SECURITY & EMERGENCY MGMT.							
OPERATING	0.6	0.6	10.7	12.8	12.8	12.8	12.8
DIRECT PERSONNEL	2.0	4.0	80.0	85.0	85.0	85.0	85.0
OFFICE OF CHIEF FINANCIAL OFFICER							
WN COST OF SERVICE PERFORMED							
OPERATING	0.1	0.1	0.0	0.0	0.0	0.0	0.0
DIRECT PERSONNEL	1	0	0	0	0	0	0
WM MANAGEMENT ADMINISTRATION							
OPERATING	0.1						
DIRECT PERSONNEL	1	1					
TOTAL OFFICE OF CHIEF FINANCIAL OFFICER							
OPERATING	0.2	0.1	0.0	0.0	0.0	0.0	0.0
DIRECT PERSONNEL	2	1					

* ESCALATION FACTORS: FY2001 AND FY2002 AT 3.0% AND 3.5% RESPECTIVELY
** CONSTANT FY2002 DOLLARS

Table 11 - Work For Others Funding (In Millions In Budget Authority)	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
NUCLEAR REGULATORY COMMISSION							
NUCLEAR REACTOR REGULATION							
OPERATING	0.7	1.6	2.7	2.8	2.8	2.8	2.8
DIRECT PERSONNEL	5	6	12	11	11	11	11
NUCLEAR REGULATORY RESEARCH							
OPERATING	4.7	4.1	4.0	4.3	4.3	4.3	4.3
DIRECT PERSONNEL	20	20	17	19	19	19	19
COMMISSION AND STAFF OFFICES							
OPERATING	1.7	1.2	1.6	1.7	1.7	1.7	1.7
DIRECT PERSONNEL	4	5	5	5	5	5	5
TOTALS-NUCLEAR REGULATORY COMMISSION							
OPERATING	7.1	6.9	8.3	8.8	8.8	8.8	8.8
DIRECT PERSONNEL	29	31	34	35	35	35	35
DEPARTMENT OF STATE							
OPERATING	5.2	5.0	6.2	6.3	6.3	6.3	6.3
DIRECT PERSONNEL	7	8	8	8	8	8	8
DEPARTMENT OF DEFENSE							
OPERATING	1.3	1.1	1.3	1.3	1.3	1.3	1.3
DIRECT PERSONNEL	4	2	5	6	6	6	6
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION							
OPERATING	1.4	3.8	3.0	4.1	4.1	4.1	4.1
CONSTRUCTION - BOOSTER APPL. FACILITY (a)	3.5	8.6	12.5	5.2	0.0	0.0	0.0
TOTAL FUNDING	4.9	12.4	15.5	9.3	4.1	4.1	4.1
DIRECT PERSONNEL	12	29	39	38	38	38	38
DEPARTMENT OF HEALTH & HUMAN SERVICES							
OPERATING	15.6	8.8	13.1	9.8	9.8	9.8	9.8
DIRECT PERSONNEL	28	36	36	36	36	36	36

Table 11 - Work For Others Funding
(In Millions In Budget Authority)

	FY 1999	FY 2000	FY 2001*	FY 2002*	FY 2003**	FY 2004**	FY 2005**
NATIONAL SCIENCE FOUNDATION							
OPERATING	**0.8**	**0.0**	**0.0**	**8.1**	**8.1**	**8.1**	**8.1**
DIRECT PERSONNEL	**0**	**0**	**0**	**32**	**32**	**32**	**32**
ENVIRONMENTAL PROTECTION AGENCY							
OPERATING	**3.0**	**2.3**	**3.4**	**3.2**	**3.2**	**3.2**	**3.2**
DIRECT PERSONNEL	**4**	**4**	**4**	**4**	**4**	**4**	**4**
OTHER FEDERAL AGENCIES							
OPERATING	**1.5**	**1.0**	**1.2**	**1.3**	**1.3**	**1.3**	**1.3**
DIRECT PERSONNEL	**12**	**2**	**7**	**8**	**8**	**8**	**8**
OTHER DOE LABS							
OPERATING	7.5	5.5	5.1	4.9	4.9	4.9	4.9
CONSTRUCTION - SPALATION NEUTRON SOURCE.		17.2	30.7	31.7	21.7	12.4	0.0
TOTAL FUNDING	**19.1**	**22.7**	**35.8**	**36.6**	**26.6**	**17.3**	**4.9**
DIRECT PERSONNEL	**83**	**105**	**110**	**109**	**109**	**109**	**109**
	ALL OTHERS						
OPERATING	**4.0**	**8.5**	**8.4**	**8.5**	**8.5**	**8.5**	**8.5**
DIRECT PERSONNEL * **	**61**	**47**	**64**	**54**	**54**	**54**	**54**

* ESCALATION FACTORS: FY2001 AND FY2002 AT 3.0% AND 3.5% RESPECTIVELY
** CONSTANT FY2002 DOLLARS
*** Includes FTE's from Non-Reportable Programs

Table 12 - Laboratory Major Programmatic Construction Projects
($ In Millions In Budget Authority)

		FUNDED		BUDGETED		PROPOSED		
	TEC	FY99	FY00	FY01	FY02	FY03	FY04	FY05
Program Related - SC								
Accelerator Improvement Projects (KA)		0.0	0.0	0.0	0.6	0.6	0.6	0.6
Accelerator Improvement Projects (KB)		1.3	1.3	2.4	5.6	5.6	5.6	5.6
Accelerator Improvement Projects (KC)		1.5	1.5	2.0	2.0	2.0	2.0	2.0
Accelerator Improvement Projects (KP)		0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects (KA)		7.4	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects (KB)		0.0	5.4	6.2	12.9	12.9	12.9	12.9
General Plant Projects (KC)		0.0	0.0	0.0	0.0	0.0	0.0	0.0
General Plant Projects (KP)		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Relativistic Heavy Ion Collider	486.9	16.6	0.0	0.0	0.0	0.0	0.0	0.0
Total		**26.8**	**8.2**	**10.6**	**21.1**	**21.1**	**21.1**	**21.1**
Program Related - NASA								
Booster Applications Facility (BAF)	30.5	3.5	9.0	12.5	5.2			
Proposed Construction - NE								
Cyclotron Isotope Research Center	34.9				18.7	11.1	3.5	1.6
Proposed Construction - SC								
User Research Center	19.6				10.0	9.6		
Total					**28.7**	**20.7**	**3.5**	**1.6**
Under Evaluation								
RHIC II								
Muon Collider Storage Ring								
Total Funded Program Construction		**30.3**	**17.2**					
Total Budgeted Program Construction				**23.1**	**55.0**			
Total Proposed Program Construction						**41.8**	**24.6**	**22.7**

Table 13 - Laboratory Major MEL/FS Construction Projects
(S In Millions In Budget Authority)

MEL/FS PROJECTS	Project Type	TEC	FUNDED FY99	FUNDED FY00	BUDGETED FY01	BUDGETED FY02	PROPOSED FY03	PROPOSED FY04	PROPOSED FY05
Funded/Budgeted									
Electrical System Modifications Ph. I (N98D0011)	3	5.7	0.8	3.9	1.0				
Sanitary System Upgrade Ph. III (A96D0029)	1	6.5	0.5	3.0	3.0				
Total:			**1.3**	**6.9**	**4.0**				
Proposed - KG01									
Electrical System Modifications Ph. II (N98D0022)	3	6.8			0.8	3.0	3.0		
AST Building (N98D0015)	5	17.0				1.5	7.0	5.0	3.5
High Speed Communication Upgrade (N98D0007)	3	7.1				0.7	3.2	3.2	
Research Support Center (AA0D0030)	5	42.5				2.5	10.0	16.0	14.0
Roof Replacement Phase II (A98D0014)	3	7.5				0.9	3.3	3.3	
Total:					**0.8**	**8.6**	**26.5**	**27.5**	**17.5**
Proposed - KG02									
Ground and Surface Water Protection (A96D0029)	1	6.0			1.9	2.9	1.2		
Life Safety Code Modifications Ph. I (A92D0148)	1	5.3							5.3
Halon System Replacement (A93D0161)	1	5.0							5.0
Total:					**1.9**	**2.9**	**1.2**	**0.0**	**10.3**
Total GPF Funded Construction			**1.3**	**6.9**					
Total GPF Budgeted Construction					**6.7**	**11.5**			
Total GPF Proposed Construction							**27.7**	**27.5**	**27.8**
***Total All Funded Construction**			**31.6**	**24.1**					
***Total All Budgeted Construction**					**29.8**	**65.5**			
***Total All Proposed Construction**							**69.5**	**52.1**	**50.5**

MEL/FS Project Types

1. ES&H Support
2. Building Rehabilitation/Upgrades
3. Utility System Rehabilitation/Upgrades
4. Roads and OSF Rehabilitation/Upgrades
5 New Building

*Totals from Tables 12 and 13

Table 14 - Environmental, Safety, Health and Infrastructure Resource Projection (FY00 $ in Millions)						
FUNDING	FY00	FY01	FY02	FY03	FY04	FY05
ESH Operating						
Laboratory (SM/G&A)	2.4	0.5	0.6	0.5	(a)	(a)
Department & Division	44.4	35.7	34.8	34.4	34.7	34.6
ESH Capital Equipment	0.5	0.3	0.3	(a)	(a)	(a)
ESH Line Item	3.0	3.7	2.9	2.4	0.0	10.3
ESH GPP						
KA Landlord	0.0	0.0	0.0	(a)	(a)	(a)
KA Program	0.0	0.0	0.0	(a)	(a)	(a)
KB Landlord	2.4	1.9	1.1	(a)	(a)	(a)
KB Program	0.0	0.0	0.0	(a)	(a)	(a)
KC Program	0.0	0.0	0.0	(a)	(a)	(a)
KP Program	0.0	0.0	0.0	(a)	(a)	(a)
ESH AIP						
KA	0.0	0.0	0.0	(a)	(a)	(a)
KB	0.0	0.5	0.0	(a)	(a)	(a)
KC	0.5	0.2	0.2	(a)	(a)	(a)
KP	0.0	0.0	0.0	(a)	(a)	(a)
Infra. Operating (SM/G&A)	0.3	1.0	0.9	1.0	(a)	(a)
Infrastructure Line Item	3.9	1.8	8.6	26.5	27.5	17.5
Infrastructure GPP	2.9	4.3	5.1	(a)	(a)	(a)
Environmental Management (EM) Funded						
Remedial Actions	14.5	17.9	16.0	17.5	23.3	26.7
BGRR D&D EM-40	1.3	3.6	6.9	5.3	9.8	6.9
Boneyard Waste Disposal	3.2	2.7				
Program Management	3.1	3.0	3.0	2.5	2.9	2.4
BGRR D&D: Office of Science	4.9	0.2				
Waste Management Operations	6.7	6.0[b]	6.0	6.0	6.0	6.0

[a] To be determined

[b] Supported by the Office of Science starting in FY 01

Appendix A: Activities by DOE Mission for FY 2001

Brookhaven National Laboratory

Science and Technology Mission

B and R	*Project Title*	*Principal Investigator*
Exploring Energy and Matter - Building Blocks from Atoms to Life		
KA-04-01-01	Research	Gordon, H.
KA-05-02-03	US ATLAS Project	Gordon, H
KB-01-01-02	Spin and Nuclear Structure Investigations with Hadronic Probes	May, M
KB-01-01-02	Laser Electron Gamma Source	Sandorfi, A
KB-02-01-02	Heavy Ion Research	Chasman, C and Remsberg, L
KB-02-02-01	CD Experimental Operations	Ludlam, T
KB-03-01-02	Nuclear Theory	McLerran, T
KB-04-01-04	National Nuclear Data Center Reference Nuclear Data for Energy Research	Dunford, C
KC-02-01-01	Theory of Alloy Phases	Weinert, M
KC-02-02-01	Neutron Scattering	Tranquada, J
KC-02-02-02	Powder Diffraction	Vogt, L
KC-02-02-02	Charge Inhomogeneity in Correlated Electron Systems	Tranquada, J
KC-02-02-02	X-Ray Scattering	Gibbs, L
KC-02-02-03	Condensed Matter Theory	Emery, V
KC-02-02-05	Electron Spectroscopy	Johnson, P
KC-06-00-00	Molecular Plant Genetics	Burr, B
KP-11-01-01	Structural Biology	Wall, J
KP-11-02-01	Technology Development for Protein Expression and Crystallization	Studier, F
KP-11-03-01	Systematic Determination of Archetypical Structures for Protein Families	Studier, F
KP-11-03-01	Genome Sequencing and Analysis	Dunn, J
KB-02-01-02	Heavy Ion Research	Chasman, C and Remsberg, L
KB-04-01-02	Solar Neutrino Research	Hahn, R
Extraordinary Tools for Extraordinary Science - National Assets		
DP-05-14-03	Safety Management Verification and Operational Readiness	Perkins, K
EW-02-MM-11C	Support EM-4 Safety and Health Policy Development	Higgins, J
EW-40-90-20	Technical Support Center for Risk Excellence	Sullivan, T
HC-11-03-10	Nuclear Safety Support Activity	Perkins, K
HC-11-03-20	Technical Support to the Office of Nuclear and Facility Safety	Carew, J
HC-11-03-40	Technical Assistance for Facility Safety Evaluation	Subudhi, M
HC-11-05-00	Integrated Safety Management Technical Assistance	Taylor, J
HC-11-05-00	Technical Support in Chemical Safety Monitoring	Todosow, M
KA	General Purpose Equipment	

Science and Technology Mission

B and R	*Project Title*	*Principal Investigator*
Extraordinary Tools for Extraordinary Science - National Assets (continued)		
KA-04-01-01	US ATLAS Computing	Gibbard, B
KA-04-03-01	Accelerator Magnet Infrastructure and R&D	Harrison, M
KA-04-03-01	Superconductor Development and Test Facility Improvements	Harrison, M
KA-04-03-01	Accelerator Test Facility Operations and Development	Ben-Zvi, I
KA-04-03-01	Accelerator R&D Infrastructure	Harrison, M
KA-04-03-01	Advanced Accelerator Research and Development - Muon Collider	Palmer, R
KA-04-03-01	Inverse Free Electron Laser Accelerator Development	Gallardo, J
KA-04-03-02	Experimental Facilities Research and Development	Gordon, H
KA-04-03-02	Detector and Electronics Research and Development Program for High energy Physics	O'Connor, P
KA-05-01-01	AGS-HEP Operating	Lowenstein, D
KA-05-01-01	Research	Roser, T
KA-05-01-02	AGS HEP Capital	
KA-05-01-02	Experimental Facility Operations for High Energy Physics	Lowenstein, D
KA-05-02-01	Large Hadron Collider Collaboration	Harrison, M
KA-05-02-03	US ATLAS Project	Gordon, H
KA-AIP	High Energy Physics Construction	
KB	Nuclear Physics Construction - AIP/GPP	
KB-01-01-02	AGS Medium Energy Physics Capital Equipment	Lowenstein, D
KB-01-02-03	AGS Medium Energy Physics	Lowenstein, D
KB-02-01-00	Detector and Electronics Research and Development Program for Nuclear Physics	O'Connor, P
KB-02-01-02	AEE Capital Equipment	Ludlam, T
KB-02-02-01	CD Facility Operations	Ludlam, T
KB-02-02-01	CD Operations	Roser, T
KB-02-02-03	Other Capital Equipment Not Related to Construction	
KC	Basic Energy Sciences Construction - AIP	
KC-02-02-02	Precision Photo-Fabrication R&D	Johnson, E
KC-02-04-01	National Synchrotron Light Source Operations and Development	Hart, M
KC-02-04-01	X-Ray Free Electron Laser R&D Program	Hart, M
KC-02-04-01	Spallation Target Studies	Hastings, J
KC-02-04-01	Optics Systems for Synchrotron Radiation Applications	Takacs, P
KC-02-04-01	Optics and Detectors for Light Sources	Smith, G

Science and Technology Mission

B and R	*Project Title*	*Principal Investigator*
Extraordinary Tools for Extraordinary Science - National Assets (continued)		
KC-02-04-01	Neutron Instrument Development and User Support	Hastings, J
KG	Multiprogram Energy Laboratory Construction	
KJ-01-01-03	Materials, Methods, Microstructure, and Magnetism	Weinert, M
KJ-01-02-00	Particle Physics Data Grid	Gibbard, B
KJ-02	Office of Science Laboratory Technology Research Program	Bogosian, M
KP-11-01-01	Design and Fabrication of a Two-Dimensional Neutron Detector For a Spallation Neutron Source	Radeka, V and Smith, G
KP-11-01-01	HFBR Structural Biology Facility Operation	Schnieder, D
KP-11-01-01	NSLS Structural Biology Facility Operation	Sweet, R
KP-11-01-01	Biophysical Instrumentation Research	Radeka, V and Smith, G
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Global Change Education	Newman, L
KP-14-01-02	Physiological Imaging	Volkow, N
KP-14-01-03	Synchrotron Medical Research Facility	Thomlinson, W
KP-14-01-05	Brookhaven Medical Research Reactor Operations	Reeside, W
KP-14-01-06	Neuroreceptor Radioligands and Synaptic Activity	Gatley, J
KX-02-01	Science Education Programs	Swyler, K
Fueling the Future		
EE-05-05	Ex-situ Preparation of Nanocomposite Materials for Use as Anodes in Lithium Batteries Using the HDDR Process	Johnson, J
KC-02-01-01	Studies of Nanoscale Structure and Structural Defects of Advanced Materials	Zhu, Y
KC-02-01-02	Mechanisms of Metal-Environment Interactions	Isaacs, H
KC-02-01-03	Superconducting Materials	Suenaga, M
KC-02-02-01	Neutron Scattering	Tranquada, J
KC-02-02-02	X-Ray Scattering	Gibbs,L
KC-02-02-02	Charge Inhomogeneity in Correlated Electron Systems	Tranquada, J
KC-02-02-02	Powder Diffraction	Vogt, L
KC-02-02-02	Structure Sensitive Properties of Advanced Permanent Magnet Materials: Experiment and Theory	Welch, D
KC-02-02-03	Condensed Matter Theory	Emery, V
KC-02-02-05	Electron Spectroscopy	Johnson, P
KC-02-03-01	Synthesis and Structures of Conducting Polymers	Mc Breen, J
KC-02-03-01	Neutron and X-ray Scattering in Materials Chemistry	Larese, J
KC-03-01-01	Thermal, Photo- and Radiation-Induced Reactions in Condensed Media	Miller, J
KC-03-01-01	Structure-Function Designs of Photosynthetic and Catalytic Porphyrins	Fajer, J

Science and Technology Mission

B and R	*Project Title*	*Principal Investigator*
Fueling the Future (continued)		
KC-03-01-01	Interfacial Charge Transfer	Feldberg, S
KC-03-01-02	Photoinduced Molecular Dynamics in the Gas and Condensed Phases	White, M
KC-03-01-02	Gas-Phase Molecular Dynamics	Muckerman, J
KC-03-02-01	Catalysis: Reactivity and Structure	Hrbek, J
KC-03-02-04	Structure and Function in Electrochemistry and Electrocatalysis	Adzic, R and McBreen, J
KC-03-02-04	Technical and Programmatic Assistance to the Office of Basic Energy Sciences - the chemical Energy Program	Melamed, D
KC-04-03-01	Study of Microgeometry of Geological Materials Using Synchrotron Computed Microtomography	Jones, K
KC-04-03-02	Geochemistry of Organic Sulfur in Marine Sediments	Vairavamurthy, A
KC-06-00-00	Modification of Plant Lipids	Shanklin, J
KC-06-00-00	Regulation of Energy Conversion in Photosynthesis	Hind, G
KJ-01-01-03	Materials, Methods, Microstructure, and Magnetism	Weinert, M
NC-05-20-06	MARKAL Macro	Lee, J
PE-04-01-00	Modifications and Refinements of the MARKAL Model	Lee, J
Manage As Stewards Of The Public Trust - Scientific and Operational Excellence		
CN-04-04-00	Counter Intelligence Program Funding	Gross, G
EW-40-40-00	Strategic Laboratory Council	Moskowitz, P
HD-20-06-10	Medical Information System Development	Breitenstein, B
HD-20-06-20	Brookhaven National Laboratory Health Surveillance System	Breitenstein, B
KB-03-01-02	Detailee to the Division of Nuclear Physics	Baltz, A
KC-02-04-01	HFBR Transition Project	Reeside, W
KD-01-00-00	Detailee to the Office of High Energy and Nuclear Physics	Baggett, N
SO-01-00-00	Site Safeguards and Security	Reaver, R
SO-10-00-00	Unclassified Cyber Security	Schlagel, T
SO-42-02-11	Radiological Assistance Program	Layandecker, S
WB-00-00-00	Building Energy Surveys/Low Cost IHEM Studies	Toscano, M
Protect Our Living Planet		
AA-15-20-30	EPA Regulation of Fossil Energy Technologies	Moskowitz, P
EW-40-10	Asbestos Conversion Technology Development	Webster, R
EW-40-90-10	Electroactive Materials for Anion Separation– Technetium from Nitrate	McBreen, J
EW-40-90-10	Collaboration on Interfacial Soil Chemistry of Radionuclides in the Unsaturated Zone	Vairavamurthy, A
EW-40-90-10	Mechanisms of Radionuclide-Hydroxycarboxylic Acid Interactions for Decontamination of Metallic Surfaces	Francis, A
HD-20-06-10	Technical Assistance for Office of Health	Breitenstein, B

Science and Technology Mission

B and R	*Project Title*	*Principal Investigator*
Protect Our Living Planet (continued)		
KC-03-02-02	Nucleation Dynamics in Microparticles and Chemical Characterization of Ultrafine-Particles	Imre, D
KC-03-02-04	Technical and Programmatic Assistance to the Office of Basic Energy Sciences - The Chemical Energy Program	Melamed, D
KP-11-02-02	DNA Damage Clusters in Low Level Radiation Responses of Human Cells	Sutherland, B
KP-11-02-02	Microbial Research in Reaction Pathways/Regulatory Networks	Dunn, J
KP-11-03-01	Genome Sequencing and Analysis	Dunn, J
KP-11-04-01	Cellular Responses to DNA Damage	Anderson, C
KP-12-01-03	Studies of Cloud Microphysical and Optical Properties	Daum, P
KP-12-01-03	Direct and Indirect Effects of Aerosols: Short-wave Radiative Forcing by Trospospheric Aerosols	Schwartz, S
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Aerosol Size Distribution	Brechtel, F
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Chemical and Microphysical Aerosol Model	Schwartz, S
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Aerosol Optical Properties and Phase Transformation	Imre, D
KP-12-02-01	Anthropogenic Aerosol Perturbation on Climate	Schwartz, S
KP-12-02-01	Perfluorocarbon Tracer Studies for Visualization/Verification of Vertical Transport and Mixing (VTMX) Processes	Dietz, R
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Multi-Phase Atmospheric Chemistry	Lee, Y
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Field Studies in Atmospheric Chemistry	Daum, P and Newman, L
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Emission Inventories of Aerosols and Aerosol Precursors	Benkovitz, C
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Instrumentation for Field Programs	Springston, S
KP-12-02-02	Forest-Atmosphere Carbon Transfer and Storage (FACTS) Biology: Mechanisms of Long-term Carbon Flux Enhancements in Elevated Carbon Dioxide.	Ellsworth, D
KP-12-02-02	Forest Atmosphere Carbon Transfer and Stroage-1 (FACTS-1) Experiment	Ellsworth, D
KP-12-02-02	Stomatal Response to CO2: A comparison of Woody and Herbaceous Species at Four Free Air Carbon Dioxide Enrichment (FACE) Sites and in Arid and Humid Climates	Ellsworth, D
KP-12-02-03	Moored Sensing Systems	Wirick, C

Science and Technology Mission

B and R	*Project Title*	*Principal Investigator*
Protect Our Living Planet (continued)		
KP-12-03-01	Molecular and Physiological Mechanisms Regulating the Acclimation of Plants to Growth at Elevated CO2	Long, S and Rogers, A
KP-12-03-02	An Integrative Modeling Framework for Free Air CO2 Enrichment (FACE) Community	Humphries, S and Hendrey, G
KP-12-03-02	Environmental Facility Planning and Development	Hendrey, G
KP-12-03-02	Free-Air Carbon Dioxide Enrichment (FACE) Facility Development	Hendrey, G
KP-12-03-02	Data Management System (DMS) for the Visualization of Free Air CO2 Enrichment (FACE) Data	Humphries, S
KP-12-03-02	Monte Carlo Neutron Photon (MCNP) Simulation to Improve Soil Carbon Measurements	Wielopolski, L
KP-13-01-01	Stabilization of Radionuclides by Anaerobic Bacteria: Molecular Genetic Analysis of Clostridia	Dunn, J
KP-13-01-01	Transformation of Heavy Metal Contaminants in Sulfate-Reducing Sub-surface Environments: The Role of Thiolated Compounds and Hydrogen Sulfide	Vairavamurthy, A
KP-14-01-02	Radiotracer Chemistry and Neuroimaging	Fowler, J
KP-14-01-03	High-Field Magnetic Resonance Imaging	Springer, C
KP-14-01-05	Neutron Capture Therapy: Preclinical Research and Clinical Investigations	Coderre, J
KP-14-01-06	Recombinant Vehicles for Tumor Imaging and for Targeted Radioisotopic/Gene Therapy of Cancer	Srivastava, S
KP-14-02-01	Intercerebral Beta Microprobe for Radiotracer Kinetics	Fowler, J
KP-14-10-05	Positron Emitter Labeled BPA for BNCT	Fowler, J
ND-02-02-00	Technical Program Support to Emergency Management Advisory Committee (EMAC) Subcommittee on Consequence Assessment and Protective Action (SCAPA)	Hansen, D
PE-01-00-00	Modifications to the MARKAL Model	Lee, J
PE-04-01-00	Modifications and Refinements to the MARKAL Model	Lee, J
ST-01-01-02	Radioisotope Production at BLIP	Mausner, L and Srivastava, S

Energy Resources Mission

B and R	*Project Title*	*Principal Investigator*
Clean and Affordable Power		
AA-15-20-30	EPA Regulation of Fossil Energy Technologies	Moskowitz, P
EB-22-01-00	National Photovoltaic Environmental, Health and Safety Assistance Center	Fthenakis V
EB-50-01-00	Practical Conductor Development for Electric Power Systems Utilizing High-Tc Oxides	Suenaga, M
EE-05-05	Battery Materials: Structure and Characterization	McBreen
EE-05-05-00	Lithium-Ion Cell Diagnostics and Evaluation	McBreen, J
GJ-12-00-00	International Nuclear Safety	Horack, W
NC-05-20-06	MARKAL Macro	Lee, J
PE-01-00-00	Modifications to the MARKAL Model	Lee, J
Efficient and Productive Energy Use		
EC-09-02-00	BTS Implementation and Deployment	McDonald, R
EC-09-04-00	Thermal Distribution Systems in Small Buildings	Andrews, J
EC-09-04-00	Combustion Technology and Space Conditioning Technology	McDonald, R
EC-17-01-00	Analysis Integration	LaMontagne, J
Reliable and Diverse Energy Supply		
AA-20-25-20	Carbon Dioxide Sequestration Via Utilization and Emission Reduction: An Integrated Approach to Carbon Dioxide Mitigation	Mahajan, D
AA-20-25-20	Chemistry in Power Plant Plumes Tagged with Conservative Perfluorocarbon Tracers	Senum, G
AB-05-50-00	Natural Gas Vehicle Fuel from Landfills	Wegrzyn, J
AC-10-05	Natural Gas and Oil Technology Partnership	Goland, A
AC-10-15	Conceptual Perfluorocarbon Tracer Field Plan Development for the Breton Air Monitoring Program (BAMP) and the Central California Regional PM Air Quality Study	Dietz, R
AC-10-15	Biochemical Upgrading of Oils and Petroleum Products	Lin, M
EB-40-01-00	Geothermal Materials Development	Berndt, M
EB-40-01-01	Advanced Processes for Geothermal Brines Multiple Resources	Lin, M
EE-06	Natural Gas Storage Systems	Wegrzyn, J

National Security Mission

B and R	*Project Title*	*Principal Investigator*
Countering Weapons of Mass Destruction Terrorism		
GC-04-01-00	On Site Systems	Sedlacek, A
GC-04-04-00	Targeted Diagnostics for Biological Non-Proliferation	Swaminathan, S
GC-04-04-00	Advanced Systems	Vanier, P
GD-06-04-02	Safeguards Science and Technology Development	Vanier, P
GJ-04-00-00	International Safeguards	Gordon, D
GJ-09-02-00	Initiatives for Proliferation Prevention (IPP) Support	Rohatgi, U
GJ-12-00-00	Policy and Technical Analysis Support	Dougherty, D
ND-02-02-00	Technical Program Support to Emergency Management Advisory Committee (EMAC) Subcommittee on Consequence Assessment and Protective Action (SCAPA)	Hansen, D.
Detecting Proliferation		
GC-04-01-00	On Site Systems	Sedlacek, A
Maintaining the Nuclear Deterrent		
DP-04-04-01	Accelerator Production of Tritium	Todosow, M
Monitoring Nuclear Treaties and Agreements		
GC-04-02-00	Treaty Monitoring	Vanier, P
GD-05-08-04	OSS Safeguards System Protocol	Gordon, D
IN-01-06-00	Technical Analysis and Program Support for the Special Technologies Programs	Lemley
Preventing Proliferation		
GC-04-04-00	Advanced Systems	Vanier, P
GD-06-04-02	Safeguards Science and Technology Development	Vanier, P
GJ-08-00-00	US- Russian Nuclear Security Programs	C. R. Kempf
GJ-12-00-00	International Nuclear Safety	Horak, W
VM-30-13	Uranium Program Transparency Measures	Dougherty, D

Environmental Quality Mission

B and R	*Project Title*	*Principal Investigator*
Enhance Future Land Use		
EX-04-C4-02	BGRR Fact Sheet	Sullivan, T
EX-04-C4-02	Decontamination and Decommissioning	Schlender, M
EX-04-C4-03	Environmental Restoration - Program Management	Schlender, M
EX-04-C4-04	BNL Environmental Restoration and Waste Management - Remedial Actions	Schlender, M
Management of Waste/Materials		
AF-55-00-00	Technical Support for the ATW Program	Todosow, M
EW-02-MM-03	Arctic Military Environmental Cooperation (AMEC)	Moskowitz, P
EW-02-MM-03	Technical Support for Integrated Spent Nuclear Fuel	Higgins, J
EW-02-MM-09B	Analysis of Experience in Radiation Protection	Moskowitz, P
EW-40-10-00	Landfill Covers Task Force	Heiser, J
EW-40-10-00	SUBCON Focus Area Technical Support	Moskowitz, P
EW-40-10-00	ASTD BGRR Subsurface Characterization	Kalb, P
EW-40-10-00	SPSS Commercialization	Kalb, P
EX-04-C4-01	Disposal of Boneyard Wastes	Schlender, M
EX-04-C4-05	Waste Management Operations	Schlender, M
KB-02-02-04	Nuclear Physics Support for Waste Management Operations	Schlender, M
KC-02-04-01	Legacy Waste Disposal	Reeside, W

Appendix B: User Facility Information

Table B1 - Experimenters at User Facilities Facility	Number of Experimenters	Number of Organizations
RELATIVISTIC HEAVY ION COLLIDER		
BNL	100	1
Other Federal Labs	91	6
University	348	40
Industry	0	0
International	491	58
	966	**105**
ALTERNATING GRADIENT SYNCHROTRON		
BNL	46	1
Other Federal Labs	6	1
University	112	31
Industry	1	1
International	276	26
	441	**60**
NATIONAL SYNCHROTRON LIGHT SOURCE		
BNL	220	1
Other Federal Labs	279	25
University	1213	141
Industry	264	61
International	354	132
Other	50	10
	2380	**370**
TANDEM VAN DE GRAAFF		
BNL	5	1
Other Federal	23	3
University	12	4
Industry	44	14
International	26	4
	110	**26**
SCANNING TRANSMISSION ELECTRON MICROSCOPE		
BNL	8	1
University	50	28
Other Federal Labs	5	2
Other	5	2
	68	**33**
ACCELERATOR TEST FACILITY		
BNL	28	1
Other Federal Labs	19	5
University	17	12
Industry	4	2
International	8	5
	76	**25**

Table B2 - Industrial and Technological Users of the National Synchrotron Light Source

3-Dimensional Pharmaceuticals, Inc.	Abbott Laboratories
Advanced Fuel Research	Air Products & Chemicals Inc.
AlliedSignal, Inc.	Amoco Corporation
Applied Physics Technologies Corp.	Area Detector Systems Corporation
Bayer Corporation	Bechtel Nevada
BioSpace International Inc.	Biological Research Center
Boehringer Ingelheim Pharmaceuticals, Inc.	Bristol-Myers Squibb
Bruker AXS, Inc.	Chevron Research & Technology Company
Containerless Research. Inc.	Corning, Inc.
Crystal Technology, Inc.	David Sarnoff Research Center
Digital Equipment Corporation	Dow Chemical Company
Eastman Chemical Company	Eastman Kodak Co.
Edge Analytical, Inc.	Emerald BioStructures, Inc.
Enraf-Nonius, Inc.	Ethicon, A Johnson & Johnson Company
Exxon Research and Engineering Co.	General Electric
GlaxoWelcome, Inc.	Hoechst Celanese
Hoffmann-La Roche	IBM Research Division
IKV Petroleum Research	Instituto Tecnologico de Aeronautica (ITA)
KLA Instruments	Kawasaki Heavy Industries, Ltd.
Kinetix Pharmaceuticals, Inc.	Lockheed Engineering
Lucent Technologies, Inc.	MVA, Inc.
Matsushita Electric Industrial Co., LTD	Memstek Products, LLC
Merck & Co.	Mobil R&D Corp.
Molecular Structure Corporation	Montell Polyolefins USA
NEC Corporation	NHK Enterprises American, Inc.
Northrop Grumman ATDC	On-Line Technologies Inc.
Oxford Instruments	PPG Industries, Inc.
Pall Corporation	Panametrics, Inc.
Pfizer, Inc.	Procter & Gamble Co.
Quantum Devices, Inc.	R&D Services, Prop.
Rohm & Haas Co.	SFA, Inc.
Sarnoff Corporation	Sci-Med
Science Applications International Corp.	SmithKline Beecham Pharmaceuticals
Southern Research Institute	Spectra-Tech Inc.
St. Gobain Industrial Ceramics	TYCOM
Texaco Research Center	The DuPont Company
The EXAFS Company	UOP
Vertex Pharmaceuticals, Inc.	Wyeth-Ayerst Research

Table B3 - Users of the Relativistic Heavy Ion Collider

Abilene Christian University
Argonne National Laboratory
Bhabba Atomic Research Center
Carnegie Mellon University
Centre de Recherches Nucleaires
City College of New York
Columbia University
Florida State University
Georgia State University
Indiana University Cyclotron Facility
Institute for High Energy Physics, Protvino
Institute of Nuclear Physics
Iowa State University
Johns Hopkins University
Kangnung National University
Kent State University
Kurchatov Institute
Laboratory of High Energy Physics @ Dubna
Lawrence Livermore National Laboratory
Lund University
Max-Planck-Institut fuer Physik
Michigan State University
Myongji University
National Central University
New York University
Ohio State University
Palaiseau (LPNHE)
Pennsylvania State University
Purdue University
RIKEN, BNL Science Center
Saclay (DAPNIA-SPHN)
St. Petersburg State Technical University (PbSTU)
Subatech
Tokyo Institute of Technology (TITech)
University of Bergen
University of Maryland
University of Tokyo
University of Alabama @ Huntsville
University of Birmingham
University of California @ Berkeley
University of California @ Los Angeles
University of Chicago
University of Muenster
University of Oslo
University of Texas @ Austin
Vanderbilt University
Warsaw University of Technology
Wayne State University
Yale University

Academia Sinica University
Banaras Hindu University
Brookhaven National Laboratory
Center for Nuclear Studies
China Institute of Atomic Energy
Clermont-Ferrand
Creighton University
Fysisk Institutt
Hiroshima University
Institut de Recherches Subatomiques
Institute of High Energy Physics, China
Institute of Particle Physics
Jagellonian University
Joint Institute for Nuclear Research
KEK, Institute for High Energy Physics
Korea University
Kyoto University
Lawrence Berkeley National Laboratory
Los Alamos National Laboratory
Massachusetts Institute of Technology
McGill University
Moscow Engineering Physics Institute
Nagasaki Institute of Applied Science
NBI
Oak Ridge National Laboratory
Orsay (IN2P3-IPN)
Particle Physics Laboratory @ Dubna
Petersburg Nuclear Physics Institute
Rice University
RIKEN, Institute for Physical and Chemical Research
Seoul National University
State University of New York @ Stony Brook
Texas A&M University
Tsukuba University
University of Kansas
University of Rochester
Universidade de Sao Paulo
University of Arkansas
University of Bucharest
University of California @ Davis
University of California @ Riverside
University of Frankfurt
University of New Mexico
University of Tennessee @ Knoxville
University of Washington
Warsaw University
Waseda University
Weizmann Institute
Yonsei University

Table B4 - Users of the Alternating Gradient Synchrotron	
Arizona State University	Lawrence Berkeley National Laboratory
University of California @ Irvine	Abilene Christian University
Argonne National Laboratory	Boston University
British Columbia University	Brookhaven National Laboratory
Carnegie-Mellon University	Christopher Newport University
College of William and Mary	Cont. Electrical Beam Accelerator Facility
Cornell University	Fairfield University
Fermi National Accelerator Laboratory	Fukui University
George Washington University	Hampton University
Illinois Institute of Technology	Institute for High Energy Physics, Protvino
Institute for Nuclear Physics, Novosibirsk	Institute for Nuclear Research, Russia
Institute for Nuclear Study	Institute of Atomic Energy, China
Joint Institute for Nuclear Research, Dubna	Karlsruhe Center for Nuclear Research
KEK	Kent State University
Kyoto University	Max Planck Institute
New York University	North Carolina A&T University
Northwestern University	Osaka University
Paul Scherrer Institute	Petersburg Nuclear Physics Institute
Purdue University	Ruder Boskovic Institute
Tohoku-Gakuin University	Tokyo Institute of Technology
Tokyo University	TRIUMF
University of New Mexico	University of Alberta
University of California @ Los Angeles	University of Colorado
University of Connecticut	University of Heidelberg
University of Houston	University of Illinois @ Champaign
University of Kentucky	University of Manitoba
University of Maryland	University of Minnesota
University of Pennsylvania	University of Regina
Valparaiso University	Virginia Polytechnic Institute
Yale University	

Table B5 - Users* of the Tandem Van De Graaff Accelerators	
Actel	Commissariat de l'Energie Atomique (CEA)
Data Device Corporation	General Dynamics Information Systems (GDIS)
High-Reliability Components Corporation (HIREC)	Intersil
Intl Rectifier	Johns Hopkins University, Applied Physics Lab
Jet Propulsion Laboratories	Lambda Advanced Analog
Lockheed Martin Missiles and Space	Lockheed Martin Space & Electronics Communication
Lockheed Martin-CPC	Matra Marconi Space
Mitsubishi Heavy Industries	Myers and Associates
NASA	Naval Research Laboratory
Sandia	Spallation Neutron Source
Space Electronics, Inc.	Stauber Enterprises
TRW Systems & Information Technology	University of Maryland
University of New Mexico	Whatman Nuclepore

* For most of FY00 the Tandem served as the ion source for RHIC; a second Tandem did not go on line until May 2000

Appendix C: Work For Others

National Aeronautics and Space Administration (NASA): The AGS currently is accelerating Fe ions to energies up to 1.0 GeV per nucleon in a radiobiology program for NASA's Space Radiation Health and Radiation Biology Division. This work will expand a very limited experimental data-base on long missions into interplanetary space by humans. This program runs for two weeks of beam-time per year, with heavy-ion irradiation's for 20-30 experiments annually. The users are approved and funded by NASA, which purchases the AGS time.

National Institute of Health (Department of Health and Human Services: Several of BNL's centers and facilities are developed and operated through partnerships with, and funding from, the National Institute of Health. Such partnerships include the development of facilities for synchrotron crystallography at the NSLS as well as support to our Center for Imaging and Neuroscience and the Scanning Transmission Electron Microscope. NIH also provides substantial support through research grants to individual investigators in the field of molecular Biology.

Environmental Protection Agency (EPA): New York Harbor is faced with an operational crisis in removing sediments and soils contaminated with a variety of anthropogenic toxic materials. The crisis was brought about by stricter regulations that reduce the amount of dredged material considered suitable for ocean disposal in the coastal Atlantic. In collaboration with the US Army Corps of engineers, the objective is to produce dredged material treatment trains which are environmentally effective and economically affordable.

International cooperation is critical to achieving EPA's mission. The EPA Office of International Activities (OIA) enlists the cooperation of other nations in solving environmental problems of concern to the United States. BNL staff assist this office in designing and overseeing the construction of a waste processing facility in Murmansk, Russia. We provide technical support in evaluating Russian waste treatment technologies, and, through OIA, are fostering environmentally sound, sustainable development initiatives in Kazakstan.

Department of Defense (DOD): We developed and demonstrated a novel high-performance oil-fired thermo-photovoltaic system for generating electric power under field conditions with DARPA funding Improvements are being made in the design to improve conversion efficiency.

Under sponsorship from the Defense Special Weapons Agency, we also are applying ultra-sensitive Plutonium Screening and Sampling Protocols used in the DOE funded Marshall Island dose-assessment program, to assay Pu-238 uptake in veterans who participated in above ground nuclear testing, or in the occupation of Hiroshima and Nagasaki.

Several key activities are underway to develop coatings and materials that will have improved abilities to resist corrosion. In addition, we are supporting the US Army in the Chemical and Biological Defense Command (CBDCOM) by assessing the fluorescence properties of humidified and coated biological particles.

US Nuclear Regulatory Commission (NRC): BNL provides technical support to and performs safety related research for the NRC. This work includes risk assessment, reliability analysis, thermal-hydraulic and neutronic-analyses, evaluations related to life extension and licensing renewal, analyses of external events, human system interface research, structural-, mechanical- and earthquake-engineering analysis, operational safety assessments, and reviews of plant-specific safety issues.

BNL constructed and operates the High-Temperature Combustion Facility (HTCF), a unique facility for investigating high-temperature, high-speed combustion phenomena (including detonations). The Laboratory provides environmental qualification information concerning aged electrical cables using experimental condition-monitoring resources housed in our Electric Cable Test Facility. BNL is heavily involved in technology transfer and training of regulatory staff in the United States and in countries of the former Soviet Union. We also collaborate in seismic research with NUPEC of Japan.

Department of State (DOS): The Department of State funds Brookhaven's International Safeguards Project Office (ISPO) which supports the IAEA in nuclear safeguards. ISPO provides ongoing technical review and management of the US Program of Technical Assistance to IAEA Standards (POTAS), as well as advice on new initiatives to enhance the effectiveness and efficiency of IAEA safeguards. Currently, ISPO tracks nearly 100 active projects. Additional funds may be secured for initiatives focussing on managing Russian radioactive waste.

We continue to provide technical support and conduct programs related to simulators, provide training to enhance the safe operation of nuclear power plants, decommissioning and decontamination, and waste management, and use our capabilities to support activities in Eastern Europe and the nations of the former Soviet Union.

Federal Aviation Administration (FAA): BNL is performing risk- and reliability-analysis and assessments of threats by insiders and outsiders to assist the FAA in aircraft system reliability, availability, maintainability, and in airport security. This work includes use of probabilistic-risk analysis techniques, developed and proven for applications to nuclear power plants, to glean risk-related insights from recent incidents and accidents in commercial aircraft and for improving the reliability of specific aircraft components.

Private Entities: BNL has over fifty projects for private entities in the United States and other countries. These projects are related primarily to energy resources and biomedical research and development. About 30 of these projects are for industry, 15 for academic institutions, and the others for foundations and organizations in other countries. This work is one of the ways that BNL supports DOE's missions in developing advanced technologies that address national needs, and disseminating technical knowledge and maintaining technical capabilities in the nation's workforce.

In Environmental Sciences, for example, BNL's staff are extensively involved in research such as the work for North Carolina State University that involves data analyses with a series of diagnostic modeling exercise to understand the photochemical process forming ozone in the Nashville area. This work leverages DOE's investments in atmospheric chemistry. Through the Woodshole Oceanographic Institute, BNL participates in the Global Ocean Ecosystem Dynamics Programs.

State and Local Governments: BNL has a variety of activities for agencies of the State of New York, related primarily to energy resources. This includes work to provide clean and affordable energy, allow efficient and productive use of energy, and test and generate advanced equipment, such as fuel cells.

Other DOE Contractors: BNL conducts over 40 projects to support work with other DOE contractors. This work provides BNL's unique capabilities to support DOE's missions by working with other DOE Contractors. Our largest endeavor involves the Spallation Neutron Source Collaboration.

Table C1 - FY 00 Work For Others by Project		
FUNDING AGENCY	TITLE	DEPARTMENT
	DEPARTMENT OF COMMERCE	
NOAA	Compilation and Analyses of Emissions Inventories for the North Atlantic Regional Experiment	EENS
NOAA	Ferredoxin & Flavodoxin as Metabolic Markers for Iron Stress	EENS
NOAA	Development and Deployment of an Aircraft Formaldehyde Measurement During NARE	EENS
NIST	Development & Scientific Application of Neutron Crystal Spectrometers for Materials Research	PHY
NOAA	Diagnostic Model Studies on Seasonal Changes in Chemistry in NARE	EENS
	DEPARTMENT OF DEFENSE	
DARPA	Molecular Logic Gates	MED
SERDP	Non-destructive Evaluation of Corrosion Under Coatings	EENS
ARMY	Design, Development & Fabrication of a Breadboard Prototype 500W TPV Power Source Phase I	EENS
ONR	Shipboard Acoustic Doppler Profiles in the Arabian Sea	EENS
ONR	A Spectral Element, Eddy, Resolving Primitive Equation Model for the North Atlantic	EENS
ARMY	Amorphous Pre-ceramic and Crystalline Organic Polymers for High Performance Coatings, Adhesives, and Composites	EENS
Navy	Chemical Digestion Process	EENS
Army	Active/Passive Noise Cancellation	EENS
Navy	Arctic Military Environmental Cooperation	EENS
DNA	Improvement of FTA Fission Track Analyses of Urine Samples From The Nuclear Test Personnel Program...	EENS
	DEPARTMENT OF HEALTH AND HUMAN SERVICES (DHHS) - PROGRAM 40	
NIH	Chemistry Department Operating Funds for Regional NIDA Neuroimaging Center	MED
NIH/NIDA	Operating Funds for Regional NIDA Neuroimaging Center	MED
NIH	Protein Data Bank	BIO
	DHHS GRANTS	
NIH	DNA Mismatch Repair in Transformation and Mutagenesis	BIO
NIH	Function of the Human DNA Activated Protein Kinase	BIO
NIH	Regulation of Adenovirus Proteinase by a Peptide J DNA	BIO
NIH	The Dual Receptor Mechanism of Adenovirus Infection	BIO
NIH	STEM Mass Mapping & Heavy Atom Labeling of Biomolecules	BIO
NIH/NIGMS	Structural and Functional Studies of E Coli DNAJ	BIO
NIH	Development for Macromolecular Crystallography at the NSLS	BIO

Table C1 - FY 00 Work For Others by Project		
FUNDING AGENCY	TITLE	DEPARTMENT
NIH	CLP: An Archetypal ATP-Dependent Protease	BIO
NIH	Enhancement of Functional and Neurochemical Brain Pattern	CHEM
NIH/NINDS	Pet Studies of Catechol -O-Methyltransferase	CHEM
NIDA	PET in Cocaine Abuse	CHEM
NIH	Radiotracer R&D in Nuclear Medicine and Neurosciences	MED
NIDA	PET Studies of Brain Dopamine in Cocaine Abusers	MED
NIAAA	Dopaminergic Brain Function in Alcoholics	CHEM
NIGM	Nondiamagnetic Agents in In-Vivo 23NA & 2H2 MR	MED
NIDA	Pharmacokinetics of Psychostimulants & Reinforcement	CHEM
NIH	PET Investigations of Neurotransmitter Interactions	CHEM
NIH	Auger Electron Therapy: Gadolinium & Thermal Neutrons	MED
NIDA	PET Studies of Brain Dopamine in Cocaine Abusers	MED
NIDA	Pharmacokinetics of Psychostimulants & Reinforcement	MED
NIMH	PET Investigations of Neurotransmitter Interactions	MED
NIH	1 HNMR Chemical Shift Imaging in Temporal Lobe Epilepsy	MED
NIH	Estimation of Synaptic Dopamine using PET & SPECT	MED
NIH	Modulation of Neutrons Matter Release by Cannabinoids	MED
NIH	Dopaminergic Brain Function in Alcoholics	MED
NIH	Structure Function Relations in Botulinum Neurotoxin	BIO
	DEPARTMENT OF STATE	
AID	International Safeguards Project Office POTAS	EENS
AID	Lisbon Project	EENS
	ENVIRONMENTAL PROTECTION AGENCY	
EPA	Barrier Materials Evaluation of Waste Forms Dumped in the Kara and Barents Seas	EENS
EPA	NY/NJ Harbor Sediment Decontamination Tech. Demonstration: Phase II Pilot Scale	EENS
EPA	Program Plan from BNL for 1998 Interagency Agreement between EPA & DOE	EENS
EPA	MARKAL-MACRO Training & Analyses	EENS
EPA	MARKAL-MARCO Outreach	EENS
EPA	Murmansk Initiative & Related Waste Management Projects in the Former Soviet Union	EENS
	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	
NASA	Representation of Aerosol Microphysics in Regional to Global Scale Models	EENS

Table C1 - FY 00 Work For Others by Project

FUNDING AGENCY	TITLE	DEPARTMENT
NASA	Validation of the SeaWiFs Atmospheric Correction Scheme using Measurement of Aerosol Optical Properties	EENS
NASA	Reaction Pathways & Thermodynamic Studies of Atmospheric Reactions	EENS
NASA	Genetic and Epigenetic Effects Produced by High Energy Heavy Ions	MED
NASA	Genetic and Epigenetic Effects Produced by High Energy Heavy Ions	BIO
NASA	Feasibility Study-Heavy Ion Beam Facility for Radiation Health Research at AGS Booster	AGS
NASA	Booster Applications Facility	AGS
NASA	Heavy Ion Beam for SEU Studies & Radiation Effects Research	AGS
NASA	Interpretation of Light Observations using an Eulerian Aerosol Model	EENS
NASA	Phase Transformations in Stratospheric & Upper Tropospheric Aerosols: Lab Studies of Single Particles	EENS
NASA	DNA Lesion Clusters in Space Radiation Damage	BIO
NASA	Germ Cell Mutagenesis in Medaka Fish Following Exposure to Heavy, High Energy Cosmic Ray Nuclei	BIO
	NUCLEAR REGULATORY COMMISSION (NRC)	
NRC	Analysis of Reactor Transients	EENS
NRC	Kalinin NPP Probabilistic Risk Assessment	EENS
NRC	Technical Support of Risks Assessments	EENS
NRC	Application of Risk Based Information to Regulatory Activities	EENS
NRC	Review of Seismic IPEEE	EENS
NRC	Strengthening Kazakhstan Nuclear Regulatory Authority	EENS
NRC	Development of Armenian Nuclear Regulatory Authority	EENS
NRC	Development of Consensus Probabilistic Risk Assessment Standard	EENS
NRC	Reactor Dosimetry and Reactor Pressure Vessel Benchmarking	EENS
NRC	Low Power and Shutdown Risks	EENS
NRC	Risk Informed 10 CFR Part 50	EENS
NRC	Reactor Oversight Program Support	EENS
NRC	Support of License Renewal	EENS
NRC	LOCA Testing of Cables	EENS
NRC	Support of Nuclear Power Plant Decommissioning	EENS
NRC	Collaboration with Japanese on Seismic Issues	EENS
NRC	Displacement Based Seismic Design	EENS
NRC	Assessment of Aged and Degraded Structures and Components	EENS
NRC	Licensing Renewal Review – Age Related issues	EENS
NRC	Licensing Renewal – Engineering Issues	EENS
NRC	Technical Support of System Safety Analysis	EENS

Table C1 - FY 00 Work For Others by Project		
FUNDING AGENCY	TITLE	DEPARTMENT
NRC	Technical Support of Inspection Program Activities	EENS
NRC	Specialist support for NRR Inspections	EENS
NRC	Human-System Interface Design	EENS
NRC	Credit for Operator Actions	EENS
NRC	Ukrainian Nuclear Regulatory Training	EENS
NRC	Inspector Assistance	EENS
NRC	Technical Support to Reviewing Licenses Renewal Applications – Reactor Coolant Systems	EENS
NRC	Steam Generator Internals	EENS
NRC	Technical Assistance – Regulatory Guides 1.52 and 1.140	EENS
NRC	Water Reactor Safety Meeting	EENS
	NATIONAL SCIENCE FOUNEENSION PROGRAM 40	
NSF	DOE National Teacher Enhancement Project	DO
NSF	Protein Data Bank Macromolecular Structure Data Base	BIO
NSF	US-Japan Joint Seminar: Probing Hadron Structure with Polarized Photons	PHY
	VARIOUS MISC. FEDERAL AGENCIES - PROGRAM 40	
DOT/FAA	FAA IAG Working Group on Airport Vulnerability Assessment Project	EENS
FAA	Applying Probabilistic Risk Assessment Methodology to Aircraft Safety	EENS
PETC	Clean Coal Fossil Fuels and Energy Efficiency	EENS
DOI/NPS	Tracer Study of Long Range Transport in Support of BRAVO	EENS
DOE NN-30	Safeguards Analysis	EENS
	PRIVATE ENTITIES	
US Civilian R&D Foundation	Fellowship for Dr. Ne	CHEM
ALS Association	Studies of the Activities of ALS Mutant SOPs Using Pulse Radiolysis Techniques	CHEM
Children's Brain Tumor Foundation	Unidirectional Microbeam Radiation Therapy of Children's Brain Tumor using Synchrotron X-rays	MED
Charles A. Dana Foundation	Cerebral Metabolism in Ketosis and Epilepsy: 1H and 31P Spectroscopic Study at 4.1T	MED
Multiple Sclerosis Society	H Spectroscopic Imaging of Multiple Sclerosis	MED
SUNY-SB	Vaccine Intervention for Lyme Borreliosis	BIO
DuPont	Development of Structural Models of Plant Soluble Fatty Acid Desaturase as a basis for Rational Design of Desaturase Double Bond Positional Specificity.	BIO

Table C1 - FY 00 Work For Others by Project

FUNDING AGENCY	TITLE	DEPARTMENT
NYU (NIH)	PET in Schizophrenia	CHEM
DuPont	Catalytic Production of Organic Chemicals Based on New Homogeneously Catalyzed Ionic Hydrogenation Technology	CHEM
Power Reactor and Nuclear Fuel	Joint Study of Improved Safeguards Methodology Using No Notice Randomized Inspections	EENS
PWR Reactors Nuclear Fuel-Tokyo	A Study of High Level Radiation Waste Material Transmutation Using an Accelerator	EENS
NUCON Systems, Inc.	Evaluation of the Radiation Stability of Ceramics	EENS
University of Valencia	Pilot Project on Improvements for Spanish Nuclear Power Plants	EENS
Univ. Minnesota	FACE Facility at Cedar Creek	EENS
Electro Energy	Preparation and Characterization of Metal Hydride Electrode Materials for Bipolar Batteries	EENS
Federal Lab Consortium	Terrestrial Magnetic Survey	EENS
Performance Safety and Health Associates	Human Performance Evaluation	
Woods Hole (NSF)	Analysis of Acoustic Data Gathered during the SHEBA Project	EENS
Woods Hole (NSF)	GLOBEC: Collection of Shipboard ADCP Data & the 1st year of the NE Channel & Scotian Shelf Water Cross-Over Moving Array	EENS
Penn State University	Investigations of Factors Determining the Occurrence of Ozone and Fine Particles in the North Eastern USA	EENS
St. Luke's (NIH)	Medical Applications Accuracy Neutron Activation	MED
Metabolic Tech.	3-Methylhistidine Kinetics as an Indicator of Muscle Mass and Metabolism	MED
JAERI	A Study of Medium and High Energy Proton Nuclear Cascade Process in Context of Accelerator Based....	EENS
Power Reactor & Nuclear Fuel	Joint Study of Improved Safeguards Methodology Using No Notice Randomized Inspection	EENS
Cornell Univ.	CADD-based Expert System for Passive Snow Control	EENS
Science Digital Visions	Registry System for Accessing NNDC Nuclear Data Bases	EENS
International Resource Group Ltd.	Energy, Environment & Economic Modeling & Policy Analysis	EENS
American Bureau of Shipping	Human Factors Engineering Guidance Development for Merchant Vessels	EENS
DuPont	Flame Acceleration and Detonation Experiments in Methane-Air Mixtures at Elevated Temperatures	EENS
Science Engineering Associates	Perfluorocarbon Tracer Testing at the Science Engineering Test Site	EENS
Enconet Consulting	Risk Informed Applications for Nuclear Power Plants	EENS
Crown Communications	Analytical Support, Methods Development and Review for the FAA	EENS

Table C1 - FY 00 Work For Others by Project		
FUNDING AGENCY	TITLE	DEPARTMENT
Radkowsky Thorium Corp	Radkowsky Thorium Fuel Project	EENS
Korean Atomic Energy Res. Inst.	Fission Product Neutron Data Evaluation	EENS
SCRAM Tech	Polyplanar Optic Display Interactivity	EENS
Cornell Univ.	Tort Law Database	EENS
Ev Products Div of II-IV	Development of Multi Channel ASICs for CdZnTe Gamma Ray Detector Arrays	INST
Symbol Tech. Inc.	Microcircuits & Sensors for Portable, Low-Power Data Collection & Transmission	INST
Korean Atomic Energy	Technical Assistance to KAERI on Low Power & Shutdown PSA of YGN 5 & 6	EENS
University of Valencia	Pilot Study & Guidance for Technical Specification Improvement for Spanish Nuclear Power Plants	EENS
KGL Inc.	Photo-irradiation Study of the Effect of Topical Imiquimod 5% Cream on Sunburn Cell....	BIO
KeySpan	Determination of Gas Flow Rates at LILCO Gas-Fired Power Stations	EENS
KeySpan	Remediation of Soils Contaminated with Lead Paint	EENS
EPRI	NARSTO-NE Ozone Formation in the NY City Urban Area Plume	EENS
Consolidated Edison	Equipment for Rapid Cable-Leak Locating and Detecting Capabilities	EENS
Korea Atomic Energy Res. Inst.	BNL Safety for the KALIMER Project	EENS
Purdue University	Quantifying the Indirect Radioactive Forcing of Sulfate Aerosols	EENS
Skidaway Inst. of Oceanography	Ocean Margins Program - Synthesis and Modeling	EENS
Insight Technologies, Inc.	BNL Technical Support on the Development of a Two-Stage Oil Burner wit Load-Tracking Control	EENS
PowerEnerCat, Inc.	Evaluation of Nanosized Particles of Molybdenum Disulfide for Slurry Phase Synthesis of Mixed Alcohols	EENS
University of Rochester	US ATLAS Barrel Cryostat Design and Procurement	Physics
Tokyo Electric Power Co.	AC Losses in Conductors Based on High Tc Superconductors	EENS
Battelle Memorial Institute	Technical Support for BMI Technology Platforms	TT
Scientific Digital Visions, Inc.	Application of Java Technologies to Nuclear Physics Databases	EENS
	STATE AGENCIES & LOCAL GOVERNMENTS	
NYS ERDA	Oil-Fired Heating System Development & Demonstration	EENS
NYS ERDA	Low Power Heating System	EENS
NYS ERDA	Pulse Fuel Flow in Oil Burning	
NYS ERDA/LIPA/Key Span	Micro Generation Field Testing and Demonstration	EENS
NY DOT	CADD Based System for Possible Snow Control	EENS

Table C1 - FY 00 Work For Others by Project		
FUNDING AGENCY	TITLE	DEPARTMENT
NY DOT	Tort Law Data Base	
Suffolk County Dept. of Health	Brown Tide Monitoring Network	EENS
Suffolk County	Dissolved Organic Nitrogen & Brown Tide Blooms in L.I.'s Coastal Waters	EENS
	OTHER DOE CONTRACTORS	
Battelle-PNNL	Various Battelle - PNL Work Orders for Continuation of LISBON Project	EENS
Battelle-PNNL	Participation and Scientific Management of ARM Program	EENS
Savannah River	MC&A Studies for SR Facilities & Review of Documents	EENS
Idaho Operations Office	Molecular Analysis of Carbohydrate Regulation in Loblolly Pine	EENS
ORNL	Design & R&D of Accumulator Rings of Rapid Cycling Synchrotrons & High Energy Beam Transport Systems	AGS/EENS
Idaho Operations Office	Biochemical Processes to Remove Undesirable Elements From Geothermal Operations	EENS
Albuquerque Office	Proton Radiography Experiment	AGS
Albuquerque Office	Enhanced Surveillance, Phytoremediation & Evaluation of Risks w/ Re-distribution. - Chernobyl (DSWA)	EENS
Idaho Operations Office	Geothermal Heat Pump Grouting Materials	EENS
Sandia	Source-Term Calculations for WIPP Performance Assessment	EENS
Idaho Operations Office	Silica Precipitation by Thermophilic Bacteria in Hot Springs	EENS
Albuquerque Operations	Management of Spent Nuclear Fuel in Kazakstan, Russia	RO
Albuquerque Office	Development of Submillimeter Microwave Spectrometers for Materials Analysis & Other Applications	PHY
Albuquerque Office	Linear Ion Source	PHY
Albuquerque Office	Improved Automated Processing of Mbp Scale DNA Sequencing	BIO
Albuquerque Office	Surveillance for Comprehensive Asset Tracking Technology	EENS
Albuquerque Office	Technology Advances to Reduce Emissions from Fossil Fuel Power Plants	EENS
Albuquerque Office	Thorium Fuel Concept	EENS
Albuquerque Office	Study of Local Magnetic Flux Distribution Related to Transport Properties of High-Tc BSCCO Superconducting Practical Tapes	EENS
Albuquerque Office	Development of Algorithms & Methods for the Recognition & Display of Hierarchical Repeat Structures in DNA Sequences	BIO
Albuquerque Office	Retargeting of Adenovirus for In-Vivo Gene Therapy	BIO
Albuquerque Office	Development of Sensitive & Specific Rapid Diagnostic Tests for Lyme Borreliosis in Russia	BIO
Sandia	Dynamics of Dislocations Near Interfaces in Thin Metal Films	PHY
FERMI	Design, Construction and Installation of the Forward Pre-shower Detector for the D Zero Upgrade Project	PHY
Lockheed Martin	Technical Support for EPA/DOE Environmental Technology Verification Program	EENS
Lockheed Martin	Biological Warfare Response Improvement Program	EENS

Table C1 - FY 00 Work For Others by Project		
FUNDING AGENCY	TITLE	DEPARTMENT
ORNL	EM Mixed Waste Focus Area	EENS
Sandia	Cement Research Project	EENS
ORNL	Spallation Neutron Project	AGS
LLNL	SCOUNGATRON Project	AGS
Sandia	SEU Testing	AGS
Battelle-PNNL	Accelerator Transmutation of Waste Workshop	EENS
FETC	Krakow Clean Coal Fossil Fuels & Energy Efficiency Program	EENS
University California	Development. of Radioactive Beam Capability at the 88-Inch Cyclotron	CO
Sandia	Use of High Temperature, CO2 Resistant Cements Developed at BNL	EENS
Oak Ridge Ops. Office	Alternate Site Identification & characterization for the National Spallation Neutron Source Project	DO
Lockheed Martin	Develop Animal Models, Prepare Rhenium-188 Labeled Stents and Evaluate the Histological Properties for ORNL	MED
Sandia	Catalysis Research	CHEM
Lockheed Martin	Assembly of a Control System for one 24 Valve Ring	EENS
FERMI	Fabricate & Deliver 4" S1 Wafer with Metalized Pixel Pattern	IO
Sandia	UAV Measurement Study	EENS
Argonne	Fabricate 3D Wire Detector 20cms x 20cms Area	IO
Lockheed Martin	Provide Depth Profiles of Vacancy Related Defects in Ion Implanted Silicon Samples from ORNL	EENS

Table C2 - CRADA Projects

SPONSOR	TITLE	DEPARTMENT
eV Prod. Div. of II-VI, Inc.	Monolithic Circuits for CZT Gamma Ray Detectors	IO
Advanced Imaging	Passive Shim Array for Improved Static Field Homogeneity in Magnetic Resonance Imaging of the Human Head	IO
Brookhaven Technology Group, Inc.	Development of a High Current, High Gradient, Laser Excited, Pulsed Powered Electron Gun	IO
Consolidated Edison Company	Equipment for Rapid Cable-Leak Locating and Detecting Capabilities	EENS
Cotton Incorporated	Improving Cotton Fiber Quality and Yield	BIO
CTI, Inc.	Non-Invasive Blood Radioactivity Monitor for Quantitative PET Imaging Studies	CHEM
Diatide, Inc.	Development of Tin-117m Stannic DTPA for the Therapy of Cancer in Bone	MED
Dow Chemical Co.	Directed Genetic Engineering of Lipid Metabolism in Plants	BIO
DuPont Agricultural Products	Development of Structural Models of Plant Soluble Fatty Acid Desaturase As A Basis for Rational Design of Desaturase Double B and Positional Specificity	BIO
DuPont Company	Catalytic Production of Organic Chemicals Based on New Homogeneously Catalyzed Ionic Hydrogenation Technology	CHEM
DuPont/Kurchatov Institute	Combustion Code for the Chemical Industry	EENS
Excom, Inc.	Development of Application of Pattern Recognition System	EENS
Excom, Inc.	Development of a Multi-Facet Pattern Recognition System	EENS
Gas Research Institute	Design and Manufacture of a Prototype Rapid Concrete Cutter Device for Opening of Concrete Pavements above Subterranean Gas Pipelines	EENS
Gould Electronics, Inc.	Development of New electrolyte and electrode Materials for rechargeable Lithium Batteries and In-situ Techniques for Battery Material Studies	EENS
International Resources Group Ltd.	Energy, Environment and Economic Modeling and Policy Analysis	EENS
Miravant Medical Technologies	Synchrotron-Based Structural Studies of Porphyrin Sensitizers for Photodynamic Therapy	EENS

Table C2 - CRADA Projects

SPONSOR	TITLE	DEPARTMENT
Niton Corp.	Development of Silicon Drift Detectors for Portable X-Ray Fluorescence Instruments	EENS
Oncogene Research Products	Development of Immunological Reagents for Analysis of DNA-Damage Responses in Human Cells	BIO
Oxford Superconducting Technology	Development of Buffer Layers Suitable for Thick Superconducting YBCO Layers By A Post Deposition Annealing Process	EENS
PhytoWorks	Aquatic Plants for Phytoremediation of Toxic Metals and Radionuclides in Sediment	EENS
PPG Industries, Inc.	An Investigation of the Chemistry of Lead During Undermining of Coatings on Steel	EENS
Radkowsky Thorium Power Corp.	Radkowsky Thorium Fuel Project	EENS
Schering AG	Development of a Non-Iodine Based Radiographic Contrast Agent and a Complementary Monochromator for CT and Planar X-ray Imaging Sources	MED
SmithKline Beecham Corp	Gene Expression and Identification of Gene Function in the Genome of Streptococcus pneumoniae	BIO
Symbol Technologies, Inc	Microcircuits and Sensors for Portable, Low-Power Data Collection and Transmission	IO
Targacept, Inc.	Development of a Radiotracer for Imaging the Brain Nicotine Receptor for Alzheimer's Disease Diagnosis	CHEM

Table C3 - BSA Patent Portfolio			
Technology Field	Inventions in Portfolio	Inventions Licensed	Inventions Commercialized
Molecular Biology	22	9	4
Medical Devices	8	2	0
Pharmaceuticals	24	4	1
Optics	18	18	0
Instrumentation	17	6	4
Materials	18	4	0
Environmental Remediation	13	5	4
Energy Production	9	2	0
Microfabrication	3	1	0
Electronics	4	1	0
Total	**136**	**52**	**13**

Table C4 - Products Marketed Under License From BNL	
PRODUCT	DEPARTMENT
Apparatus and Method for Biological Purification of Wastes	EENS
T7 Gene Expression System, Vectors and Protein Products Produced with the T7 System	BIO
Red Blood Cell Labeling Kit for Selectively Labeling Whole Blood with Tc-99m	MED
Recombinant Plasmids for Encoding Restriction Enzymes Dpn I and Dpn II of Streptococcus Pneumoniae	BIO
Fast Repetition Rate Fluorometers and Method for Measuring Fluorescence and Photosynthetic Parameters	EENS
Surface Profiling Interferometers for Accurately Measuring Irregularities in the Surfaces of Mirrors and Lenses	IO
Cytoplasmic Bacteriophage Display System	BIO
Autogenes Encoding RNA Polymerases	BIO
Polyethylene Encapsulation of Radioactive and Mixed Wastes	EENS
Asbestos Remediation	EENS

Table C5 - BSA Licensing Revenue ($1000)				
	FY 96	FY 97	FY 98	FY 99
Gross Revenue	889	1342	1656	2771
Net Revenue	488	992	1196	2136

Appendix D: Sites and Facilities

D.1 Introduction

The BNL site is approximately 5,320 acres, about 30% of the total area is developed. There are approximately 400 buildings in use with a total area of 4.36 million square feet and a replacement value of approximately $4 Billion (Table D1). Many buildings date back to World War II and some before. Most of the major permanent buildings, excluding those constructed for RHIC, were constructed in the 1960s (Figure D1). The site is served by site-wide utility systems that include electrical, steam, sanitary sewer, storm sewer, and potable water. In addition, there are limited distribution systems for chilled-water and compressed air. Figures D2 and D3 illustrate the condition and use of existing Laboratory space.

Table D1 - Laboratory Space Distribution and Replacement Value

LABORATORY SPACE DISTRIBUTION

Location	Area (Sq. Ft.)
BNL Site	4,235,771
Portable Structures	121,122
Leased Off-Site	1,000
TOTAL	**4,357,893**

Source: FIMS 4/20/00

FACILITY REPLACEMENT VALUE

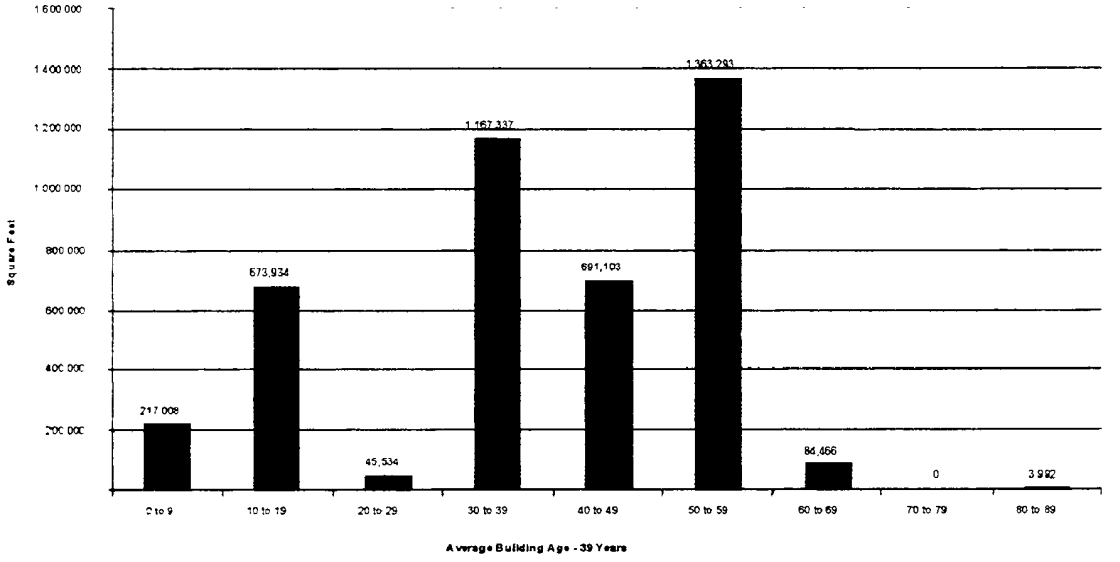
Facility Type	Current $
Buildings	3,438,832,103
OSF	593,176,605
TOTAL	**4,032,008,708**

Source: FIMS 4/20/00

D.2 Trends

Buildings and Space Utilization: Approximately 78% of BNLs building space is at least 30 years old, and 34% over 50 years old. The costs of maintenance, repair, and capital renewal are high, the buildings are small and dispersed across the site. Over the past five years there has been a small rise in the total square footage, primarily due to RHIC related construction and an addition to the Department of Applied Science, Building 815. Within this same period, the Laboratory measured each building, developed accurate key plans and identified every structure as either a building or portable structure. The reporting of several assets was reconfigured to align more closely with the actual use of the facility. These simultaneous changes make it difficult to baseline the data, and there is no clear trend indicated at this time. Consistent with efforts to consolidate staff into better space, an effort is underway to increase the use of office space in permanent buildings and vacate space in 50-year-old wood construction that can then be demolished.

Figure D1 - Age of Laboratory Buildings in Years (Average is 38 years)



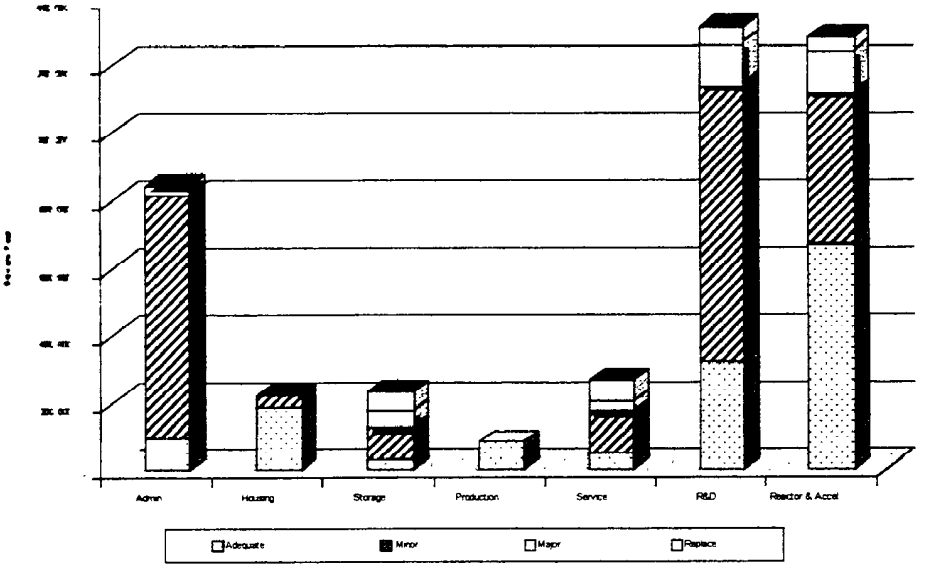
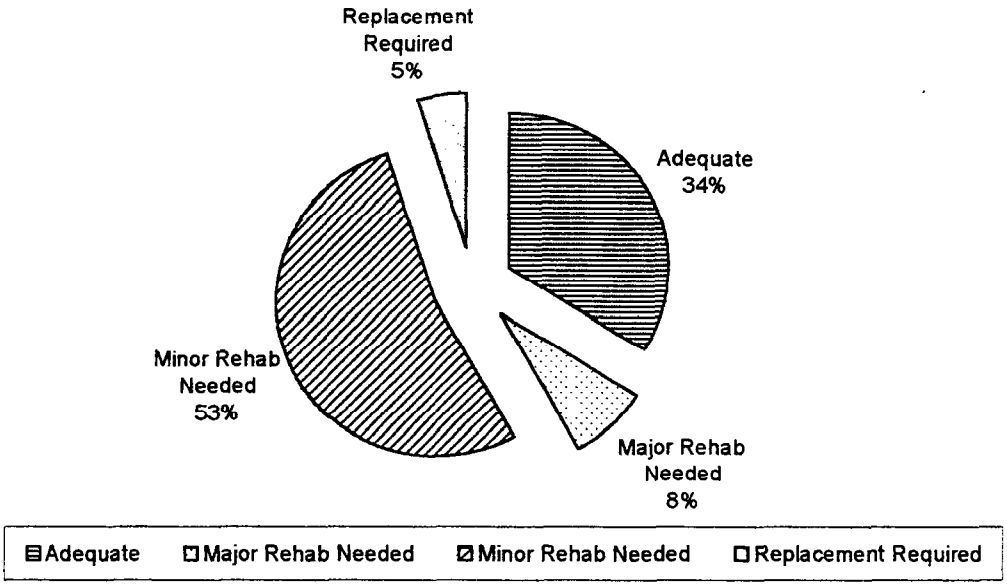


Figure D2 - Use and Condition of Laboratory Space

Figure D3 - Condition of Laboratory Space



NOTES:
1. Condition based on FIMS criteria and data as of 4/20/00
2. BNL believes this overestimates the condition. While it reflects recorded backlog of deficiencies it does not take in account the suitability of the space to perform current and projected research or the operational inefficiencies inherent when 50 year old space is used in a modern technological environment.

Portable Structures: There is no clear definition of trailers, however, BNL tracks all portable structures used to house people and equipment or used for storage. All portable structures are included in the space charge program. This has prompted the removal of approximately 120 portable structures over the past 5 years. Within the last year the number of portable structures rose by 4 to 383.

Surplus Facilities: The number of contaminated surplus facilities had not changed since 1994. On April 12, 2000, a Memo of Agreement (MOA) was signed by DOE Office of Science, Office of Nuclear Energy Science and Technology and Office of Environmental Management that transferred 9 buildings, part of the recently shutdown High Flux Beam Reactor (HFBR) complex to EM for disposition. This increased the total number of contaminated surplus buildings to 19. The number of non-contaminated surplus facilities has decreased from 7 to 6 since BNL delayed the demolition of Building 118 until suitable replacement space can be found. Surveillance and maintenance costs of surplus facilities are not tracked separately. Actual maintenance costs are recorded in FIMS and updated annually. Maintenance costs associated with non-contaminated surplus facilities are nominal and funded by the budget derived from the space charge

Off-Site Leases: One existing lease has been in effect since 1996 for a 1000 sq. ft apartment for staff involved in a program in North Carolina.

Utilities: Site-wide utility systems have been a high priority for maintenance and capital renewal, and we received good support from the DOE Multiprogram Energy Research Facilities Support (MEL/FS) program. General Plan Project (GPP) funds also have been used to address smaller more lo-

calized utility issues. These projects have ensured operational continuity. There are, however, remaining issues, such as the reliability of electric and the extent and reliability of networking systems.

Maintenance: From FY98 to FY99 the deferred maintenance reported in Facility Management Information System (FIMS) increased from $50 to $106 million. The increase is due primarily to our continuing efforts to accurately identify all sources of deferred maintenance. Recent increases in maintenance budgets, as a result of the space charge program, have brought maintenance funding back to their highest levels since FY94. In FY95 funds were curtailed as part of DOE's efforts to reduce overhead at the sites, and as BNL directed more funds to meet emerging ES&H needs.

D.3 Assets Management

The Laboratory maintains a comprehensive Assets Management Program encompassing all use, control and disposal of assets in a cost-effective, efficient manner.

Real Property: Real property records are maintained in the DOE's FIMS and reconciled with the Laboratory's financial records. During field surveys as part of the Facility Inspection Program, FIMS records and building key plans are reviewed for accuracy. Information on building conditions, deficiency lists, and requests for upgrades are reviewed to assess facility life cycle and to identify those assets for which further capital investment is warranted or for which demolition is preferred. The Laboratory seeks either the DOE's Office of Science landlord funds or the DOE's Environmental Management funds for buildings that need to be demolished.

Personal Property: The Laboratory uses an active Walk-Through Program to ensure that all appropriate equipment is identified and properly controlled and to monitor and identify any idle or surplus materials. The Laboratory also uses a site inspection program to monitor the accumulation of materials. These programs, coupled with the Waste Minimization Program, allow the Laboratory to quickly and efficiently dispose of surplus assets, consistent with the appropriate Federal and DOE Property Management Regulations.

Space Management: In FY98 BNL began a charge-back program that charges departments and divisions for actual use of space. It includes all buildings and portable structures. Occupied space rates are adjusted each quarter. Each space is classified and assigned rate categories shown in Table

Table D2 - Space Charge Rate Categories

Type of Space	Description
0	Common Space (corridors, bathrooms, electrical and mechanical space associated with operations of the facility.)
1	Normally unoccupied space, such as • Programmatic equipment support spaces, electrical and mechanical space associated with the operation of the program • Storage spaces
2	Normally occupied, space such as • Industrial space, such as machine shops, technical and craft shop areas • Non-laboratory high bay industrial areas, such as manufacturing, testing and

Type of Space	Description
	assembly areas • Commercial space, such as the Research Library
3	Normally occupied space such as • Offices • Laboratories • Conference Rooms and Department/Division libraries.

The space charge does have a benefit. This has been particularly true for those groups that have reorganized and who tend to look at space use as they plan their revised organizations.

D.4 Energy Management

Energy management initiatives have been very successful at BNL, as demonstrated by measured reductions in energy use. The site building energy use per square foot for FY 99 was 28% less than in FY 85, well ahead of the DOE goal of a 20% reduction by FY 2000; and resulting in $3 million in savings when compared to FY 1985.

D.5 Site and Facilities Plans

There are many factors that influence to our site & facilities plans. Some significant issues include the following:

- Past budget constraints have created extended deferrals of capital renewal and replacement projects, and annual maintenance.
- Lack of available space requires the continued use of, wood-frame buildings, most greater than 50 years old. Through our planning efforts, we identified those facilities where extension, and those facilities where demolition is the best course of action. These wood buildings have the following problems:
- Maintenance and energy costs are higher than for structures that are considered permanent.
- These facilities do not meet current structural standards for wind and seismic loads, and do not comply with the current Life Safety Code requirements.
- Retrofitting older facilities to comply with current ES&H standards is extremely costly.
- There is a lack of adequate space for users.
- Many departments and divisions are dispersed in several buildings lowering their operational efficiency. In addition, the older space is not easily modified to accommodate current needs. The ability to realize future new program initiatives will be affected by the Laboratory's ability to provide a working environment suitable for the quality personnel it must attract.
- Roofing systems are failing or have failed and require replacement. It is estimated that $1.3 million per year is required to replace roofs on a 30-year cycle. This funding level exceeds the available funds causing backlogs to increase. Prolonged water infiltration from roof leaks can lead to equipment damage, structural damage, and the shutdown of facilities for extensive repairs, or require abandonment or replacement.

- With RHIC now operating, the Laboratory's peak electrical demand will grow by about 30%. Transformer capacity is adequate to meet the load; however, future additions will be necessary to re-establish firm capacity. The primary 13.8 kV distribution feeders are aging; sixteen are over 40 years old, seven of these are over 50-years-old. Failure of the feeders continues to be the most prevalent cause of unplanned facility shutdowns.

As part of our current effort to update our Master Site Plan and respond to the above other concerns, several high-level planning assumptions were developed to guide that planning. Those assumptions most directly related to Site & Facilities planning are the following:

- The 50's/60's vintage office/lab buildings will require major refurbishing.
- Modern warehousing is needed.
- Maintenance service centers should be modernized and consolidated.
- Support groups should be consolidated into a single or fewer facilities.
- Better facilities are needed to receive visitors.
- Utility systems will need continued modernization.
- Additional housing will be needed to accommodate visitors and their families.
- Departments will continue to reorganize / realign to accommodate mission.
- Additional and upgraded flexible user space will be required. Space should be a combination of office and light lab and be configurable to meet changing mission needs.
- Additional flexible experimental assembly & equipment storage facilities will be needed.

The current funding levels, have been static for many years, and declining if inflation is included, this challenges the Laboratory's ability to significantly improve infrastructure. At the same time, operating costs have increased as the maintenance of aged buildings and utility systems becomes more difficult and expensive.

Increased levels of GPP and/or MEL/FS Line Items would allow construction of new facilities. The current GPP backlog is approximately $60 million; $29 million high priority projects. In addition, over the past few years, we average approximately $10 million per year in new projects. This exceeds the funding average of slightly over $6 million per year causing increases in the backlogs. To reduce backlogs, GPP funding levels will need to be increased to at least $10 million per year.

The proposed above-target Applied Science and Technology Building will reduce at least the equivalent amount of 50-year-old space, provide modern facilities and allow consolidation of workgroups to increase the operational efficiency of the research group.

The proposed above-target proposed Research Support Center would reduce backlogs in the areas such as Life Safety compliance, roofing, duct cleaning, and mechanical equipment replacement, etc. New larger multi-story buildings would reduce roof area, and associated replacement costs, improve energy efficiency, and improve operational efficiency by co-locating support staff reducing the number of facilities the research staff would need to go do during the course of normal business.

The proposed above-target User Support Center will provide better facilities to attract and support users. This type of facility would be more efficient and more conducive to collaborative research.

The overall vision is to consolidate staff from the 50-year-old wooden structures and to modernize the 35-year-old permanent facilities. This will provide the quality-of-facility needed to support continued world-class research, at an efficiency level conducive to attracting new and sustaining existing research with facilities that are more easily maintained at achievable maintenance funding levels.

D.6 General Purpose Facilities Plans and Facilities Resource Requirements

The Laboratory historically relied on General Plan Projects (GPP) for small, urgent project needs. BNL developed a process for assigning priorities to ES&H, Infrastructure and Program Support projects and has been used and refined over the past two funding cycles. While the size of the GPP project increased to $5 million and opportunities exist to make significant improvements and realize cost-savings by replacing and consolidating buildings, it is unlikely that BNL can use this increased flexibility, because of the large backlog of projects. The GPP backlog continues to grow and will grow faster as BNL accelerates its CAS inspections.

Beginning in FY95 pressure to reduce overhead funded activities and increase spending on ES&H activities resulted in a downward trend in maintenance spending. In FY99 the trend began to reverse and maintenance spending is now approaching the FY94 level. However, during this time additional facilities were added to the inventory, existing facilities continue to age, and the maintenance backlog has grown. The deferred maintenance reported in FIMS for FY00 is $106 M. A significant portion of this backlog is roofing projects and BNL has proposed the Roof Replacement Phase II project. (See Section D.7)

While site maintenance funding levels are rising after a five year decline, particularly in the area of Recurring Maintenance where the backlog is approximately $30 million. Recurring maintenance excludes replacement of 1/30th of the roofs each year, annual cleaning of ducts, etc, and medium and large size maintenance projects that must be prioritized prior to implementation. With funding at about $2 million per year and the number of CAS inspections increasing this backlog will continue to grow.

BNL will continue to use the funds available through the MEL/FS Program to upgrade environment, safety, and health (ES&H) protection, improve utility systems, increase efficiency through consolidation, and replace, mothball, or demolish aged inefficient facilities. The anticipated MEL/FS line item requirements from FY 01 to FY 05 are approximately $88 million. Based on a ten-year average funding level of $5.5 million, a $60.5 million shortfall is expected by 2005. A summary of MEL/FS projects can be found in the following section.

Inadequate funding for the General Purpose Facilities sub-program is continuing the cycle of high operating and maintenance costs rather than securing prudent reductions through increased investment in new facilities. The Laboratory is concerned about the inability of the MEL/FS Program to address ES&H needs while dealing with infrastructure needs.

Various assessments identified the need for new facilities. BNL's new Master Plan that will identify facilities that should be replaced and propose more efficient, adaptable replacement facilities. With the expanding RHIC operations, facilities are needed to accommodate approximately 250 more scientific users. We are developing strategies to address these concerns in the near-term, but longer-term solutions, such as the proposed Applied Science and Technology Building, Research Support Center and the User Support Center, will be necessary.

Other proposed projects described in the Section D.7 include the following:

- Ground and Surface Water Protection project which will remedy several issues relating to protecting Long Island's sole source aquifer and will move the Laboratory to a more proactive position in protecting ground- and surface-water. This project will close inactive wells, modify storage facilities to prevent contaminated run-off, and remove underground tanks and lines.
- Electrical System Modifications Phase II and High Speed Communication Upgrade, which will provide utility system reliability improvements, required to support operations.

- Life Safety Code Modifications and Halon System Replacement to address ES&H concerns.

D.7 Multi-program Energy Laboratories Facilities Support (MEL/FS) Program

The following projects are proposed as new starts for FY02 to FY05 based on BNL's anticipated/expected requirements, and developed to allow the Laboratory to meet its mission and critical outcomes.

Proposed Projects - General Purpose Facility (KG-01)

Advanced Science & Technology Center (FY02): The proposed building will provide the Energy, Environment and National Security (EENS) Directorate with 34,000 square feet of state-of-the-art laboratory, office and support space. EENS is currently spread over twenty-four buildings, many are wood frame barracks left over from Camp Upton World War II era, which could then be demolished. This decentralized distribution of staff in old, ineffective buildings decreases effective interchanges between staff members and adversely impacts the quality of the work life.

High-Speed Communications Upgrade (FY02): We propose to install additional fiber optic cable to the primary buildings on the BNL site. The additional cables will assure against prolonged interruption in site wide network communications, data processing, and Internet access, in the event of a failure at the hub at Building 515. The additional cables also would enhance performance of the site wide fire alarm and energy management control system (EMCS). A prolonged interruption in communications would have a drastic effect on the many research programs which process and share experimental data at multiple locations on the site. Only limited access to the Laboratory's standards on safety and quality assurance would be available since they are now maintained and only available on a Web based system.

Research Support Center (FY02): Through this project we will construct a five-story office complex to house essential support services for laboratory personnel and visiting scientists in a single location. Currently these services are located in over a dozen different buildings. Twenty support groups including will be efficiently co-located to a central building on site.

The new building will contain 144,000 square feet of modern, energy efficient, low-maintenance office, reception, lobby and support area. Both the groups providing services and those using the services will derive an inherent benefit when they are provided at a single source. Services will improve as a result of better communication and shared resources, and those requiring services will have their needs met more efficiently and effectively.

Roofing Phase II (FY01): This project is the second phase of roof replacements at BNL and will provide for the replacement of 265,000 sq. ft. of deteriorated roofing that has outlived its useful life. Roofing on many BNL buildings has deteriorated from age and normal weathering. Insufficient funding has prevented the Laboratory from replacing these roofs with regular maintenance funds. Competing maintenance and pressing ES&H requirements have allowed only a fraction of roof replacements. Replacing the roofs on the 22 buildings included in this project will help ensure the viability of research and support activities conducted in each facility and greatly reduce the backlog of leaking roofs at BNL.

Electrical System Modifications - Phase II (FY01): This project continues the progress made in Phase I by replacing old deteriorating underground electric 13.8 kV cables, and adding supporting underground ductbank. The existing cables have outlived their useful life and will be replaced with solid dielectric shielded cables. Based on condition assessments, other electrical equipment including transformers and switchgear, will be replaced or retrofitted to extend its useful life.

Proposed Projects - ES&H Support (KG-02)

Ground and Surface Water Protection (FY01): This project will implement several upgrades to systems and facilities needed to comply with Suffolk County Sanitary Code Article 12, and protect Long Island's sole-source aquifer. The upgrades will include eliminating non-compliant discharges, reducing non-contact cooling water, eliminating radiologically contaminated cooling systems, and installing secondary containment and leak detection on several systems containing hazardous fluids.

Life Safety Code Modifications - Phase I (FY05): Sixteen buildings will be upgraded to comply with National Fire Protection "Life Safety Code" NFPA 101. This project will bring the facilities into compliance and make them safer for the occupants. Upgrades include modifying building egress, stairwells, fire walls, sprinkler systems, emergency lighting, smoke detector systems, and other related systems.

Halon System Replacement (FY05): This project includes replacing Halon Systems to meet the environmental mandates of the Clean Air Act (1990). The Montreal Protocol and 1993 amendments require the phase-out of Halon systems. Through this project BNL will decommission and replace these systems with acceptable alternatives to maintain compliance with DOE's Fire Protection Standards. The Laboratory has less than 100 Halon systems. The replacement systems will include sprinkler systems, and very-early-warning detection (VESDA) or carbon dioxide systems for unoccupied areas. Halon fire extinguishers also will be replaced with suitable alternatives.

Appendix E: Supplemental Tables

Education Program Participation

Brookhaven National Laboratory Staff Composition

Brookhaven National Laboratory Equal Employment Opportunity Data

Subcontracting and Procurement Data

Small and Disadvantaged Business Procurement Data

Brookhaven National Laboratory

Table E1 - Annual Participation in Science Education Programs									
		FY1998			FY1999			FY 2000	
Post-secondary Programs	Total	Minority	Female	Total	Minority	Female	Total	Minority	Female
UNIVERSITY PROGRAMS									
Nuclear Chemistry Summer School	12	0	5	13	1	8	13	1	9
Summer Students/ERULF	45	7	22	50	17	20	69	11	27
SERS/ERULF SemEENSer	14	3	10	20	7	3	26	6	10
Special Groups: BSP									
Student	2	2	1	1				Not Offered	
Faculty	0	0	0	0					
Special Groups Gallaudet									
Student	1	0	0	Not Offered				**Not Offered**	
Faculty	0	0	0						
NSLS/HFBR Faculty-Student Teams		**Not Offered**			**Not Offered**			**Not Offered**	
Graduate School Fair (EENS.)		**Not Offered**			**Not Offered**			**Not Offered**	
COMMUNITY COLLEGE TA									
CCHP Summer Students/CCI	10	10	2	25	16	13	20	8	10
Faculty	0	0	0	1	1		0		
SemEENSer Co-Op	8	3	1	0			1		
Northeast Consortium (SUMS) and CC Mini-semEENSers	17	17	6	16	13	9	23	14	10
TOTAL	**109**			**126**			**152**		

Brookhaven National Laboratory

Table E1 - Annual Participation in Science Education Programs (continued)

Pre-college Programs	FY1998 Total	FY1998 Minority	FY1998 Female	FY1999 Total	FY1999 Minority	FY1999 Female	FY 2000 Total	FY 2000 Minority	FY 2000 Female
SCHOOL DISTRICT TA (SDTA)									
Community Summer Science (HS)	40			40	3	17	31	1	11
NYS Summer Environmental Institute (HS)		**Combined with CSSP**			**Combined with CSSP**			**Not Offered**	
SemEENSer Research Interns	7	0	5	1		1	1		
Women in Science (HS)	29	0	29	28		28	35		35
DOE Science Bowl (HS)		**Not Offered**			**Not Offered**			**Not Offered**	
Saturday Science (JHS)	0			0				**Not Offered**	
Magnets-to-Go (5-6)		**Not Supported by OEP**			**Not Supported by OEP**			**Not Supported**	
Science Fair (K-6)	650			747			660		
Visiting Scientist/Scientists in Residence	150				**Not Funded**			**Not Funded**	
NYS Mentoring Program	20			20			20		
SDTA Special Services (teacher/admin)	77			250			32		23
SDTA Special Services (students)	220			25	8	25	144	24	130
MINORITY PIPELINE (SUMS)									
Northeast Consortium		**Not Supported by OEP**			**Not Supported by OEP**			**Not Supported**	
Environmental Education Outreach		**Not Offered**			**Not Offered**			**Not Offered**	
MHSAP/NIH Summer Apprenticeships	30	30		29	29	14	23	23	
NIH Summer Research Apprenticeship		**Not Offered**			**Not Offered**			**Not Offered**	
Introduction to Computers		**Not Supported by OEP**			**Not Supported by OEP**			**Not Supported**	
SUMS HS Mini-semEENSer		**Not Offered**			**Not Offered**			**Not Offered**	
SUMS Exploration Days		**Not Offered**			**Not Offered**			**Not Offered**	
TOTAL:	**1223**			**1140**			**946**		

Table E1 - Annual Participation in Science Education Programs (continued)

	FY 1998			FY1999			FY 2000		
	Total	Minority	Female	Total	Minority	Female	Total	Minority	Female
TECHNICAL ED/MST INT (PAST)									
MAGLEV Tech Ed Consortia (approximate)	300			300			300		
Technology Educator's Workshops	30	1	0	30			15		
MST Conference Workshops	40			40				**Not Offered**	
Annual BNL Systemic conference		**Not Offered**			**Not Offered**			**Not Offered**	
TEACHER ENHANCEMENT (PTEP)									
Annual BNL Systemic Conference (SITE)	15								
NYU Teacher Res. Association and	2	2	0	3	2	2		**Not Offered**	
DOE Teacher Res. Association (TRAC)	2			**Combined with NYR Teacher Res. Association**				**Not Offered**	
NSF/DOE National Teacher Enhancement (NTEP)	6	1	4	3	0	3	3	0	3
NSF Elementary MST (MSTe)	61	6	47	180	35	130	307		
HS Teachers' In-Service Course				20					
SUMS MHSAP Internships		**Not Offered**			**Not Offered**			**Not Offered**	
DOE/NSF Co-op Appointments	6			0			0		
TOTAL	**462**			**576**			**625**		

Table E2 - Brookhaven National Laboratory Staff Composition Effective October 2000	PhD		MS/MA		BS/BA		OTHER		TOTAL	
	#	%	#	%	#	%	#	%	#	%
PROFESSIONAL STAFF										
Scientists	475	74.8	81	12.8	69	10.9	10	1.6	635	22.3
Engineers	93	19.6	184	38.8	157	33.1	40	8.4	474	15.9
Management & Administrative	39	9.9	105	26.7	119	30.3	130	33.1	393	13.2
Other Professional	6	1.9	12	3.8	56	17.7	243	76.7	317	10.6
SUPPORT STAFF										
Technicians	0	0.0	7	1.8	46	12.1	327	86.1	380	12.7
All Others	0	0.0	9	1.2	61	7.8	712	91.0	782	26.2
LABORATORY TOTAL	**613**	**20.6**	**398**	**13.4**	**508**	**17.0**	**1462**	**49.0**	**2981**	**100.0**

Table E3 - Brookhaven National Laboratory Equal Employment Opportunity Effective October 2000														
Occupational Codes	Total		Minority Total		White		Black		Minority Hispanic		Native American		Asian/Pacific Islanders	
Gender	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Officials/Managers														
	408	80	36	12	372	68	7	4	6	2	0	0	23	6
	83.6%	16.4%	7.4%	2.5%	76.2%	13.9%	1.4%	0.8%	1.2%	0.4%	0.0%	0.0%	4.7%	1.2%
Professional Staff														
Scientists & Engineers	759	141	153	45	606	96	13	4	16	7	0	0	124	34
	84.3%	15.7%	17.0%	5.0%	67.3%	10.7%	1.4%	0.4%	1.8%	0.8%	0.0%	0.0%	13.8%	3.8%
Management & Administrative	271	160	29	23	242	137	10	13	3	4	1	1	15	5
	62.9%	37.1%	6.7%	5.3%	56.1%	31.8%	2.3%	3.0%	0.7%	0.9%	0.2%	0.2%	3.5%	1.2%
Technicians	347	33	38	3	309	30	17	2	15	0	2	0	4	1
	91.3%	8.7%	10.0%	0.8%	81.3%	7.9%	4.5%	0.5%	3.9%	0.0%	0.5%	0.0%	1.1%	0.3%
All Other														
	439	343	109	102	330	241	71	77	24	20	6	2	8	3
	56.1%	43.9%	13.9%	13.0%	42.2%	30.8%	9.1%	9.8%	3.1%	2.6%	0.8%	0.3%	1.0%	0.4%
Totals	**2224**	**757**	**365**	**185**	**1859**	**572**	**118**	**100**	**64**	**33**	**9**	**3**	**174**	**49**
	74.6%	**25.4%**	**12.2%**	**6.2%**	**62.4%**	**19.2%**	**4.0%**	**3.4%**	**2.1%**	**1.1%**	**0.3%**	**0.1%**	**5.8%**	**1.6%**

Table E4 - Subcontracting and Procurement Dollars in Millions-Obligated [1]	FY 2000	Estimated FY 2001	Estimated FY 2002	Estimated FY2003
Subcontracting and Procurement from:				
Universities	1.6	2.0	2.0	2.0
All Others	140.4	145.0	150.0	155.3
Transfers to other DOE Facilities	3.5	4.0	4.0	4.0
Total External Subcontracts and Procurement	**145.5**	**151.0**	**156.0**	**161.3**

(1)Show total dollars obligated within each fiscal year.

Table E5 - Small and Disadvantaged Business Procurement Dollars in Millions – Budget Authority [1]	FY 2000	Estimated FY 2001
Procurement from S&DB	6.2	7.0
Percent of Annual Procurement	5.2	5.5

(1) Show total dollars obligated within each fiscal year.