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Brookhaven National Laboratory

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Operated by
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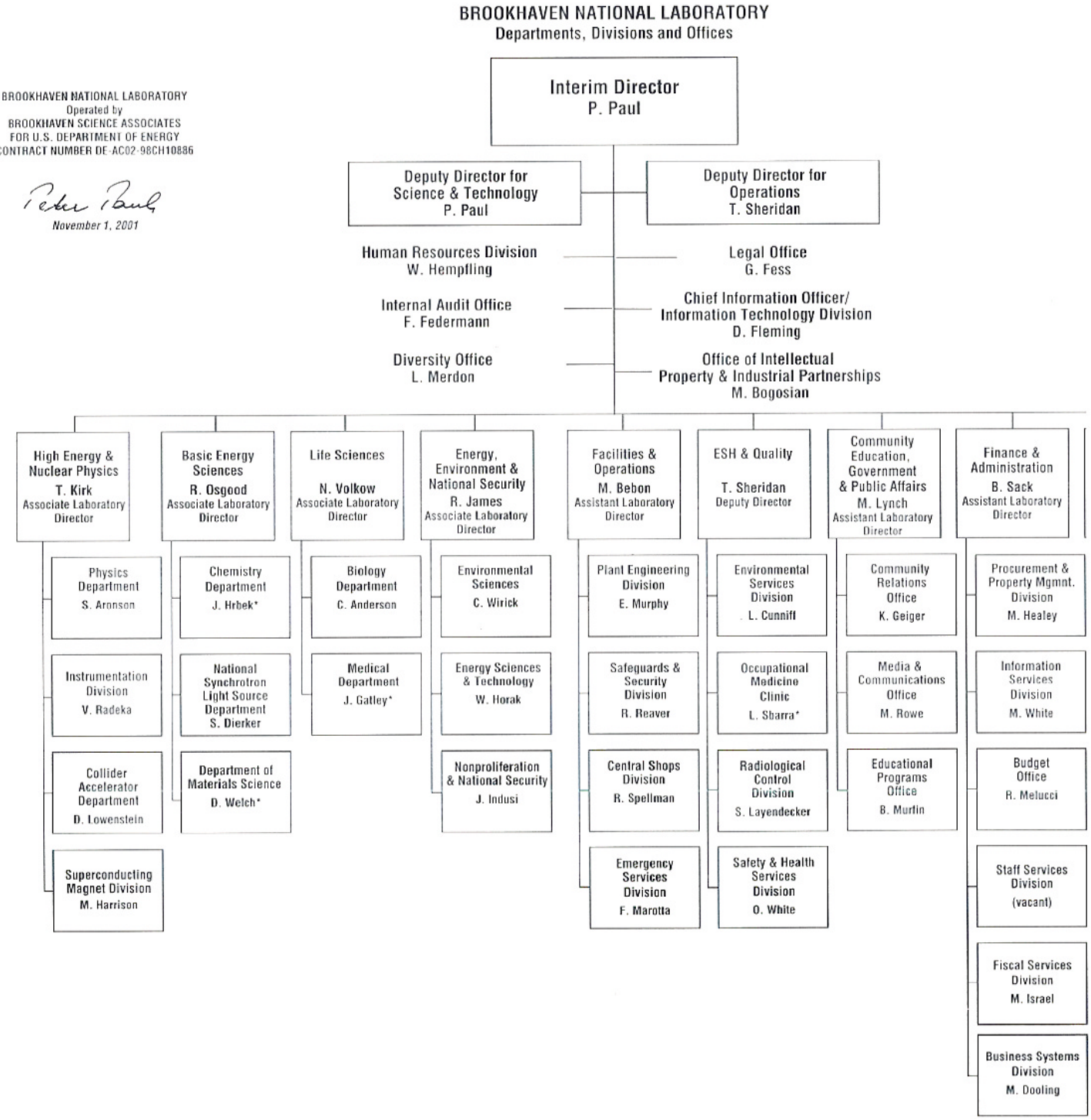

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Executive Summary

Brookhaven National Laboratory is a multidisciplinary laboratory in the Department of Energy (DOE) 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 community and environmental 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 DOE 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 about 3000 employees and an annual budget of more than $450 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 it's 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 the past year:

- Scientists at Brookhaven, in collaboration with researchers from 11 institutions in the US, Russia, Japan, and Germany, announced an experimental result from the g-2 experiment that directly confronts the Standard Model of particle physics.
- At the Quark Matter 2001 Conference at Stony Brook University, nearly 700 physicists from around the world gathered to hear breaking news about the exploration of a new frontier recently opened by the operation of the Relativistic Heavy Ion Collider (RHIC). Among the findings: collisions between gold ions have created nuclear matter resulting from the highest energy density ever achieved in a scientific experiment.

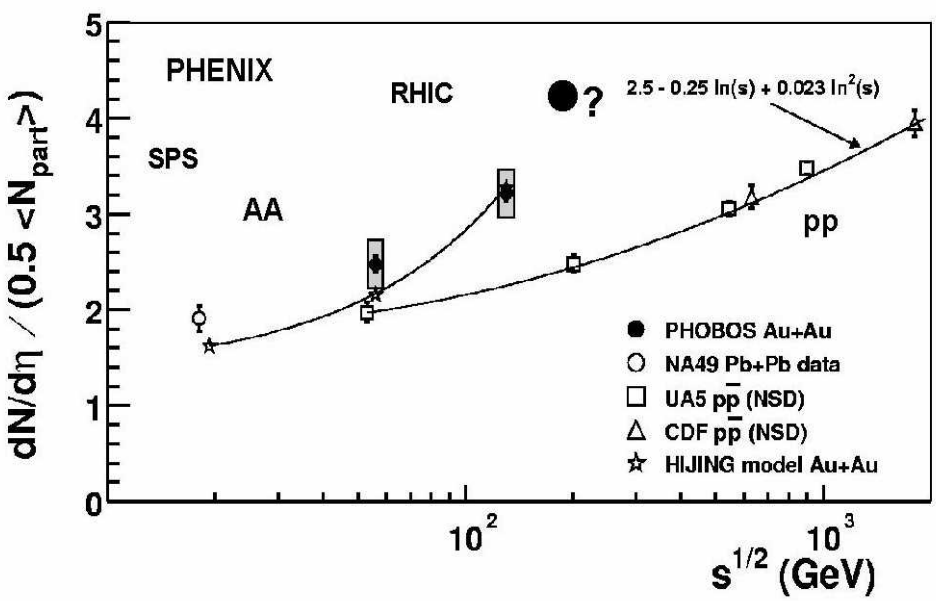


Figure 1 - Density of Particles Produced Per Interacting Nucleon
First RHIC results, first from PHOBOS and then confirmed by BRAHMS, PHENIX, and STAR, at E(cm)+130 GeV show the highest density ever observed in nuclear matter. The observed energy density lies significantly above that expected for incoherent nucleon-nucleon collisions. The density expected at full RHIC energy is indicated by the large dot.

- BNL and Stanford University scientists may have developed molecular wires millions of times smaller in diameter than a human hair.
- Researchers at Brookhaven developed a technique using a Transmission Electron Microscope to detect defects in materials with picometer accuracy. This is the highest accuracy ever achieved in such measurements, akin to finding a speck of dust in an area as big as the United States.
- Researchers obtained new insight into the mechanism of simultaneous two-electron ionization induced by strong-field laser excitation using a unique electron-ion coincidence spectrometer developed at Brookhaven.
- BNL chemists in collaboration with DuPont discovered a new class of homogeneous catalysts using inexpensive metals, molybdenum, or tungsten that operate by an unconventional ionic hydrogenation mechanism of ketones. This is an important step in the production of chemicals in the agricultural and pharmaceutical industries.
- Using a unique combination of mass spectrometry, isotope labeling and diode-laser adsorption spectroscopy, chemists accurately determined the reaction rates and product branching ratios for the $CH_3 + O$ radical-radical reaction which is important for accurate modeling of hydrocarbon combustion reactions.
- Using synchrotron based high-resolution photoemission spectroscopy; chemists at BNL discovered that upon adsorption of sulfur on TiO_2 (110) at 600 K, the top layer of the oxide surface is converted to a sulfide in a self-limiting and thermodynamically unlikely surface reaction. First-principles density-functional calculations also suggest that the mechanism of the $O \rightarrow S$ place exchange reaction is driven by enhanced segregation of bulk oxygen vacancies to the surface.
- BNL and University of Stony Brook chemists recently found that incorrect accounting for equilibrium transcytolemmal water exchange kinetics results in significant errors in the quantitative analyses of contrast reagents routinely used in clinical magnetic resonance imaging examinations.
- In the wake of the completion of the human genome sequencing project, BNL has joined four New York research institutions in a collaborative effort to turn that knowledge into promising drug targets. The National Institutes of Health awarded the New York Structural Genomics Research Consortium (NYSGRC) $4.5 million to develop high-speed methods to decipher the three-dimensional structures of proteins. In addition to BNL, the member institutions of the consortium are Albert Einstein College of Medicine, Mount Sinai School of Medicine, The Rockefeller University, and Weill Medical College of Cornell University. As part of the New York Structural Genomics Research Consortium, 123 proteins have been cloned, 114 are expressed, 59 purified, 15 crystallized and the structures of 10 have been determined
- PET researchers have developed new methods to produce tracers for imaging the brain-nicotine system; for tracking the distribution of boronophenylalanine for cancer treatment; for imaging the distribution of the addiction treatment drug GVG and for imaging the brain distribution of toluene, a solvent that is abused by children.
- BNL researchers have gained new insights into the biochemical changes in the brain, which are produced by drug-related cues. They have also investigated drugs to interfere with these cue-related changes, which are a major cause of relapse in the recovering drug addict
- Scientists have determined that obese people have fewer receptors for dopamine, a neurotransmitter that helps produce feelings of satisfaction and pleasure. The findings imply that obese people may eat more to try to stimulate the dopamine "pleasure" circuits in their brains, just as addicts do by taking drugs.
- Using brain imaging, researchers have been able to understand why Ritalin is effective in the

treatment of Attention Deficit Disorder. PET imaging has shown that Ritalin (a drug used to treat the disorder) increases dopamine in the human brain thus explaining how it helps people to focus on a specific task.

- New research on Ritalin, a drug prescribed to millions of American children each year with Attention Deficit Hyperactivity Disorder, shows for the first time how the drug acts in the human brain and why it is so effective. This latest study, on humans, indicates that Ritalin significantly increases levels of dopamine in the brain, thereby stimulating attention and motivational circuits that enhance the ability to focus and complete tasks.
- In research that could help assess the radiation risks faced by astronauts, improve the cancer-killing potential of radiation therapy, and distinguish between DNA damage caused by normal living and that caused by low-level radiation, scientists at BNL developed a new way to detect and quantify varieties of radiation damage that previously could not be measured.
- A research team working at the BNL has determined the three-dimensional structure of a key protein on the bacterium that causes Lyme disease. Called OspC, the protein is derived from two strains of the Lyme disease bacterium. This research may lead to a second-generation vaccine that would be more effective than the current one.
- By studying the bacteria that cause the Black Plague, plant infections, and colds researchers have discovered that these three very different microorganisms share a common strategy: they all prevent the cells they are attacking from calling out for help. All three organisms produce a similar protein to interfere with the infected cells chemical signaling pathways, which are designed to alert the immune system to attack the germs.
- BNL biologists, in collaboration with scientists at the DOE Joint Genome Institute and scientists in Belgium, recently completed the genetic sequence of *Ralstonia metallidurans*, a toxin tolerant microbe. Understanding the genetic makeup of microbes that thrive in polluted environments will help scientists engineer bacteria that can clean contaminants from soil. Another Genome group collaboration has led to the completion of 100kb of contiguous sequence of a DNA repair gene.
- Scientists continued to study the molecular component of rice that may limit its productivity. 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 DOE has recognized Brookhaven National Laboratory with three Energy 100 Awards for scientific and technological achievements it has produced during the DOE's 23-year history, from 1977-2000. The awards recognize outstanding work by scientists in DOE laboratories that have contributed to society by helping consumers save money and improve their quality of life. The three areas of Brookhaven research that were recognized are, studies of drug addiction and drug action using Positron Emission Tomography (PET), invention of the Flame Quality Indicator, a device that measures flame brightness in oil burners, and Lyme disease prevention and diagnosis.
- The International Association selected Brookhaven National Laboratory as the "Organization of the Year" for Public Participation (IAP2). IAP2 recognized Brookhaven "for integrating public participation into its operations, which ensures that stakeholders are kept informed and have a voice in decisions and issues that may affect them".

2.0 Director's Statement

Brookhaven National Laboratory participates in each of the Department of Energy missions of Science, Energy Resources, Environmental Quality, and National Security. Its primary mission focus is on the Office of Science theme of providing Extraordinary Tools for Extraordinary Science. The Laboratory serves a large and demanding science community with a combination of "big science" facilities and basic science and technology departments. Research and development activities are conducted in a variety of modes, from long-term collaborations to short term visits.

Brookhaven is a world leader in accelerator-based science and technology. It is the site of the world's frontier nuclear physics facility – the Relativistic Heavy Ion Collider (RHIC) – and it operates what by some measures are the world's most productive coherent light sources at the National Synchrotron Light Source. Both facilities center on departments that combine technology and basic science to ensure continuing leadership in the design, construction, and operation of high quality accelerator-based beams of light and matter for scientific purposes. 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.

Since accelerator-based science has a huge compass, research at Brookhaven can be focused at only a few points within a broad spectrum of science and technology. Research in the Laboratory's traditional departments of physics, chemistry, and biology is mostly discovery-oriented. In the newly created departments of Energy Science, Environmental Science, and National Security, and the traditional Medical Department, the work is mostly issue-oriented. 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 such areas as medical imaging or nanotechnology.

Because traditional departmental titles do not adequately convey evolving research priorities, theme areas have been identified to render these directions more explicit. The themes provide a more focused framework for departmental activity, including planning, staff recruitment and proposal preparation.

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 emerging from an intensive three year period of management culture change in which major new systems have been implemented for work planning and control, resource allocation, environmental and safety management, goal planning and assessment, and community involvement. Reviews in these and related areas have confirmed strong improvement over the period, with outstanding performance in many areas previously judged to be deficient. Management attention is now turning to the close linking of these systems to the scientific priorities of the Laboratory, and to the development of initiatives to ensure continued scientific leadership and productivity during the coming decades.

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 focusing its effort and working with the Department of Energy to create a better environment for employees and users. 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 achieve its aspirations. To this end, 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 and continues to be a leader in DOE's mission in Science and Technology also making important contributions to the other missions. 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 regional level. BNL's continuing success depends on our ability to maintain alignment of our mission, goals, and objectives with those of the DOE.

3.1 Mission

Brookhaven National Laboratory's role for the DOE is to produce excellent science and advanced technology with the cooperation, support, and appropriate involvement of our scientific and local communities. The fundamental elements of the Laboratory's role in support of the four DOE strategic missions are the following:

- To conceive, design, construct, and operate complex, leading edge, user-oriented facilities in response to the needs of the DOE and the international community of users.
- To carry out basic and applied research in long-term, high-risk programs at the frontier of science.
- 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 facilities and technologies 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, biomedical and imaging sciences, energy and environmental sciences and technologies, and systems analysis and modeling.

These core capabilities support an impressive array of facilities at Brookhaven:

- 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), Whole Body Composition Facility, Clinical Research Center and Animal Facility.
- For Data and Computation: RHIC Computing Facility (RCF), RIKEN Teraflop Computer, National Nuclear Data Center (NNDC), Visualization Center, and Atmospheric Radiation Measurement (ARM) External Data Center.
- For Medical Treatment: Radiation Therapy Facility (RTF)
- For Production: Brookhaven Linac Isotope Producer (BLIP), Target Processing Laboratory (TLP) for producing radiopharmaceuticals, PET Isotope Production Cyclotrons, and Tandem Van de Graaff Facility.

3.3 FY01 R&D Resource Profile

In FY 2002, the Presidential Budget for DOE funding at BNL is a total of $345M. BNL expects an additional $80M in Work For Others. Work For Others includes funding from other DOE laboratories or operations offices, and other federal, state, local, and private entities. The majority of BNL's support (~80%) is provided by the DOE Office of Science (OS) and supports the operations of our unique user facilities, research programs in high energy and nuclear physics, basic energy sciences, and biomedical and environmental sciences, and selected site operations. BNL also contributes to the DOE mission in Energy Resources, and National Security. In FY 2002 DOE will fund ~$4M for R&D in geothermal energy, natural gas storage systems, practical conductors for electric power systems using high Tc oxides, research on battery materials, and studies on efficient and affordable buildings. We expect ~$30 M from DOE to support work in nuclear non-proliferation through the US-Russian Nuclear Non-Proliferation Program. Our role in Environmental Quality is focused primarily on activities to restore the BNL site and to manage radioactive and hazardous wastes. We expect ~$27M from the DOE Office of Environmental Management for the remedial action programs including work to decontaminate/decommission the Brookhaven Graphite Research Reactor and complete transition of the High Flux Beam Reactor to DOE-EM. In FY 01 the DOE Office of Science assumed responsibility for the ongoing waste management operations and provides ~$6M to support those activities.

BNL contributes 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 02 we are projecting a total income of ~$80M from Work For Others (WFO), which includes about $34M from other DOE laboratories/operations offices.

The Work For Others programs that are aligned with the DOE Science and Technology mission total ~$65M. 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 development and research at the NSLS, support for the Neuroimaging Center, and for the operations of the Scanning Transmission Electron Microscope. BNL also projects a significant amount of funding from NIH for biomedical research and from NASA for radiobiological research in support of manned space missions. EPA will continue to support the NY Harbor clean-up project, and this year NSF will support research at BNL on Rare Symmetry Violating Processes.

The Human Proteome Project is a large-scale, multi-disciplinary, cooperative effort involving national laboratories, universities, and industry. Along with several other centers, BNL has been piloting procedures for the cost-effective large-scale determination of protein structures by X-ray crystallography.

In partnership with Rockefeller University, the Albert Einstein College of Medicine, Cornell Medical School, and Mt. Sinai School of Medicine, BNL recently received an NIH grant to support further development of structural genomics technologies and to establish a pilot structure-production center.

In Energy Resources, funding from others is expected to exceed that provided directly by the DOE. The Nuclear Regulatory Commission provides more than $6M for work on reactor safety, technical support to the Commission, and support for work on Russian and Ukraine reactors. The Department of State provides the most support in National Security to support the program office on international safeguards.

3.3.1 DOE Science and Technology Mission

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

Consistent with DOE's goals, BNL provides 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 several major collaborations, and operation of our Imaging Center. In FY 2002, over $100M will support the operation of the Relativistic Heavy Ion Collider (RHIC), the nation's newest major science facility for nuclear physics. This facility will be in its second 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 staff continues to participate in the national R&D program for the next generation of light sources.

The Laboratory initiatives, RHIC II, e-RHIC, Photoinjected Energy Recovery Linac (PERL), 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. Neutron scientists at BNL have engaged in the development of neutron sources and instrumentation for other facilities such as the Spallation Neutron Source and the High Flux Irradiation Reactor. 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 FY 01 and continuing in FY 02 and 03, 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 (CDIC) 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. The CDIC will receive some program funding from the DOE starting in FY 02. In computing, BNL also will receive funds from the Office of Science for a collaborative program with Thomas Jefferson Lab, Fermilab, and five university partners to develop a 20 Tera Flop (peak) Lattice Gauge Center at BNL. Through this program, BNL will host the most powerful facility in the world for the very important new particle and nuclear physics theory field of lattice gauge physics.

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, materials and 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 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 will receive ~$1M in FY 02 for design and engineering of a new Nanoscience Center.

BNL's crosscutting biomedical initiatives would expand the DOE's role in biomedical research by supporting the basic tools and facilities needed to advance the 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 was redirected in FY 01. While funding for several projects was terminated, new funding was obtained for projects related to the Characterization of Protein Structures and Complexes, the Analysis of Human Proteins Induced in Response to Ionizing Radiation, and the Operation and Development of the STEM.

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 02 DOE will support basic research that includes 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 ~$18M to address the challenges of "Protecting the Living Planet". In the biomedical area, this supports research in radiotracer chemistry and neuroimaging, high-field magnetic resonance imaging and radioisotope production. In FY 02 BNL will receive new funding for an initiative in "Universal Imaging". Our program initiatives in Biomedical Sciences will enhance our capabilities in cellular biology, functional genomics, cancer research, and imaging. Collaborative participation of scientists from BNL's Biology and Medical Departments in the DOE "Genomes to Life" initiative is expected to grow over the next five years.

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 02 DOE will provide over $15M 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 and to provide adequate services, utilities, and space for staff and visitors. Section 8 summarizes the Laboratory's Strategic Facilities Plan.

3.4 BNL Planning Principles

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 maximizes use of the capabilities of the Laboratory. The Laboratory's internal planning principles include the following:

- We will fully align our missions, goals, objectives, and expectations with those of our customer, the DOE, and other sponsors and stakeholders. We will assure the quality and alignment of our science and technology programs through a robust peer review program.
- 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 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 meet BNL's assigned goals for the Spallation Neutron Source, the Large Hadron Collider, and the ATLAS detector.
- 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.
- We will strive to increase BNL support from other federal agencies to assure the availability of our facilities throughout the government.
- 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 add critical competencies needed to strengthen our overall strategic position and support the advancement of our programs. We will make the attraction and retention of high-quality scientific staff a Laboratory priority. We will develop our human resources through training, recruitment, incentives, and a focus on diversity.
- 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.

4.0 Laboratory Strategic Plan

Science-based multi-disciplinary planning at Brookhaven National Laboratory involves strategic 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 chair, who develops a strategic plan for the department. These plans and the DOE planning initiatives and priorities form the vision for the four Science and Technology Directorates for their three-year to ten-year planning horizons. These visions are presented as a group at the major Strategic Planning meeting that involves all senior science managers, augmented by selected science and technology group leaders. The products 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.

The Laboratory Initiatives presented here are BNL's long-term priorities and centers of internal investment. They are updated every year, but are not expected to change rapidly. 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. For example, throughout its 50-year history BNL scientists have played a role of innovation in many scientific areas, but especially in accelerator physics and accelerator-related science. The RHIC II initiative, the e-RHIC initiative and the PERL initiative are related through a common new technology – high-power, high-brightness electron beams. This technology is a union of the technologies of high-brightness photo-injectors and energy recovery linacs.

Both the programmatic initiatives, included in Section 5, and the Laboratory Initiatives are updated and validated at a second planning meeting that takes place during the second quarter of the fiscal year. The senior science managers and all the chairs of the departmental planning committees attend this meeting. Some initiatives that have scientific merit but were not supportive of current DOE planning have been replaced. The time scale of the selected initiatives ranges from three years to ten years. 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.

4.1 Next Generation RHIC (NP)

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 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 any 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.

4.1.2 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 x 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. Full design energy was achieved in the spring of 2001. We will over time 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 (R&D plus construction) for the RHIC II Project is $148M and is distributed as shown in Table 1.

Table 1 - Cost Elements for RHIC II Initiative

RHIC II ELEMENTS	
Accelerator Upgrades	
Electron beam cooling	$60 M
Detector Upgrades	$88 M
Total Estimated Costs:	$148 M

The cost estimates are preliminary 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 accelerator 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 four 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.

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 also 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) 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.

4.1.3 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 collide with the circulating heavy ion beam, unique experiments probing QCD in the nuclear medium at normal or even very low 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-gold 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-gold and electron/proton operation could be implemented in such a way that it would be transparent to the regular RHIC heavy ion program.

As part of the EIC 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 5x 10^{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 have been submitted to the Long Range Plan for Nuclear Science and have received wide support. The Laboratory plans to request funds for accelerator R&D for this project.

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 Next Generation Light Sources (KC)

Synchrotron radiation research has grown rapidly over the last decade, playing an important role in the life, materials, chemical and environmental sciences and technologies. As the quality of the synchrotron radiation source improved, new research techniques became feasible. New scientific vistas will open in response to continued advances in synchrotron radiation sources. At the National Synchrotron Light Source (NSLS), we are pursuing two initiatives to develop the next generation synchrotron radiation source. The first, Photoinjected Energy Recovery Linac (PERL), takes advantage of recent progress in photo-injectors and energy recovery linacs to provide higher brightness and shorter pulses than existing sources can offer. The second, Laser Seeded Free Electron Laser seeks to develop a high peak power, short-wavelength free-electron laser with excellent temporal and spatial coherence, capable of producing femtosecond pulses. The pursuit of both of these new sources requires aggressive R&D programs at the cutting edge of source technology.

4.2.1 Photo-injected Energy Recovery Linac (PERL) Light-Source

PERL is BNL's plan to upgrade and modernize the National Synchrotron Light Source through the use of the most advanced technology available, as well as establish a new "Extraordinary Tool for Extraordinary Science".

The NSLS serves a large community, in excess of 2500 users, in a wide variety of scientific, medical, and industrial research and development activities, particularly significant for researchers in the eastern United States. A new light source, with ultra-short pulse and high-brightness capability, such as described below would provide the opportunity for groundbreaking research for US science. Given the outstanding track record of the NSLS, the strength of its user community, and its scientific infrastructure, BNL is the right place for this source.

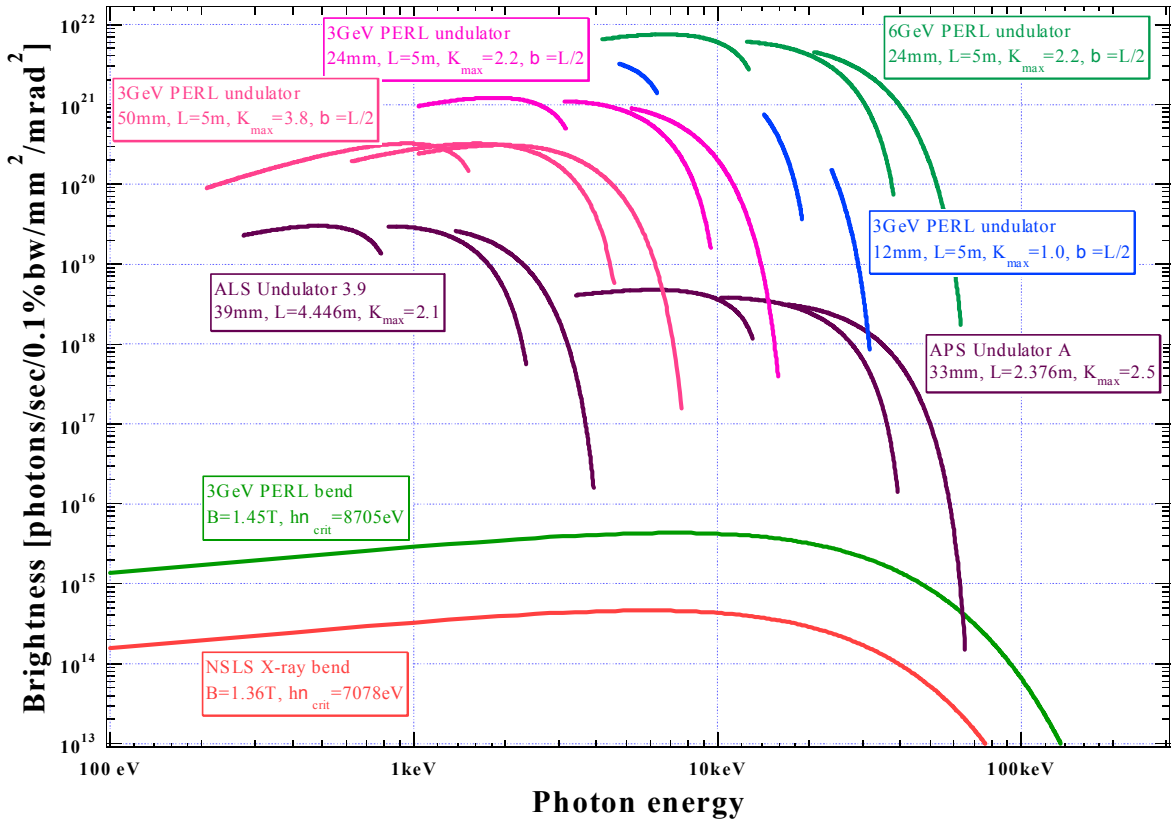
The upgrade is based on the Photo-injected Energy Recovery Linac (PERL), a machine emerging from the union of two technologies: laser-photocathode RF guns (photo-injectors) and superconducting linear accelerators with beam energy recovery (Energy Recovery Linac). The upgrade has the potential to bring the NSLS users many new insertion device beam lines, brightness that is at the cutting edge of light-source performance and ultra-short pulse capabilities, much shorter than any extant synchrotron light source. If it were possible to circulate the PERL beam through the existing NSLS X-ray ring, state-of-the-art brightness would be made available to all beam lines, leveraging the large investment in the existing programs.

In the PERL, a beam of high brightness and high average current is produced in a photo-injector. The beam is accelerated to a high energy in a linear accelerator. This beam is taken through insertion devices to produce synchrotron radiation and then returned to the linac. At this point, the beam is decelerated and its energy is recovered, allowing very high efficiency operation.

Using a high average current linac (approaching 200 mA) and an electron beam energy comparable to the world's leading X-ray storage ring sources, a PERL will provide photon beams with more than a tenfold increase in brightness and with the same flux as the world's best synchrotron sources. In addition, there is an opportunity to have pulse lengths in the 100s of femtosecond range, which is not possible with storage ring technology. This unique capability can be utilized to open new horizons in the study of time-dependent phenomena in many scientific disciplines.

The brightness of PERL insertion devices, shown in Figure 1, was calculated using the expected electron beam emittance and energy spread.

Figure 2 - PERL Brightness Comparison
PERL Insertion Devices and bend source brightness compared to ALS and APS sources as a function of photon energy on a log-log scale. An insertion device of a 6 GeV PERL is presented by the highest brightness curve. Insertion Devices of a 3 GeV PERL are presented by the next three highest brightness curves. For comparison, the ALS and APS sources are shown. At the bottom, a 3 GeV PERL bend is compared to an NSLS bend.



PERL offers crucial advantages for a new user-oriented X-ray light source, including very high brightness, a large degree of spatial coherence, and ultra-fast temporal structure. These characteristics are key to both current and future applications of synchrotron radiation. The following provides a brief account of some of these applications.

Ultra-fast Processes and Time-Dependent Measurements: PERL provides pulses of X-rays as short as 100 femtoseconds. These femtosecond pulses can provide a new source of X-rays for performing time-domain structural dynamics measurements in condensed matter samples on the time scale of chemical bond formation and lattice vibrations. The PERL's picosecond and sub-picosecond X-ray pulses also can be used to study the temporal and spatial dependence of the response, such as magnetization and polarization of condensed matter samples on the picosecond time scale. For example, one of the key issues in the development of advanced magnetic recording materials is the speed of magnetization reversal.

Ultrahigh Spatial Resolution: A second application of PERL, which uses its high brightness, requires high transverse coherence. Two major uses of high transverse coherence sources, microscopy and coherent X-ray scattering, probe matter with nanometer to Angstrom-scale spatial resolution.

The intensity at the ideal focal point of an X-ray microscope is determined by the transverse spatial coherence of the incident beam. This is directly related to its brightness. PERL, which will have brightness comparable to or greater than the most advanced storage rings, is ideally suited for microscopy. The spot sizes of X-ray microscopes based on the PERL would be very small and thus a wide range of imaging and nanoprobe applications are anticipated. In addition, the circular X-ray beam geometry from PERL, as opposed to the highly elliptical shape from storage ring sources, is ideally matched to Fresnel zone plates and will lead to X-ray microscopes of much higher efficiency. Finally, the short-pulse format of PERL allows dynamics to be measured.

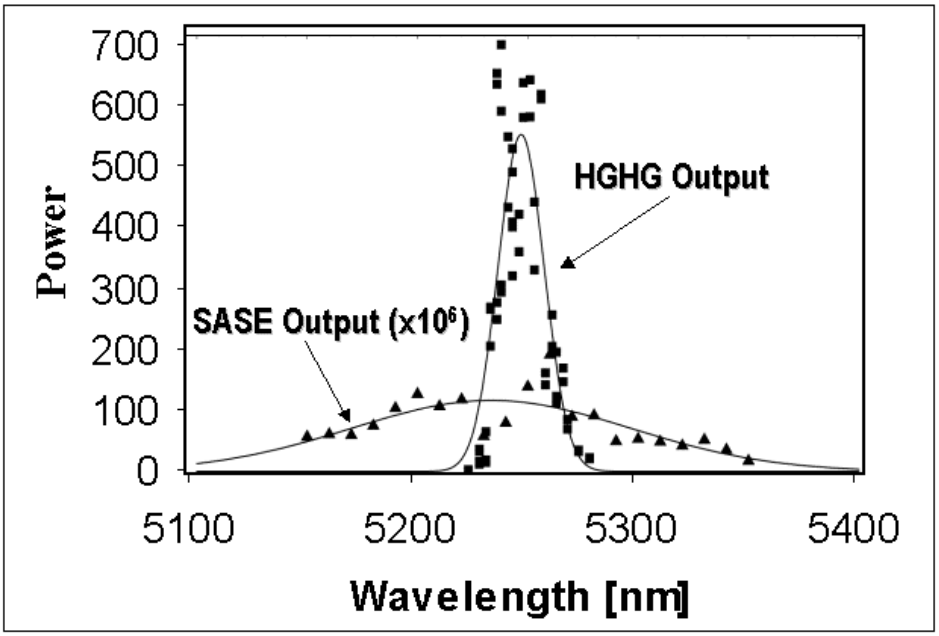
Coherent X-ray Scattering: Researchers recently have begun to exploit the potential of coherent X-rays. For example, a group at the NSLS has demonstrated that it is possible to reconstruct the electron density of an aperiodic object from its speckle pattern generated by coherent soft X-ray scattering. This technique allows imaging of an object with nanometer, perhaps even Angstrom, spatial resolution with a wide variety of contrast mechanisms, such as spin, chemical composition, and oxidation state. By combining the speckle measurement and reconstruction algorithm with the sub-picosecond pulses from PERL, this technique can be used to probe fast dynamics in real space and in the time domain instead of reciprocal space and frequency domain. In complex systems, there are clear advantages to this approach. The increased brightness provided by PERL will also benefit the recently developed technique of X-ray photon correlation spectroscopy, i.e., time auto-correlation function of the speckle pattern, which is used to study equilibrium dynamics of material surfaces.

Membrane Proteins: Because of the extraordinary brightness of PERL, it can be expected to play an important role in addressing one of the most difficult problems in protein crystallography, i.e, solving the structures of membrane proteins. Membrane proteins are an extremely important class of protein, notoriously difficult to crystallize, so that in many cases only very small crystals are available. The increased brightness of PERL will certainly be important in this work.

4.2.2 Laser Seeded Free Electron Laser

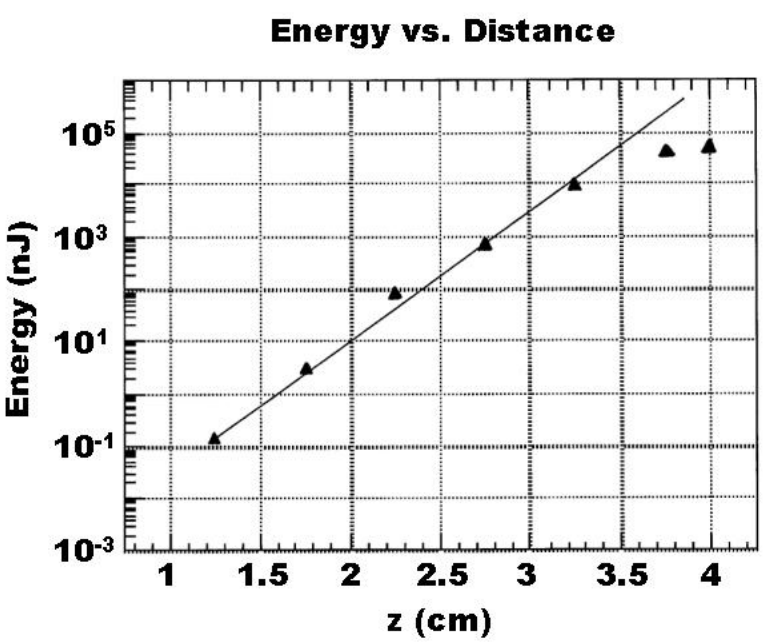
This Laboratory initiative is BNL's plan to contribute to the national effort towards X-ray Free Electron Lasers (FELs) and to support the Linear Coherent Light Source (LCLS) project. It is a coordinated program using BNL's expertise to develop key elements of X-ray FEL sources and to define the science. 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 resources 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. 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.

Figure 3 - Comparison of SASE and HGHC
The figure shows the narrow linewidth achieved with laser seeding as compared to the broad linewidth seen with SASE.



The Accelerator Test Facility has a preeminent position in the development of RF photocathode electron gun technology, and has impacted signifycantly 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.

Figure 4 - SASE Energy vs. Position
Evidence of Saturation after only 3.5m obtained in a small-gap undulator with strong focusing.



The ATF has hosted two important proof-of-principle FEL experiments, the BNL-NSLS High-Gain Harmonic Generation experiment in collaboration with ANL-APS, and the Visible Self-Amplified Spontaneous Emission (VISA) experiment that is part of the pre-construction R&D for the LCLS. The VISA experiment is testing and characterizing SASE FEL operation in the visible, where high quality optical diagnostics are readily available. It is a collaboration involving BNL, LANL, LLNL, SLAC, and UCLA. VISA, using a novel 4 meter

long undulator with strong focusing fields, has recently demonstrated a gain of 2 x 10^6 and an exponential growth rate (intensity gain length) of 18.5 cm. There also is evidence of saturation of the FEL intensity at about 3.6 m from the undulator entrance. The experiment successfully demonstrated that FEL gain is determined by the slice emittance and provides the existence of a working point of the LCLS that reaches saturation at 90 m.

The Leone panel recommended integrating conventional laser technology with accelerator technology to optimize performance of the next light sources. 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 Laser Electron Accelerator Facility (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. 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 trade-off 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.

Another 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 l00 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.

4.3 Nanoscale Science (KC)

Many of the physical and chemical properties of a material change dramatically as the object reaches a 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 ultra-small devices, resulted in a major national and DOE program in nanoscience and technology. Within the last year, BNL has developed an interdisciplinary plan in nanoscience that is aligned with the DOE nanoscience goals. The BNL planning involved collaboration among six internal departments or divisions and capitalized 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 Transmission Electron Microscopy (TEM). The proposed program expands our materials programs through collaborations with nearby university partners, Columbia, Stony Brook, and Princeton. The plan includes steps to enhance our capabilities through significant LDRD internal investments, selective new hires and proposal submissions for nanoscale science and a related research center.

The scientific goals of our nanoscience research will be to establish an understanding of the chemical and physical response of functional nanomaterials and to develop new nanoscale materials probes, particularly involving the NSLS and the emerging high resolution TEM facility. It is intended that this research will be carried out under the auspices of our proposed Nanocenter. There are six scientific thrust areas envisioned for nanoscience research at BNL. These include:

- *Functional nanoscale strongly correlated oxides.* The work will take a radically new approach in condensed matter physics, working at the nanoscale both to understand bulk behavior and to extend it.
- *Magnetic nanoassemblies.* This work will elucidate, at the most detailed level possible, the physical and chemical factors that control the collective magnetic state in magnetic nanoassemblies.
- *Nanocatalyst materials.* This research will focus on the electronic structure of metal-containing nanoparticles as a basis for understanding and controlling their catalytic activity and selectivity.
- *Charge transfer in molecular nanosystems.* The focus of this research is to obtain a fundamental understanding of the mechanism of charge transport on the nanoscale and in nanomaterials.
- *Functional thin organic films.* This research addresses the fundamental questions regarding nanoscale molecular organization, the relationship between structure and physical properties, and the

development of more advanced thin film organics.

- *Applications in nanoscience.* This research will explore applications of nanoscience to real world problems such as advanced device development and advanced energy needs.

BNL is participating in the Presidential Interagency National Research Initiative, "National Nanotechnology Initiative - Leading to the Next Industrial Revolution". The Laboratory assembled a Task Force to develop the program. This Task Force organized a coherent portfolio of Laboratory Directed R&D (LDRD) nanoscience projects that received a total of $1.5 million in FY 2001. This investment 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 LDRD projects include; nanomagnetism, charge transfer in molecular materials, and catalytic materials.

This "superproposal" approach to LDRD research 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 capabilities in nanofabrication and nanomaterials synthesis.

The Laboratory also is engaged in the DOE program in Nanoscience. BNL submitted three nanoscience proposals in areas aligned with our internal programs and our planning for the BNL Nanocenter. These programs are collaborative with many nearby universities and make use of our unique facilities and strengths. We also have submitted a proposal to design and construct a Center for Functional Nanomaterials (see section 4.8).

Our long-term goal is to establish BNL as a regional leader in the fundamental physics, chemistry, and materials science of nanoscience while building on past successes in bulk functional materials such as piezoelectrics, to change the approach to materials research at BNL, and to forge major and permanent links to the nearby university programs in this area. The BNL Nanocenter will be a focal point and enabler of advanced materials research in the northeast.

4.4 Cyclotron Isotope Research Center (NE)

BNL is committed to advancing medical radioisotope production and to the development of the Cyclotron Isotope Research Center (CIRC), a facility to serve as a reliable year-round domestic source of medical isotopes for nuclear medicine, for R&D, and for education and 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 Single Photon Computed Tomography (SPECT) and Positron Emission Tomography (PET) radioisotopes. CIRC would be available year-round for medical radioisotope research and production and will serve as a much-needed national resource for the education and training of future radiochemists and radiopharmaceutical scientists. It would enable the development of new and more effective radiopharmaceuticals for diagnostic PET and SPECT imaging and also catalyze and advance the relatively new but very promising field of radionuclide therapy for cancer and other diseases.

The centerpiece of CIRC is a negative ion cyclotron that would provide protons at energies of up to 70 MeV and continuous beam currents of up to 2 mA. CIRC will produce an uninterrupted supply of radioisotopes, in sufficient quantity to support research investigations on a national scale, as well as multi-center clinical research with human subjects. Up to four beam lines will allow simultaneous multiple user capability for research, production, and commercial partnering.

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

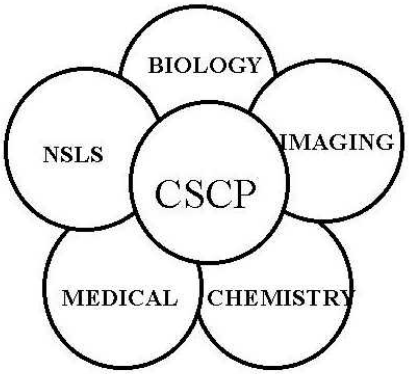
diagnosis and treatment of medical conditions, including heart disease and cancer. The missions are consistent with BNL's role as a provider of unique and sophisticated user facilities that serve as research tools to advance scientific knowledge for the benefit of mankind. It will complement other major existing facilities at BNL such as the AGS, RHIC, NSLS, and BAF.

4.5 Center for Structure of Complex Membrane Proteins (OBER)

Membrane proteins are critical elements of biological processes 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 than 1% of known 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 PET technology; therefore, it is a prime candidate for structural analysis to advance our understanding of how to facilitate crystallization of membrane proteins.

Figure 5 - The Center for Structure of Complex Membrane Proteins
The Center will provide a cluster of user facilities and bring together many disciplines to study membrane proteins and complexes.



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. This is the Center for Structure of Complex Membrane Proteins. 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 Stony Brook University 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. Similarly, expertise from other BNL and Stony Brook departments will add depth and broaden the knowledge base that can support the Center.

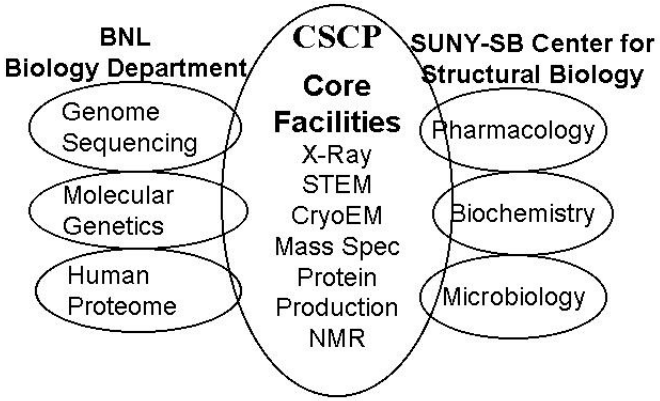
To initiate the CSCP, the Biology Department has hired three new staff. One is a young membrane protein biochemist, Dr. Dax Fu, who solved the structure, by X-ray crystallography of GlpF, a membrane channel protein that regulates glycerol transport in *Escherichia coli*. He will extend these studies to additional bacterial channel proteins while developing basic principles for the expression, purification, and crystallization of other membrane proteins. Drs. Daniel van der Lelie and Safiyh Taghavi will join BNL at the end of the year. They are molecular soil microbiologists who have pioneered the genetic characterization of *Ralstonia metallidurans*, a soil bacterium that is being developed

as an indicator of bioavailability and for bioremediation of metal contaminated soils. Metal bioremediation requires a complex of membrane bound transporter proteins.

A component of the CSCP will be a new Cryogenic Electron Microscope (Cryo-EM) facility for the analysis of two-dimensional arrays of membrane proteins, isolated complex particles, and frozen tissue sections. The Cryo-EM will complement the STEM facility. Support from the DOE Office of Biological and Environmental Research will permit the acquisition of a 200kV cryo-equipped electron microscope with a field emission gun in FY 02. This microscope will facilitate analyses of membrane protein complexes including heavy metal antiporters and membrane bound oxido-reductases of relevance to the DOE bioremediation effort. Additional support from Laboratory funds will be required to recruit an appropriate electron microscopist with experience in electron microscopy.

To provide adequate analytical capabilities for the expression and analysis of complex proteins and protein complexes, additional scientists will be recruited as resources permit. A critical component of any modern protein center is mass spectrometry. Both MALDI-TOF and MS-MS capabilities will be required for protein identification and quality control. Additional capabilities in membrane protein biochemistry will be necessary to assure the success of the Center.

Figure 6 - Center Facilities and Expertise
The facilities and expertise of BNL and Stony Brook University complement each other and form the critical mass needed for the Center.



4.6 Environmental Facilities Initiative (KP)

BNL's Environmental Facilities Initiative focuses on how to effectively use distributed facilities to address specific questions about global change. For example, the DOE funds facilities where researchers can study the effects of enhanced carbon dioxide on terrestrial ecosystems (FACE Facilities) and facilities that measure the flux of carbon dioxide at fixed locations using eddy flux covariance techniques (Ameriflux). With the Environmental Facility Initiative we are 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. The ability to acquire and manage these large data flows, in near-real time, from widely distributed facilities is crucial to the success of the enterprise. We are building specific tools such as the Research Platform software,

and developing Internet-based data communications tools to provide real-time control and measurements from widely distributed experimental sites. A growing user community is using the new tools. Since the terrestrial biosphere is the primary driver for the annual variability of carbon dioxide in the atmosphere, our efforts facilitate the development and use of coupled terrestrial-atmosphere models that can extrapolate today's observations to larger scales and to the hotter, wetter climate that is likely in the next century

A new type of research capability is needed to enable long-term organized research to understand how terrestrial ecosystems will respond to rapid environmental change. Over the next century ecosystem sciences must provide insightful understanding of which ecosystems will be most severely impacted, how ecosystems of the future will look, and which ecosystems are most vulnerable to rapid environmental change. Designing experiments to address these questions is the grand challenge for ecologists working to understand ecosystems of the future. Brookhaven collaborates with the other national laboratories in developing science plans for the manipulation and modeling of research required to answer these difficult questions. Existing ecosystem research facilities do not provide the research community with the capability to conduct the crucial multi-factor ecosystem experiments. BNL's Environmental Facility Initiative and complementary initiatives at other national laboratories are contributing to the conceptual design of a new distributed facility that can provide the required capabilities. This facility will probably have a long-term mission, on the order of 10-30 years, a large scale, encompass tens of square kilometers, and have the capability to manipulate CO_2, temperature, water, nutrients and other parameters.

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. The 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.

4.7 Center for Data Intensive Computing (KJ)

Advanced computational science is a critical factor for the success of DOE's science programs. Advances in hardware make the acquisition of adequate computational resources within the reach of most laboratories. In addition, there is a major national effort to develop techniques that take advantage of the terascale computing platforms currently in design. However, there is a need for an intellectual atmosphere and culture of scientific computing in which new algorithms and new methods in applied mathematics are brought to bear on scientific problems. To meet this need Brookhaven established the Center for Data Intensive Computing, which is directed by the Chair of the Department of Applied Mathematics and Statistics at Stony Brook University. The mission of the Center includes the following:

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

Current efforts are in accelerator science, medical imaging, materials and chemical science, and climate change as well as basic computational science research. We are participants in a multi-lab proposal, "The Terascale Simulation Tools and Technologies Center", designed to enable application scientists to easily use multiple mesh and discretization strategies within a single simulation on terascale computers. We also are involved in research efforts in data distribution via the Internet for RHIC.

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 and the development of automated systems for the analysis of images of individual neurons. In materials and chemical science, we 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. We are continuing 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 Galaxy - a cluster of more than 100 Intel processors running Linux.

The aim of the CDIC is to build up a portfolio of programmatically supported research activities. 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.

4.8 BNL Center for Functional Nanomaterials (KC)

BNL is participating in the DOE efforts to establish DOE Nanoscale Science Research Centers at the National Laboratories. BNL developed a center around the unifying theme of "tailoring the chemical and physical response of nanoscale functional materials." The BNL Center will enable research in six scientific thrust areas:

- the physics of functional correlated metal oxide electron materials in low, nanoscale dimensional structures,
- magnetic interactions in magnetic nanoassembly materials,
- new approaches to forming nanocatalyst structures and understanding their structure and reactivity,
- low dimensional molecular materials structures (e.g., nanowires and dots),
- structure and self-assembly of nanometer-thick films of organic materials, and
- new applications of nanoscale functional materials.

In addition, the Center will house research on the development of new nanoprobing techniques and instruments. The capabilities of the Center are complementary to those at other national laboratories such as Argonne and Oak Ridge. A major goal of the Center is to enable a significant expansion of our interactions and collaborations with our university partners. This includes more user facilities, the expansion of joint appointments, and the expansion of graduate students working at BNL. To date, we have submitted our proposal for the BNL Nanocenter and been awarded funds for pre-conceptual planning of the Center. Through this planning effort we sharpened the concepts and requirements of the Center's five laboratory areas and defined an organized means for interfacing with the users

The NSRC at BNL will be a Center for Functional Nanomaterials, which will integrate Brookhaven's unique capabilities in a broad range of synchrotron characterization techniques with new capabilities in nanomaterials synthesis and nanofabrication. Our focus of tailoring the chemical and physical response of nanoscale functional nanomaterials complements those of other planned Centers; it capitalizes on the NSLS leadership in materials probes and builds on the strengths of BNL's BES programs in strongly correlated electron systems, catalysis, molecular materials, electrochemistry, and nanostructure in complex functional materials. In addition to the Light Source, other major existing

facilities at BNL will be used; the 300 kV Transmission Electron Microscope (TEM), the Laser Electron Accelerator Facility (LEAF), ultra-fast lasers and scanning probes.

The centerpiece of the BNL Center is a new building located contiguous to the existing NSLS facility. The building will house clean rooms, general laboratories, and wet and dry laboratories, as well as office space for BNL staff, other university and industrial users, and space for seminars and conferences. The Center will have five major laboratory clusters: nanopatterning, scanning probe and optical microscopy, electron microscopy, materials synthesis, and ultrafast short wavelength sources. Instrumentation for these laboratories will be purchased as part of the project. To take advantage of the capabilities of the NSLS, the Center will have dedicated beamlines at the NSLS, including the soft X-ray and hard X-ray microprobes, UV soft X-ray and X-ray spectroscopy, soft X-ray and X-ray scattering, near field IR, and *in situ* characterization.

The BNL Nanocenter will draw researchers from many different disciplines. This is a natural consequence of developing a highly interdisciplinary science program and provides the advantage of attacking problems from several diverse scientific points of view. Because it will be highly inter-disciplinary in nature the organization will parallel closely that at the NSLS, a large user-oriented facility. A senior scientist will head each of the five laboratory clusters with responsibility for user interface, development of new scientific techniques, and supervision of any user scientific and technical staff in the laboratory complex. The proposed Nanocenter beamlines will be handled as a "sixth" laboratory cluster. Researcher in the six scientific thrust areas of the Center will use these laboratory clusters for their research, each having a different mixture and emphasis of the laboratory clusters for their research. Proposed research and allocation of laboratory and instrument time will be determined by groups of BNL scientists and external users. An Advisory Committee will guide the overall science direction. The BNL Center will bring together many organizations within BNL doing materials research including the Chemistry Department, the Materials Science Department, the National Synchrotron Light Source Department, the Condensed Matter Section of the Physics Department, the Biology Department, and the Instrumentation Division. The Center also integrates Brookhaven's unique capabilities in a broad range of synchrotron spectroscopies with new material and nanofabrication capabilities. The Center will be a focal point for collaborations with nearby universities in studies of functional materials at the nanoscale, particularly the State University of New York at Stony Brook, Columbia University, and Princeton University.

The complete design and construction of the Center is expected to take 4 years with an anticipated completion in FY 2005. Our near-term goals are to advance our planning for the BNL Nanoscale Research Center into Critical Decision 0, to win at least two nanoscience proposals, and to establish a case for a DOE Center in Nanocatalysis at BNL. The latter effort will involve an intensive collaboration with the NSLS and several universities.

4.9 User Research Center (MEL/FS)

RHIC provides the highest energy man-made collisions of heavy ions and the facilities for a worldwide community of researchers to use these collisions in experiments to explore new states of matter at temperatures and densities more extreme than exist now even in the cores of the hottest stars.

In all, some 1,000 scientists are presently involved in the experiments at RHIC, and that number will grow as the facility continues to collect experimental data. Experiments at RHIC use a number of collider detectors that were designed and built by international collaborations of scientific groups. The four RHIC detectors involve collaborators from some 90 universities and laboratories representing about 20 countries. Hundreds of visiting scientists will be working at RHIC at any given time to coordinate the experiments, operate the detectors, and analyze data, working alongside a Brookhaven staff of about 150

scientists and support personnel dedicated to this research. During short periods (e.g. workshops, collaboration meetings, etc.) an additional 100 to 200 visitors will be present at Brookhaven for work involving RHIC. It is essential for the success of this important national program that BNL become a vital and effective center, not only for the operation of RHIC and its detectors, but also for the intellectual activity involved in analyzing and understanding the exciting new data that is being collected.

Presently, there is not enough space at BNL to accommodate such large numbers of visiting users for the RHIC facility. Moreover, since Brookhaven will be the focal point of a worldwide effort to carry out and analyze these experiments, the success of the activity requires space at BNL where large groups can work together, meet, exchange ideas, and maintain close contact with the experimental equipment. Additionally, proximity to the existing computing facility in Building 510, which is essential for analysis of data, as well as the BNL research staff there, will leverage the investment in this vital research machine. At present, there is no facility at Brookhaven to allow for this kind of consolidation of the RHIC research activity.

Appropriate facilities must be constructed to support the influx of the science community to this new source of data and discovery. The User Research Center will provide a permanent facility for the BNL/RHIC scientific staff and the short- and long-term visiting scientific community to carry out the program's mission. With this project, BNL will construct a new 54,500 square foot office building next to the Physics Department, Building 510. The User Research Center will be located on Brookhaven Avenue at the core of the BNL site. The Center will include individual as well as multi-person offices, a large seminar room, two conference areas, transient user space for visiting collaborators, with access to computer terminals, and a lobby suitable for public displays and visitor orientation. A center such as this will be a true Science Center for RHIC users – an area where all the research groups can work together, share ideas as well as resources, and engage in the kind of intellectual interchange that is essential to fully exploit a truly world-class accelerator facility.

4.10 Energy Sciences Building (MEL/FS)

Brookhaven National Laboratory is committed to strengthening its programs in applied sciences currently conducted in the BNL Departments of Environmental Sciences, Energy Sciences and Technology, and Nonproliferation and National Security, as well as the Office of Technology Transfer. The Energy Sciences Building Project is a key element in BNL's plan to upgrade and modernize facilities essential to perform the DOE mission in applied sciences. With this project, BNL will construct laboratory and office facilities to replace old, outdated, inefficient WW II era facilities that are incapable of meeting mission needs. Execution of this project is essential to perform multi-program DOE initiatives in environmental sciences, carbon management, nano-technology and energy sciences, and to promote industrial collaboration and technology transfer.

The affected departments are currently dispersed among 24 buildings, of these buildings, only two are considered suitable for continued use for applied sciences research programs, even though they are in excess of 40 years old. The Environmental Sciences Department alone is dispersed among 14 buildings where over 65% of the occupied square footage is wood frame structures constructed as temporary barracks during WW II. These buildings were modified into laboratories and offices in the late 1940s, have far outlived their economic life and are unsuitable for continued use as applied science facilities. The problems associated with these buildings include the following:

- Unsuitable Structural Layout – The buildings were originally small barracks buildings cobbled together to create larger buildings. They cannot be further modified to provide the common areas, conference space, and large laboratory space needed to support the mission.
- Dispersion of Facilities – The existing buildings are dispersed over a wide area of the BNL site. The

dispersion of the staff means that scientists are isolated from their peers discouraging collaboration and negatively impacting productivity and creativity.

- High Maintenance and Operating Cost – The existing wood frame structures are costly to operate and maintain. Wood rot, leaking roofs, sagging floors, structural members not up to current code design, asbestos and lead hazards, old HVAC and electrical systems, old windows, old lighting and poor insulation will all require large continued investment just to maintain a minimum functional capability. Energy costs of $1.50/SF are double the amount for a similar size modern office building.
- Reduced Productivity – The poor existing conditions result in lower worker productivity due to inefficient layouts of office and laboratories. The inability to share resources results in additional supplies, less efficient use of space, and additional support staff that would not be required in a modern, purpose-built facility. The lower reliability of the aged facilities and equipment negatively impacts productive research output and leads to less valid data produced for a given investment. Industry currently expects a 10% productivity increase from their employees after investing in new research facilities.
- Impact on Scientific Staff – The unattractive and unsuitable condition of the existing facilities has made it difficult to retain qualified scientific staff or to attract new staff. While part of the staff reduction seen in recent years is due to DOE programmatic realignment, the reduction in staff (nearly 50%) far exceeds that attributable to program changes. There are many vacant positions that have not been filled due to the competitive disadvantage posed by BNL's facilities.

The proposed Energy Sciences Building will provide approximately 40,000 square feet of laboratory, office, and support space. The two-story structure will be constructed in close proximity to the existing applied science buildings 815 and 830, creating of an "Applied Sciences Campus" and consolidating staff into 3-4 buildings.

The facility will include, individual offices, two-person offices, state-of-the-art laboratories, and transient user space for visiting collaborators with access to computer terminals, a large seminar room, and conference rooms on each floor. The building will incorporate designs to encourage peer interactions and collaborative visits by staff around the Laboratory; e.g., in addition to offices and laboratories, it will house "interaction areas" for informal discussions. This design approach is commonly regarded as the state-of–the–art in research facility design. The building will house capabilities that are used by scientists across disciplines including laser laboratories and two microscopy laboratories. Three general-purpose laboratories and preparation labs also will be constructed to accommodate a wide array of research needs.

Table 3 - Resource Projections for Laboratory Initiatives

Resource Projections For Laboratory Initiative (FY 01$ In Million)						
	FY 01	**FY 02**	**FY 03**	**FY 04**	**FY 05**	**FY 06**
RHIC II		0.5	2.0	4.0	12.0	25.0
e-RHIC[(a)]	0.1	0.2	0.2	0.5	5.0	5.0
Laser Seeded FEL[(b) (c)]	0.8	2.9	3.2	TBD	TBD	TBD
PERL[(b) (c)]	0.3	2.9	4.0	TBD	TBD	TBD
70 MeV Cyclotron			17.8	10.2	3.2	1.4
Nanoscience Initiative[(b) (c)]	1.6	1.7	2.0			
BNL Nanocenter For Functional Materials[(d)]	0.3	1.0	23.8	54.7		
Center for Structural Biology and Membrane Proteins[(b)]	1.0	1.0	1.1	2.1	2.0	2.0
Environmental Facilities Initiative[(b,e)]						
Data Intensive Computing [(b)]	0.60	1.2	2.0	3.0	3.0	3.0
User Research Facility			7.5	7.5		
Energy and Environmental Science Building			1.8	7.2	8.4	

[(a)] The resource timetable has not been developed; funds in FY02-FY04 are for planning and development.
[(b)] Funds for FY 01 were provided through the Laboratory Directed Research and Development Program.
[(c)] Funds for FY 02 are provided through the Laboratory Directed Research and Development Program.
[(d)] The Nanocenter proposal will be updated for submission in FY02 – Costs are expected to change.
[(e)] BNL's role in the out years will be defined as the TERF/EFI concept matures.

5.0 Department of Energy Programs

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.

There are several factors, which affect the Laboratory's planning.

- DOE increasingly competes for program funds.
- User needs continue to grow.
- In-house research focuses on interdisciplinary activities, and advanced computation needs will continue to increase.
- The future big machines will be confined to the developed core of the site.
- Information technology will increasingly dominate work-style.

The vision for the Laboratory is one in which interdisciplinary interaction will be the norm with a focus on key science themes where BNL has and continues to demonstrate leadership. We will provide a coherent user experience and quality workplaces for our users and employees, and we will continue to build core capabilities in areas such as advanced computation to further all our research endeavors.

5.1 Science and Technology Facilities

Brookhaven National Laboratory is a multidisciplinary accelerator laboratory with ion/particle acceleration and electron/photon capabilities. The Laboratory has a strong core specialization in accelerator research, advanced magnets, instrumentation, and computation to support our existing facilities and to design and develop new facilities as well as new applications for existing facilities. In the future BNL will continue as a "center of excellence" for accelerator based science, including detector, magnet, and computing technologies. The following sections describe our major user facilities and plans for the future. These plans, in conjunction with our proposed initiatives, will assure our continued success in meeting the DOE Science and Technology mission well into the future.

5.1.1 Relativistic Heavy Ion Collider (KB)

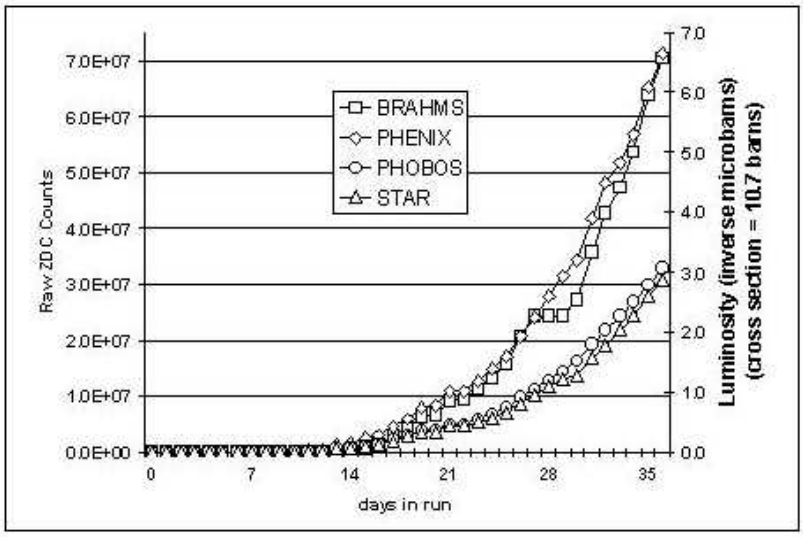
Present Program: The Relativistic Heavy Ion Collider (RHIC) is the largest facility for nuclear physics in the US and the most powerful source of heavy ion collisions in the world, creating conditions, which occurred microseconds after the "Big Bang". Additionally, RHIC has the capability to accelerate, store, and collide polarized proton beams as a result of the collaborative efforts with the RIKEN Institute of Japan. RHIC offers the 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, and full energy collisions were produced in FY 2001. The rapid ramp-up of the performance of the accelerator and the four detectors exceeded expectations. The crucial RHIC Computing Facility (RCF) was able to accept flawlessly the huge data flow from the detectors and to store and make date accessible for rapid analysis.

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.

Figure 7 - Integrated Luminosity Delivered to Experiments at RHIC
(FY 2000 run: Au on Au 130 GeV/nucleon). The total number of events collected was as follows: PHENIC: 4.5M min-bias events; STAR: 1.6M total trigger (0.8 min bias,0.8M central); PHOBOS; 3M min bias events; BRAHMS: 7M min bias events.



Near-term Program: For FY 02 RHIC will operate for about 28 weeks for the heavy ion and spin programs. For the near term, the heavy ion program will continue with a mix of polarized proton operation that optimizes the physics output. We also will 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) 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 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 (KB/KA)

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 increases our 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, 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 de Graaff.

Near-term Program: Since 1999 the prime mission of the AGS is to inject heavy ions into RHIC on an as need basis (about twice a day). 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. BNL's High Energy and Nuclear Physics Program Advisory Committee must endorse all experiments at the AGS. 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 supports a radiobiology research program using heavy ion beams. This compatible Work for Others 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 the radiobiology program at the AGS and expand the program with the use of the Booster.

5.1.3 National Synchrotron Light Source (KC)

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 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 to 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 users by discipline is given in Table 4 and shown in Figure 8.

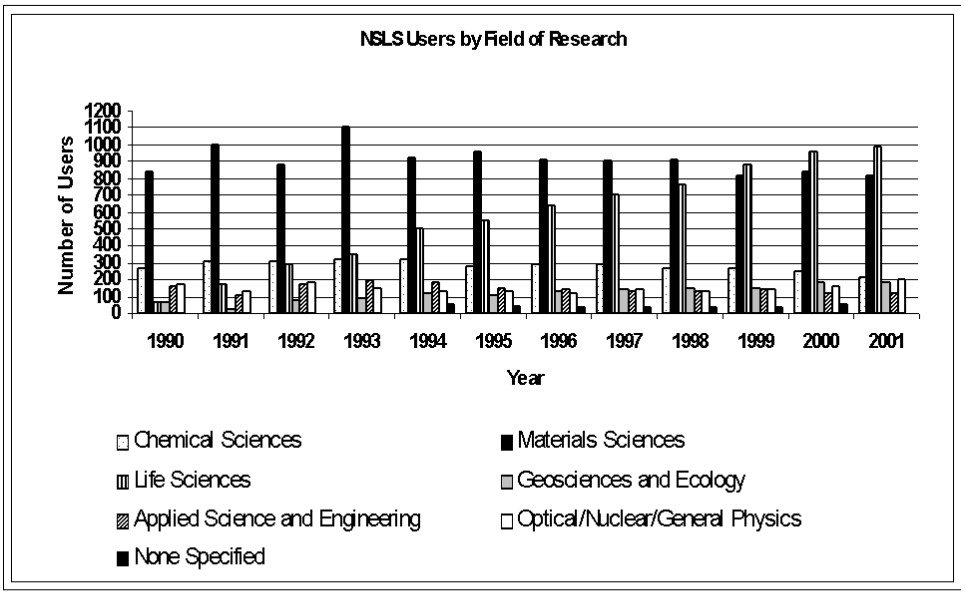
A number of improvements have been made to the facility including the following major upgrades. A new digital orbit feedback system has significantly improved the orbit stability on the VUV ring. The upgrade of beamlines on the VUV ring has re-vitalized the user program. During the upgrade, 6 new IR beamlines and 4 upgraded soft X-ray beamlines were brought into operation, and a new 5-30 MeV beamline was established at U13. These innovations produced new state-of-the-art capabilities and enhanced the scientific program as evidenced by increasing numbers of users and publications. A

new sextupole power supply system was completed allowing the X-ray ring to routinely operate in the low emittance lattice at 2.8GeV (up from 2.5GeV).

Table 4 - Distribution of NSLS Users by Discipline

Discipline	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Chemical Sciences	264	304	303	318	321	281	292	285	268	265	244	214
Materials Sciences	837	993	882	1104	929	952	916	902	914	819	842	822
Life Sciences	62	167	286	354	503	548	642	701	761	881	953	987
Geosciences and Ecology	62	26	75	80	113	106	123	136	147	147	177	184
Applied Science and Engineering	155	106	167	186	177	147	138	126	127	134	119	117
Optical/Nuclear/General Physics	170	129	183	151	129	128	116	136	131	138	162	197
None Specified	0	0	1	0	56	44	34	34	32	32	54	2
Total	**1550**	**1725**	**1897**	**2193**	**2228**	**2206**	**2261**	**2320**	**2380**	**2416**	**2551**	**2523**

Figure 8 - Distribution of NSLS Users by Scientific Discipline



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. The NSLS will construct the remaining two new RF cavities for the X-ray ring. Major progress has been made in the construction of a new National Institutes of Health funded beamline for structural biology. There is now an initiative to improve the insertion device beamlines on the X-ray ring. A new high-resolution monochromator has been procured for the soft X-ray undulator beamline X1B. The superconducting wiggler beamlines at X17 are being reconfigured to increase the experimental throughput. On X21, photon beam transport is provided to bring X-rays into the back hutch to establish a new end-station for materials science. On X25, a new cryogenically cooled monochromator and a state-of-the-art 9-cell CCD detector have been purchased. In addition, we are building new in-vacuum undulators that will be installed in the RF straight-sections at X29 and X9, increasing the number of insertion devices on the X-ray ring to eight.

Long-term Program: Building on the success of the National Institutes of Heath (NIH) funded research in macromolecular crystallography, the NIH is funding the construction of additional beamlines and purchasing new detectors. A consortium of protein crystallography beamlines has been formed with NIH funding. The result has been a major increase of user support in this area and a dramatic increase in productivity. This suggests that consortia should be developed for other scientific disciplines. If funding can be acquired, the advantages of coordinating the activities of groups of beamlines and providing enhanced user support could have a very positive impact on the experimental program.

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 foster 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.

A very exciting area of R&D at the NSLS is the possible future upgrade of the facility using a Photo-injected Energy Recovery Linac (PERL). At the present time, most synchrotron radiation research is carried out on electron storage rings. In such devices, the electron beam's transverse emittance, bunch length, and energy spread are determined by equilibrium between the quantum fluctuations due to the emission of discrete photons and the damping resulting from the average energy loss. Storage ring sources have been optimized in recent years to provide high brightness, stability, and reliability. One apparent limitation of storage ring sources is that there is no practical scheme to provide very short electron bunches with duration below a few picoseconds, but short electron bunches of duration down to 100 femtoseconds can be obtained using linear accelerators. Now is the time to consider the type of accelerator that will be the basis of future synchrotron radiation sources. Linear accelerators are widely used to drive free electron lasers because of the high peak currents and small emittances that are achievable. In the last few years, several research groups have been considering the potential of using linac sources to provide incoherent synchrotron radiation. One reason this is not commonly done is that achieving high average currents, on the order of a few hundred mA, has been commonplace in storage rings but has not yet been achieved in linacs. Recent developments at Thomas Jefferson National Accelerator Facility indicate the possibility that average currents of a few hundred mA can be achieved in linacs with energy recovery. PERLs therefore have the potential to provide electron beams of 3-6 GeV, with average currents of 100 mA, emittances on the order of 0.1 nm-rad, and bunch lengths of 100 femtoseconds. PERLs are a very attractive basis for the next generation of synchrotron radiation sources at BNL.

The NSLS continues to contribute to the national R&D program for the next generation light sources. The High-Gain Harmonic-Generation (HGHG) experiment at the BNL Accelerator Test Facility (ATF) successfully demonstrated the proof-of-principle for a new approach to free-electron lasers. The high peak power output is both spatially and temporally coherent. We plan to extend the success achieved at the ATF in the infrared to shorter wavelengths at the Deep Ultraviolet Free Electron Laser (DUV-FEL) now being installed in building 729 adjacent to the NSLS. In addition, the Visible Self-Amplified Spontaneous Emission (VISA) experiment, a collaboration including BNL, LANL, LLNL, SLAC, and UCLA, has successfully demonstrated a gain of $2x10^6$, using a novel 4-meter long undulator with strong focusing. The NSLS also will continue to play an active role in promoting the development of scientific applications for the Advanced X-ray Source facilities and in providing facilities for conducting proof of principle experiments.

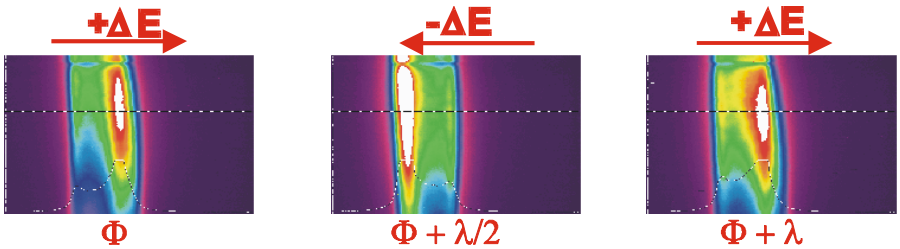
5.1.4 Accelerator Test Facility (KA)

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. 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 about 75 in FY 01 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 (STELLA) experiment. Next year we expect to continue work in the plasma acceleration field using the new terawatt picosecond CO_2 laser.

Figure 9 - STELLA Electron Beam Energy Spectrum
This set of spectra illustrates phase control over the two-stage acceleration process in STELLA. The sequence obtained when the optical delay of the accelerating laser beam changes half wavelength from the maximum acceleration to ultimate deceleration of electrons



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 photocathode 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

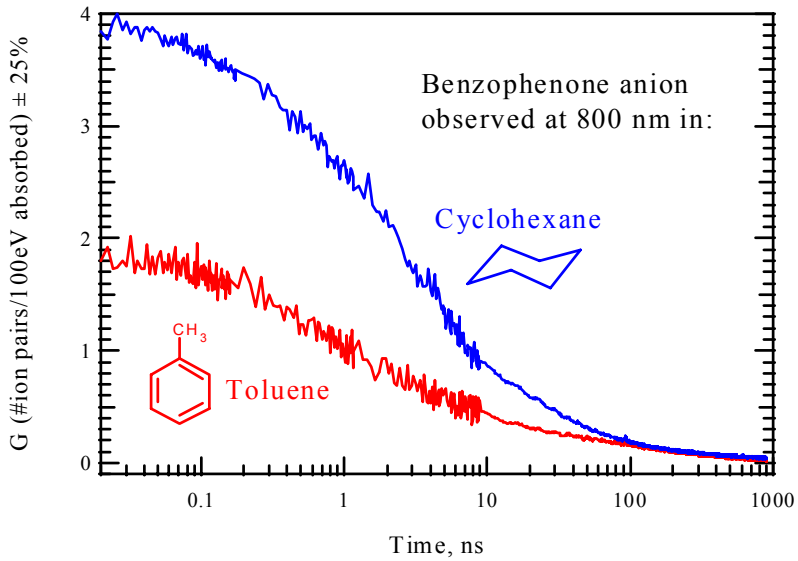
compressor, upgrade the high-energy beam transport system, begin operations with the terawatt picosecond CO_2 laser, and increase the facility's energy to 120 MeV.

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 Laser Electron Accelerator Facility (KC)

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 way to study the fundamentals of ionization in condensed media on fast time scales. Two operational detection systems obtain transient absorption data either rapidly with ~ 1 nanosecond time resolution or, in more time-consuming "pulse-probe" experiments, with 7 picosecond time resolution.

Figure 10 - LEAF: Geminate Recombination in Hydrocarbons
LEAF's pulse-probe data shows a high yield of ion pairs 20 picoseconds after electron radiolysis. Almost all the ion pairs recombine due to mutual electrostatic attraction, resulting in a very small yield at 1 microsecond (digitizer data). The initial electron-hole pair distributions can be inferred from the shapes of the survival curves. Comparison of cyclohexane and toluene data shows how the electronic structure of the solvent strongly affects the initial ion pair yield and distribution. This information is needed to understand how energy is deposited in materials during radiolysis.



Future Program: Experiments combining electron pulse and laser pulse excitation are anticipated to achieve ~ 0.1 picosecond time resolution. This will give LEAF a unique ability to combine the well-defined energetics of accelerator experiments with the high time-resolution of laser experiments. For example, experiments at LEAF will characterize the nature of ion recombination reactions and probe the unusual species formed when supercritical fluids are ionized. Lifetimes of excited ions, which could function as energy-storage intermediates, will be measured to ~0.1 picosecond for the first time. Concurrently the performance of existing detection systems will be improved. The LEAF facility also holds significant promise for new studies related to radiation-induced chemistry relevant to electron transport in molecular-scale electronics and devices in support of BNL's nanoscience initiatives.

5.1.6 Transmission Electron Microscopy Facility (KC)

Present Program: The Transmission Electron Microscopy (TEM) facility has a unique and powerful 300kV field-emission high-resolution microscope, one of the best microscopes in the US, with capabilities of transmission and scanning high-resolution atomic imaging, magnetic imaging, nano-probe spectroscopy, energy filtered electron diffraction, and electron holography. The TEM research activities at present focus on understanding nanoscale crystal structure and structural defects and their role in determining the physical properties of advanced materials such as high temperature superconductors, permanent magnets, transition-metal oxides, and other nano structured materials.

BNL developed a novel interferometric technique based on coherent electron diffraction coupled with imaging to measure lattice displacement in crystal defects with unprecedented accuracy down to 1 picometer. This is about a tenfold improvement over any existing technique. BNL also developed and implemented electron holography to study potential variation and space charge at grain boundaries in superconductors. Using various magnetic imaging methods, researchers studied the *in-situ* magnetic behavior and local induction distribution in $Nd_2Fe_{14}B$ hard magnets as a function of temperature and field.

Near-term Program: BNL is extending its unique abilities in structural characterization to address important issues in materials science. We will continue to study grain-boundaries including electromagnetically characterized bi-crystals doped with various cations to measure interfacial potential, charge, and displacement. We also study nano-particles and assemblies that exhibit emerging optical and magnetic properties because of their fine length scale. BNL also will continue to explore and develop new approaches to the phase problem for non-periodic object that has fundamental importance in microscopy both for electron and synchrotron X-rays. Work is progressing on TEM based electron lithography and research for electron sensitive precursor materials to fabricate *in-situ* nano-structures. We are searching for a new technology to design an aberration-free microscope with sub-angstrom image-resolution and sub-electron-volt spectroscopic-resolution.

Long-term Program: Our mission is to develop and apply advanced quantitative electron microscopy techniques to fundamental problems in materials science. The TEM facility and expertise complements the capabilities in Physics, NSLS, Chemistry, and Biology. The following are focal points over the next few years:

- The study of atomic structure, bonding characteristics, and charge variation at nano-structure interfaces with unprecedented spatial resolution using quantitative electron diffraction, imaging, X-ray and electron energy-loss spectroscopy, Z-contrast, and structural modeling techniques including those developed at BNL.
- In-situ experiments and dynamic observations of magnetic, ferroelectric behaviors, and shape-memory effects of various functional materials and devices including p-n junctions, under controlled stress, magnetic and electric fields.
- Nano-science and technology related areas, including fabricating quantum-structure using electron lithography with spatial resolution (line width) below 5nm.
- Development of a single atom imaging and imaging analysis technique in conjunction with BNL biologists for biology and materials research.
- Expanded collaboration with scientists at Stony Brook University to work on semiconductors, nano-magnetic composites, polymers, and biomaterials.
- Development of a new generation achromatic microscope (<0.07nm spatial resolution and <0.1 energy resolution) incorporated with monochromator, aberration corrector, omega filter, and

Lorentz lens. This work will be in collaboration with the National Transmission Electron Acromatic Microscope (NTEM) project initiated by four other DOE electron microscope facilities.

5.2 Science and Technology Programs

While BNL operates the world's frontier facilities for nuclear science and one of the world's most productive coherent short wavelength light sources, these facilities rely on the R&D programs at BNL that focus on combining accelerator technology and basic science to ensure continued leadership in the next generation of accelerator based beams of light and matter. Other R&D programs at the Laboratory lead in the use of facilities to advance knowledge and take advantage of the Laboratory's wealth of talent and capabilities for discovery and issue-oriented research. These fundamental components, large scale or complex facilities, supporting technologies, and the science programs link the facilities to the users and to the DOE missions.

For planning purposes, the emphasis is on interdisciplinary themes and their relation to DOE missions, user needs, and BNL's core capabilities. These themes provide a focused framework and identify the "bright spots" of the Laboratory's research activities within a potentially broad spectrum. The following sections describe BNL's programs and, in conjunction with the program initiatives, define the future direction for our science and technology endeavors.

5.2.1 Nuclear and High Energy Physics (KA/KB)

The DOE Office of Science, High Energy and Nuclear Physics program offices sponsor experimental and theoretical Nuclear and High Energy Physics. Scientists in the Physics Department conduct most of the R&D, while solar neutrino research is managed by the Chemistry Department.

5.2.1.1 Nuclear Physics - Quark Gluon Plasma, Solar Neutrinos 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, which complements the user facilities operated by the Laboratory 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 01 the detector groups completed construction of all four detectors and participated in the start-up of RHIC Collider operation. 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.

A third area of nuclear science receiving significant attention in recent years is solar neutrino research, specifically the search for neutrino flavor oscillations and neutrino mass. For a decade, BNL has had an active participation in GALLEX at the Gran Sasso Laboratory in Italy, and since 1996 has been involved in running the Sudbury Neutrino Observatory (SNO) at the Creighton Mine in Ontario Canada. The first phase data acquisition for SNO, with one kiloton of ultra-pure deuterium oxide (D_2O) began in October 1999. The first published SNO results confirmed that the model of the sun predicts the number of electron neutrinos produced by the sun, and that transformation to other neutrinos occurs as the neutrinos travel from the sun to the earth.

The Laboratory is building 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 FY 2001, BNL research in this area continued to focus 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, using low energy kaon beams, two experiments were conducted on the non-mesonic decay of lambda- He^4 and on hypernuclear gamma rays. These will continue into 2002.

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, Stony Brook University, and Yale). RBRC is located at BNL and is a complementary theory and experimental physics institute. Scientists at RBRC are an integral part of the Nuclear Physics research at BNL and are funded primarily by the RIKEN Institute of Wako, Japan. RBRC and BNL scientists, together with outside users, form the RHIC Spin Group.

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 four 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 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 will lead in defining and accomplishing the work, in cooperation with the entire RHIC experimental community.

At SNO, the emphasis will shift in 2001 from measuring the neutrino charged-current (CC) and elastic-scattering interaction in pure D_2O to searching for evidence for the neutro-current (NC) interaction. This will be accomplished, first by adding sodium chloride (NaCl) to the D_2O to accentuate the NC signal, and subsequently in 2002, after the NaCl has been removed, by inserting ^3He filled neutron counters into the D_2O. If evidence is found that the NC signal is greater than the CC signal, that will constitute definitive proof for the occurrence of neutrino oscillations, since some of the electron-neutrinos from the sum will have transformed into the other known neutrino flavor.

The two real-time solar neutrino detectors that have operated to date, Super Kamiokande and SNO have thresholds of ~ 5 MeV. They are sensitive only to ^8B neutrinos. Only the radiochemical solar neutrino detectors had thresholds below 1 MeV and were capable of observing ^7B (Homestrake) neutrinos and pp and ^7B neutrinos (GALLEX and SAGE). A concept is under study at BNL for a new neutrino detector with a very low threshold, ~0.25 MeV. The design goals for this detector, the Low Energy

Neutrino Spectrometer, LENS, are to measure the energy spectra and fluxes of pp and ^{7}B neutrinos in real time, as a means to complete our knowledge of solar neutrino interactions. R&D on LENS will continue through 2001, the goal is to design and build a prototype in 2002. If this proof-of-principle test is successful, a proposal will be made to DOE in 2002-2003 for ~100 ton LENS neutrino detector.

5.2.1.2 High Energy Physics - Standard Model Tests and Rare 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, the 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 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 definitive measurement of the very rare Kaon decay, $K^{+} \rightarrow B^{+}$ <<. 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 the 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 producing 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. In FY01, the collaboration published results that gave the first indications of a deviation from the Standard Model. This experiment will conclude its data-gathering phase in 2002 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 <$_{L}$ to <$_{\cdot}$ 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 ATLAS groups.

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 (KA/KB/KC)

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 diverse accelerators (AGS, RHIC, NSLS, Tandem, ATF, etc.) has one of the largest concentrations of innovative accelerator scientists in the US. BNL staff members also 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 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 through 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. The design of a 70 MeV cyclotron for research and isotope production was completed for a potential DOE-NE supported construction project. We also are designing a 250 MeV rapid cycling medical synchrotron. The University of Pennsylvania has expressed interest in acquiring such an accelerator for their cancer therapy facility. There also are discussions planned with other interested major cancer therapy centers in the US.

BNL staff participate in the "Neutrino Factory and Muon Collider Collaboration," an international group of accelerator physicists who pursue R&D on the concept of capturing an intense beam of muons in an accelerator/storage ring complex. 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. The BNL Center for Accelerator Physics provides a focus for this work. 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. 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. In addition to simulations and other design studies, BNL has a specific mission within this collaboration to conduct an experimental targeting study, E951, using high-intensity proton beams from the AGS. 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.

Future Program: Three new programmatic needs, electron cooling of RHIC ions, electron-ion collider (e-RHIC) and a next generation synchrotron light source, converge to a common new accelerator, the Photoinjected Energy Recovery Linac (PERL). The commonality is driven by the need for high power electron beams, ranging from 50 MeV to possibly 10 GeV. Work is underway at the Budker Institute, Novosibirsk, Russia to study the feasibility of electron cooling. Preliminary results indicate that it is a viable approach. We expect to collaborate with other US laboratories such as TJNF and Cornell to develop the recirculating linacs.

A short-term muon R&D objective is completion of the BNL site-specific feasibility study of a muon storage ring as the neutrino factory. This plan includes 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 3000 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 sections 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. 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 premier research facility for the worldwide physics community and as a pilot for the TeV region collider. The muon collider/storage ring R&D program will require about a decade to reach its presently defined technical goals.

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: Since the 1980s a primary BNL core competency is the design, construction and testing of substantial numbers of large, superconducting magnets, especially for accelerator applications. 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 focus on the magnet requirements of future accelerator facilities, in addition to producing innovative magnets for operating facilities.

Near-term Program: The current 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. BNL developed unique designs 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 fields and attention has moved to both Nb_3Sn and high temperature superconductors (HTS). These materials are difficult to work with, but both materials are capable of operating to these fields

Muon Colliders produce a different set of challenges; the decay of the intense muon beams deposits a large amount of energy into the magnet. The superconductor needs to be shielded from this radiation for this magnitude of magnetic field. High-temperature superconductors that exhibit a very small temperature dependence when cooled to helium temperatures would be effective. A conceptual design of a magnet that removes the coils from the mid-plane has been developed as an alternative to a large bore magnet where most of the aperture is filled with shielding.

During the past year, production work continued on both the helical dipoles and the DESY magnets. Two prototype LHC magnets were fabricated and successfully tested. Production of the initial LHC magnets is now underway. In the area of high field magnets, BNL wound and tested several 1 m test magnets made with new superconductors to study magnetization effects, material degradation, and "quench" characteristics. These magnets were made with a variety of materials (HTS tape, HTS cable, Nb_3Sn cable) using vacuum impregnation. Tests are progressing in support of the engineering design of a magnet capable of withstanding the mechanical forces at 12 Tesla.

BNL entered into a R&D collaboration with the GSI Laboratory in Germany to look at developing rapid-cycling superconducting magnets. The R&D will involve changes to the superconducting cable and the method of its manufacture into a coil. While the GSI-proposed in-house program determines the initial requirements, there are other potential applications of possible interest to BNL.

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. BNL also will continue work on a 12 Tesla dipole based on Nb_3Sn technology as a fall back technology if needed. The present goal of this program is to demonstrate a muon collider style proof-of-principle magnet.

Plans are proceeding to increase the luminosity of RHIC by "cooling" the beams of heavy ions with electrons. This facility will include a solenoid magnet with tight tolerances on alignment and field uniformity. The Magnet Division will design and construct this magnet as part of its support to the RHIC program.

The Laboratory also is investigating the potential application of HTS to 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 engaged in informal discussions with three laboratories about the development of specialized superconducting magnets for their facilities: the BEBC electron-positron collider in Beijing, China, the PEP-II electron-positron collider at the Stanford Linear Accelerator Center, and a proposed proton radiography facility at Los Alamos National Laboratory. These projects would involve the production of a small number of magnets that would extend the capability of the Magnet Division.

The R&D and the production work in the Superconducting Magnet Division 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 Superconducting 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 magnets 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 includes the following technical areas:

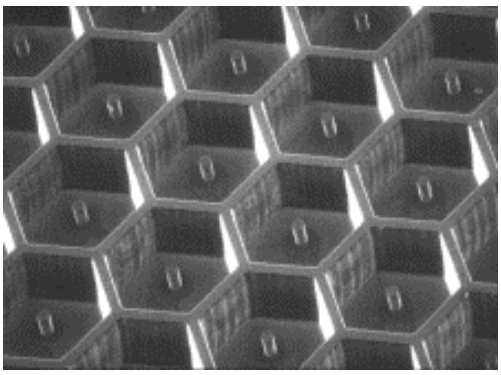
- Semiconductor detectors
- Gas and noble liquid detectors
- Lasers and optics
- Monolithic circuits
- Micro- and nano-fabrication

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 will 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 that 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 six beamlines at the NSLS making the facility a leading center for the characterization of materials using infrared radiation.

Figure 11 - Detector Array
High aspect ratio micro-fabrication with SU-8 photoresist is being used to fabricate both one-dimensional and two-dimensional position-sensitive detector arrays that have the potential to greatly increase the data collection rates of X-ray diffraction experiments at the NSLS and other synchrotrons.



Currently, in collaboration with the Advanced Photon Source (APS) and the Geophysical Laboratory, we are developing techniques for inelastic scattering at high pressure. The BNL Physics Department is a leading member of the CMC CAT at the APS where BNL staff is 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 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, new detectors for protein crystallography, 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 reactions 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 and FY 02, BNL submitted Field Work Proposals to DOE for direct support of these R&D activities. A major thrust also will be to obtain a more extensive nanofabrication capability and systems for thin film growth.

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 on the study of phase transitions in the bulk and at surfaces. In addition, a joint program in the Physics and Materials Science Division is developing a vibrant in-house materials synthesis capability, including Pulsed Laser Deposition (PLD) thin film and single crystal oxide growth that will eventually become part of the Nanoscience Center. Much of the experimental work requires instruments developed at Brookhaven's major user facilities and fosters continuing interactions of facility and BNL staff. The research is also 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,
- nanoscience, and
- energy utilization.

Researchers are investigating the basic relationships between microscopic structures and macroscopic properties of advanced superconductors, providing the basic data and defining the fundamental materials science required for their effective practical use. Emphasis is on studies of high temperature superconducting cuprates, including investigations of the physical properties of lattice defects, especially their role in altering superconducting properties as well as kinetics of the formation of these oxides in practical conductors. BNL researchers extensively use transmission electron microscopy, neutron diffraction, and X-ray diffraction and spectroscopy techniques at the NSLS. Other researchers focus on developing an understanding of electroresponsive conducting polymers, using 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 applications to real devices. New efforts are concerned with nanoscience, including growth and characterization of functional materials, magnetic composites, and oxide surfaces.

Recent results in material and condensed matter include the discovery of polar nano-domains in relaxor ferroelectrics, the discovery of the freezing of a quantum spin liquid in an applied magnetic field, the demonstration that the coupling to collective modes in high T_c and dichalcogenide materials is electronic in origin, the observation of orbitally ordered domains on nanolength scales in manganites, and characterization of the pressure dependence of the structural and electronic properties of the new MgB_2 superconductors.

New programs have been initiated in materials synthesis and in soft condensed matter. BNL has recruited an expert in oxide single crystal growth and successfully commissioned a new facility for Pulsed Laser Deposition. In addition, BNL also hired an Assistant Scientist to focus on nanofabrication and characterization of self-assembled block co-polymer systems. These initiatives involve collaborations, which cross department boundaries at BNL and are part of BNL's response to the Nanoscience and Complex Materials Initiatives. A significant step has been taken toward rebuilding the Condensed Matter Theory Group with the hiring of Alexei Tsvelik, a world-renowned theorist. Finally, a collaborative effort led by the Center for Neutron Science and including the Physics and Chemistry Neutron Scattering Groups has accomplished its near-term goals of moving HFBR instrumentation to HFIR, NIST and ANTSO, of establishing a BNL presence at HFIR for construction of a cold triple axis facility, and laid out plans for the design and construction of three future SNS instruments in which BNL will play a leading role.

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 research 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 in nickelates. The interplay between electronic, magnetic, and structural degrees of freedom in these systems, and the nanoscale spatial inhomogeneity that can result from competing interactions, are of particular interest. Other systems of current interest include dimensional cross-over in systems of weakly coupled spin-chains, quantum critical phenomena, the effects of nano-domains in relaxor ferroelectrics, and shape-memory alloys exhibiting Martensitic phase transformations. Neutron scattering is a unique tool for studying these phenomena, and experiments are done at other neutron facilities in the US and abroad. In many cases, this work is complemented by parallel studies using X-ray scattering or electron spectroscopy available at the NSLS. These research efforts respond to the DOE initiatives in Complex Materials and in Nanoscience. This year researchers observed the freezing of a quantum spin liquid in an applied magnetic field, polar nano-domains in a relaxor ferroelectric, and competition between local magnetic order and superconductivity in cuprates.

Future Program: Next year, researchers will continue to study quantum phase transitions in low dimensions, especially spin chains, nano-properties of ferroelectrics, and the origins of high T_c superconductivity in complex materials. An expert in single crystal oxide growth will develop a new program in this area, starting with $Bi_2Sr_2CaCu_2O_{6+\delta}$, to look for evidence of stripe correlations. A major long-term initiative will involve developing the conceptual design of a direct-geometry time-of-flight instrument for spectroscopy at the Spallation Neutron Source (SNS) in collaboration with BNL's Center for Neutron Science and the SNS. Once a suitable concept exists, a larger collaboration will be formed, including university scientists to fund and build the instrument.

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, in industry, and at other national laboratories, as well as scientists from other departments at Brookhaven. There is a collaborative focus on the DOE initiatives in Complex Materials and in Nanoscience. Experiments are carried out primarily at the Group's NSLS and APS beamlines. It is noteworthy in this regard that the CMC undulator beamline at the APS, led by BNL, is now in the commissioning mode with full operations anticipated soon.

This year researchers observed orbitally ordered domains of tens of nanometers in size in a wide range of manganites, suggesting that these phenomena may be ubiquitous; discovered magnetic roughening at the surface of an antiferromagnet, and carried out the first resonant X-ray scattering studies of a liquid metal surface, showing coexistence of a Gibbs monolayer of Bi with a wetting layer of Ga-Bi in a Ga-Bi alloy.

Future Program: Next year, researchers will extend their studies of thin transition metal oxide films to characterize nanodomains at surfaces and explore nanowetting of liquids at patterned interfaces. An Assistant Physicist has been hired to initiate a new program in soft condensed matter, focusing on

nanofabrication and characterization of self-assembled block co-polymer systems. In the longer term, BNL has initiated and will lead an effort to design and build a dedicated facility for inelastic X-ray scattering at the APS. A 16-institution collaborative access team has been formed and a proposal approved by the APS. Funding is currently being sought from the NSF and the DOE.

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, a focus that is consistent with the DOE initiative in Complex Materials and Nanoscience. 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 also 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. BNL also maintains a small synthesis effort for systematic studies of stoichiometry and compositional fluctuations and will be joined with the oxide growth effort now underway in the Neutron Scattering Group.

This year the researchers continued studies of the technologically important material lead-zirconate-titanate, showing that a narrow region of monoclinic phase discovered earlier this year is enlarged in an electric field; carried out pressure-dependent studies of the structure of the new superconductor MgB_2; and found macroscopic phase separation in electron-doped manganites at low temperature.

Future Program: Researchers will extend their studies of ferroelectrics to thin films, explicitly probing their properties on the nanoscale, and conduct structural studies of germanium zeotypes and other meso-/micro- porous materials, and of H and Li insertion into alloys, which make up batteries. A major, long-term project involves upgrading NSLS beamline X7A to be compatible with *in situ* pulsed laser, chemical vapor, and plasma deposition.

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 and Nanoscience Initiatives.

This year researchers carried out high-resolution photoemission studies (HPES) showing that the coupling to collective modes in high T_c materials and layered dichalcogenides is electronic in origin, and characterized the optical properties of $CaCu_3Ti_4O_{12}$ – perhaps the largest dielectric constant material ever observed. The Pulsed Laser Deposition (PLD) facility was commissioned, and work is underway to grow a range of thin films, including transition metal oxides, ferroelectrics, and dielectrics with embedded nanocomposites.

Future Program: High-resolution photoemission studies of other two-dimensional charge-density-wave systems and high T_c materials will continue. The current project involving HPES studies of doped C_{60} molecules will be extended to carbon nanotubes as part of BNL's program in nanoscience. Thin films of the new superconductor MgB_2 will be grown by PLD and their optical properties examined. In the longer term, the PLD facility will be upgraded to include laser assisted MBC growth together with *in situ* photoemission studies. Experiments will be carried out to explore the possibility of using time-dependent photoemission studies as a means of learning more about quasi-particle self-energies.

5.2.3.5 Condensed Matter Theory

Present Program: BNL's condensed matter theory research group 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 initiatives in Complex Materials, Nanoscience, and Scientific Computing.

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 have accounted for the magnetic excitations observed in coupled haldane spin-chains within a simple random field model, developed a general theory for an electronic smectic fixed point of the stripe phases of doped, layered Mott insulators, demonstrated that anticorrugation in scanning tunneling microscopy images of metals could be induced by electric fields, and characterized the electronic properties of the new MgB_2 superconductors. A significant step toward rebuilding the Theory Group was taken with the hiring of Alexei Tsvelik, a world-renowned theorist.

Future Program: Researchers will use non-perturbative techniques to study spin transport in nanowires and quantum dots, investigate the formation of antiphase domain walls in doped antiferromagnets, explore experimentally determined optical conductivities of "bad metals" using approaches beyond Fermi liquid theory, and carry out first principles studies of the electronic and magnetic properties of complex materials, including bulk and nano-patterned thin films of transition metal oxides. A longer-term goal is to establish an Institute for the Study of Correlated Systems to serve as a worldwide focal point in correlated electron studies. The Institute will host short and long-term visitors, spearhead workshops, and organize coherent attacks on outstanding problems, thereby establishing BNL as a leader in the coming revolution in this area.

5.2.3.6 Program Initiative

Center for Neutron Science: This initiative will develop a comprehensive neutron research program at BNL, which sustains the world-class neutron science capabilities that BNL has had for more than 50 years, and will continue to support the major investment in neutron facilities and research at other DOE facilities. Currently, the research activities of the BNL neutron scientists are conducted at the NIST reactor and ISIS. BNL's Center for Neutron Science will evolve a new neutron program. This initiative involves the following components:

- Develop a test facility beamline at the AGS for research and development in support of spallation neutron instrumentation and components, focused on the SNS. Presently, for example, there are several experiments involving international collaborations using the record proton per pulse intensity from the AGS to study shielding and moderator issues.

- Develop 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, a hybrid spectrometer for the SNS, and a triple axis spectrometer optimized for cold neutrons produced at HFIR.
- Develop 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 correlated-electron systems, new nanocatalytic materials, hydrogen storage and micro- and macro-porous materials, and block copolymers. 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 and catalytic materials.
- Develop a regional education and training program based at BNL. This program will train graduate students and postdocs at BNL by interaction with BNL scientists doing both neutron-science measurements and instrumentation design.

The Laboratory's near term goals are: (1) to develop with DOE BES an agreed-upon plan for Neutron Science at BNL, (2) to continue joint international experiments on neutron shielding effectiveness at the BNL neutron test facility with colleagues at JAERI, (3) to present to the IOC planning committee, in collaboration with the national SNS project, a proposal for two neutron instruments, and (4) to develop closer working relationships with HFIR and NIST. Our long-term goal is to reestablish and maintain a vigorous neutron science and instrumentation program at BNL.

Materials Science Revitalization: A number of actions are underway to foster a closer integration of programs in materials physics, metallurgy, and materials chemistry with those in condensed matter physics and several areas of chemistry. Our goal is to strengthen traditional core programs and compete more effectively with interdisciplinary responses to DOE initiatives. Recently the management of the Materials and Chemical Sciences Division (MCSD) within the Energy Sciences and Technology Department has been transferred to the Basic Energy Sciences Directorate. We are in the process of reviewing the research portfolio within the MCSD in order to effectively plan strategies for revitalizing, and possibly redirecting, traditional core strengths (e.g., the materials science of metal-environment interactions and superconducting materials) as well as initiate new thrust areas (e.g., biomaterials). The Laboratory recently made LDRD and Program Development investments that have significantly strengthened the MCSD capabilities in nanoscale functional materials, including the materials science of magnetic and semiconductor nanocomposites, electron beam micro- and nanoscale characterization and fabrication of nanostructures, and the materials chemistry and physics of nanotube-nanoparticle systems. The latter was facilitated by the recent joint appointment of Stanislaus Wong as Assistant Professor/Assistant Scientist in the Department of Chemistry, Stony Brook University, and the MCSD, respectively. There also is a planned joint effort between the Center for Data Intensive Computing and MCSD that will lead to a strengthened capability in the theory, modeling, and simulation of advanced materials.

The management changes are intended to extend MCSD capabilities and to augment and strengthen the current BES program in the materials science of functional materials. From our program review activities, we are proposing several new areas of emphasis.

- Inorganic Functional Materials: This includes current programs in the areas of superconducting materials (KC-02-01-030) and magnetic materials (KC-02-02-020). The emphasis is on the science of nanoscale structure, its effects on physical properties, and the control of nanoscale structure through the understanding of advanced synthesis and processing methods.
- Nanoscale Structure of Advanced Materials: This features state-of-the-art methods of electron microscopy.
- Molecular Materials: This includes the materials chemistry and chemical physics of photosynthetic and catalytic porphyrins (KC-03-01-010) and an interdisciplinary approach to the fundamental understanding of electroresponsive conducting polymers.
- Electrochemical Properties and Processes in Advanced Materials: This includes an interdisciplinary study of structure and function in electrochemistry and electrocatalysis leading to a basic understanding of the relationships between the multi-scale structure of electrodes and their function in electrochemical reactions (KC-03-02-040) as well as the basic mechanistic understanding of passivity and localized corrosion of metals and alloys.

5.2.4 Energy Sciences (KC)

BNL's Energy Science R&D focuses 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 in 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 related to DOE's Energy Resource Mission area. These are summarized in Section 5.3.

BNL's energy science research 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. 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 spectroscopic techniques (e.g., photoemission, inelastic neutron scattering, XAS, state-resolved laser ionization) with structural tools that probe short and long-range order, 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 magnesium oxide (MgO) powders with highly uniform particle size distributions and precise transition metal doping (zinc, copper, iron).

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.

Near-Term Program: 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. The Ultra-High-Vacuum (UHV) STM instrument is used as a nanoscale probe for surface structure of model metal catalysts and their reactivity is probed by a high-resolution photoemission instrument currently being upgraded at the NSLS U7A beam line. This work will emphasize metal-on-metal and metal-cluster growth. The goal is to control cluster dispersion and density and to understand the parameters controlling the stability of cluster morphology. Reactivity studies of model metal catalysts and nanoparticles will be complimented by a new molecular beam scattering apparatus, which can provide information on the nature of barriers and the role of internal energy in activated gas-surface reactions and can act as a bridge between high-pressure and UHV reactivity studies.

Future Program: In the future, the program will focus on reactivity and structure correlations of nanoscale materials, which hold considerable promise as chemical and photo-catalysts 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 such as near-field optical IR and UV spectromicroscopy.

5.2.4.2 Photo- and Radiation-Induced Chemistry

Present Program: Researchers apply the complementary techniques of excitation by photons or fast electrons to glean basic knowledge relevant to the capture and storage of light energy in useful chemical forms. Researchers investigate electron transfer reactions, motions of charges in condensed media (including glasses and supercritical fluids), dipole-moment changes in charge transfer transitions, formation of excited states of molecules, transition metal complexes, radicals and radical ions, and chemical and physical transformations of excited and highly reactive species. LEAF contributes a new dimension to our capabilities for these studies. Theoretical and experimental efforts of a wide range of donor/acceptor systems are elucidating the factors that control excited-state lifetimes and electron transfer rates, the roles of nuclear-configuration and free-energy changes, electronic configuration, orbital symmetry, donor/acceptor separation, bridging groups, and solvent dynamics. A major focus is mechanistic studies of systems that couple photo-induced electron transfer processes to the bond-forming reactions required in the photogeneration of dihydrogen and the photoreduction of carbon dioxide to carbon monoxide or methanol. Kinetic and mechanistic studies of transition metal hydride complexes are designed to elucidate the factors governing the rates and mechanisms of metal-hydrogen bond cleavage; the knowledge gained helps to guide the development of new homogeneously catalyzed reactions.

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: Long-term storage of solar energy as fuels or valuable chemicals requires efficient coupling of light absorption and chemical transformations. Experiments coupled to theory will investigate chemical systems for solar energy storage. Researchers will study the photo- and radiation-induced charge injection and transport in nanoscale materials. Experiments at LEAF will characterize the nature of ion recombination reactions and probe the unusual species formed when supercritical fluids are ionized. Lifetimes of excited ions, which could function as energy-storage intermediates, will be measured to ~0.1 picosecond for the first time. The nature of "dry-electron" capture will be probed, and a search will be launched for unstable ions of metal hydrides that may be intermediates in reactions catalyzed by these species. The search for methods to photo-reduce energy-poor substances (carbon dioxide to carbon monoxide or methanol) will continue. Catalysis for energy storage by metal complexes and metal macrocycles will be investigated by transient optical absorption, transient Fourier Transform Infrared, and a variety of structural techniques enabled by the NSLS. Electro-absorption spectroscopy will elucidate charge transfer events in metal complexes and dyes adsorbed on nanoparticles.

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 and theory of radical species such as CH_2, C_2H_5, HOCO 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 focused on the $CH_3 + O$ radical-radical reaction for which the carbon monoxide (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 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 reacts with nitrogen to form nitrogen-containing combustion products. A new program on experimental and theoretical studies of the electronic structure of metal-containing cluster compounds cuts across 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 Stony Brook University 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

Plants represent vital sources of food and materials for our society. They have been bred for thousands of years for specific desired traits. However, traditional breeding is a technique that is empirically based and lacks the level of accuracy and sophistication that can be achieved by a systematic understanding of the fundamental processes underlying agronomic traits.

Present Program: The plant program at BNL brings the most advanced biochemical-genetic techniques available to develop a conceptual framework for understanding the factors that contribute to the complexity of plant traits. In the short term, BNL's research focuses on model plant systems. Our long-term goal is to understand specific plant processes in sufficient detail that will enable scientists to rationally and systematically improve crop plants in various ways; for example, by advanced methods of gene transfer that will use the information developed from model systems to modify the genes of crop plants, or in some cases, even apply the identified or modified genes to crop plants. The majority of our research effort is directed at understanding the principles that lead to the accumulation of specific plant products that are of great agricultural importance, plant oils and cotton fiber. The balance of our effort focuses on plant adaptation to environmental changes that are mediated by enzymes that allow for the "tuning" of photosynthetic efficiency with environmental light conditions.

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, to regulate the energy conversion process, modify their basic biochemical processes, and may be modified to produce renewable energy resources.

In the past year, researchers used an integrated approach combining X-ray crystallography, spectroscopy, molecular genetics, and biochemistry to probe structure-function relationships, which set the stage for identifying the enzymes responsible for adjusting the efficiency of photochemical reactions, and elucidating the specific details of how lipid metabolized enzymes work. This is a necessary step in tailoring enzymes to produce renewable oils for industrial applications. Specific advancements include the microarray analysis and validation of cotton fiber-specific genes by quantitative polymerase chain reaction, continued definition and maintenance of the Maize physical genetic map, and development of a novel strategy for directed evolution of enzymes.

Future Program: The anticipated long-term advances that should result from the present lines of research include:

- Provide a context for general improvement of both corn and cotton crops by understanding the genome structure and mapping the quantitative trait loci for agronomic and model traits.
- Develop a common context to redesign lipid modification enzymes to enable the introduction of chiral chemical modifications at will along the acyl chain to produce feedstocks that will serve as alternates to currently used fossil reserves.
- Develop plants that are better able to respond to changes in the quality of light without sustaining damage, a trait that may improve the productivity of crops in existing locations and allow expansion of the range of existing crops to improve productivity per land area.

Within the next five years the genomes of at least two plant species will be sequenced, and sequencing of several other plant genomes will be underway by DOE and others. BNL will seek to

expand and renew its 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: The DOE Office of Biological and Environmental Research and the Office of Basic Energy Sciences support BNL's *environmental science programs*. 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 of 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,
- analysis of the Texas 2000 Air Pollution Study and the Vertical Transport and Mixing Experiment.

BNL also is a partner in the DOE-OBER Atmospheric Radiation Measurement and maintains the ARM External Data Center. In another partnership, BNL will participate in the new DOE-BER Water Cycle Pilot Program to investigate the hydrologic cycle. A specific objective of the pilot is to estimate rainfall in the Walnut River, Oklahoma watershed using measurements from cloud radars.

DOE-OBER 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 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 complete sequencing regions of high biological relevance. A related program is exploring the transformations of heavy metal ions in anaerobic systems undergoing bacterial sulfate reduction. Researchers also are determining the principal mechanisms by which microbes alter radionuclide-organic complexes and the impacts on radionuclide solubility and stability.

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 research in X-ray microtomography to determine the micro-geometry and micro-composition of different types of geological materials. Research includes measurements on core samples from the Ocean Drilling Program, sea floor black smoker chimneys, sandstone, and carbonates at a spatial resolution of 0.0002 mm. 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.

Near Term 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, Philadelphia, and Houston areas 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 future field programs. 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 size-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 down-welling 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 develop practical field instruments to measure carbon in soil using inelastic neutron scattering.

We propose to continue the OBER NABIR efforts. We also will explore the interactions between humates and Uranium-organic complexes at the NABIR Field Research Site. 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.

For the Office of Basic Energy Science, BNL expects to develop a general picture of the 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. Experiments to investigate the composition and structure of black smoker chimneys will be extended to several sea floor locations. Research also will continue on the transformation of organic matter during the progression from early to late diagenesis. Researchers plan to expand work on marine sediments to include the nitrogen speciation in macromolecular organic matter using XANES spectroscopy.

Future Program: 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 three areas. The NSLS accelerator physicists and environmental scientists are exploring new synchrotron applications for the molecular environmental science community. Scientists with modeling and visualization skills will complement the already strong experimental programs in Atmospheric Science and Terrestrial Carbon Cycle research. 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 (KP)

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 for 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 to develop 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 developing tracers to characterize the molecular properties of tumors and to use imaging to investigate different facets of radiation therapy. There are two cyclotrons (41" and 60"), one radio frequency quadupole (RFQ) accelerator, two PET scanners, one Single Photon Emission Computed Tomography (SPECT) scanner, and an animal PET (MicroPET).

The PET program was expanded with the addition of the 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 radiotracers to probe nicotine and marijuana receptors will be extended to human subjects.

The Magnetic Resonance Imaging (MRI) facility is equipped with a 4 Tesla instrument for human and animal studies. The major research goal at the *High-Field MRI Laboratory* at BNL is to develop and refine innovative Nuclear Magnetic Resonance (NMR) techniques to image and measure the physiology, function, and chemistry of tissues *in vivo*. The recent upgrade of the Magnetic Resonance Imaging (MRI) scanner makes it possible to perform these functional and physiological measurements using ultrafast MRI scans. The techniques developed at the *High-Field MRI Laboratory* are continuously transferred to the human arena to improve our understanding of brain function and chemistry in healthy subjects and patients with disorders such as drug abuse, HIV infection, Alzheimer's, and other neuropsychiatric diseases.

Furthermore, the integration of PET and MRI imaging modalities within a single center at BNL provides a unique opportunity for basic research in the development, validation, and application of novel imaging methods and for investigating the synergistic uses of multiple imaging modalities to probe molecular mechanisms involved in normal brain function and disease. The MRI program will be expanded with the recruitment of three new scientists and the proposed acquisition of a 7 Tesla MRI instrument.

Future Program: In the next year we will integrate the Micro-PET with our radiotracer R&D efforts including the validation of its use in quantitative PET studies. DOE-OBER has provided funding for a new cyclotron dedicated to isotope production for the PET program. It will replace the 41" cyclotron, which has become increasingly unreliable and difficult to repair. This will be a modern negative ion cyclotron for isotope production for the Brookhaven PET Program. This machine will have enhanced reliability, simpler operation, and the capability to simultaneously irradiate two targets thereby alleviating some of the time constraint experienced with the present cyclotrons and the need to supply isotopes for three scanners.

We also will pursue acquisition of a new high field animal magnetic resonance imaging instrument for functional and spectroscopic studies in animals, launch an initiative in biomedical engineering, finalize software for routine fusion of PET and MRI data sets, 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 (or those not in production elsewhere) 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 radiopharmaceutical 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 cancer therapy and for the treatment of painful 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. These 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, matrix metalloproteinase (MMP) inhibitors, and STTR-binding peptides.

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

5.2.6.3 Cancer Research

Present Program: Our goals in cancer research are to develop new forms of radiation based treatments for cancer, including Microbeam Radiation Treatment (MRT) using the National Synchrotron Light Source.

In conventional radiation therapy, damage to normal tissues surrounding the tumor is thought to arise largely from injury to the endothelial cells of the microvasculature, leading to disruption of blood perfusion and eventually tissue death. Recent results from the Microbeam Radiation Treatment (MRT) research conducted at the NSLS suggest that MRT spares normal tissue up to very large doses. MRT uses

arrays of parallel, microscopically thin (<100μm) planar slices of synchrotron X-rays, and is administered in a single exposure. The tolerance of normal tissues to microbeams versus the tolerance to conventional broad beams, both administered in a single fraction, is 6-fold higher for the rat skin tissue, 4-fold higher for adult rat brain, and 3-fold higher for the brain tissue of duck embryos. A second remarkable effect of microbeams is that they ablate brain tumors by single-direction irradiation at doses that are tolerated well by the surrounding tissues. MRT administered in the cross-fired geometry also showed strong tumoricidal effects.

In parallel, we are developing radiotracers for PET imaging that may be useful for the early detection of cancer. Included among these is [^{11}C]boro-phenylalanine, which is the amino acid analog, formerly used with Boron Neutron Capture Treatment (BNCT). This ligand can be used to provide information on the delivery of *p*-boronophenylalanine or BPA into the tumor. This is important for appropriate treatment planning for BNCT.

Future Program: We propose to extend the microbeam research to:

- understand the radiobiological bases for MRT effects in normal and cancerous tissues;
- optimize the MRT beam width and spacing in the array, as well as the array administration geometry (i.e., unidirectional versus different cross-fired configurations) to determine the best therapeutic index in certain tumor models;
- irradiate animals inside a plastic head phantom to simulate the effects of tissue depth in clinical MRT, and
- study the potential of microbeams in tumor re-treatment.

Our long-term goal is to extend these studies to large animals to examine effects such as the damage to the proximal normal tissue in irradiation of deeply seated tumors, cardiosynchronous tissue pulsation, and long-term central nervous system effects in large animals with the purpose of evaluating the potential of MRT in clinical radiation therapy. If these studies and others indicate a clear clinical application, limited Phase I human studies could be conducted at the NSLS X17 beamline. Recent advancements in the design and fabrication of small, dedicated synchrotron storage rings of high beam energy and intensity indicate that such a facility could be developed for MRT in a clinical setting.

5.2.6.4 Medical and Imaging Science Program Initiatives

For BNL's long-term program, we are proposing several 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: A new initiative, "Imaging Gene Expression" received support from DOE in FY 2001. Our goal is to measure *in vivo* binding of labeled oglionucleotide to mRNA. This will allow gene expression imaging using PET. If successful, this work will be highly complementary and supportive of the major DOE initiative of bringing the "Genomes to Life." We plan 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 Initiative: We will build on our current strengths in radiotracer development and nuclear imaging, radiation therapy, and the applications of the NSLS 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 Stony Brook University. We also will continue to investigate the use of radioisotopes, such as (Sn-117 nDTPA) and other isotopes produced at 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 will recruit 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 also will further the Neuro-Informatic Initiative at NIH since it will require the development of new analytical tools for data analyses.

Biomedical Engineering Initiative: In a related effort, we are launching a major initiative in biomedical engineering. We submitted a pre-proposal in response to the DOE Biomedical Engineering Request For Proposal and were selected to submit a full proposal on "Imaging the Awake Animal Brain." This is a very important topic since imaging studies currently can only be performed during anesthesia to minimize motion artifacts. However, it is extremely difficult to assess brain function, chemistry, and physiology in animals that are in an artificial coma. The main goal of this initiative is to develop novel technologies, particularly for PET and MRI, that can image the awake animal (rat or mouse) brain in real-time and in natural physiological conditions. This includes developing motion tracking and restraint devices, as well as research into reducing acoustic noise in MRI. Most of the techniques will have applications beyond animal imaging, such as motion compensation and correction in human PET and MRI studies. We have compiled a strong multidisciplinary research team involving investigators from five BNL department/divisions, from Lawrence Berkeley National Laboratory, and from the Stony Brook University Medical Center.

Imaging Instrumentation Development for PET: We initiated a program to 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). We are evaluating prototypes for these devices, and results are very encouraging. We have obtained DOE bioengineering funds and entered into a Cooperative Research and Development Agreement (CRADA) to partially fund this initiative. However, a major cost and limiting factor will be to obtain funds for scintillation crystal detector modules and associated electronics needed to scale up the prototype devices.

Imaging Instrumentation Development in MRI: We are working with the scientists from BNL's Magnet Division to evaluate the possibility of designing an MRI that will allow motion during scanning. This would be particularly desirable when performing MRI studies in animals for which the use of anesthesia would directly affect the processes one is attempting to investigate.

Space Biomedical Engineering Initiative: The recent characterization of neural stem cells has stimulated considerable hope that these cells might be potentially useful for repair of the human central nervous system in degenerative neurological diseases, recovery after trauma, and as delivery vehicles for gene therapy. The goal of this initiative is to investigate the possible utility of microgravity conditions for the proliferation and expansion of such cells by analyzing their multi-potentiality, differentiation capacity, and functional activity *in vitro* and *in vivo*. In collaboration with the NASA Johnson Space Center and the Biotechnology Center at Stony Brook University, we will establish a laboratory to develop *in vitro* systems using bioreactors and animal models to study the biology of neural stem cells and neurons.

Diffraction Enhanced Imaging Initiative: Despite recent advancements in mammography, MRI, and Computed Tomography (CT), there are still challenges. The rate of false negatives in mammography is still about 10%; cartilage is difficult to visualize by radiological means, and the contrast of chest X-ray is too low to detect early stages of emphysema and edema. Diffraction Enhanced Imaging (DEI) is a new radiography method that extracts, in addition to traditional absorption contrast, X-ray phase-contrast information. Chapman, Thomlinson, et al. developed the method in the mid 1990s at the NSLS in a collaboration that included scientists from the University of North Carolina, and was applied mainly to mammography studies. Such studies are currently ongoing at the NSLS X15A beamline. We have submitted a proposal to the National Institutes of Health to extend the current DEI studies. The proposed program includes pre-clinical imaging studies in breast, lung, and cartilage using a wide range of beam energies, 18-60 keV, from both the X15A bending magnet beamline and the X17B1 superconducting wiggler beamline. The larger beam energy improves beam transmission through large body sections and reduces absorbed radiation dose to the subject. The proposed research also includes finer angular acceptances, compared to those used in current studies to enhance the sensitivity of DEI, and finer spatial resolution to improve image quality. The studies will be carried out in both the planar radiography and the CT mode.

Low Dose Radiobiology Initiative: Mammalian cells exposed to very low doses of low Linear Energy Transfer (LET) radiation not only suffer damage, mainly to their DNA, but also exhibit altered signals over prolonged periods of time. Although it is known that altered signaling relates to adaptive responses, includes conventional protection against endogenous DNA damage, and disappears with increasing dose, its mechanisms are not well understood. These phenomena are at the center of interest today and are the underlying effects that determine the risk from environmental and occupational radiation. Study of these effects will allow us to re-examine the scientific validity of the linear-no-threshold hypothesis.

We plan to study the low-dose effects using a special monochromatic X-ray microbeam from the X15A beamline of the NSLS to target separately the cell nucleus or the cell cytoplasm *in vitro*. A proposal will be submitted to the DOE OBER. The work is a collaboration among BNL, Columbia University, and New Jersey Medical School.

Radiotracer Applications to Environmental Studies: BNL and Stony Brook University, Department of Ecology and Evolution, are engaged in a collaboration to use short-lived radiotracers to probe the mechanisms of 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 (KP)

In FY01, BNL's Biology Department formed the Center for Complex and Membrane Protein Structures. Membrane proteins are critical elements of biological processes 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 important targets in cell signaling, human function, and bioremediation. They function in the brain as receptors for neurotransmitters and in microbes as transporters, yet they account for less than 1% of the known protein structures. 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. The Biology Department has strengths in protein expression and protein engineering. The staff has been enhanced by the addition of a Membrane Protein Crystallographer, a critical component for this center. Two soil molecular microbiologists who have expertise in membrane protein systems relevant to bioremediation have been recruited to focus on the DOE Environmental Quality Mission.

The Center, as well as the Department's other research programs, requires state-of-the-art analytical tools. A key component is a new Cryogenic Electron Microscope (CryoEM) facility for the analysis of two-dimensional arrays of membrane proteins, isolated complex particles, and frozen tissue sections. DOE provided funds for the purchase of a CryoEM, and BNL is in the process of acquiring the equipment. Additional capital equipment was purchased, including a Mass Spectrometer and Stopped-Flow Flourometer. The Mass Spectrometer will enhance our crystallographic capabilities, allowing us to precisely measure the mass of proteins. The Stopped-Flow Fluorometer can simultaneously measure absorption, circular dichroism, and fluorescence. It will be modified for the simultaneous measurement of linear dichroism and fluorescence polarization anisotropy.

In addition to creating the Center for Complex and Membrane Protein Structures, the Department has made significant advances in other areas that are an essential aspect of the DOE strategic goals in exploring matter and energy, including structural biology, molecular biology, genomics and bioremediation.

The Biology Department continues to operate the Scanning Transmission Electron Microscopy Facility. This group has been overseeing the Cryo-Electron Microscope Facility effort since it will be an integral part of the STEM facility. The Department also operates a Macromolecular Crystallography Facility that includes five beamlines at the NSLS. The beamlines continue to be over-subscribed and fully utilized, and "FedEx" operations have been expanded. This is the process wherein outside users mail specimens to BNL for data collection by our staff. Beamline X26C is now equipped with a triple beam diffractometer. Recently, visiting scientists utilized this diffractometer to advance their investigation of the protein-solvent interface on insulin. This Macromolecular Crystallography Facility operation is described in more detail in section 6.1, Work for Others.

User facilities also are available for radiation biology research, including cell cultures and small animal facilities. These include the shielding cave containing the beam and the biological experimental station and laboratory facilities. A 10 ft. long optical bench for sample exposures is available in the cave, as well as beam handling, sample changing, and dosimetry instrumentation. The biological experimental

station contains one area for cell culturing equipped with a laminar flow hood and incubator, a short-term animal holding facility, and an area for physics/run-control. Laboratory space and animal facilities accredited by the AAALAC are available.

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. 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 genomes, gene expression, and proteomes of model organisms,
- understanding enzymes and enzyme systems that carry out fundamental processes required for life,
- utilizing 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.

BNL researchers have 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 (LET) 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. For example, 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 those that 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 proven 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 ongoing. 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 gain an understanding of protein structures. 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.

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 a 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.

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 Stony Brook University for research and training in bioinformatics and computational biology are planned as part of the Center for Data Intensive Computing. 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 Educational Programs (KX)

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

- to enrich the training of future scientists and engineers, and to build the capacity of undergraduate institutions in support of DOE's scientific mission,
- to provide educational and career pathways in mathematics, science, and engineering for a diverse population of students in undergraduate and pre-college institutions,
- to increase science literacy in schools and support the enhancement of teacher preparation in pre-college mathematics, science, and technology (MST) teaching,
- to provide resources and activities that support the Laboratory's efforts in Community Involvement

and Public Outreach, and contribute to the Laboratory's role as an educational resource and valuable asset to the local and national community.

The *Undergraduate Internships* program develops 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 125 undergraduates.

Topical Conferences, Workshops or Summer Schools offer educational enrichment in areas where the Laboratory has unique capabilities. These include a Nuclear Chemistry Summer School, Undergraduate 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 2000, 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 pre-college 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.

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 the 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 (EE/FE/NE) - 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 most important energy challenges in the world. On-going projects include non-proliferative nuclear reactor designs, energy/economic modeling, energy infrastructure reliability, and energy production, 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, the DOE Basic Energy Science Program described previously sponsors much of the underlying basic research supporting the DOE's Energy Resource mission.

The DOE, in its April 1998 Comprehensive National Energy Strategy (CNES), outlined the Department’s goals and objectives for the nation’s energy future. The DOE R&D portfolio analysis for Energy Resources identified 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 has several local, national, and international energy R&D partnerships that support continued US leadership in the energy field. This work supports DOE and NRC, EPA, New York State, and private industry programs.

5.3.1 Energy Efficiency and Renewable Energy (EE)

Present Program: BNL continues research on corrosion resistant materials and cements for reducing costs associated with the use of geothermal energy. During this past year researchers focused on 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. This work will continue into next fiscal year.

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.

BNL also develops more efficient and nonpolluting heating systems as well as improvements to the distribution and use of energy in buildings. Researchers are developing advanced low NO_x oil burner technologies for use in homes and commercial buildings. Flame quality indicators developed at BNL are

licensed and are becoming available commercially. BNL is involved with large-scale field tests of this technology, which was named by DOE as one of the Energy 100 technologies.

Researchers also are 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. A large-scale field test of this work is now in progress. Many of these programs are done in cooperation with the New York State Energy Research and Development Agency.

Scientists are 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. Work continues on novel methods to make new fuel cell electrocatalysts that substantially reduce the platinum requirements for fuel cells. These programs make use of the National Synchrotron Light Source for materials characterization.

BNL also will continue research on the material properties of high temperature superconductors. This research, which focuses on their manufacture and application, makes extensive use of our Transmission Electron Microscope (TEM) facility.

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. Some of our 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. Some of this research is co-sponsored by EPA Region 2.

Future Program: BNL will place more emphasis on combined cooling, heating, and power technologies, which offer substantial efficiency gains. During the next year, we will be participating in a field test of a gas-fired micro-turbine power generator, fuel cells, and an oil-fired microturbine.

Recently, the BNL oil research program was transferred to the DOE Office of Power Systems, Building Cooling, Heating, and Power (BCHP) program, where there is strong interest in renewed emphasis on oil R&D for building, cooling, heating and power applications. This DOE Office challenged BNL and the industry to prepare a comprehensive five-year plan that would provide clear benefits to homeowners through the development of advanced oil combustion technologies. BNL coordinated the development of the 5-year oil research plan, which proposes the commercialization of low NO_x heating burners and very high efficiency heating systems. The program also will promote use of better quality petroleum fuels as well as domestic biofuels.

MARKAL-MACRO has been selected by the Energy Information Agency as the modeling tool for the next world energy outlook report. BNL is working with EIA to develop a world model for their use. We also are developing hemispheric models for use by DOE and EPA.

5.3.2 Energy Efficiency and Renewable Energy Initiatives

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 focus initially on the reliability of power transmission cables.

Wind Power: Interest in wind energy is rapidly growing as the need for alternative energy resources becomes more urgent. This interest includes the installation of both land and offshore wind turbines. Implementation of large-scale wind turbines requires solution of unique problems with regard to system dynamics and foundations. BNL is proposing to develop an engineering capability in the wind area by combining knowledge from previous BNL research in computational mechanics and materials engineering. The objectives of this program are to establish a methodology for evaluating the dynamic response of large wind turbine systems and to evaluate alternative foundation materials. The key element in the proposed research is that turbine-tower-foundation systems will be treated computationally as a whole, rather than as separate components. The computational methodology developed under this project to conduct dynamic analysis of the integrated system will represent a significant technical advancement in this field and may lead to a commercially attractive software package. Alternative foundation materials that will be investigated include high fly ash content concrete and fiber reinforced concrete. Use of such materials is a new approach with great potential for improving the economics of wind energy.

Distributed Power: Distributed power 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 working on standards for local interconnected micro-grids and developing reliability management tools.

5.3.2 Fossil Energy (FE)

Present Program: The Laboratory has several programs that develop next generation options for the production, transmission, storage, and use of fossil fuels. Several of these projects could lead to significant reductions in greenhouse gas emissions. Key projects include fuel cells, thermophotovoltaic power generation, and distributed energy systems. 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.

In FY 2001, 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 the 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 are pursuing research in areas such as the kinetics of transformation and the application of BNL tracer technologies to the safety and stability of methane hydrate production.

Thermophotovoltaics (TPV) technology is used to generate 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.

Future Program: The Department of Energy's goal is to ensure reliable, clean, and diverse domestic fuels supplies. We will continue our program on deep sulfur removal for liquid fuels. This will include continuing research on biochemical upgrading of oils and other petroleum products. Several

bacteria strains have been selected for testing for desulfurization, denitrification, and hydrocarbon redistribution.

We will expand our work on developing techniques for the conversion of liquid fuels on a micro-scale for multiple purposes. Microcombustion will be a major research area in which we will expand our small-scale burner technology. We will initiate research on advanced gasifier technology for use in distributed power sources.

5.3.2.1 Fossil Energy Initiatives

The DOE has two new initiatives: 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 ultra-clean liquid fuels for use in diesel applications. Over the last decade, BNL built an international reputation in the area of Liquid Phase Low Temperature (LPLT) methane conversions. Our initiative focus is 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 ongoing work in bioprocesses for upgrading crude oil.

5.3.3 Nuclear Energy (NE)

Present Program: BNL core competencies are fully aligned with the DOE Office of Nuclear Energy, Science and Technology (NE), four major research initiatives: the Advanced Accelerator Applications (AAA) program, the Nuclear Energy Research Initiative (NERI), the Generation-IV Advanced Reactors, and the Nuclear Energy Plant Optimization (NEPO).

The AAA program represents a merging of the Accelerator Production of Tritium (APT) and Accelerator Transmutation of Waste (ATW) programs and includes a proposal for an Accelerator Driven Test Facility (ADTF). The ADTF is a steady state, accelerator-driven spallation neutron source, with provisions for a sub-critical multiplier blanket, and a broad range of irradiation capabilities. The ADTF will be capable of addressing the testing and demonstration requirements for advanced nuclear systems such as accelerator-driven transmutation systems, Generation IV Advanced Reactors, isotope production, and other advanced applications of nuclear science and technology. The AAA program is managed jointly by DOE/DP and DOE/NE, led by Los Alamos and Argonne with participation by Brookhaven, Livermore and Sandia, several major universities, and appropriate industrial groups. BNL was involved in the APT program since the late 1980's and was a member of the Steering Committee, which developed the ATW R&D Roadmap in FY 1999. BNL continues to support spallation target development and sub-critical multiplier design and analyses.

Under the first NERI competition (FY 1999), BNL received funds for two projects on non-proliferative reactor designs. In FY 2000, BNL received funds for an additional project, which examines the application of the thorium cycle to existing reactors to enhance proliferation resistance and waste characteristics.

DOE/NE has recently initiated a Generation IV Nuclear Energy System Roadmap study; BNL is participating as a member of the Technical Working Group considering water-cooled reactor options.

DOE and the Electric Power Research Institute, to pursue technologies that foster life-extension and optimize electrical generation from existing power plants, are developing NEPO jointly. 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.

Future Program: BNL will expand its work on proliferation resistant reactors. This research will be an international collaboration with Russian research institutions and US industry. We will continue to support the accelerator applications research of DOE, and we will work with the Center for Data Intensive Computing to expand its capabilities in computational fluid dynamics for all energy resource applications.

5.4 National Security Mission (NN)

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

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.

A BNL 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 to determine the radiation signatures of US nuclear weapons and components. For domestic safeguards, DOE has accepted the methodology developed by BNL for confirmation of the presence of highly enriched uranium in warheads returned from DOD. In addition, staff members participate in the Integrated Technology Development Plan, which coordinates DOE and DOD activities in the design, testing, and authentication of instruments for international arms control treaty monitoring.

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:

- γ-ray spectrometry at room temperature with resolution adequate 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 and long-range detection of nuclear devices improvised by terrorists.

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

Present Program: This program incorporates environmentally oriented components into nuclear, chemical, and biological safeguards, nonproliferation, and weapons 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) funded by DOE, DOD, and EPA, and the Murmansk Initiative, funded by EPA, BNL is helping the Russian Ministries of Defense and Atomic Energy install technologies and processes to more safely manage nuclear wastes produced during the dismantlement of Russian nuclear-powered ballistic missile launching submarines. Of special interest is the installation of an automated radiation measurement system at a Russian naval shipyard. Under the DOE Nuclear Cities Program, BNL is helping develop energy and environmental projects in the Russian Closed Cities of Snezhinsk, Sarov, and Zheleznogorsk. Under joint sponsorship of NN-24 and NN-45, BNL is leading an effort to explore the feasibility of using a Russian designed spent nuclear fuel cask to transport materials from Russia, Former Soviet Union States, and Taiwanese reactors. BNL also provides technical support to the US Delegation to the IAEA Contact Expert Group (CEG). The objective of the CEG is to focus international efforts on Russian radioactive waste management problems. In this context, BNL helped draft a report to the US Congress, in response to Public Law 106-255: Cross-Border Cooperation and Environmental Safety in Northern Europe Act of 2000, on the threat presented by RF maritime reactors.

Future Program: We hope to expand the Nuclear Cities concept to include regions of Russia where the Russian Northern and Pacific nuclear naval fleets operate. The objective of this national security program is to reduce the proliferation threat presented by underemployed or unemployed Russian naval shipyard personnel. BNL hopes to assist DOE and NNSA develop and implement a program that responds to the threats presented by Russian maritime reactors and spent nuclear fuel. Lastly, BNL hopes to implement an "Urban Antiterrorism Technical Support Center." The goal of this Center is to help safeguard US facilities, particularly in the Northeast, from the threats presented by conventional, nuclear, chemical, and biological weapons attacks.

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

Present Program: Brookhaven has been involved in non-proliferation programs at Russian facilities since 1994. Congress recognized the importance of these programs and continues to authorize funding for the Department of Energy at approximately $150M annually. BNL has played a lead or supporting role in the following areas of the MPC&A Program:

- Introduction of technologies for very precise measurements of bulk nuclear materials, both liquid and solid forms, during storage and processing operations.
- Development and implementation of comprehensive physical inventory statistical sampling plans, measurement requirements and performance procedures.

- Use of measurement control techniques.
- Support to Minatom and Gosatomnadzor for the development of regulatory documents pertaining to nuclear materials protection, control, and accounting in Russian facilities.

The first of these activities has provided unprecedented access to the largest of the Russian production facilities, the Siberian Chemical Combine, Mayak Production Association, and the Mining and Chemical Combine.

BNL's activities involve direct interaction and collaboration with Russian technical specialists. BNL maintains a key technical role in several projects at Russian facilities. A significant recent achievement, conducted with BNL oversight, was the successful completion of a material balance for the production of BOR-60 fast reactor fuel assemblies at the Research Institute for Atomic Reactors (RIAR) in Dimitrovgrad, Russia. BNL is a principal proponent of extending this effort to accounting for special nuclear materials at all Russian facilities, including material to be processed under the recently signed plutonium disposition agreement.

BNL plays a major role in the Nuclear Materials Conversion and Consolidation (MCC) project, an important component of the MPC&A program. Currently there are MCC activities at the Luch and Dimitrovgrad facilities. Critical goals for the MCC project are to reduce the number of sites and buildings that contain special 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. BNL staff have identified, researched, and evaluated potential Russian MPC&A equipment vendors who might help Russia sustain the MPC&A upgrades over the long term. The goal is to identify, prioritize, and support potential vendor-to-vendor initiatives that will sustain a capability in Russia to service, maintain, operate, and upgrade MPC&A related equipment and instrumentation. In a related activity, a catalog of material control and accounting equipment was published and is maintained jointly by BNL and a leading Russian institute (The All-Russian Research Institute of Automatics). The catalog is widely used for selecting measurement and material control equipment and also gives measurement capabilities and methodologies.

A BNL scientist is leader of the Technical Survey Team (TST). The TST is 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. The TST will play an expanding role in influencing the future direction of the multi-year MPC&A Program activities in Russia. In a new activity, BNL is developing an analytical model that will use information in the database to estimate the reduction, in terms of relative risk, associated with implementation of MPC&A upgrades.

Future Program: BNL will continue to support all of the aspects of the MPC&A Program described above. In addition, BNL will assume the leadership of the MPC&A Awareness Project. This project will address the need to ensure that MPC&A is fully integrated into the institutional mission of the Russian sites, government ministries, and public awareness. BNL also expects to assist the Russians in conducting initial comprehensive physical inventories and material balances on some of their very large uranium and plutonium processing operations. These activities bring together all the MPC&A upgrades introduced at the facilities and provide a good quantitative assessment of the improvements in accounting for nuclear materials. Once these activities are completed, the program emphasis will be directed toward gaining assurances that the Russians continue to implement, and can sustain, the upgrades.

5.4.4 Nonproliferation and National Security Department Initiative: Urban Anti-Terrorism Support Center

There has been an increased concern over potential acts of terrorism directed against US facilities and personnel. The attack on the New York City World Trade Center is a recent example of a state-backed terrorist group acting on US soil. Various official and other sources have warned against the possibility of terrorist attacks involving nuclear, chemical, biological, and radiological weapons or agents. The DOE and several other government agencies established programs to protect against acts of terrorism and threats to the national infrastructure.

BNL's initiative will establish an urban anti-terrorism support center in the northeast region of the US to further the understanding and response capabilities of natural (air, water, soil, etc.), engineered (building HVAC, subways, etc.), and human (skin, lung, etc.) systems to nuclear, chemical, biological, and radiological weapons or agents.

BNL is the logical site for this work for several reasons because BNL has significant scientific and technical expertise and capabilities in key areas such as:

- Nuclear, Biological and Chemical Source Detection, Characterization and Measurement,
- Agent Transport,
- Pre- and Post-Event Control,
- Mitigation Systems, and
- Physical Security, Vulnerability Assessment.

In addition, BNL's location in the New York Metropolitan area places it in close proximity to potential targets. Also, there are nearby federal facilities that can augment BNL capabilities in certain areas such as the DOE Environmental Measurements Laboratory, the USDA Plum Island Animal Research Center, and the Cold Spring Harbor Laboratory.

In FY 2002, we expect to be able to achieve the following:

- Focus BNL's technical programs on gaps in the nuclear/biological/chemical area.
- Develop an integrated research portfolio.
- Establish relationships with potential partners.
- Support intra-lab efforts, and
- Market BNL capability and skills to likely funding sources such as DOE and DOD.

We estimate that approximately $600K will be required in FY 2002 to establish the Center, including the recruitment of a project leader.

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, decontaminate and decommission the Brookhaven Graphite Research Reactor, and Waste Management Operations. The DOE Office of Environmental Management supports the remediation programs. BNL is using an innovative tracer technology and 3D-visualization techniques to accelerate the characterization of structures that are part of the Brookhaven Graphite Research Reactor Decommissioning Project. The Office of Science Nuclear Physics program provides support for Waste Management Operations.

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 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 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. 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 the 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 than 986 scientists from 5 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 began in 2000.

Large Hadron Collider (LHC): Brookhaven plays an important role for the 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 also will provide operations management and oversight for all US scientists participating in the ATLAS experiment and will operate the BNL-located Tier-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 also is 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 six 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. BNL has now provided new apparatus, the Preshower Detector, to upgrade D0. The upgrade was completed, and data acquisition began, 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.

Solar Neutrino Collaboration: BNL has been part of the SNO Collaboration since 1996, operating the Sudbury Neutrino Observatory in Canada. SNO is the premier solar neutrino detector currently funded by DOE. Participating institutions represent Canada, the US, and the UK. BNL also is a charter member of the recently formed LENS Collaboration, which is doing R&D on a new Low Energy Neutrino Spectrometer. Participants represent institutions from the US, France, Germany, Italy, Japan, and Russia.

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.

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 other agency participants from the National Oceanographic and Atmospheric Agency and National Space and Aeronautics Agency. National coordination and integration is essential for developing a unified climate change research program.

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 (IPP). The goal of this program is to engage scientists and engineers with experience in developing weapons of mass destruction (WMD) in the Newly Independent States (NIS) of the Former Soviet Union to develop technologies appropriate for commercialization and to create long-term employment. The program seeks to develop partnerships between NIS scientists, BNL, and US businesses in non-weapons

related research and commercial activities. BNL has initiated over fifty individual projects that reflect the overall research portfolio of the Laboratory. The projects span a wide range of topics such as high-energy physics, reactors, waste management, smart video, software development, and biotechnology. BNL will expand the existing program by developing additional Cooperative Research and Development Agreements with US industry, make use of our interactions with LISTNET to engage local software development companies in this program, and extend efforts to recruit businesses from New York State and the northeast to participate in IPP. We also will take part in the Nuclear Cities Initiative that seeks to create jobs by providing commercial opportunities for the former weapons scientists in the ten closed cities of the Russian Federation.

5.7 Laboratory Directed Research and Development (LDRD)

The purpose of the LDRD program is to encourage and support the development of new ideas that could lead to new programs, projects, and directions. The LDRD Program focuses on early exploration and exploitation of creative and innovative concepts, which enhance the ability of the Laboratory to carry out its current and future mission objectives in line with the goals of the Department of Energy. This discretionary research and development tool is an important way of maintaining the scientific excellence of the Laboratory. It stimulates the scientific-technological community by fostering new ideas, maintaining staff excellence, and focusing on advancing the national agenda within the overall mission of the DOE. Projects that are appropriate candidates for the LDRD Program are normally small, ranging from $50,000 to $200,000 per year, with a preference for smaller projects. They are generally funded for periods of two years with a possible continuation for a third year. Typically they include but are not limited to:

- New or unexplored directions in the forefront areas of basic and applied science and technology for the primary purpose of enriching laboratory capabilities.
- Advanced exploration of new hypotheses, new concepts, or innovative approaches to scientific or technical problems.
- Experiments and analyses directed toward "proof of principle" or early determination of the utility of new scientific ideas.
- Conceptual and preliminary technical analysis of experimental facilities or devices.

The responsibility for the LDRD program resides with a Scientific Program Director who reports to the Deputy Director for Science and Technology. The Scientific Program Director coordinates and provides oversight and administration of the program. A Committee consisting of the Deputy Director, the LDRD Scientific Program Director, all Associate Laboratory Directors, and two senior scientists chosen from the Brookhaven Council review all proposals, obtain additional information deemed necessary, and select the projects to be funded as well as determine the amount of each award.

The LDRD program is a crucial and indispensable ingredient in promoting the vital mission of BNL as a multidisciplinary laboratory dedicated to the advancement of physics, chemistry, the life sciences, energy and environmental sciences as well as key technological areas. LDRD fosters the advancement and full utilization of user facilities. Aside from leading to new or promising programs at the Laboratory and producing especially noteworthy research, the LDRD Program has resulted in numerous publications in various professional and scientific journals, presentations at meetings and forums, and patent applications and patents. The program contributes to the education of the nation's

future scientists as it supports a number of post-doctoral students. Accordingly, BNL is increasing its relatively modest expenditures for the LDRD Program from its present level of less than 2 percent of its budget to about 4 percent, still significantly less than the DOE mandated cap of 6 percent.

Table 5 - Proposed LDRD Funding Levels (In Millions)

Fiscal Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Budget	5.5	6.0	7.0*	8.0*	9.0*	10.0*

* Projected

6.0 Work For Others and Technology Transfer

6.1 Federal Sponsors

Several of our biomedical programs and facilities operate through partnerships with, and funding from, other federal agencies. 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 benefit 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 the 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, Stony Brook University, and the BNL Biology Department.

These stations will be joined by the proposed X-6 PRT, which recently became available for re-development. It is situated in the first X-ray ring quadrant that has biological support laboratories provided as part of 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 provided a grant of $2.6 M to build and equip this station and funded the operation starting in FY 2001.

Along with several other centers, BNL has been piloting procedures for the cost-effective large-scale determination of protein structures by X-ray crystallography. In partnership with Rockefeller University, the Albert Einstein College of Medicine, Cornell Medical School, and Mt. Sinai School of Medicine, BNL recently received an NIH grant to support further development of structural genomics technologies and to establish a pilot structure-production center.

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 Stony Brook University Medical Center for genomic, biochemical, and protein structural analysis of the Lyme disease bacterium and emerging pathogens of regional interest.

Brookhaven National Laboratory

The construction and operation of the Booster Applications Facility (BAF) for NASA represents DOE's ongoing partnership with NASA to provide extraordinary facilities and capabilities for research on issues related to the NASA mission. This is consistent with BNL's goal to provide innovative science, 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 Booster Applications Facility (BAF) will be a new experimental facility and accelerator that takes advantage of heavy-ion beams from the Brookhaven Alternating Gradient Synchrotron Booster for studies on radiation effects related to the space program. BAF will provide protons and heavy ions (Fe, Si, C, Ni, Ar, Au, etc) for space radiobiology studies and radiation effects on microelectronics. BAF is slated to be fully operational in 2003. The facility will have laboratories to meet the specific needs of NASA's Space Radiation Health Program (SRHP) and National Space Biomedical Research Institute (NSBRI) research programs. BAF will include laboratories for *in vitro* and *in vivo* experiments, as well as for physics experiments. The experimental facility will be housed in a well-shielded irradiation area and in a support building containing ready-rooms, laboratories, and offices. Other existing on-site facilities, such as extensive tissue culture laboratories and animal handling installations, also will be used. Dosimetry and local access control will be provided through a local facility control room. BAF will offer investigators a unique workplace in which they can pursue space radiation research.

The NASA and the DOE major goals are the following:

- Use BNL's unique accelerator facilities, such as the Alternating Gradient Synchrotron (AGS) and the Booster, to simulate aspects of the space radiation environment.
- Support investigations of the response of living systems to radiation exposure in space.
- Promote developments in science and technology that meets 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 to complete Title 1 civil construction and initiate Title 2, engineer the beam equipment, and expedite the Tandem upgrade. Construction will continue through FY 2002.

The Space Biomedical Research program is a collaborative effort of BNL's Medical, Collider-Accelerator Department, Biology Department, and the Instrumentation Division with Stony Brook University. The program focuses on understanding the biological consequences of long-term space flight.

The National Space Biomedical Research Institute (NSBRI) is a consortium of 12 institutions working to prevent or solve health problems related to long-duration space travel and prolonged exposure to microgravity. BNL is one of the twelve NSBRI consortium institutions since 1999. Our current NSBRI projects focus on the risk assessment and chemoprevention of HZE-induced Central Nervous System damage, development of a heavy-ion microbeam and micron resolution detector for radiation studies, heavy-ion induced cluster DNA damage, and the development of educational programs on space radiation effects.

Since 1995, the National Aeronautic and Space Administration (NASA) also has supported research at BNL's Alternating Gradient Synchrotron (AGS) on the radiobiological effects of high-energy heavy ions. The AGS is the only accelerator in the US capable of providing heavy ion beams at energies of interest for space radiobiology. These experiments address the particular problem of high-energy heavy ion radiation exposure during future long-term deep space flights. The principal objective of this

research is to improve our understanding of the biological effects of low fluences of charged particles on living cells and tissues. These experiments continue in collaboration with investigators from universities, national laboratories, and other research institutes from the US and international research community.

We plan to expand our space neuroscience projects beyond the study of the effects of space radiation. Areas of critical interest include the use of state-of-the-art neuroimaging techniques to understand the neurochemical and functional alterations induced by long-term space flight. Of particular interest are sleep disorders and psychosocial problems.

Since BNL has a state-of-art space radiobiology facility on-site, we propose development of a Space Radiobiology Center at the Laboratory in partnership with NASA, NSBRI, and other national and international partners (ISA, NASDA, etc). The center will provide a mechanistic and functional framework for risk analysis and countermeasure development in support of the NASA manned space program. This will enhance our current programs and align with NASA's strategic plan.

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 in the areas of 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) manages the US Support Program which assists the International Atomic Energy Agency (IAEA) in developing safeguards verification approaches, new measurement and surveillance systems, and integrated safeguards approaches which integrate traditional safeguards with new 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 Stony Brook University 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.

Following several years of decline, the work supported by the Nuclear Regulatory Commission at BNL has stabilized. We expect funding to continue at the same or higher level in future years as new

reactor concepts such as the pebble bed modular reactor, and new fuel concepts such as high burn-up mixed-oxide fuel, are open to regulatory review. In addition, the introduction of risk informed regulation and the submission of license renewal applications will continue to require support from BNL.

6.2 Technology Transfer

A goal of the Science and Technology Program is 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 Intellectual Property and Industrial Partnerships 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 granted. At the close of FY 01, there were 165 technologies in BSA's Patent Licensing Portfolio; 49% of these technologies are licensed to industry, and 9.6% of the licensed technologies have 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, 23% in FY 99, 29% in FY 00 and 27% in FY 01 (Licensing Information is provided in Appendix C).

Brookhaven National Laboratory

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 provide 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.

The instrumentation capabilities at BNL are used in two active CRADAs, funded by LTR, with Long Island companies. 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. BNL researchers established new methods of *in-situ* X-ray absorption and X-ray diffraction spectroscopy for studying 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 also 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. Researchers in the Biology Department conduct 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 to expand 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.

6.2.1 Sponsored Research

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, materials sciences, 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 Pennsylvania State University by investigating the relationship among conditions leading to high ozone concentrations and increased levels of particulates in the urban polluted environment. The Laboratory participates in a program sponsored by Science Engineering Associates 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 participated 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. 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. The staff uses 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 universities and foundation sponsors. 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. The Laboratory's research in Magnetic Resonance Imaging (MRI) includes several studies funded by the National Multiple Sclerosis Society.

7.0 Management and Operations Systems

Brookhaven National Laboratory's strategic planning processes align BNL's management and operating systems to support the DOE national missions and strategic plans. Several of those systems are central to BNL's ability to meet these challenges. These are described in this section.

BNL implemented an integrated set of non-overlapping management systems that embody the requirements defined by DOE for Integrated Safety Management (ISM). These systems collectively form the Standards Based Management System (SBMS) – BNL's highest level operating and business processes defining how work is conducted at the Laboratory. Management System Descriptions identify the processes, standards of performance, external requirements, and the set of Lab-wide procedures and guidelines that fulfill the requirements of each system. Tailoring work controls to the hazards presented ensures that work processes incorporate appropriate environment, safety and health, and quality considerations into each element of BNL's work.

The Laboratory also enhanced the 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 workplace risks. Field ES&H subject matter experts assist line managers in meeting these responsibilities.

Brookhaven National Laboratory is committed to implementing Performance Based Management to achieve our and DOE's mutual goals in a changing science and technology environment with increased competition for funds, by institutionalizing modern, effective management practices and business systems. We are making a concerted and focused effort to plan our future and manage our assets. We will accomplish our goals by continuous alignment of our missions with the DOE missions and national goals and by setting an expectation of "excellence in performance" for every employee.

7.1 Human Resources and Diversity

Our Human Resource goal is to develop, implement, and continually improve personnel programs, processes, and policies that enable the Laboratory to attract, hire, develop, compensate, retain, and reward a highly qualified and diverse workforce. Within that mission we focus on the following areas:

- Establishing and maintaining a work environment of opportunity and empowerment.
- Pursuing increased employee and leadership effectiveness.
- Capitalizing on and improving the diversity of Laboratory staff.

A range of programs will enhance the Laboratory's attractiveness as an employer. We will provide enhanced opportunities for employees through internal placements, career planning, and training for a wider range of staff in an extensive range of relevant areas. Training will be targeted to current and anticipated Laboratory needs. Career development will be expanded, and the scientific career advisory program will be strengthened.

We will continue to review and improve the effectiveness of Human Resource processes, programs, and systems needed to define work, organize staff, and improve work results. This includes making the tools more accessible and usable by employees, primarily through web-based tools such as the new Human Resources System. Employee performance appraisal will be emphasized and refined to gain greater acceptance with Laboratory managers; succession planning and 360º feedback programs will be used more widely to develop more effective managers.

We continue to evaluate our Affirmative Action Programs for their effectiveness, relevance in the marketplace, and their ability to address BNL's staffing needs. Our diversity program goals focus on increased representation of women and minorities in the managerial and professional ranks. BNL continues to promote the hiring of women and underrepresented minorities as post-doctoral Research Associates and Scientific Staff. Working together with Human Resources, the Diversity Office will strengthen recruitment and outreach to Historically Black and Hispanic Colleges and Institutions. Brookhaven values its diverse employee population and the richness of their cultural and ethnic backgrounds, and our Diversity Office partners with employees to provide programs and celebrations that recognize these heritages.

7.2 Information Technology Management

The Information Technology program supports the scientific research and business processes of the Laboratory by directing IT resources to realize the Laboratory's mission and goals. The Information Technology Leadership Council serves as an executive body for major IT issues and developed an IT Strategic Plan driven by the goals and objectives of the scientific programs and support operations.

The major strategic objectives for Information Technology are the following:

- Support Advanced Computation Research and provide an effective scientific computing infrastructure.
- Enhance network capabilities to meet the growing needs of the research program.
- Provide effective computer and network security.
- Implement a communications infrastructure and standardization program.
- Improve the usability and applications integration of PeopleSoft and related business tools.
- Implement a comprehensive Knowledge Management program.
- Sustain a program of IT training and professional development both for IT staff and the user community.
- Implement an Information Technology benchmarking and metrics program.

BNL is revitalizing scientific computing support. One of the goals is to sustain and enrich the major computational centers of the Laboratory, the Center for Data Intensive Computing, the RHIC Computing Facility, and the BNL RIKEN QCDSP and QCDOC facilities. At the same time, we are broadening the client base of the general-purpose Brookhaven Computing Facility, by better understanding the scientific objectives of the user community and providing more relevant and attractive systems and services. This will include enhancements of the Linux Cluster, Silicon Graphics Onyx, and Sun Solaris platforms, and introduction of modern software products such as Java, XML, and the Globus grid suite. In the well-established Visualization program, the emphasis is on providing hyper-resolution facilities, and extending high quality visualization capabilities to the researchers' desktop. These improvements will be in evidence in FY 2002 and will continue incrementally thereafter.

Local and wide-area network capabilities are perhaps the most strategic asset. Effective and secure networking is vital to the highly collaborative research environment of the Laboratory's major programs and infuses every area of the Laboratory's business. By 2002, wide area network bandwidth must increase from 200 to 600 Mb/sec, and within five years, be extended to 2500 Mb/sec to meet the estimated needs of the BNL research program, led by the requirements of RHIC and ATLAS. The Local area backbones must increase commensurately, extending a high quality gigabit network to most areas of the site, and providing three to five times that bandwidth over the projection period.

A Communications Infrastructure and Standardization Program ensures maximum interoperability among applications meant to exchange information or work together and optimizes efficiency in operations and maintenance. Expanded use of software licenses encourages use of common software tools and reduces software costs. An Enterprise Management System will be fully operational in FY 2002.

The Cyber Security initiative is particularly important to the Laboratory. BNL is implementing the BNL Unclassified Cyber Security Program Plan (CSPP) with the assistance of the Laboratory's Computer Security Advisory Council. By FY 2002, there will be a complete Perimeter Defense Network, and host-based security and authentication services. However, the dynamic nature of cyber security demands constant re-assessment of BNL's security posture, including related tools and techniques, as the threats become more pervasive and sophisticated.

Our Business Information Management 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. Recently, the Laboratory implemented several major new administrative information systems, starting with integrated financial management programs followed by human resource management programs, all purchased from PeopleSoft, Inc. Currently, all existing applications, except Labor Cost Distribution and Travel have been moved from the legacy systems to a new Windows NT operating environment. During 2001, a new web-enabled version of PeopleSoft will be implemented. The web client of PeopleSoft will allow the rollout of many improvements, including new self-service functions within PeopleSoft. With this capability, administrative support areas will be able to provide better support without increasing resources. After 2001, we intend to replace the remaining legacy systems. This will move BNL to a totally integrated environment for financial and human resource support systems.

BNL is building a Laboratory-wide Knowledge Management System with commercial Web Content Management and Records Management Systems. The Web Content Management System enables the indexing and archiving of information captured on our institutional web site and facilitates the application of consistent standards to the Laboratory's public web pages. The Records Management System will provide web-based search and retrieval of Laboratory records and enhanced functionality for the management of records. In the future, BNL will add a site-wide Enterprise Document Management System, which when integrated with the Web Content and Records Management Systems, will provide cradle-to-grave information management as well as search capability across designated repositories. This will let users locate, re-use, and leverage the information resources in support of BNL's research and business management objectives.

A Benchmarking and Metrics program was established to monitor efficiency, quality, and customer satisfaction. Key IT service categories and associated metrics were defined in FY 01, the baseline year. IT Metrics are being collected, reported, and published. A formal review process enables a cycle of continuous improvement of the Benchmarking and Metrics Program. The emphasis for FY 02 is to refine the existing metrics.

Information Technology support is spread across the Laboratory's departments and divisions. General IT support is the responsibility of the Information Technology Division, the Business Systems Division, and the Information Services Division. Because of the dispersed nature of this function, IT infrastructure will benefit significantly from the consolidation and improvement opportunities envisioned in the BNL Site Master Plan and Strategic Building Plan.

7.3 Communications Management

BNL has been successful in promoting the value of our science programs to the general public. Physics research projects such as RHIC and g-2 were featured prominently in the national and international media. A wide variety of other fields and disciplines at BNL, such as medical research in addiction, genomics, protein imaging, and air quality also have received increased attention in all media. At the same time, the Laboratory continues an ongoing dialogue with the community and a broad spectrum of stakeholders regarding legacy environmental issues and our commitment to protect the environment and minimize waste generation.

Our three- to five-year goal is to increase confidence and trust in our cleanup efforts and to generate community enthusiasm for our research programs and new initiatives. To achieve these goals 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, internationally renowned and contributing to the educational and economic benefit of Long Island,
- seek input from stakeholders on issues of importance to them,
- involve stakeholders and the general public through 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.

BNL will vigorously pursue efforts to strengthen the foundation of trust and confidence it has built with the community. We will continue to enhance those community programs that have been useful and informative to the public and effective and beneficial to the Laboratory. For example, the museum education and tour programs have brought more than 75,000 students and visitors to the Laboratory in the past three years. We will sustain this level of students and visitors and strive to enhance their positive experience.

The Laboratory also will continue to support programs that reach out to the community, including the Ambassador Program, Envoy Program, Exhibits, Speakers' Bureau, and the Stakeholder Relations Program, emphasizing the following messages.

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

The Community Advisory Council (CAC) advises the Director on issues of importance to the community at large, and to the organizations represented on the CAC. The Laboratory supports an

ongoing dialogue with the CAC on programs of interest, supplying 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.

We will prominently feature developments in the exciting search for quark matter at the Relativistic Heavy Ion Collider (RHIC), addiction research, the Spallation Neutron Source collaboration, the ATLAS detector, and other advances in biotechnology, chemistry, and physics.

The World Wide Web is a critical vehicle for communicating the mission and achievements of the Laboratory to all stakeholders, internal and external, local and international. Information on the Laboratory's web site will be timely, accurate, interesting, and useful. Stakeholders will see www.bnl.gov as a primary source of reliable information about the Laboratory.

7.4 Environment, Safety, Health and Quality Management (ESH&Q)

Activities related to the protection of the environment, safety and health of workers and others, and the quality with which all work is done, are integrated into work from the planning stages to completion. ESH&Q 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. 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.

BNL has successfully implemented Integrated Safety Management (ISM), achieved ISO 14001 registration, reduced injury/illness statistics, and improved radiological controls, chemical safety, pollution prevention, line ownership, and staff awareness of ESH&Q responsibilities. While the Laboratory has an improved reputation, continued success is imperative. New Laboratory initiatives such as RHIC II, e-RHIC and PERL will require continuous involvement of ESH&Q disciplines to maintain work planning and control processes consistent with our commitment to safe workplaces and environmental stewardship.

Our goal is to achieve and sustain operational excellence, i.e., operations that are safe, environmentally responsible, and cost-effective. As part of our strategy, we will make every effort to reduce indirect costs by eliminating redundancy and non-value added work. New approaches to achieving efficient support that we will consider include:

- shared resources between support units,
- purchased services from the Laboratory support organizations (e.g., Waste Management, QA, Project Management, Information Technology, Facility & Operations), and
- purchased services from outside the Laboratory.

Our objective is to reprogram savings into investments in our core capabilities and to support business development, while maintaining charge-out rates in the competitive range.

7.4.1 Environmental Management

BNL continues to reduce, eliminate, and prevent environmental impacts from its operations and to restore the environmental quality of the site. The key elements of our approach include protection, pollution prevention, and environmental cleanup.

BNL minimizes environmental impacts through the implementation of our ISO 14001 designed Environmental Management System (EMS) for all facilities and operations. The Laboratory stresses

continuous improvement to lessen or eliminate the environmental impact over time, and BNL will continue to seek reductions in its operational discharges and potential impacts to the environment.

A second key component of the environmental management system is our multi-media environmental monitoring program. This program is an integrated activity to ensure coordination among program customers and to strengthen the capabilities and comprehensiveness of the Laboratory's environmental monitoring program.

Our waste minimization and pollution prevention programs are strategically important for avoiding waste creation and the production of excess materials that might become waste. The approach is to plan for waste avoidance at the earliest stages of planning an experiment, to continually look for opportunities to drive down the cost of managing wastes and to minimize waste-related risks to the environment.

Concurrent with the pollution prevention activities, our waste management program goals are to minimize waste generation, to use recycling and reduction options in lieu of treatment and disposal, and to manage wastes off-site to prevent stockpiling. With the transition of the Waste Management function from the DOE Office of Environmental Management to the DOE Office of Science (SC), Laboratory organizations that generate waste are given an "allotment" from the waste management budget from SC. Management costs of waste generated in excess of that "allotment" are funded by the organization generating the waste. This further motivates effective pollution prevention and waste minimization. BNL is actively managing an inventory of excess materials for final disposition including former experimental apparatus, shielding materials, chemicals, and recyclable metals. This inventory is systematically characterized, packaged, and submitted for dispositioning or disposal.

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

BNL is committed to accelerating completion of its environmental restoration mission. The Laboratory's restoration program is fully engaged in several substantial cleanup projects involving contaminated soils, groundwater, the river environment within and adjacent to the BNL property, and facility decommissioning. We intend to accelerate our efforts through the use of sound project management practices, value engineering, and innovative contracting strategies.

In FY 01 BNL continued to make significant progress in Environmental Management. Several notable accomplishments include the following:

- Achieved Lab-wide ISO 14001 registration in August 2000.
- Completed annual environmental reviews and updates of 130 industrial processes and 1870 experiments, identifying all wastes, emissions and effluents, regulatory requirements, and pollution prevention opportunities.
- Executed meaningful pollution prevention projects. In FY 01, BNL funded projects are expected to provide an annual savings of $155,500 with a payback period of less than one year. BNL received two DOE Pollution Prevention Awards; one was for excellence in environmental management and the second for the Process Evaluation Project.
- Processed and disposed of a majority of wastes at the former Hazardous Waste Management Facility.
- Expanded groundwater monitoring and integrated environmental restoration and environmental surveillance monitoring, while systematically streamlining the groundwater monitoring to reduce costs.

- Completed several important environmental restoration activities including,
- Final Records of Decision for the cleanup of groundwater and soil contamination at BNL and for Operable Unit VI.
- Excavation and disposal of radiologically contaminated landscaping soil.
- Draft Proposed Remedial Action Plan and Record of Decision for Operable Unit V, Peconic River Clean--up, and finalized the Record of Decision for the Sewage Treatment Plant.
- Construction and commissioning of seven treatment systems for removing contamination in groundwater and treated more than a billion gallons of groundwater to date.
- Installation of an additional groundwater treatment system for tritium plume source control at the High Flux Beam Reactor.
- The baseline planning for the BGRR Decommissioning Project and three key removal actions leading to the decommissioning and partial dismantlement of the former Graphite Research Reactor complex.

In FY 02 and beyond the Laboratory will focus on the following:

- Improving the Environmental Management System.
- Completing development of the Environmental Information Management System to provide Internet access to monitoring data to all stakeholders.
- Improving operational and engineered controls to improve the groundwater protection program, emphasizing prevention of any further insults to groundwater quality.
- Ensuring that wastes from current Laboratory activities are managed properly to ensure regulatory compliance and cost efficiency.
- Identifying excess material inventories, characterizing and developing plans for disposal/treatment options to reduce inventories.
- Focusing on reducing the total project costs for the Environmental Restoration Program and achieving or accelerating milestones for remediation.
- Planning for and implementing long-term stewardship of remedial actions.

7.4.2 Safety and Health

BNL will continue to improve our radiation exposure-monitoring database, chemical exposure database, process reviews, experimental safety reviews, Risk Trac, Workers Compensation database, Injury/Illness database, and LWCRRP.

The completion of ISM verification set the stage for the maturing of many ESH initiatives. Continuous emphasis on the ISM core functions and guiding principles will help the Laboratory prioritize its efforts to capture work planning and controls as the fundamental building block of BNL's ESH&Q program. We continue to improve the clarity with which we define each worker's roles and responsibilities (R2A2) and the overall depth and effectiveness of our self-assessments. We will increase the field presence of safety and health professionals by supplementing the existing field staff with backup from other members of the Safety Evaluation Group. The addition of a certified industrial hygienist whose primary duties includes field support, work planning and control assistance has resulted in positive feedback from customers.

BNL achieved significant reduction in accident statistics and exceeded the contract Off-Ramp expectations. Continued scrutiny and improvements will assure continuation of this downward trend.

7.4.3 Quality Management

The Laboratory's Quality Management Program meets the requirements of DOE O 414.1A and 10CFR830.120. Quality requirements are incorporated directly into Management Systems and subject areas. This approach assures incorporation of quality activities in the everyday operations of the Laboratory and reinforces the understanding that quality is each employee's responsibility.

The Quality Management Program maturity varies. Through the Quality Integration Project, the Laboratory implemented supporting subject areas to bring the Laboratory into full conformance with DOE Order 414.1A and 10CFR830.120. The maturity level of quality-related institutional processes will be assessed in 2001 using a Malcolm Baldrige-based methodology. This process is consistent with the Laboratory's approach to Integrated Safety Management. Based on the assessment results, management system stewards will develop and execute a risk-based Improvement Plan.

7.5 Safeguards and Security Management

Safeguards and Security supports the basic scientific mission of DOE and the Laboratory by:

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

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

Safeguards and Security staff establish guidelines, plans, and strategies to protect sensitive or classified information, export information, Cooperative Research and Development Agreements, protocol visits, and Work for Others.

The Counterintelligence (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 CI 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 efforts to maintain an up-to-date list of sensitive technologies.

The Safeguards and Security Enhancements Plan is a long-range plan to ensure security is continuously improved in an efficient and cost-effective manner. Subject-matter experts annually review the Plan to ensure that the necessary protective measures are systematically planned to identify and prioritize vulnerabilities.

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Construction of the Visitor Reception Center is a much-needed long-range security enhancement project. BNL currently has no facilities for visitors, vendors, or contractors to obtain necessary information regarding programs, regulations, restrictions, or training requirements prior to entering the site. This facility would provide contractor indoctrination and safety training; employee orientation training including; security education, a training film library, the housing office, badging and vehicle registration services, a public relations information area, a public reading room, Human Resources information, and parking and vehicle inspection areas. All of these functions would take place before entering the BNL site. This will result in better access control; informed and better trained employees, guests, and contractors, and enhanced community relations.

8.0 Strategic Facilities Plan

Brookhaven National Laboratory is a world leader in accelerator-based science and technology. Much of the research is interdisciplinary. In the future, BNL will continue exploratory, long-lead research in support of DOE's missions, exploiting the capabilities of the user facilities, and playing a leadership role in advancing the development of high quality accelerators of matter and light. The goals and objectives of BNL's Strategic Facilities Plan are derived from the Laboratory's strategic science planning, fully support the Laboratory's institutional mission and vision, and are fully consistent with the DOE's Strategic Vision for the 21st Century Laboratories. The primary infrastructure goals are:

- Establish quality workplaces for users and employees, and create a coherent user experience.
- Consolidate essential Laboratory capabilities, and encourage interdisciplinary interactions.
- Incorporate information technology as an integral component of the infrastructure.
- Establish openness and a strong community orientation.
- Support safe, environmentally sound, and cost-effective operations.

8.1 Current Situation

The infrastructure of the Laboratory must be a platform for the science and technology mission. While the current physical plant has facilitated BNL's mission for many years, inadequacies in the condition, capability, and location of facilities now hamper the efficient and cost-effective execution of that mission, affect the ability to attract and retain top scientists, limit BNL's ability to perform certain aspects of it's mission, causing higher than necessary operating costs, and restrain the efficiency of staff and users.

Many buildings date back to World War II, some older. Most of the permanent buildings, excluding those constructed for RHIC, were constructed in the 1960s. 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. Some departments are dispersed over many buildings on site and the demand for user space is increasing. Most operations support organizations are housed in WWII era buildings. Funding has not been sufficient to construct new space and demolish older areas. The trend is to renovate older, less efficient areas to provide space that meets the demands.

In general, the utility systems are sound, but there is a need to improve the reliability of the electrical distribution system, replace aged components of the potable water and steam distribution systems, expand the Chilled Water Facility, and expand and improve the reliability of the networking system.

Deferred maintenance has increased over the years and the estimated backlog for buildings has increased to $76M. Non-programmatic maintenance expenditures for buildings range from 0.5% (base maintenance budget) to about 1.1% of the non-programmatic Replacement Plant Value (RPV), depending on maintenance charged-back to programs and other operating accounts. Industry recommended levels range from 1% to 1 1/2%. Without an aggressive capital renewal campaign, funding for maintenance and repair projects will need to increase significantly to prevent many infrastructure deficiencies from becoming environmental, safety or health issues, and/or causing further damage to the infrastructure assets. These expenditures will steadily consume a larger share of the science dollars.

The current backlog of General Plant Projects (GPP) is $63M. Over the past years, BNL has averaged an outlay of ~$10M/year in combined GPP and Multiprogram Energy Laboratory Facility Support (MEL/FS). With a GPP budget that has averaged slightly over $5.5M annually, it has been extremely difficult to tackle larger building projects since a single project would have consumed up to 90% of a fiscal year GPP budget. This backlog is expected to increase faster as existing facilities continue to age.

Line item construction for new program-support facilities and general-site facilities has not kept apace with the program needs or the needs of the site. For example, if the DOE-MEL/FS program levels (~$5.5M/year) remain the same, BNL will have a $116M backlog by the year 2005. The bulk of capital funds needed to meet the infrastructure objectives of the Laboratory would need to be provided through line item construction projects and third party financing. There are several categories of projects:

- New buildings that are DOE funded,
- New buildings that have potential for 3rd party financing,
- Major renovations of permanent science buildings, and
- Utility improvements.

These projects total over $566M with approximately $90M in programmatic needs, $85M in third party financed construction (e.g., short- and long-term housing), and the balance, $391M in MEL/FS funding needs.

8.2 Planning Assumptions

There are many factors that influenced the Strategic Facility Plan. Among these are the following:

- The Department of Energy increasingly competes for program funds. Laboratory operating funds are not likely to grow more than inflation.
- Past budget constraints have created extended deferrals of capital renewal/replacement projects and annual maintenance.
- The lack of available space necessitates the continued use of wood-frame buildings that are over 50 years old and forces the dispersal of departments over several buildings, resulting in decreased operational efficiency.
- User space is inadequate, and user needs will continue to increase.
- The Laboratory's information infrastructure needs significant upgrades.
- Roofing systems are failing or have failed and need replacement.
- Peak electrical demands will increase with full operation of RHIC.

In developing the Strategic Facility Plan (SFP), these and other factors, including assumptions about the future of the science programs at BNL, the general and administrative services that need to provide more efficient support, the nature of the site and utilities, and the quality of life for both users and staff served as the planning base.

If we are to establish quality workspaces for our employees and users, we must replace over 1,000,000 square feet of the 50-61 year old wood and masonry buildings, space originally constructed to support the WW II war effort. In addition, we must provide modern laboratory and office space that has the flexibility to adapt to changing program needs and is supportive of multi-discipline teams. Modern

office and other workspaces also must be provided for non-scientific organizations to ensure efficient operations that effectively support the scientific mission.

To create a coherent user experience, we must make changes that facilitate navigation around the site, group support services together to make user access and interactions with these services easier, and provide modern, efficient workspaces and attractive, comfortable, as well as affordable living accommodations.

If we are to keep our business practices efficient and provide reliable scientific facilities to obtain, process, and analyze data, we must embrace the latest changes in information technology. This includes ensuring that the latest advances in high-speed networking and cyber-security are deployed and seamlessly integrated into our scientific and business practices.

Finally, to establish a feeling of openness with our surrounding community, we must be cognizant of their concerns and provide facilities that encourage them to visit the Laboratory, to learn about our science and technology as well as the history and heritage of the site. We also must provide support facilities that ensure their entire experience on site is a positive one.

Implementation of the Strategic Facilities Plan will transform BNL's infrastructure into an exciting, world-class platform able to support the full range of 21st century science and technology. With many of the projects offering an attractive return on investment, operating costs will be lowered and maintenance needs matched to capabilities. Environmental, safety and health, and operational excellence will be assured. Most importantly, the new and renovated facilities will create an aesthetically impressive, intellectually stimulating environment that will leverage the DOE investment in major user facilities to produce unprecedented levels of outstanding scientific output for the balance of the 21ST century and beyond.

8.3 Plan for Modernization

The Strategic Facility Plan and companion Site Master Plan provide a roadmap for creating a flexible site framework for growth and renewal. The fundamental elements of the plan include the following.

- Replace obsolete, inefficient wood-frame buildings, and renovate permanent facilities.
- Construct new facilities that are "Green Buildings," designed to be environmentally friendly and energy efficient, meet current health and safety requirements, and meet ADA requirements.
- Reorganize the BNL campus into functional and efficient zones for research activity, support services, and residential functions.
- Stimulate intercommunication and a sense of community among BNL scientists by concentrating daily activities into a central area easily accessible by pedestrian traffic.

This roadmap would lead to consolidation of the current diffused facilities by concentrating function and constructing in the already developed central areas. The plan establishes a flexible framework for renewal of the site over 10-20 years and well into the foreseeable future. The site would consist of a "Main Street" with adequate parking located adjacent to primary buildings, redirection of traffic and pedestrian flow patterns, and a reorganization of housing that provides long-term housing remote from the central campus, medium-term housing adjacent to central functions, and short-term transient housing with immediate access to research activities.

The plan proposes improvements that increase the productivity of our users while at BNL, thus increasing the scientific output from DOE's investment in our major user facilities. New facilities would consolidate RHIC users and BNL scientific staff participating in RHIC science into modern space, including offices, conference rooms, and administrative support and seminar space. Existing permanent lab/office space would be renovated and made available for NSLS users. The user support areas at the NSLS would be expanded. The network infrastructure serving users' workspaces would be improved.

Science in the future will be more interdisciplinary, and existing buildings will need to be reconfigured and supplemented with new flexible laboratory buildings that can accommodate multidisciplinary teams. The plan proposes renovating facilities whose projected lifetime is well beyond 20 years, but whose systems (mechanical, electrical, etc.) have reached the end of their service life. The renovations would include modifications to increase the flexibility and adaptability of the space to meet future mission needs. New general-purpose laboratory/office facilities would be constructed to allow the reorganization or consolidation of staff into more efficient workgroups and to promote the interaction of interdisciplinary teams. New science and administrative facilities would be located for ease of access to the core of the site, and the site layout would be modified to provide a central campus with walkways.

The plan proposes facilities that would streamline user orientation and training, group support organizations and "community services" (bank, post office, etc.) into "one stop shopping," and provide support for the educational and recreational needs of users and their families. Adequate conference and videoconference facilities would be available for scientific meetings and discussions, and the library facilities would accommodate the state-of-the-art needs of the staff and users. All facility upgrades and new facilities would incorporate appropriate information technology infrastructure; facilities would be available to receive, orient, and document visitors to the site and to support community outreach and cultural resource programs. Demolishing older structures and renovating permanent buildings would eliminate ESH deficiencies. Consolidation of support services would improve efficiency, reduce operating costs, and improve customer services.

Twenty-three project initiatives would fully implement the renewed site vision. The resource chart provided in the Strategic Facility Plan represents one means of implementing the Plan over the next 10 years. Short descriptions are provided in Appendix D.8. The resource needs are summarized below.

Real Property Maintenance: Funding levels for maintenance have increased under BSA management. A new category of funds for "recurring maintenance" allows the Laboratory to accomplish critical maintenance tasks that are beyond the capability of the in-house shops. Similarly, under BSA, "non-capital" projects funds or "Operating Funded Projects" (some of which are maintenance related) increased to $2.7M in FY 00 and are assigned by the Laboratory Director at the beginning of the fiscal year. This allows far more effective planning, prioritization, and use of these funds.

If the projects proposed in the Strategic Facility Plan are implemented, the current maintenance backlog will be reduced significantly over time and eventually eliminated. The replacement of WW II wood frame buildings with new, modern structures will eliminate the maintenance backlog associated with these structures, as well as the capital renewal projects that are needed over the next 10 years to sustain them in operation. Similarly, the comprehensive renovation program we have proposed for the permanent lab/office facilities will address the maintenance backlog in these facilities.

The upgraded physical plant would result in reduced operating costs. Even at the same rate of G&A, there would be sufficient revenue to sustain the infrastructure on an ongoing basis.

The projects proposed for third party funding also would be removed from the maintenance effort and would be self-sustaining. As a result, we would project a flat maintenance budget over the ten-year

planning period. The efficacy of this level will be reviewed annually over the planning period as new projects are implemented and RPV is adjusted. The goal is to ensure that any investments in new facilities are appropriately protected.

General Plant Projects (GPP): GPP projects presented in the Strategic Facility Plan were broken down into two parts: baseline GPP and large projects referred to as "super GPP." To achieve BNL's infrastructure goals and objectives, a significant increase in GPP is required. This increase would be in the form of a modest rise in the GPP baseline over inflation, coupled with incremental funds to support the "super GPP" projects that have been identified and programmed over the planning period. Adding these components and averaging them out over the planning period, the GPP would have to double, increasing to approximately $12M/year in FY 02 dollars. A listing with brief descriptions of "super GPP" projects can be found in Appendix D.8.

Line-Item Construction: The bulk of the capital funds needed to meet the infrastructure objectives of the Laboratory would be funded through line item construction projects (programmatic and MEL/FS) and third party financing

Many of the proposed projects will replace WW II wood structures and would generate an attractive return on investment (ROI) that results from increased staff productivity, reduced energy and maintenance costs, and the inherent efficiencies of consolidation (shared office equipment, administrative support, reduced vehicle needs, etc.). The projects will also result in a smaller overall physical plant, since new space is expected to be less total square feet than that demolished, further reducing site-related maintenance and operating costs. Ultimately, the driver for this investment is the positive impact it will have on the science and technology programs of the Laboratory. Brief descriptions of proposed line-item construction projects for this planning period are provided in Appendix D.8.

Based on the Laboratory's strategic plan for science and technology, the permanent lab/office buildings (e.g. Chemistry, Biology, Medical, and Physics) are suitably configured and equipped to support science at Brookhaven well into the 21st century, if rehabilitated and modernized. A series of projects are proposed to rehabilitate BNL's permanent lab/office buildings. These structures are sound and have at least another 50 years of useful life, but interior finishes and mechanical and electrical systems require replacement.

A series of utility-related projects are proposed to address the continuing needs of the utility infrastructure and ensure that utility systems are appropriately reconfigured to support the projects proposed in this plan.

Third-Party Funded Projects: BNL has identified housing projects as the most likely candidates for third party funding. The Laboratory has both short-term (dormitory & Guest House) and long-term (apartment and cottage) housing accommodations for users and guests. The housing stock is approximately 85% WW II wood frame construction (with the remainder mostly 35 years old) and is substandard, despite cosmetic improvements over the years. Additional housing is also needed, since BNL has been unable to fully accommodate the summer housing needs of the user community.

Housing is rented to users and guests at market rates (verified by GSA), and the rental revenue should provide an attractive cash flow to a developer. The concept is similar to third party Military Family Housing (MFH) construction that has been successful in the Department of Defense. While enabling legislation for DOE is not yet in place, we are confident that the regulatory obstacles can be overcome.

9.0 Resource Projections

The following tables show the resource projections for BNL for FY 02-06. FY 02 numbers are based on the FY 02 Presidential Requests. All data are as of October 31, 2001. Changes will be reflected in the next Institutional Planning Cycle.

TABLE 6 - Laboratory Funding Summary ($ In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003**	2004**	2005**	2006**
DOE EFFORT	294.4	327.2	290.3	367.9	367.9	367.9	367.9
WORK FOR OTHER THAN DOE	42.6	41.0	42.1	45.9	45.9	45.9	45.9
TOTAL OPERATING	337.0	368.2	332.4	413.8	413.8	413.8	413.8
CAPITAL EQUIPMENT	32.5	32.3	24.8	41.1	41.1	41.1	41.1
PROGRAM CONSTRUCTION(a)	35.3	46.0	51.9	99.7	119.1	59.9	63.5
GENERAL PURPOSE EQUIPMENT(GPE)	4.0	3.5	4.4	7.1	7.1	7.1	7.1
GENERAL PLANT PROJECTS(GPP)	5.4	6.1	6.1	14.7	14.7	14.7	14.7
TOTAL LABORATORY FUNDING	**414.2**	**456.1**	**419.6**	**576.4**	**595.8**	**536.6**	**540.2**
(a) Includes Spallation Neutron Source Construction							
* Escalation Factors: FY2002 And FY2003 At 3.8% And 3.8% Respectively							

TABLE 7 - Laboratory Personnel Summary (Personnel In FTE)							
	FISCAL YEAR						
	2000	2001	2002	2003	2004	2005	2006
DIRECT							
DOE EFFORT	1219	1203	1185	1356	1356	1356	1356
WORK FOR OTHER THAN DOE	264	295	296	289	289	289	289
TOTAL DIRECT	1483	1498	1481	1645	1645	1645	1645
INDIRECT							
TOTAL ORGANIZATIONAL BURDEN	196	187	162	159	159	159	159
LABORATORY DIRECTED R&D	33	49	43	36	36	36	36
TOTAL MATERIAL BURDEN	89	72	70	70	70	70	70
DISTRIBUTED/ALLOCATED SERVICES	378	362	76	552	552	552	552
TOTAL INDIRECT	799	712	594	610	610	610	610
TOTAL LABORATORY PERSONNEL	**2978**	**2880**	**2919**	**3072**	**3072**	**3072**	**3072**

TABLE 8 - Funding By Assistant Secretarial Office ($ In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003**	2004**	2005**	2006**
DEPARTMENT OF ENERGY PROGRAMS							
DIRECTOR, OFFICE OF SCIENCE							
OPERATING	229.7	239.4	211.0	300.8	300.8	300.8	300.8
INVENTORIES	0.0	-3.6	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	32.5	32.2	24.8	41.0	41.0	41.0	41.0
GENERAL PURPOSE EQUIPMENT	4.0	3.5	4.4	7.1	7.1	7.1	7.1
GENERAL PLANT PROJECTS	5.4	6.1	6.1	14.7	14.7	14.7	14.7
CONSTRUCTION	9.5	10.1	11.0	47.7	92.7	59.9	63.5
TOTAL	**281.1**	**287.7**	**257.3**	**411.3**	**456.3**	**423.5**	**427.1**
A/S CONSERVATION & RENEWABLE ENERGY							
OPERATING	3.9	6.2	4.1	6.2	6.2	6.2	6.2
CAPITAL EQUIPMENT	0.0	0.1	0.0	0.0	0.0	0.0	0.0
TOTAL	**3.9**	**7.0**	**4.1**	**6.2**	**6.2**	**6.2**	**6.2**
A/S ENVIRONMENT, SAFETY & HEALTH							
TOTAL	**0.4**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**
A/S NONPROLIFERATION AND NATIONAL SECURITY							
TOTAL	**24.9**	**32.0**	**30.3**	**19.4**	**19.4**	**19.4**	**19.4**
A/S DEFENSE PROGRAMS							
TOTAL	**0.4**	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
A/S ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT							
OPERATING	30.9	38.9	27.3	24.0	24.0	24.0	24.0
CAPITAL EQUIPMENT	0.1	0.1	0.0	0.0	0.0	0.0	0.0
CONSTRUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	**31.0**	**39.0**	**27.3**	**24.0**	**24.0**	**24.0**	**24.0**
A/S FOSSIL ENERGY							
TOTAL	**0.5**	**0.2**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**
OFFICE OF NUCLEAR ENERGY							
OPERATING	2.5	3.0	3.1	2.8	2.8	2.8	2.8
CONSTRUCTION	0.0	0.0	0.0	9.4	26.4	0.0	0.0
TOTAL	**2.5**	**3.0**	**3.1**	**12.2**	**29.2**	**2.8**	**2.8**
OFFICE OF POLICY, PLANNING, AND ANALYSIS							
TOTAL	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
OFFICE, SECURITY & EMERGENCY MGMT.							
TOTAL	**0.6**	**9.6**	**11.6**	**12.8**	**12.8**	**12.8**	**12.8**
ENERGY INFORMATION ADMINISTRATION							

TABLE 8 - Funding By Assistant Secretarial Office ($ In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003**	2004**	2005**	2006**
TOTAL	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
OFFICE OF CHIEF FINANCIAL OFFICER							
TOTAL	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
OFFICE OF COUNTER INTELLIGENCE							
TOTAL	**0.3**	**1.0**	**2.0**	**1.1**	**1.1**	**1.1**	**1.1**
TOTALS-DOE PROGRAMS							
OPERATING	294.4	330.8	290.3	367.9	367.9	367.9	367.9
INVENTORIES	0.0	-3.6	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	32.5	32.3	24.8	41.1	41.1	41.1	41.1
PROGRAM CONSTRUCTION	9.5	10.8	11.0	57.1	119.1	59.9	63.5
GENERAL PURPOSE EQUIPMENT	4.0	3.5	4.4	7.1	7.1	7.1	7.1
GENERAL PLANT PROJECTS	5.4	6.1	6.1	14.7	14.7	14.7	14.7
TOTAL	**345.7**	**379.9**	**336.6**	**487.9**	**549.9**	**490.7**	**494.3**
* Escalation Factors: FY2002 And FY2003 At 3.8% And 3.8% Respectively							
** Constant FY2004 Dollars							

Table 9 - Work For Others ($ In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003**	2004**	2005**	2006**
WORK FOR OTHER THAN DOE							
NUCLEAR REGULATORY COMMISSION							
TOTAL	**6.9**	**7.4**	**7.0**	**7.4**	**7.4**	**7.4**	**7.4**
DEPARTMENT OF DEFENSE							
TOTAL	**1.1**	**0.6**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**
NATTIONAL AERONAUTICS AND SPACE ADMINISTRATION							
OPERATING	3.8	1.5	1.9	2.1	2.1	2.1	2.1
CAPITAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CONSTRUCTION - BOOSTER APPL. FACILITY	8.6	8.3	10.9	4.4	0.0	0.0	0.0
TOTAL	**12.4**	**9.8**	**12.8**	**6.5**	**2.1**	**2.1**	**2.1**
DEPARTMENT OF STATE							
TOTAL	**4.7**	**6.7**	**3.7**	**3.6**	**3.6**	**3.6**	**3.6**
NATIONAL SCIENCE FOUNDATION							
TOTAL	**0.0**	**0.0**	**1.3**	**6.3**	**6.3**	**6.3**	**6.3**
DEPARTMENT OF HEALTH AND HUMAN SERVICES.							
TOTAL	**8.8**	**8.9**	**12.3**	**10.8**	**10.8**	**10.8**	**10.8**
ENVIRONMENTAL PROTECTION AGENCY							
TOTAL	**2.3**	**1.8**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
OTHER FEDERAL AGENCIES							
TOTAL	**0.5**	**1.0**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**
OTHER DOE LABS							
OPERATING	5.5	5.3	4.5	4.4	4.4	4.4	4.4
CONSTRUCTION -SPALLATION NEUTRON SOURCE	17.2	26.9	30.0	38.2	0.0	0.0	0.0
TOTAL	**22.7**	**32.2**	**34.5**	**42.6**	**4.4**	**4.4**	**4.4**
ALL OTHERS							
TOTAL	**9.0**	**7.8**	**7.5**	**7.6**	**7.6**	**7.6**	**7.6**
TOTALS-WORK FOR OTHER THAN DOE							
OPERATING	42.6	41.0	42.1	45.9	45.9	45.9	45.9
CONSTRUCTION	25.8	35.2	40.9	42.6	0.0	0.0	0.0
TOTAL	**68.3**	**76.2**	**83.0**	**88.5**	**45.9**	**45.9**	**45.9**
LABORATORY TOTALS							

Table 9 - Work For Others							
($ In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003**	2004**	2005**	2006**
OPERATING	337.	371.8	332.4	413.8	413.8	413.8	413.8
INVENTORIES	0.0	-3.6	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	32.5	32.3	24.8	41.1	41.1	41.1	41.1
PROGRAM CONSTRUCTION	35.3	46.0	51.9	99.7	119.1	59.9	63.5
GENERAL PURPOSE EQUIPMENT	4.0	3.5	4.4	7.1	7.1	7.1	7.1
GENERAL PLANT PROJECTS	5.4	6.1	6.1	14.7	14.7	14.7	14.7
TOTAL	**414.2**	**456.1**	**419.6**	**576.4**	**595.8**	**536.6**	**540.2**
* Escalation Factors: FY2002 And FY2003 At 3.8% And 3.8% Respectively							
** Constant FY2004 Dollars							

Table 10 - Laboratory Personnel Summary (Personnel In FTE)							
	2000	2001	2002	2003	2004	2005	2006
DEPARTMENT OF ENERGY PROGRAMS							
OFFICE OF ENERGY RESEARCH	1060	1018	994	1157	1157	1157	1157
CONSERVATION & RENEWABLE ENERGY	16	19	16	20	20	20	20
ENVIRONMENT, SAFETY & HEALTH	2	2	2	2	2	2	2
A/S NUCLEAR ENERGY	11	8	10	10	10	10	10
NONPROLIFERATION AND NATIONAL SECURITY	29	24	27	27	27	27	27
OFFICE OF COUNTER INTELLIGENCE	2	5	5	5	5	5	5
DEFENSE PROGRAMS	2	0	0	0	0	0	0
ENVIRONMNTL. RESTORATION & WASTE MGMT.	89	53	49	48	48	48	48
FOSSIL ENERGY	3	0	2	1	1	1	1
OFFICE, POLICY, PLANNING, AND ANALYSIS	0	0	0	0	0	0	0
OFFICE OF SECURITY & EMERGENCY OPERATION	4	74	79	85	85	85	85
ENERGY INFORMATION ADMINISTRATION	0	0	1	1	1	1	1
OFFICE OF CHIEF FINANCIAL OFFICER	1	0	0	0	0	0	0
TOTAL DOE PROGRAMS	**1219**	**1203**	**1185**	**1356**	**1356**	**1356**	**1356**
WORK FOR OTHER THAN DOE							
NUCLEAR REGULATORY COMMISSION	31	25	26	26	26	26	26
DEPARTMENT OF DEFENSE	2	2	2	2	2	2	2
DEPARTMENT OF STATE	8	7	6	6	6	6	6
NAT'L AERONAUTICS AND SPACE	29	29	33	20	20	20	20

Table 10 - Laboratory Personnel Summary (Personnel In FTE)							
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
ADMINISTRATION							
DEPARTMENT OF HEALTH AND HUMAN SERVICES	36	47	53	53	53	53	53
NATIONAL SCIENCE FOUNDATION	0	0	7	17	17	17	17
ENVIRONMENTAL PROTECTION AGENCY	4	3	3	3	3	3	3
OTHER FEDERAL AGENCIES	2	1	1	1	1	1	1
OTHER DOE LABS	105	121	127	125	125	125	125
ALL OTHERS	47	60	38	36	36	36	36
TOTAL WORK FOR OTHER THAN DOE	**264**	**295**	**296**	**289**	**289**	**289**	**289**
TOTAL LABORATORY-DIRECT	**1483**	**1498**	**1481**	**1645**	**1645**	**1645**	**1645**
TOTAL ORGANIZATIONAL BURDEN	196	187	162	159	159	159	159
LABORATORY DIRECTED R&D	33	49	43	36	36	36	36
TOTAL MATERIAL BURDEN	89	72	70	70	70	70	70
DISTRIBUTED/ALLOCATED SERVICES	378	362	569	552	552	552	552
TOTAL INDIRECT	**799**	**712**	**594**	**610**	**610**	**610**	**610**
TOTAL LABORATORY-PERSONNEL	**2978**	**2880**	**2919**	**3072**	**3072**	**3072**	**3072**

Table 11 – Funding -DOE Office of Science (In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003*	2004**	2005**	2006**
DEPARTMENT OF ENERGY – OFFICE OF SCIENCE							
KA-05 FACILITY OPERATIONS							
OPERATING	6.5	12.3	8.1	9.7	9.7	9.7	9.7
CHANGES IN INVENTORIES	0.0	-0.7	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	15.3	10.2	8.5	8.9	8.9	8.9	8.9
CONSTRUCTION (AIP)				0.6	0.6	0.6	0.6
TOTAL	**21.8**	**21.8**	**16.6**	**19.2**	**19.2**	**19.2**	**19.2**
DIRECT PERSONNEL	72	91	74	49	49	49	49
KA-04 RESEARCH AND TECHNOLOGY							
OPERATING	17.5	16.5	14.1	24.8	24.8	24.8	24.8
CAPITAL EQUIPMENT	0.0	0.0	1.0	0.2	0.2	0.2	0.2
TOTAL	**17.5**	**16.5**	**15.1**	**25.0**	**25.0**	**25.0**	**25.0**
DIRECT PERSONNEL	76	80	69	109	109	109	109
KA HIGH ENERGY PHYSICS							
OPERATING	24.0	28.8	22.2	34.5	34.5	34.5	34.5
CHANGES IN INVENTORIES	0.0	-0.7	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	15.3	10.2	9.5	9.1	9.1	9.1	9.1
GENERAL PURPOSE EQUIPMENT (GPE)	0.0	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	**39.3**	**38.3**	**31.7**	**44.2**	**44.2**	**44.2**	**44.2**
DIRECT PERSONNEL	148	171	143	158	158	158	158
KB-01 MEDIUM ENERGY PHYSICS							
OPERATING	2.6	5.0	4.6	5.6	5.6	5.6	5.6
CAPITAL EQUIPMENT	0.1	0.1	0.1	2.0	2.0	2.0	2.0
TOTAL	**2.7**	**5.1**	**4.7**	**7.6**	**7.6**	**7.6**	**7.6**
DIRECT PERSONNEL	15	22	23	26	26	26	26
KB-02 HEAVY ION PHYSICS							
PHYSICS RESEARCH	6.0	6.0	6.1	8.0	8.0	8.0	8.0
FACILITY OPERATIONS							
AGS/TVDG OPERATIONS							
RHIC OPERATION	74.2	72.0	72.7	94.9	94.9	94.9	94.9
RHIC PRE-OPS/ INVENTORY	40.0						
RHIC EXPERIMENTAL SUPPORT	25.2	29.7	30.0	38.9	38.9	38.9	38.9
TOTAL FACILITY OPERATIONS	99.4	101.7	102.7	133.8	133.8	133.8	133.8
TOTAL OPERATING	105.4	107.7	108.8	141.8	141.8	141.8	141.8
CAPITAL EQUIPMENT							
ADDITIONAL EXPERIMENTAL EQUIPMENT	7.3	4.3	5.1	11.9	11.9	11.9	11.9
RHIC OPERATIONS-EQUIPMENT	0.3	1.7	0.0	0.2	0.2	0.2	0.2
RHIC EXPERIMENTAL SUPPORT-	2.4	4.9	4.1	5.3	5.3	5.3	5.3

Table 11 – Funding -DOE Office of Science (In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003*	2004**	2005**	2006**
EQUIPMENT							
GENERAL PURPOSE EQUIPMENT	4.0	3.5	4.4	7.1	7.1	7.1	7.1
OTHER PROGRAMMATIC	0.0	0.1	0.0	0.0	0.0	0.0	0.0
TOTAL CAPITAL	14.0	14.5	13.6	24.5	24.5	24.5	24.5
GENERAL PLANT PROJECTS	5.4	6.1	6.1	14.7	14.7	14.7	14.7
CONSTRUCTION (AIP)	1.3	2.3	2.5	5.9	5.9	5.9	5.9
TOTAL CONSTRUCTION	6.7	8.4	8.6	20.6	20.6	20.6	20.6
TOTAL	**126.0**	**130.6**	**131.0**	**186.9**	**186.9**	**186.9**	**186.9**
DIRECT PERSONNEL	475	460	474	519	519	519	519
KB-03 NUCLEAR THEORY							
TOTAL	**3.8**	**4.4**	**4.2**	**5.2**	**5.2**	**5.2**	**5.2**
DIRECT PERSONNEL	19	21	20	23	23	23	23
KB-04 LOW ENERGY PHYSICS							
OPERATING	0.7	0.7	0.7	1.0	1.0	1.0	1.0
CAPITAL EQUIPMENT	0.1	0.0	0.1	0.1	0.1	0.1	0.1
TOTAL	**0.8**	**0.7**	**0.8**	**1.1**	**1.1**	**1.1**	**1.1**
DIRECT PERSONNEL	3	3	2	4	4	4	4
KB NUCLEAR PHYSICS							
OPERATING	112.5	117.8	118.3	153.6	153.6	153.6	153.6
CAPITAL EQUIPMENT	14.1	14.6	13.8	26.6	26.6	26.6	26.6
CONSTRUCTION							
GENERAL PLANT PROJECTS	5.4	6.1	6.1	14.7	14.7	14.7	14.7
CONSTRUCTION (AIP)	1.3	2.3	2.5	5.9	5.9	5.9	5.9
TOTAL CONSTRUCTION	6.7	8.4	8.6	20.6	20.6	20.6	20.6
TOTAL	**133.2**	**140.8**	**140.7**	**200.8**	**200.8**	**200.8**	**200.8**
DIRECT PERSONNEL	512	506	519	572	572	572	572
KC-02 MATERIALS SCIENCES							
OPERATING (RESEARCH)	10.8	11.0	10.1	18.1	18.1	18.1	18.1
NSLS OPERATIONS	20.4	23.0	22.5	41.6	41.6	41.6	41.6
HFBR OPERATIONS	19.4	18.2	1.2	1.3	1.3	1.3	1.3
TOTAL OPERATING	50.6	52.2	33.8	61.0	61.0	61.0	61.0
CHANGES IN INVENTORIES		-2.9					
CAPITAL EQUIPMENT	3.0	4.3	3.9	6.0	6.0	6.0	6.0
CONSTRUCTION							
CNTR FOR FUNCTIONAL NANOMATERIALS (b)			1.0	23.8	54.7	0.0	0.0
ARAM	1.3	1.4	1.4	2.0	2.0	2.0	2.0
TOTAL CONSTRUCTION	1.3	1.4	2.4	25.8	56.7	2.0	2.0
TOTAL	**54.9**	**55.0**	**40.1**	**92.8**	**123.7**	**69.0**	**69.0**
DIRECT PERSONNEL	255	215	214	268	268	268	268

Table 11 – Funding -DOE Office of Science (In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003*	2004**	2005**	2006**
KC-03 CHEMICAL SCIENCES							
OPERATING (RESEARCH)	9.6	9.9	8.6	13.5	13.5	13.5	13.5
NSLS OPERATIONS	7.6	7.3	7.3	8.1	8.1	8.1	8.1
TOTAL OPERATING	17.2	17.2	15.9	21.6	21.6	21.6	21.6
CAPITAL EQUIPMENT	1.5	2.1	1.4	3.2	3.2	3.2	3.2
TOTAL	**18.7**	**19.3**	**17.3**	**24.8**	**24.8**	**24.8**	**24.8**
DIRECT PERSONNEL	37	38	35	53	53	53	53
KC-04 ENGINEERING AND GEOSCIENCES							
OPERATING	1.0	0.3	0.0	0.5	0.5	0.5	0.5
CAPITAL EQUIPMENT	0.1	0.1	0.0	0.0	0.0	0.0	0.0
TOTAL	**1.1**	**0.4**	**0.0**	**0.5**	**0.5**	**0.5**	**0.5**
DIRECT PERSONNEL	2	2	2	2	2	2	2
KC-06 ENERGY BIOSCIENCES							
OPERATING	1.5	1.2	0.8	1.4	1.4	1.4	1.4
CAPITAL EQUIPMENT	0.1	0.1	0.1	0.0	0.0	0.0	0.0
TOTAL	**1.6**	**1.3**	**0.9**	**1.4**	**1.4**	**1.4**	**1.4**
DIRECT PERSONNEL	5	4	4	4	4	4	4
KC BASIC ENERGY SCIENCES							
OPERATING (RESEARCH)	22.9	22.4	19.5	33.5	33.5	33.5	33.5
NSLS OPERATIONS	28.0	30.3	29.8	49.7	49.7	49.7	49.7
HFBR OPERATIONS	19.4	18.2	1.2	1.3	1.3	1.3	1.3
TOTAL OPERATING	70.3	70.9	50.5	84.5	84.5	84.5	84.5
CHANGES IN INVENTORIES	0.0	-2.9	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	4.7	6.6	5.4	9.2	9.2	9.2	9.2
CONSTRUCTION							
CNTR FOR FUNCTIONAL NANOMATERIALS (b)	0.0	0.0	1.0	23.8	54.7	0.0	0.0
ARAM	1.3	1.4	1.4	2.0	2.0	2.0	2.0
TOTAL CONSTRUCTION	1.3	1.4	2.4	25.8	56.7	2.0	2.0
TOTAL	**76.3**	**76.0**	**58.3**	**119.5**	**150.4**	**95.7**	**95.7**
DIRECT PERSONNEL	299	259	255	327	327	327	327
KG MULTIPROGRAM ENERGY LABS							
USER RESEARCH CENTER (b)	0.0	0.0	0.0	7.5	7.5	0.0	0.0
CONSTRUCTION	6.9	6.4	6.1	7.9	22.0	51.4	55.0
TOTAL	**6.9**	**0.0**	**6.1**	**15.4**	**29.5**	**51.4**	**55.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
KP BIOLOGICAL & ENVIRONMENTAL							
OPERATING	20.2	19.3	17.7	21.5	21.5	21.5	21.5

Table 11 – Funding -DOE Office of Science (In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	**2001**	**2002***	**2003***	**2004****	**2005****	**2006****
CAPITAL EQUIPMENT	2.3	4.3	0.5	3.2	3.2	3.2	3.2
TOTAL	**22.5**	**23.6**	**18.2**	**24.7**	**24.7**	**24.7**	**24.7**
DIRECT PERSONNEL	91	74	72	86	86	86	86
KJ COMP. AND TECH. RESEARCH							
TOTAL	**2.1**	**2.2**	**1.6**	**5.9**	**5.9**	**5.9**	**5.9**
DIRECT PERSONNEL	10	8	5	14	14	14	14
KX UNIVERSITY AND SCIENCE EDUCATION							
TOTAL	**0.6**	**0.4**	**0.7**	**0.8**	**0.8**	**0.8**	**0.8**
DIRECT PERSONNEL	0	0	0	0	0	0	0
TOTALS - OFFICE OF SCIENCE							
OPERATING	229.7	239.4	211.0	300.8	300.8	300.8	300.8
CHANGE IN INVENTORIES	0.0	-3.6	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	32.4	32.2	24.8	41.0	41.0	41.0	41.0
GENERAL PURPOSE EQUIPMENT (GPE)	4.0	3.5	4.4	7.1	7.1	7.1	7.1
GENERAL PLANT PROJECTS (GPP)	5.4	6.1	6.1	14.7	14.7	14.7	14.7
CONSTRUCTION	9.5	10.1	0.0	0.0	0.1	0.1	0.1
TOTAL	**281.2**	**287.7**	**257.3**	**411.3**	**456.3**	**423.5**	**427.1**
DIRECT PERSONNEL	1060	1018	994	1157	1157	1157	1157
(b) PROPOSED							
* ESCALATION FACTORS: FY2002 AND FY2003 AT 3.8% AND 3.8% RESPECTIVELY							
** CONSTANT FY2004 DOLLARS							

Table 12 – Funding – Other DOE Program Secretarial Offices
(In Millions In Budget Authority)

	FISCAL YEAR						
	2000	**2001**	**2002***	**2003***	**2004****	**2005****	**2006****
A/S CONSERVATION & RENEWABLE ENERGY							
EB SOLAR AND RENEWABLE RES. TECHNOLOGIES							
TOTAL	**1.7**	**2.0**	**1.5**	**2.2**	**2.2**	**2.2**	**2.2**
DIRECT PERSONNEL	8	8	7	8	8	8	8
EC BUILDINGS AND COMMUNITY SYSTEMS							
OPERATING	1.2	1.3	1.2	2.4	2.4	2.4	2.4
CAPITAL EQUIPMENT	0.0	0.1	0.0	0.0	0.0	0.0	0.0
TOTAL	**1.2**	**1.4**	**1.2**	**2.4**	**2.4**	**2.4**	**2.4**
DIRECT PERSONNEL	4	5	5	7	7	7	7
EE TRANSPORTATION							
TOTAL	**1.0**	**2.6**	**1.4**	**1.6**	**1.6**	**1.6**	**1.6**
DIRECT PERSONNEL	4	5	4	5	5	5	5
EH POLICY AND MANAGEMENT - EERE							
TOTAL		**0.1**					
DIRECT PERSONNEL		1					
WB IN-HOUSE ENERGY MANAGEMENT							
OPERATING		0.2					
CONSTRUCTION		0.7					
TOTAL		**0.9**					
DIRECT PERSONNEL							
TOTALS-CONS. & RENEWABLE ENERGY							
OPERATING	3.9	6.2	4.1	6.2	6.2	6.2	6.2
CONSTRUCTION	0.0	0.7	0.0	0.0	0.0	0.0	0.0
CAPITAL EQUIPMENT	0.0	0.1	0.0	0.0	0.0	0.0	0.0
TOTAL	**3.9**	**7.0**	**4.1**	**6.2**	**6.2**	**6.2**	**6.2**
DIRECT PERSONNEL	16	19	16	20	20	20	20
A/S ENVIRONMENT,SAFETY & HEALTH							
HC ENVIRON. SAFETY AND HEALTH (NON-DEF.)							
TOTAL	**0.2**	**0.1**	**0.2**	**0.3**	**0.3**	**0.3**	**0.3**
DIRECT PERSONNEL	1	1	1	1	1	1	1
HD ENVIRONMENT, SAFETY AND HEALTH (DEFENSE)							
TOTAL	**0.2**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	1	1	1	1	1	1	1

Table 12 – Funding – Other DOE Program Secretarial Offices
(In Millions In Budget Authority)

	FISCAL YEAR						
	2000	**2001**	**2002***	**2003***	**2004****	**2005****	**2006****
TOTALS-ENVIRONMENT, SAFETY, AND HEALTH							
TOTAL	**0.3**	**0.3**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**
DIRECT PERSONNEL	2	2	2	2	2	2	2
A/S NONPROLIFERATION AND NATIONAL SECURITY							
NN NONPROLIFERATION AND NATIONAL SECURITY PROGM DIRECTION							
TOTAL	**24.9**	**32.0**	**30.3**	**19.4**	**19.4**	**19.4**	**19.4**
DIRECT PERSONNEL	29	24	27	27	27	27	27
A/S OFFICE OF COUNTER INTELLIGENCE							
CN COUNTER INTELLIGENCE							
TOTAL	**0.3**	**1.0**	**2.0**	**1.1**	**1.1**	**1.1**	**1.1**
DIRECT PERSONNEL	2	5	5	5	5	5	5
A/S DEFENSE PROGRAMS							
DP OTHER WEAPONS ACTIVITIES							
TOTAL	**0.4**	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	2	0	0	0	0	0	0
A/S ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT							
EW ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT							
OPERATING	30.9	38.9	27.3	24.0	24.0	24.0	24.0
CAPITAL EQUIPMENT	0.1	0.1					
TOTAL	**31.0**	**39.0**	**27.3**	**24.0**	**24.0**	**24.0**	**24.0**
DIRECT PERSONNEL	89	53	49	48	48	48	48
A/S, FOSSIL ENERGY							
AA COAL							
TOTAL	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	0	0	0	0	0	0	0
AB GAS							
TOTAL	**0.1**	**0.0**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	0	0	2	1	1	1	1
AC PETROLEUM							
TOTAL	**0.3**	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	3	0	0	0	0	0	0
TOTALS-FOSSIL ENERGY	**0.5**	**0.2**	**0.4**	**0.2**	**0.2**	**0.2**	**0.2**

Table 12 – Funding – Other DOE Program Secretarial Offices
(In Millions In Budget Authority)

	FISCAL YEAR						
	2000	**2001**	**2002***	**2003***	**2004****	**2005****	**2006****
DIRECT PERSONNEL	3	0	2	1	1	1	1
OFFICE OF NUCLEAR ENERGY							
ST ISOTOPE PRODUCTION AND DISTRIBUTION PROGRAM							
OPERATING	2.3	2.4	2.9	2.1	2.1	2.1	2.1
CYCLOTRON ISOTOPE RESEARCH CTR (b)		0.0	0.0	9.4	26.4	0.0	0.0
TOTAL	**2.3**	**2.4**	**2.9**	**11.5**	**18.5**	**2.1**	**2.1**
DIRECT PERSONNEL	9	7	8	8	8	8	8
AF NUCLEAR ENERGY RESEARCH & DEVELOPMENT							
TOTAL	**0.2**	**0.6**	**0.2**	**0.7**	**0.7**	**0.7**	**0.7**
DIRECT PERSONNEL	2	1	2	2	2	2	2
TOTALS-OFFICE OF NUCLEAR ENERGY							
OPERATING	2.5	3.0	3.1	2.8	2.8	2.8	2.8
CONSTRUCTION	0.0	0.0	0.0	9.4	26.4	0.0	0.0
TOTAL	**2.5**	**3.0**	**3.1**	**12.2**	**29.2**	**2.8**	**2.8**
DIRECT PERSONNEL	11	8	10	10	10	10	10
OFFICE OF POLICY, PLANNING, AND ANALYSIS							
PE POLICY, ANALYSIS AND SYSTEMS STUDIES							
TOTAL	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	0	0	0	0	0	0	0
OFFICE OF SECURITY AND EMERGENCY OPERATION							
SO SECURITY AND EMERGENCY MGMT.							
TOTAL	**0.3**	**0.4**	**0.3**	**0.5**	**0.5**	**0.5**	**0.5**
DIRECT PERSONNEL	1	1	1	1	1	1	1
GD NUCLEAR SAFEGUARDS & SECURITY							
TOTAL	**0.0**	**0.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	1	0	0	0	0	0	0
FS SAFEGUARDS & SECURITY							
OPERATING	0.0	8.6	11.0	11.9	11.9	11.9	11.9
CAPITAL	0.0	0.0	0.0	0.1	0.1	0.1	0.1
TOTAL	**0.0**	**8.6**	**11.0**	**12.0**	**12.0**	**12.0**	**12.0**
DIRECT PERSONNEL		71	75	81	81	81	81
ND EMERGENCY MANAGEMENT							

Table 12 – Funding – Other DOE Program Secretarial Offices
(In Millions In Budget Authority)

	FISCAL YEAR						
	2000	**2001**	**2002***	**2003***	**2004****	**2005****	**2006****
TOTAL	**0.3**	**0.2**	**0.3**	**0.4**	**0.4**	**0.4**	**0.4**
DIRECT PERSONNEL	2	2	3	3	3	3	3
TOTAL: OFFICE OF SECURITY & EMERGENCY MGMT.							
OPERATING	0.6	9.6	11.6	12.8	12.8	12.8	12.8
CAPITAL	0.0	0.0	0.0	0.1	0.1	0.1	0.1
TOTAL	**0.6**	**9.6**	**11.6**	**12.9**	**12.9**	**12.9**	**12.9**
DIRECT PERSONNEL	4.0	74.0	79.0	85.0	85.0	85.0	85.0
ENERGY INFORMATION ADMINISTRATION							
TA NATIONAL ENERGY INFORMATION SYSTEM							
TOTAL	**0.3**	**0.2**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**
DIRECT PERSONNEL	0	0	1	1	1	1	1
OFFICE OF CHIEF FINANCIAL OFFICER							
WN COST OF SERVICE PERFORMED							
TOTAL	**0.1**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
DIRECT PERSONNEL	1	0	0	0	0	0	0

(b) Proposed

* Escalation Factors: FY2002 And FY2003 At 3.8% And 3.8% Respectively

** Constant FY2004 Dollars

TABLE 13 – Funding – Work For Others
(In Millions In Budget Authority)

	FISCAL YEAR						
	2000	**2001**	**2002***	**2003***	**2004****	**2005****	**2006****
NUCLEAR REGULATORY COMMISSION							
NUCLEAR REACTOR REGULATION							
TOTAL	**1.6**	**2.4**	**1.6**	**1.7**	**1.7**	**1.7**	**1.7**
DIRECT PERSONNEL	6	8	7	7	7	7	7
NUCLEAR REGULATORY RESEARCH							
TOTAL	**4.1**	**4.0**	**4.1**	**4.3**	**4.3**	**4.3**	**4.3**
DIRECT PERSONNEL	20	14	15	15	15	15	15
COMMISSION AND STAFF OFFICES							
TOTAL	**1.2**	**1.0**	**1.3**	**1.4**	**1.4**	**1.4**	**1.4**
DIRECT PERSONNEL	5	3	4	4	4	4	4
TOTALS-NUCLEAR REGULATORY COMMISSION							
TOTAL	**6.9**	**7.4**	**7.0**	**7.4**	**7.4**	**7.4**	**7.4**
DIRECT PERSONNEL	31	25	26	26	26	26	26
DEPARTMENT OF STATE							
TOTAL	**4.7**	**6.7**	**3.7**	**3.6**	**3.6**	**3.6**	**3.6**
DIRECT PERSONNEL	8	7	6	6	6	6	6
DEPARTMENT OF DEFENSE							
TOTAL	**1.1**	**0.6**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**
DIRECT PERSONNEL	2	2	2	2	2	2	2
NATIONAL AERONAUTICS AND SPACE ADMININISTRATION							
OPERATING	3.8	1.5	1.9	2.1	2.1	2.1	2.1
CAPITAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CONSTRUCTION-BAF (a)	8.6	8.3	10.9	4.4	0.0	0.0	0.0
TOTAL	**12.4**	**9.8**	**12.8**	**6.5**	**2.1**	**2.1**	**2.1**
DIRECT PERSONNEL	29	29	33	20	20	20	20
DEPARTMENT OF HEALTH & HUMAN SERVICES							
TOTAL	**8.8**	**8.9**	**12.3**	**10.8**	**10.8**	**10.8**	**10.8**
DIRECT PERSONNEL	36	47	53	53	53	53	53
NATIONAL SCIENCE FOUNDATION							
TOTAL	**0.0**	**0.0**	**1.3**	**6.3**	**6.3**	**6.3**	**6.3**
DIRECT PERSONNEL	0	0	7	17	17	17	17
ENVIRONMENTAL PROTECTION AGENCY							
TOTAL	**2.3**	**1.8**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**
DIRECT PERSONNEL	4	3	3	3	3	3	3

TABLE 13 – Funding – Work For Others (In Millions In Budget Authority)							
	FISCAL YEAR						
	2000	2001	2002*	2003*	2004**	2005**	2006**
OTHER FEDERAL AGENCIES							
TOTAL	**0.5**	**1.0**	**0.6**	**0.5**	**0.5**	**0.5**	**0.5**
DIRECT PERSONNEL	2	1	1	1	1	1	1
OTHER DOE LABS							
OPERATING	5.5	5.3	4.5	4.4	4.4	4.4	4.4
CONSTRUCTION - SNS		26.9	30.0	38.2	0.0	0.0	0.0
TOTAL	**22.7**	**32.2**	**34.5**	**42.6**	**4.4**	**4.4**	**4.4**
DIRECT PERSONNEL	105	121	127	125	125	125	125
ALL OTHERS							
TOTAL	**9.0**	**7.8**	**7.5**	**7.6**	**7.6**	**7.6**	**7.6**
DIRECT PERSONNEL ***	47	60	38	36	36	36	36
(a) Funded							
* Escalation Factors: FY2002 and FY2003 at 3.8% and 3.8% respectively							
** Constant FY2004 Dollars - Note: (1)Dept of state amount corrected from $5M to $4.7M. (2) State agency $.5M moved from other Fed agency to All other category.							
*** Includes FTE's from Non-Reportable Programs							

Table 14 - Laboratory Major Programmatic Construction Projects
($ In Millions In Budget Authority)

		Funded		Budgeted		Proposed		
	TEC	**FY00**	**FY01**	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**
Program Related - SC								
Accelerator Improvement Projects (KA)					0.6	0.6	0.6	0.6
Accelerator Improvement Projects (KB)		1.3	2.0	2.5	5.9	5.9	5.9.5.9	
Accelerator Improvement Projects (KC)		1.3	1.4	1.4	2.0	2.0	2.0	2.0
Accelerator Improvement Projects (KP)								
General Plant Projects (KA)								
General Plant Projects (KB)		5.4	6.1	6.1	14.7	14.7	14.7	14.7
General Plant Projects (KC)								
General Plant Projects (KP)								
Total		**8.0**	**9.5**	**10.0**	**23.2**	**23.2**	**23.2**	**23.2**
Program Related - WFO - NASA								
Booster Applications Facility (BAF)	35.4	8.6	11.5	10.9	4.4			
Proposed Construction – NE								
Cyclotron Isotope Research Center	35.8				9.4	26.4		
Proposed Construction - SC								
User Research Center (KB)	15.0				7.5	7.5		
Cntr for Functional Nanomaterials (KC)	82.0			3.5	23.8	37.3		
Total		**8.6**	**11.5**	**14.4**	**40.7**	**71.2**		
Under Evaluation								
RHIC II								
Photo-injected Electron Recovery Linac								
Muon Collider Storage Ring								
Total Funded Program Construction		**16.6**	**21**					
Total Budgeted Program Construction				**24.4**	**63.9**			
Total Proposed Program Construction						**94.4**	**23.2**	**23.2**

Table 15 - Laboratory Major MEL/FS Construction Projects
($ In Millions In Budget Authority)

			Funded		Budgeted		Proposed		
MEL/FS Projects	**Project Type**	**TEC**	**FY00**	**FY01**	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**
Funded/Budgeted									
Electrical System Mods Ph. I (N98D0011)	3	5.7	3.9	1.0					
Sanitary System Upgrade Ph. III (A96D0029)	1	6.5	3.0	3.0					
Electrical System Mods Ph. II (N98D0022)	1	6.8		0.6	3.3	2.9			
Ground & Surface Water (A93D0340)	1	6.1		1.9	2.8	1.4			
Total:			**6.9**	**6.4**	**6.1**	**4.3**			
Proposed - KG01									
Energy Science Center (N98D0015)	5	17.4				1.8	7.2	8.4	
Research Support Center – Ph I (AA0D0030)	5	18.2				1.8	3.8	7.0	5.6
Chilled Water – Ph II (N98D0069)	3	8.5					1.0	5.0	2.5
Research Support Center – Ph II (AA1D0006)	5	18.2					1.6	4.0	7.0
Roof Replacement Phase II (A98D0014)	3	11.6					1.6	5.0	5.0
Renovate Science Labs – Ph I (AA1D0017)	2	29.3					1.3	15.0	13.0
Support Shops Addn – Ph I (AA1D0009)	5	5.5					0.5	4.0	1.0
Central Steam Dost – Ph I (N98D0046)	3	8.0					1.0	5.0	2.0
Research Support Center – Ph III (AA1D0007)	5	18.2						1.6	4.0
Renovate Science Labs – Ph II (AA1D0018)	2	14.3						1.3	6.0
Research Support Center – Ph IV (AA1D0008)	5	18.2							1.6
Renovate Science Labs – Ph III (AA1D0019)	2	25.3							1.3
Potable Water System – Ph II (AA1D0026)	3	8.0							1.0
Total:						**3.6**	**18.0**	**56.3**	**50.0**
Proposed - KG02									
Halon System Replacement (A93D0161)	1	5.0						1.0	4.0
Total:								**1.0**	**4.0**
Total GPF Funded Construction			**6.9**	**6.4**					
Total GPF Budgeted Construction					**6.1**	**7.9**			
Total GPF Proposed Construction							**18**	**56.3**	**54.0**

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

Table 16 - Environmental, Safety, Health And Infrastructure Resource Projection (Costs In Millions)						
Funding	**FY01**	**FY02**	**FY03**	**FY04**	**FY05**	**FY06**
ESH Operating						
Laboratory (OFP/G&A)	2.9	3.3	3.0	(a)	(a)	(a)
Department & Division	36.8	37.1	37.5	54.6	54.8	55.0
ESH Capital Equipment	0.4	0.2	0.3	0.3	0.3	0.3
ESH Line Item	5.9	4.1	0.0	0.0	0.0	0.0
ESH GPP						
KA	0.0	0.0	0.0	(a)	(a)	(a)
KB	2.1	3.6	1.1	(a)	(a)	(a)
KC	0.0	0.0	0.0	(a)	(a)	(a)
KP	0.0	0.0	0.0	(a)	(a)	(a)
ESH AIP						
KA	0.0	0.0	0.0	(a)	(a)	(a)
KB	0.0	0.0	0.0	(a)	(a)	(a)
KC	0.0	0.0	0.1	(a)	(a)	(a)
KP	0.0	0.0	0.0	(a)	(a)	(a)
Infra. Operating (Space/G&A)	16.7	16.7	16.7	(a)	(a)	(a)
Infrastructure Line Item	0.8	3.0	6.6	22.0	50.4	51.0
Infrastructure GPP	3.1	8.1	4.3	(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[(b)]	6.0	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: Field Work Proposal

The Field Work Proposals are listed by DOE Mission, Goal, and Challenge. Several Field Work Proposals will be listed more than once, since the research contributes to more than one area.

Science and Technology Mission

B and R	Project Title	Principal Investigator
	Exploring Energy and Matter	
Complex Systems		
KC-02-02-01	Neutron Scattering	Tranquada, J
	Nanoscale Functional Materials: The Role of Scale and Dimensionality	Gibbs, D.
	X-Ray Scattering	Gibbs, D.
KC-02-02-02	Charge Inhomogeneity in Correlated Electron Systems	Gibbs, D
	Electron Spectroscopy	Johnson, P
KC-02-02-03	Condensed Matter Theory	Weinert, M.
KC-02-02-03	Quantum Monte Carlo Studies of Electron Correlation in Complex Oxides	Davenport, J.
KC-06-00-00	Molecular Plant Genetics	Burr, B
Components of Matter		
KA-04-01-01	Research	Littenberg, L., Gordon, H. and Others
KA-05-02-03	U.S. ATLAS Project	Gordon, H
KB-01-01-02	Laser Electron Gamma Source	Sandorfi, A
	Spin and Nuclear Structure Investigations with Hadronic Probes	Bunce, J.
KB-02-01-02	Heavy Ion Research	Chasman, C and Remsberg, L
KB-02-02-01	RHIC Experimental Operations	Aronson, S. and Others
KB-03-01-02	Nuclear Theory	McLerran, T
KC-02-01-01	Theory of Alloy Phases	Weinert, M
KC-02-02-01	Neutron Scattering	Tranquada, J
	Powder Diffraction	Vogt, L
	Nanoscale Functional Materials: The Role of Scale and Dimensionality	Gibbs, D.
	X-ray Scattering	Gibbs, D.
KC-02-02-02	Charge Inhomogeneity in Correlated Electron Systems	Gibbs, D.
	BNL Center for Functional Nanomaterials	Taylor, J.
	Electron Spectroscopy	Johnson, P
KC-02-02-03	Condensed Matter Theory	Weinert, M.
KP-11-01-01A	Analysis of Human Proteins Induced in Response to Ionizing Radiation	Studier, W.
KP-11-03-01	Genome Sequencing and Analysis	Dunn, J
Origin and Fate of the Universe		
KB-02-01-02	Heavy Ion Research	Chasman, C and Remsberg, L
KB-04-01-02	Solar Neutrino Research	Hahn, R

Science and Technology Mission (Continued)

B and R	Project Title	Principal Investigator
	Extraordinary Tools for Extraordinary Science	
Institutional Capacity		
KA-AIP	High Energy Physics Construction	
KB	Nuclear Physics Construction - AIP/GPP	
KC	Basic Energy Sciences Construction - AIP	
KC-02-02-02	BNL Center for Functional Nanomaterials	Taylor, J.
KC-02-04-011	Optics Systems for Synchrotron Radiation Applications	Takacs, P
	Optics and Detectors for Light Sources	Smith, G
KG	Multiprogram Energy Laboratory Construction	
KJ-02	Office of Science Laboratory Technology Research Program	Bogosian, M
KX-02-01	Science Education Programs	Swyler, K
Instrumentation for the Frontiers of Science		
KA-04-01-01	U.S. ATLAS Computing	Gibbard, B. and Wenaus, T.
KA-04-03-01	Advanced Accelerator Research and Development - Muon Collider	Palmer, R
	Accelerator R&D Infrastructure	Harrison, M
	Inverse Free Electron Laser Accelerator Development	Gallardo, J
	Accelerator Magnet R&D	Gupta, R.
	Superconductor R&D and Testing	Sampson, W.
	Accelerator Test Facility Operations and Development	Ben-Zvi, I
KA-04-03-02	Experimental Facilities Research and Development	Gordon, H
	Detector and Electronics Research and Development Program for High energy Physics	O'Connor, P
KA-05-01-01	Accelerator Operations for High Energy Physics	Roser, T.
KA-05-01-02	Experimental Facility Operations for High Energy Physics	Pile, P.
KA-05-02-01	U.S. Large Hadron Collider Collaboration	Willen, E.
KA-05-02-03	U.S. ATLAS Project	Gordon, H, Lissauer, D. and Others
KB-01-02-03	Accelerator Operations for Medium Energy Physics	Roser, T.
KB-02-01-00	Detector and Electronics Research and Development Program for Nuclear Physics	O'Connor, P
KB-02-02-01	RHIC Collider Accelerator Operations	Roser, T
KB-02-02-03	Other Capital Equipment Not Related to Construction	
KC-02-02-01	Neutron Instrument Development and User Support	Hastings, J
KC-02-02-02	Precision Photo-Fabrication R&D	Johnson, E
	BNL Center for Functional Nanomaterials	Taylor, J.
KC-02-04-01	Spallation Target Studies	Hastings, J
KC-02-04-011	Photoinjected Energy Recovery Linac (PERL)	Krinsky, S.
	National Synchrotron Light Source Operations and Development	Krinsky, S.
	X-ray Free Electron Laser R&D	Krinsky, S.
KP-11-01-01	Design and Fabrication of a Two-Dimensional Neutron Detector For a Spallation Neutron Source	Radeka, V and Smith, G
	Biophysical Instrumentation Research	Radeka, V and Smith, G

Science and Technology (Continued)

B and R	Project Title	Principal Investigator
	Extraordinary Tools for Extraordinary Science (Continued)	
KP-11-01-01	NSLS Structural Biology Facility Operation	Sweet, R
KP-14-01-02	PET Substance Abuse Studies	Volkow, N.
KP-14-01-04	Functional and Physiologic Magnetic Resonance	Ernst, T.
	Physiological Imaging	Volkow, N
KP-14-01-05	Brookhaven Medical Research Reactor Project	Reeside, W
Scientific Simulation		
KA-04-01-01	U.S. ATLAS Computing	Gibbard, B and Wenaus, T.
KB-03-01-04	National Nuclear Data Center Reference Nuclear Data for Energy Research	Dunford, C
KC-02-02-03	Quantum Monte Carlo Studies of Electron Correlation in Complex Oxides	Davenport, J.
KJ-01-01-01	Scalable Algorithms for Multiscale and Stochastic Coupled Elliptic Systems	Glimm, J.
KJ-01-01-03	Materials, Methods, Microstructure, and Magnetism	Weinert, M
KJ-01-02-00	Particle Physics Data Grid	Gibbard, B
	Fueling the Future	
Clean Power		
EB-22-01-00	Health and Environmental Effects of Photovoltaic Energy	Fthenakis, V.
KC-02-01-03	Superconducting Materials	Suenaga, M
KC-02-02-01	Neutron Scattering	Tranquada, J
	X-Ray Scattering	Gibbs, D.
	Nanoscale Functional Materials: The Role of Scale and Dimensionality	Gibbs, D.
	Powder Diffraction	Vogt, L
KC-02-02-02	Charge Inhomogeneity in Correlated Electron Systems	Gibbs, D.
	Electron Spectroscopy	Johnson, P
KC-02-02-03	Condensed Matter Theory	Weinert, M.
KC-02-03-01	Synthesis and Structures of Conducting Polymers	Mc Breen, J
KC-03-02-04	Structure and Function in Electrochemistry and Electrocatalysis	Adzic, R
KJ-01-01-03	Materials, Methods, Microstructure, and Magnetism	Weinert, M
Efficient Energy Use		
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-03-01-02	Photoinduced Molecular Dynamics in the Gas and Condensed Phases	White, M
	Gas-Phase Molecular Dynamics	Muckerman, J
KC-03-02-01	Catalysis: Reactivity and Structure	Hrbek, J
TA-01-00	Out of Cycle FWP	
TA-01-00-00	Global MARKAL Model Development (EIA)	Lee, J.

Science and Technology Mission (Continued)

B and R	Project Title	Principal Investigator
	Fueling the Future (Continued)	
New Fuels		
KC-02-02-02	Structure Sensitive Properties of Advanced Permanent Magnet Materials: Experiment and Theory	Welch, D
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
	Structure-Function Designs of Photosynthetic and Catalytic Porphyrins	Fajer, J and Feldberg, S.
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	Regulation of Energy Conversion in Photosynthesis	Hind, G
KC-06-00-00	Modification of Plant Lipids	Shanklin, J
	Protect Our Living Planet	
Impacts on People and the Environment		
AA-20-25-20	Mercury Risk Assessment	Moskowitz, P.
EW-02-MM-04	DOE CEG/AMEC	Moskowitz, P
EW-40-90-20	DOE Center for Risk Excellence International Risk Assessment Network	Moskowitz, P.
KP-11-01-01	Analysis of Human Proteins Induced in Response to Ionizing Radiation	Studier, W.
KP-11-02-02	DNA Damage Clusters in Low Level Radiation Responses of Human Cells	Sutherland, B
KP-11-03-01	Genome Sequencing and Analysis	Dunn, J
KP-12-01-03	Direct and Indirect Effects of Aerosols: Short-wave Radiative Forcing by Trospospheric Aerosols	Schwartz, S
KP-12-01-03	Studies of Cloud Microphysical and Optical Properties	Daum, P
KP-12-02-01	Chemistry and Microphysics of the Troposphere: Field Studies in Atmospheric Chemistry	Daum, P and Newman, L
	Chemistry and Microphysics of the Troposphere: Diagnostic Model Studies Using Field Observations and Eulerian Model Output	Kleinman, L.
	Eddy-Covariance Flux Tower and Tracer Support for the University of Georgia Proposal: "From Tower to Pixel: Integration of Patch Size NE Using Experimental Modeling and Footprint Analysis	Hendrey, G.
	Chemistry and Microphysics of the Troposphere: Aerosol Optical Properties and Phase Transformation	Imre, D
	Perfluorocarbon Tracer Studies for Visualization/Verification of Vertical Transport and Mixing (VTMX) Processes	Dietz, R
	Chemistry and Microphysics of the Troposphere: Emission Inventories of Aerosols and Aerosol Precursors	Benkovitz, C
	Chemistry and Microphysics of the Troposphere: Multi-Phase Atmospheric Chemistry	Lee, Y

Science and Technology Mission (Continued)

B and R	Project Title	Principal Investigator
	Protect Our Living Planet (Continued)	
Impacts on People and the Environment		
	Chemistry and Microphysics of the Troposphere: Instrumentation for Field Programs	Springston, S
	Chemistry and Microphysics of the Troposphere: Chemical and Microphysical Aerosol Model	Schwartz, S
	Anthropogenic Aerosol Perturbation on Climate	Schwartz, S
	Chemistry and Microphysics of the Troposphere: Aerosol Size Distribution	Brechtel, F
KP-12-02-02	Observations, Analysis and Modeling of the Water Cycle	Miller, M.
	Eddy Covariance Flux Tower and Tracer Technology Support	Hendrey, G.
	Forest-Atmosphere Carbon Transfer and Storage (FACTS) Biology: Mechanisms of Long-Term Carbon Flux Enhancements in Elevated Carbon	Ellsworth, D
	Forest Atmosphere Carbon Transfer and Stroage-1 (FACTS-1) Experiment in a Forest Ecosystem Off-site	Hendrey, G.
KP-12-03-01	Molecular and Physiological Mechanisms Regulating the Acclimation of Plants to Growth at Elevated CO2	Long, S and Rogers, A and Hendrey, G
KP-12-03-02	Free-Air Carbon Dioxide Enrichment (FACE) Facility Development	Hendrey, G
	Monte Carlo Neutron Photon (MCNP) Simulation to Improve Soil Carbon Measurements	Wielopolski, L
ND-02-02-00	Technical Program Support to Emergency Management Advisory Committee (EMAC) Subcommittee on Consequence Assessment and Protection	Hansen, D
NN-20-01-00	Infrared Signatures	McGraw, R.
Prevention and Protection		
EW-40-90-10	Mechanisms of Radionuclide-Hydroxycarboxylic Acid Interactions for Decontamination of Metallic Surfaces	Francis, A
EW-40-90-10	Collaboration on Interfacial Soil Chemistry of Radionuclides in the Unsaturated Zone: EXAFS Studies	Vairavamurthy, A
	Mechanism of Radionuclide Hydroxcarboxylic Acid Interactions for Decontamination of Metallic Surfaces	Francis, A.
	Mechanism of Radionuclide Hydroxcarboxylic Acid Interactions	Francis, A.
KC-03-02-02	Thermodynamics on the Nanoscale	Imre, D
KP-11-01-01B	Non-Homogeneous End Joining DNA Repair: Characterization of Protein Structures and Complexes	Anderson, C.
KP-11-02-02	Microbial Research in Reaction Pathways/Regulatory Networks	Dunn, J
KP-13-01-01	Stabilization of Radionuclides by Anaerobic Bacteria: Molecular Genetic Analysis of Clostridia	Dunn, J
	Reductive Precipitation and Stabilization of Uranium Complexed With Organic Ligands by Anaerobic Bacteria	Francis, A.
	Stabilization of Heavy-Metal contaminants in Subsurface Environments: Microbially Mediated Precipitation of Metal Sulfides from Complexes with Organic Chelates	Vairavamurthy, A.
KP-14-01-02	Radiotracer Chemistry and Neuroimaging	Fowler, J
KP-14-01-03	High-Field Magnetic Resonance Imaging	Ernst, T.
KP-14-01-04	Functional and Physiological Magnetic Resonance	Ernst, T.
	Physiological Imaging	Volkow, N

Science and Technology Mission (Continued)

B and R	Project Title	Principal Investigator
	Protect Our Living Planet (Continued)	
Prevention and Protection		
KP-14-01-05	Positron Emitter Labeled BPA for BNCT	Ding, Y.
KP-14-01-06	Imaging Gene Expression	Gatley, S.J.
	Neuroreceptor Radioligands and Synaptic Activity	Gatley, J
ST-01-01-02	Radioisotope Production at BLIP	Mausner, L and Srivastava, S
Source and Fate of By-Products		
KP-12-02-02	*In Situ* Non-Invasive Soil Carbon Measurement (SCM)	Wielopolski, L.
	Manage As Stewards Of The Public Trust	
Management Effectiveness and Efficiency		
CN-04-04	Technology Review	Gross, G.
	Counter Intelligence Program Funding	Gross, G
FS-10-01	Site Safeguards and Security and Cybersecurity	Reaver, R
HC-11-03-00	Integrated Safety Management Systems Support	Perkins, K.
HC-11-05-00	BNL Support for DOE Orders, Standards and Rules	Perkins, K.
SO-42-02-11	Radiological Assistance Program	Layandecker, S
WB-00-00-00	Building Energy Surveys/Low Cost IHEM Studies	Toscano, M
Protect Workers, the Public and the Environment		
DP-05-14-03	Safety Management Verification and Operational Readiness	Perkins, K
HC-11-03-00	Integrated Safety Management Systems Support	Perkins, K.
HC-11-05-00	BNL Support for DOE Orders, Standards, and Rules	Perkins, K.
HD-20-06-10	Medical Information System Development	Breitenstein, B
HD-20-06-20	Brookhaven National Laboratory Health Surveillance System	Breitenstein, B
Scientific Excellence and Mission Relevance		
EW-40-40-00	Strategic Laboratory Council	Wirick, C.
KD-01-00-00	Detailee to the Office of High Energy and Nuclear Physics	Baggett, N

Energy Resource Mission

B and R	Project Title	Principal Investigator
	Clean and Affordable Power	
Clean and Affordable Power		
AF-70-00-00	Special Purpose Fission Technology Task 2.2: NTR Fuel System Analysis	Todosow, M.
Enhancing Utility Infrastructure		
EB-50-01-00	Practical Conductor Development for Electric Power Systems Utilizing High -Tc Oxides	Suenaga, M
	Efficient and Productive Energy Use	
Clean and Efficient Vehicles		
EE-05-01-00	Lithium-Ion Cell Diagnostics and Evaluation	McBreen, J
EE-05-05	Battery Materials: Structure and Characterization	McBreen
Efficient and Affordable Buildings		
EC-09-04-00	Oil Heat Research	McDonald, R
EC-09-04-00	Thermal Distribution Systems in Small Buildings	Andrews, J
	Reliable and Diverse Energy Supply	
Enhancing Domestic Supplies		
AB-05-40-00	Structure Characterization and Sono-Simulated Kinetic Study with Tracers in Pressure Vessels: An Integrated Approach to the Study of Natural Gas Hydrates	Mahajan, D.
AC-10-05-00	Natural Gas and Oil Technology Partnership	Goland, A
EB-40-01-00	Geothermal Materials Development	Berndt, M
	Advanced Processes for Geothermal Brines Multiple Resources	Lin, M
EE-06-02-00	Natural Gas Storage Systems	Wegrzyn, J

National Security Mission

B and R	Project Title	Principal Investigator
	Countering Weapons of Mass Destruction Terrorism	
Nuclear		
IN-01-06-00	Technical Analysis and Program Support for the Special Technologies Programs	Lemley, J.
NN-40-06-01	Initiatives for Proliferation Prevention (IPP) Support	Rohatgi, U
Responding to Chemical and Biological Proliferation		
ND-02-02-00	Technical Program Support to Emergency Management Advisory Committee (EMAC) Subcommittee on Consequence Assessment and Protection	Hansen, D.
NN-20-04-00	Targeted Diagnostics for Biological Non-Proliferation	
NN-40-06-01	Initiatives for Proliferation Prevention (IPP) Support	Rohatgi, U
	Monitoring Nuclear Treaties and Agreements	
Nuclear Non-Proliferation and Arms Reduction Monitoring		
GD-05-08-04	OSS Safeguards System Protocol	Gordon, D
NN-20-02-00	R&D - NN20	Gordon, D.
NN-31-00-00	Uranium Program Transparency Measures	Dougherty, D
NN-40-03-00	International Safeguards	Gordon, D
	Nuclear Deterrent	
Production and Manufacturing Technology		
DP-08-17-02	Accelerator Production of Tritium	Todosow, M
Stockpile Assessment and Certification		
DP-05-14-03	Safety Management Verification and Operational Readiness	Perkins, K.
	Preventing Proliferation	
Fissile Material Disposition		
NN-40-06-02	Nuclear Cities (Environmental)	Moskowitz, P.
Nuclear Materials Protection		
GD-06-04-02	Safeguards R&D	Gordon, D.
NN-40-01-00	NN 40-01 Russian Subcontracts	Indusi, J.
NN-40-06-01	Initiatives for Proliferation Prevention (IPP)	Rohatgi, U.
NN-50-01-00	U.S.- Russian Nuclear Security Programs	Kempf, C.

Environmental Quality Mission

B and R	Project Title	Principal Investigator
	Disposal/Disposition of Waste/Materials	
Mixed, Low-Level and TRU Wastes		
KB-02-02-04	Nuclear Physics Support for Waste Management Operations	Carney, K.
KC-02-04-011	Legacy Waste Disposal	Hill, L.
	Enhance Future Land Use	
Deactivation and Decommissioning		
EX-04-C4-02	Decontamination and Decommissioning: BGRR	Hill, L.
Environmental Remediation		
EW-02-MM-200	HQ EM20 Support to Integration and Disposition	
EW-40-10-00	Development of Perfluorocarbon Tracers for Verification of Long Term Capping	Heiser, J
EW-40-10-00	Subsurface Contaminants Focus Area - Laboratory Technical Support	Sullivan, T.
EW-40-40-50	STCG/SLC Support (Ch06PS01)	Moskowitz, P.
EW-40-90-100	EM Science Program	
EX-04-C4-04	BNL Environmental Restoration and Waste Management - Remedial Actions	Hill, L.
	BNL Environmental Restoration and Waste Management - Program Management	Hill, L
	Management of Waste/Materials	
Management of Waste/Materials		
AF-55-00-00	Technical Support for the ATW Program	Todosow, M

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/TANDEM VAN DE GRAAFF COMPLEX		
BNL	40	1
Other Federal Labs	64	11
University	95	32
Industry	56	25
International	144	46
	394	116
NATIONAL SYNCHROTRON LIGHT SOURCE		
BNL	257	1
Other Federal Labs	239	29
University	1357	156
Industry	189	72
International	365	152
Other	116	262
	2523	436
SCANNING TRANSMISSION ELECTRON MICROSCOPE		
BNL	8	1
University	55	42
Other Federal Labs	12	4
Other	0	0
	75	47
ACCELERATOR TEST FACILITY		
BNL	22	1
Other Federal Labs	13	3
University	25	10
Industry	10	2
International	18	8
	88	24

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	Academia Sinica University
Argonne National Laboratory	Banaras Hindu University
Bhabba Atomic Research Center	Brookhaven National Laboratory
Carnegie Mellon University	Center for Nuclear Studies
Centre de Recherches Nucléaires	China Institute of Atomic Energy
City College of New York	Clermont-Ferrand
Columbia University	Creighton University
Florida State University	Fysisk Institutt
Georgia State University	Hiroshima University
Indiana University Cyclotron Facility	Institut de Recherches Subatomiques
Institute for High Energy Physics, Protvino	Institute of High Energy Physics, China
Institute of Nuclear Physics	Institute of Particle Physics
Iowa State University	Jagellonian University
Johns Hopkins University	Joint Institute for Nuclear Research
Kangnung National University	KEK, Institute for High Energy Physics
Kent State University	Korea University
Kurchatov Institute	Kyoto University
Laboratory of High Energy Physics @ Dubna	Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory	Los Alamos National Laboratory
Lund University	Massachusetts Institute of Technology
Max-Planck-Institut fuer Physik	McGill University
Michigan State University	Moscow Engineering Physics Institute
Myongji University	Nagasaki Institute of Applied Science
National Central University	NBI
New York University	Oak Ridge National Laboratory
Ohio State University	Orsay (IN2P3-IPN)
Palaiseau (LPNHE)	Partical Physics Laboratory @ Dubna
Pennsylvania State University	Petersburg Nuclear Physics Institute
Purdue University	Rice University
RIKEN, BNL Science Center	RIKEN, Institute for Physical and Chemical Research
Saclay (DAPNIA-SPHN)	Seoul National University
St. Petersburg State Technical University (PbSTU)	State University of New York @ Stony Brook
Subatech	Texas A&M University
Tokyo Institute of Technology (TITech)	Tsukuba University
University of Bergen	University of Kansas
University of Maryland	University of Rochester
University of Tokyo	Universidade de Sao Paulo
University of Alabama @ Huntsville	University of Arkansas
University of Birmingham	University of Bucharest
University of California @ Berkeley	University of California @ Davis
University of California @ Los Angeles	University of California @ Riverside
University of Chicago	University of Frankfurt
University of Muenster	University of New Mexico
University of Oslo	University of Tennessee @ Knoxville
University of Texas @ Austin	University of Washington
Vanderbilt University	Warsaw University
Warsaw University of Technology	Waseda University
Wayne State University	Weizmann Institute
Yale University	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	

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 database on long missions into interplanetary space by humans. This program runs for two weeks of beam-time per year, with heavy-ion irradiations for 20-30 experiments annually. The users are approved and funded by NASA, which purchases the AGS time.

National Institutes 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 Institutes 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. BNL is working in collaboration with the US Army Corps of Engineers to produce dredged material treatment trains that 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 assists 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.

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 focusing 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-analyses 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 scientists are extensively involved in research such as the work for North Carolina State University that involves data analyses with a series of diagnostic modeling exercises to understand the photochemical process forming ozone in the Nashville area. This work leverages DOE's investments in atmospheric chemistry. Through the Woods Hole Oceanographic Institution, 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 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	DEPARTMENT OF COMMERCE	
NOAA	Aerosol Measurements at Cheju Island	EENS
	Airborne Measurements of Single Particle SiZc and Chemical Composition during Intercontinental Transport	EENS
	Development of an Operational Aerosol Model for ACE - Asia Field Intensives	EENS
	DEPARTMENT OF DEFENSE	
ARMY	Structural Studies on Intact Clostridium Botulinum Neurotoxin Complexed with Inhibitors	BO
	Differential Expression of DNA Double Strand Break Repair Proteins in Breast Cells	BO
	PET Imaging of Estrogen Metabolism in Breast Cancer	CO
	Non-destructive Evaluation of Corrosion Under Coatings	EENS
	Design, Development & Fabrication of a Breadboard Prototype 500W TPV Power Source Phase I	EENS
	Development of a Visual Data Archive of Contaminant Distributions in the Passaic River	EENS
	Amorphous Pre-ceramic and Crystalline Organic Polymers for High Performance Coatings, Adhesives, and Composites	EENS
	Active/Passive Noise Cancellation	EENS
NAVY	Shipboard Acoustic Doppler Profiles in the Arabian Sea	EENS
	Arctic Military Environmental Cooperation	EENS
DNA	Simulator for LISBON (NIS) Project	EENS
DARPA	Molecular Logic Gates	MO
	DEPARTMENT OF HEALTH AND HUMAN SERVICES (DHHS) - PROGRAM 40	
NIAAA	Dopaminergic Brain Function in Alcoholics	CO
NIDA	Chemistry Department Operating Funds for Regional NIDA Neuroimaging Center	CO
	Operating Funds for Regional NIDA Neuroimaging Center	MO
	PET in Cocaine Abuse	MO
	PET Studies of Brain Dopamine in Cocaine Abusers	MO
	Pharmacokinetics of Psychostimulants & Reinforcement	MO
NIGMS	Structural and Functional Studies of E Coli DNAJ	BO
	Development for Macromolecular Crystallography at the NSLS	BO
	CLP: An Archetypal ATP-Dependent Protease	BO
	Is There a Threshold in the Radiation Dose Response Curve?	BO
	Genetic Variation in Human NHEJ DNA Repair Genes	BO
	DNA Mismatch Repair and Mutation Avoidance	BO
	Nondiamagnetic Agents in In-Vivo 23NA & 2H2 MR	MO
NIH	Monitoring Methyamphetamine Abuse Treatment with Proton Magnetic Resonance Spectroscopy	MO

	Table C1 - FY 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
NIH	DNA Damage Quantitation by Single Molecule Laser Sizing	BO
	Vaccine Intervention for Lyme Borreliosis	BO
	Adenovirus Receptor Interaction Structure Function	BO
	DNA Mismatch Repair in Transformation and Mutagenesis	BO
	Regulation of Adenovirus Proteinase by a Peptide J DNA	BO
	STEM Mass Mapping & Heavy Atom Labeling of Biomolecules	BO
	PET Investigations of PET Neurotransmitter Interactions	CO
	4 Tesla MRI Bolus CR Studies of Human Brain BBB Permeability	CO
	Radiotracer R&D in Nuclear Medicine and Neurosciences	MO
	Ceramid and Radiation Induced Apoptosis in CNS Gila	MO
	Doperamergic Brain Function in Alcoholics	MO
	Brain Imaging and Drug Abuse	MO
	Positron Encoding Detectors for PET/SPECT Imaging	MO
	Project 2: PET and SPECT Radiotracers for Brain Cannabinoid System	MO
	Activation Studies in Early HIV Dementia	MO
	Neuroimaging of HIV Progress in Cocaine Users	MO
	Magnetic Resonance Spectroscopy to Monitor HAART in HIV Brain Injury	MO
	1 HNMR Chemical Shift Imaging in Temporal Lobe Epilepsy	MO
	Estimation of Synaptic Dopamine using PET & SPECT	MO
	Modulation of Neutrons Matter Release by Cannabinoids	MO
	NSLS Upgrade	NSLS
	Protein Crystallography Beamline	NSLS
NINDS	PET Studies of Catechol -O-Methyltransferase	CO
	DEPARTMENT OF STATE	
AID	International Safeguards Project Office POTAS	EENS
	ENVIRONMENTAL PROTECTION AGENCY	
EPA	NY/NJ Harbor Sediment Decontamination Tech. Demonstration: Phase II Pilot Scale	EENS
	Program Plan from BNL for 1998 Interagency Agreement between EPA & DOE	EENS
	Barrier Materials Evaluation of Waste Forms Dumped in the Kara and Barents Seas	EENS
	Development of a Mobil Modular Treatment Facility for Liquid Radioactive Waste	EENS
	Data Analysis and Field Studies in Support of the SOS and BRAVO Programs	EENS
	Murmansk Initiative & Related Waste Management Projects in the Former Soviet Union	EENS

	Table C1 - FY 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	
NASA	Genetic and Epigenetic Effects Produced by High Energy Heavy Ions	BO
	Biological Beam Experiments	BO
	Diagnostic Microarrays for Emiliania Huxleyi Blooms: Design Based On Serial Analysis of Gene Expression	BO
	Germ Cell Mutagenesis in Medaka Fish Following Exposure to Heavy, High Energy Cosmic Ray Nuclei	BO
	Feasibility Study-Heavy Ion Beam Facility for Radiation Health Research at AGS Booster	CA
	Booster Applications Facility	CA
	Heavy Ion Beam for SEU Studies & Radiation Effects Research	CA
	Genetic and Epigenetic Effects Produced by High Energy Heavy Ions	CA
	Representation of Aerosol Microphysics in Regional to Global Scale Models	EENS
	Validation of the SeaWiFs Atmospheric Correction Scheme using Measurement of Aerosol Optical Properties	EENS
	Reaction Pathways & Thermodynamic Studies of Atmospheric Reactions	EENS
	Comparison of Large Scale Aerosol Models	EENS
	Genetic and Epigenetic Effects Produced by High Energy Heavy Ions	MO
	Support for Animal and Dell Biological Experiments	MO
	NUCLEAR REGULATORY COMMISSION (NRC)	
NRC	Japanese Collaboration on Seismic Issues	EENS
	Assessment of Aged and Degraded Structures and Components	EENS
	Review of Environmentally Assisted Age Related Degradation Issues Associated with License Renewal	EENS
	Specialist Support for Fire Protection Inspections	EENS
	Turkey Point Fire Protection Inspection	EENS
	Training Materials for Fire Protection Inspections	EENS
	ANO Fire Protection Inspection	EENS
	Reactivity Transients	EENS
	Technical Assistance in Support of Plant Systems Licensing Activities	EENS
	Credit for Operator Action	EENS
	Methods for Calculating Vessel Fluence	EENS
	Technical Assistance to Support Review of License Renewal Application	EENS
	Loss of Coolant Accident Testing of Cables	EENS
	Water Reactor Safety Information Meeting	EENS
	Development of Review Guidance for NUREG-0700 Rev. 2	EENS
	EQ/Aging Power Cables and Electrical Penetrations	EENS

	Table C1 - FY 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	Technical Assistance in Support of Regulatory Licensing Improvements Activities	EENS
	Technical Assistance in Support of the Review of ISI Relief Request Licensing Actions	EENS
NRC	Safety and Regulatory issues Related to the Permanent Shutdown of Nuclear Reactor Plants Awaiting Decommissioning	EENS
	Technical Support for the Russian Kalininskaya WER - 1000 Probabilistic Risk Assessment	EENS
	Support in the Development of Risk Information Associated with Low Power Shutdown Operation Level 2	EENS
	Screening Reviews of Seismic Individual Plant Examination of External Events Submittals and Insight Programs	EENS
	Support in Development of Consensus PRA Standards	EENS
	Risk-Informing 10CFR50	EENS
	BWR Vessel Analysis	EENS
	Technical Support in Risk Assessment	EENS
	Reactor Dosimetry and Vessel Fluence Benchmark Problems	EENS
	Inspection and Assessment Program Development	EENS
	Benchmark and maintenance of NRC SDP Inspection Notebooks	EENS
	Implementation of Risk Informed Regulation	EENS
	Strengthening the Kazakhstan Regulatory Authority	
	Strengthening the Armenian Regulatory Authority	EENS
	NATIONAL SCIENCE FOUNDATION PROGRAM 40	
NSF	Charged Species in Supercritical Fluids	CO
	OTHER FEDERAL AGENCIES - PROGRAM 40	
DOT/FAA	Development of a Variable Frequency Approach for Monitoring Condition of Aircraft Wiring	EENS
FAA	Applying Probabilistic Risk Assessment Methodology to Aircraft Safety	EENS
DOE NN-30	Safeguards Analysis	EENS
DOI/NPS	Tracer Study of Long Range Transport in Support of BRAVO	EENS
DOT/FAA	Applying Probabilistic Safety Assessment to Aircraft Safety	EENS
PETC	Clean Coal Fossil Fuels and Energy Efficiency	EENS
	PRIVATE ENTITIES	
ALS Association	Studies of the Activities of ALS Mutant SOPs Using Pulse Radiolysis Techniques	CO
Amer. Fed. Aging	In Situ Correlation of Tau Protein Structure and Neuron Integrity in Alzheimer's Disease	NSLS

	Table C1 - FY 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
American Bureau of Shipping	Human Factors Engineering Guidance Development for Merchant Vessels	EENS
Battelle Memorial Institute	Technical Support for BMI Technology Platforms	TT
Burroughs Welcome	A New Anti Malarial Agent	BO
Charles A. Dana Foundation	Cerebral Metabolism in Ketosis and Epilepsy: 1H and 31P Spectroscopic Study at 4.1T	MO
Chevron Research	Catalytic Coprocessing of CO and Carbon Dioxide Into Methanol	EENS
Children's Brain Tumor Foundation	Unidirectional Microbeam Radiation Therapy of Children's Brain Tumor using Synchrotron X-rays	MO
Concurrent Technology	Advanced Zn Phosphate Conversion Coatings for Electrogalvanized Steel	EENS
Consolidated Edison	Equipment for Rapid Cable-Leak Locating and Detecting Capabilities	EENS
Cornell Univ.	CADD-based Expert System for Passive Snow Control	EENS
Cornell Univ.	Tort Law Database	EENS
Dow Chemical	Directed Genetic Engineering of Lipid Metabolism in Plants	BO
DuPont	Development of Structural Models of Plant Soluble Fatty Acid Desaturase as a basis for Rational Design of Desaturase Double Bond Positional Specificity.	BO
DuPont	Flame Acceleration and Detonation Experiments in Methane-Air Mixtures at Elevated Temperatures	EENS
Electro Energy	Preparation and Characterization of Metal Hydride Electrode Materials for Bipolar Batteries	EENS
Enconet Consulting	Risk-Informed Applications for Nuclear Power Plants	EENS
Energy Research Cntr.	NY State Premium Low Sulfur Fuel Marketplace Demonstration	EENS
EPRI	Tall Building Site Participation in TexAQ2000 Study	EENS
Ev Products Div of II-IV	Development of Multi Channel ASICs for CdZnTe Gamma Ray Detector Arrays	IO
Ev Products Div of II-IV	Monolithic Circuit for CZT Gamma Ray Detectors	IO
Federal Lab Consortium	Terrestrial Magnetic Survey	EENS
Georgia Inst. Technology	Measurement of Particle Chemical Composition During NARE TRACE P	EENS
Global Nuclear Fuels	Global Nuclear Fuels-KazAtomProm/ULBA Project	EENS
GRI	Development of a Device to Breakup Concrete Pavement	EENS
IAEA	Fellowship for P. Stasica	CO
Insight Technologies	Field Tests of Flame Quality Monitor	EENS
Insight Technologies, Inc.	BNL Technical Support on the Development of a Two-Stage Oil Burner wit Load-Tracking Control	EENS
International Resource Group Ltd.	Energy, Environment & Economic Modeling & Policy Analysis	EENS
JAERI	A Study of Medium and High Energy Proton Nuclear Cascade Process in Context of Accelerator Based....	EENS
John Hopkins Univ.	Multi-Institutional NSCORT Consortium In Radiation Health	MO
Key Span	Recycled Waste Based Cement Composite Patch Materials for Rapid/Permanent Road Restoration	EENS

	Table C1 - FY 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
Key Span	Polymer Grouts and Polymer Composite Liners for Retaining Excavated Wall	EENS
Key Span	CBC Filled Wire Mesh Composite Capping for Retaining, Berm Foundation	EENS
KeySpan	Determination of Gas Flow Rates at LILCO Gas-Fired Power Stations	EENS
KeySpan	Remediation of Soils Contaminated with Lead Paint	EENS
KGL Inc.	Photo-irradiation Study of the Effect of Topical Imiquimod 5% Cream on Sunburn Cell….	BO
Korea Atomic Energy Res. Inst.	Technical Assistance to KERI on Low Power and Shutdown PSA of YGN 5 and 6	EENS
Korea Atomic Energy Res. Inst.	BNL Safety for the KALIMER Project	EENS
Korean Atomic Energy	Technical Assistance to KAERI on Low Power & Shutdown PSA of YGN 5 & 6	EENS
Metabolic Tech.	3-Methylhistidine Kinetics as an Indicator of Muscle Mass and Metabolism	MO
Multiple Sclerosis Society	H Spectroscopic Imaging of Multiple Sclerosis	MO
Multiple Sclerosis Society	Quantitation of Blood Brain Barrier Permeability in MS Lesion Development	CO
NARSAD	Gabergic Inhibition of Cue-induced Increases in Nucleus Accumbens Dopamine	CO
National Res. Council	Cobase Grant	CO
National Space Biomedical Research Inst.	4T fMRI Detects Neural Process Associated with Muscle Response to Altered Force Loading	CO
National Space Biomedical Research Inst.	Risk Assessment and Chemoprevention of HZE Induced CNS Damage	MO
National Space Biomedical Research Inst.	Subjects with Spinal Cord Injury, an Earthbound Human Model for Microgravity	MO
NATO	Assistance for Relational Databases for Nuclear Data	EENS
Niton Corporation	Development of Si Drift Detectors for Portable X-ray Fluorescence Instruments	IO
Penn State University	Investigations of Factors Determining the Occurrence of Ozone and Fine Particles in the North Eastern USA	EENS
Penn State University	Development of Cloud Property Retrieval Algorithms at Boundary Facilities	EENS
Performance Safety and Health Associates	Human Performance Evaluation	EENS
Power Reactor & Nuclear Fuel	Joint Study of Improved Safeguards Methodology Using No Notice Randomized Inspection	EENS
PowerEnerCat, Inc.	Evaluation of Nanosized Particles of Molybdenum Disulfide for Slurry Phase Synthesis of Mixed Alcohols	EENS
Public Works and Gov. Services	Assistance to AECB in Developing a Regulatory Position on Sever Accident Management for Existing Reactors	EENS
Purdue University	Quantifying the Indirect Radioactive Forcing of Sulfate Aerosols	EENS
PWR Reactors Nuclear Fuel-Tokyo	A Study of High Level Radiation Waste Material Transmutation Using an Accelerator	EENS

	Table C1 - FY 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
Radkowsky Thorium Corp	Radkowsky Thorium Fuel Project	EENS
Rockefeller Univ.	Center for Structural Genomics	BO
Schwartz Foundation	Automated Analysis of Neurite Outgrowth of Explants	EENS
Scientific Digital Visions, Inc.	Application of Java Technologies to Nuclear Physics Databases	EENS
Skidway Inst. of Oceanography	Ocean Margins Program - Synthesis and Modeling	EENS
St. Luke's (NIH)	Medical Applications Accuracy Neutron Activation	MO
Sub Terral Sensors, LLC	Terrestrial Magnetic Surveyor - TEMASU	EENS
SUNY-SB	Vaccine Intervention for Lyme Borreliosis	BO
SUNY-SB	Regulation of Tissue Repair	BO
Target Inc.	Development of Radiotracer for imaging the Brain Nicotine Receptor for Alzheimer's Disease Diagnosis	CO
Tokyo Electric Power Co.	AC Losses in Conductors Based on High Tc Superconductors	EENS
Univ. Minnesota	FACE Facility at Cedar Creek	EENS
Univ. of Tokyo	Japan Cooperative Program on Neutron Scattering	PO
Univ. Penn	Pre-conceptual Design of a Rapid Cycling Medical Synchrotron	CA
University of Rochester	US ATLAS Barrel Cryostat Design and Procurement	PO
University of Valencia	Pilot Project on Improvements for Spanish Nuclear Power Plants	EENS
University of Valencia	Pilot Study & Guidance for Technical Specification Improvement for Spanish Nuclear Power Plants	EENS
US Civilian R&D	Hadronic Matter and Quark Gluon Plasma in Relativistic Nuclear Collisions	PO
Woods Hole (NSF)	GLOBEC: Collection of Shipboard ADCP Data & the 1st year of the NE Channel & Scotian Shelf Water Cross-Over Moving Array	EENS
	STATE AGENCIES & LOCAL GOVERNMENTS	
NY DOT	Tort Law Data Base	
NYSERDA	Oil-Fired Heating System Development & Demonstration	EENS
NYSERDA	Variable Firing Rate Oil Burner Using Pulsed Fuel Flow Control	EENS
NYSERDA	Improved Electric Power Efficiency in Heating Equipment	EENS
NYSERDA	Pulse Fuel Flow in Oil Burning	EENS
Mass. Water Resource Authority	Boston Harbor Project/Waste Water Treatment on Deer Island	EENS
Suffolk County	Dissolved Organic Nitrogen & Brown Tide Blooms in L.I.'s Coastal Waters	EENS
	OTHER DOE CONTRACTORS	

	Table C1 - FY 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
Albuquerque Office	Proton Radiography Experiment	AGS
	Enhanced Surveillance, Phytoremediation & Evaluation of Risks w/ Re-distribution. - Chernobyl (DSWA)	EENS
	Development of Submillimeter Microwave Spectrometers for Materials Analysis & Other Applications	PHY
	Linear Ion Source	PHY
	Surveillance for Comprehensive Asset Tracking Technology	EENS
	Thorium Fuel Concept	EENS
	Study of Local Magnetic Flux Distribution Related to Transport Properties of High-Tc BSCCO Superconducting Practical Tapes	EENS
	Retargeting of Adenovirus for In-Vivo Gene Therapy	BIO
	Development of Sensitive & Specific Rapid Diagnostic Tests for Lyme Borreliosis in Russia	EENS
Argonne	Atmospheric Radiation Measurement Program	IO
Battelle-PNNL	Various Battelle - PNL Work Orders for Continuation of LISBON Project	EENS
	Atmospheric Radiation Measurement Program	EENS
	Tracer Preparation and Analysis for Full 2000 VTMX-CBNP Experiments	EENS
	Tritium Target Qualification Project	EENS
Chicago Operations Office	Waste Policy Center - Technical and Regulatory Support	ERD
FERMI	Design, Construction and Installation of the Forward Pre-shower Detector for the D Zero Upgrade Project	PHY
FETC	Krakow Clean Coal Fossil Fuels & Energy Efficiency Program	EENS
Idaho Operations Office	Amorphous Silica	EENS
	Disposal Unit Source Term Code	EENS
LLNL	Nuclear Closed Cities Initiative	AGS
Lockheed Martin	Develop Animal Models, Prepare Rh-188 Labeled Stents	MO
	Assemble a Control System for One 24 Valve Ring	EENS
LANL	Treatment of Elemental Mercury and Mercury Contaminated Glassware	EENS
Oak Ridge Ops. Office	Proliferation Resistant BWR	EENS
	NERI Initiative	EENS
	Demonstration of SASE Principle with the VISA Experiment	NSLS
	Optimization of Heterogeneous Use of Th in PWRs to Enhance Proliferation Resistance	EENS
ORNL	Spallation Neutron Project	AGS
	Mercury Waste Profiling	EENS
PPP	Disposal of Radium - Beryllium Sources	WM
Rocky Flats Ops. Office	Biomobility of Actinides	EENS
SNL	Source-Term Calculations for WIPP Performance Assessment	EENS
	Dynamics of Dislocations Near Interfaces in Thin Metal Films	PHY
	SEU Testing	AGS

	Table C1 - FY 01 Work For Others by Project	
FUNDING AGENCY	**TITLE**	**DEPARTMENT**
	Use of High Temperature, Carbon Dioxide Resistant Cements Developed at BNL	EENS
	Design of a Plasma Porthole in a Wind Tunnel Experiment	CD
	UAV Measurement Study	EENS
Savannah River	Subcon Focus Area Lab Team for Long Term Capping Strategy Development	EENS
University California	Development of Radioactive Beam Capability at the 88-Inch Cyclotron	CO

Table C2 - CRADA Projects

SPONSOR	**TITLE**	**DEPARTMENT**
eV Prod. Div. of II-VI, Inc.	Monolithic Circuits for CZT Gamma Ray Detectors	IO
Advanced Energy Systems	Development of High Average Current, High Brightness, All Niobium, Superconducting RF Injector	IO
BioCat, Inc.	Biochemical Upgrading of Petroleum	EENS
BioCat, Inc.	Development of Methods to Enhance Heavy Oil Production in Offshore Environments	EENS
Brookhaven Technology Group, Inc.	Development of a High Current, High Gradient, Laser Excited, Pulsed Powered Electron Gun	IO
Burle Industries	Project to Develop a Red Side Window Photomultiplier Tube and a Mesh Dynode Proximity Focusing Photomultiplier Tube	PO
Chevron	Catalytic Coprocessing of CO and CO2 Into Methanol Via the BNL Low Temperature Methanol (BNL-LTM) Process	EENS
Consolidated Edison Company	Equipment for Rapid Cable-Leak Locating and Detecting Capabilities	EENS
Cotton Incorporated	Improving Cotton Fiber Quality and Yield	BO
CTI, Inc.	Non-Invasive Blood Radioactivity Monitor for Quantitative PET Imaging Studies	CO
Diatide, Inc.	Development of Tin-117m Stannic DTPA for the Therapy of Cancer in Bone	MO
Dow Chemical Co.	Directed Genetic Engineering of Lipid Metabolism in Plants	BO
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	BO
DuPont/Kurchatov Institute	Combustion Code for the Chemical Industry	EENS

Table C2 - CRADA Projects

SPONSOR	TITLE	DEPARTMENT
Excom, Inc.	Development of Application of Pattern Recognition System	EENS
Excom, Inc.	Development of a Multi-Facet Pattern Recognition System	EENS
GRI	Design and Manufacture of a Prototype Rapid Concrete Cutter Device for Opening of Concrete Pavements above Subterranean Gas Pipelines	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
Niton Corp.	Development of Silicon Drift Detectors for Portable X-ray Fluorescence Instruments	IO
Oncogene Research Products	Development of Immunological Reagents for Analysis of DNA-Damage Responses in Human Cells	BO
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
Scheering AG	Development of a Non-Iodine Based Radiographic Contrast Agent and a Complementary Monochromator for CT and Planar X-ray Imaging Sources	MO
Sub-Terra Sensors	Terrestrial Magnetic Surveyor (TEMASU)	EENS
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	CO

Table C3 - BSA Patent Portfolio

Technology Field	Inventions in Portfolio	Inventions Licensed	Inventions Commercialized
Molecular Biology	26	10	4
Medical Devices	9	0	0
Pharmaceuticals	22	9	1
Optics	34	34	0
Instrumentation	17	9	5
Materials	29	4	0
Environmental Remediation	18	11	5
Energy Production	5	2	0
Microfabrication	2	0	0
Electronics	3	1	1
Total	**165**	**80**	**16**

Table C4 - Examples of Products Marketed Under License From BNL

PRODUCT	DEPARTMENT
Apparatus and Method for Biological Purification of Wastes	EST
T7 Gene Expression System, Vectors and Protein Products Produced with the T7 System (three separate inventions)	BO
Red Blood Cell Labeling Kit for Selectively Labeling Whole Blood with Tc-99m	MO
Recombinant Plasmids for Encoding Restriction Enzymes Dpn I and Dpn II of Streptococcus Pneumoniae	BO
Fast Repetition Rate Fluorometers and Method for Measuring Fluorescence and Photosynthetic Parameters	EST
Surface Profiling Interferometers for Accurately Measuring Irregularities in the Surfaces of Mirrors and Lenses	IO
Cytoplasmic Bacteriophage Display System	BO
Polyethylene Encapsulation of Radioactive and Mixed Wastes	ES
Monolithic Amplifier	IO

Table C5 - BSA Licensing Revenue ($1000)

	FY 98	FY 99	FY 00	FY 01
Gross Revenue	1656	2771	2068	2439
Net Revenue	1196	2136	1463	1777

Appendix D: Sites and Facilities

D.1 Description

BNL's site is approximately 5,320 acres, of which 30% is developed. There are 392 buildings (30 are surplus) and 381 portable structures. Portable structures are facilities not meeting the criteria for real property buildings that house people, equipment, or are used for storage. These structures consist of trailers, sheds, containers, railroad cars, HAZMAT storage units, etc.

Table D1 - Laboratory Space Distribution and Replacement Plant Value

LABORATORY SPACE DISTRIBUTION

Facility Type	Area (Sq. Ft.)
Active Buildings	3,960,598
Surplus Buildings	282,029
Portable Structures	115,469
Leased Off-site	1,000
TOTAL	4,359,096

Source: DOE FIMS Database 5/1/01

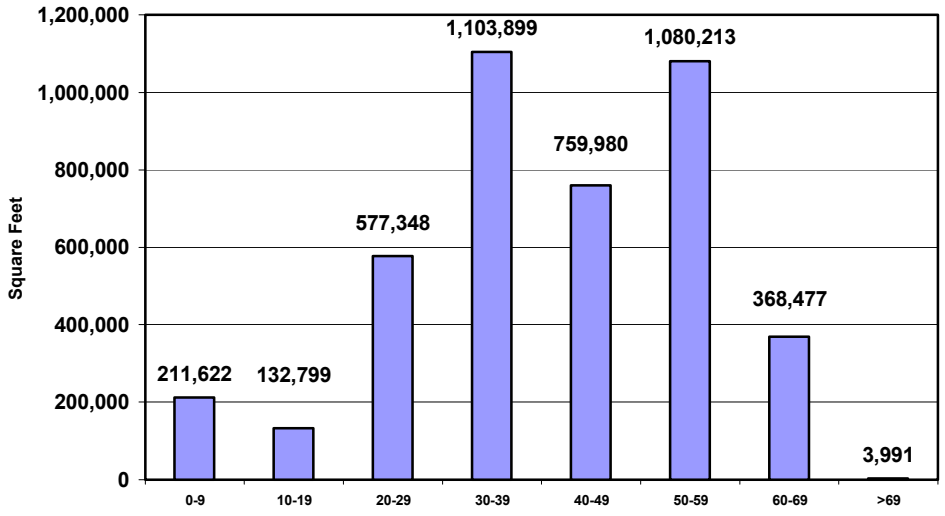
REPLACEMENT PLANT VALUE

Facility Type	Current $
Active Buildings	1,175,855,823
Surplus Buildings	1,085,314,672
Active OSF	694,053,731
Excess OSF	60,602,624
TOTAL	3,015,826,850

Source: DOE FIMS Database 5/1/01

Many buildings date back to World War II, some earlier. Most major permanent buildings, excluding those constructed for RHIC, were built in the 1960s (Figure D1).

Figure D1 - Age Distribution of Buildings in Years
(Average Age, Weighted by Square Footage = 40)



BNL is served by site-wide utilities that include electrical-, steam-, sanitary sewer-, storm sewer-, and potable water systems. In addition, there are limited distribution systems for chilled-water and compressed air. Figures D2 through D5 illustrate the condition and use of existing Laboratory space. These figures use two different data sets. The first reflects BNL's assessment

of the condition of space and the suitability or its use based on criteria developed for the Strategic Facilities Plan, while the second data set is based on FIMS data

Figure D2 - Use & Condition of Non-Surplus Space – Using SFP Approach

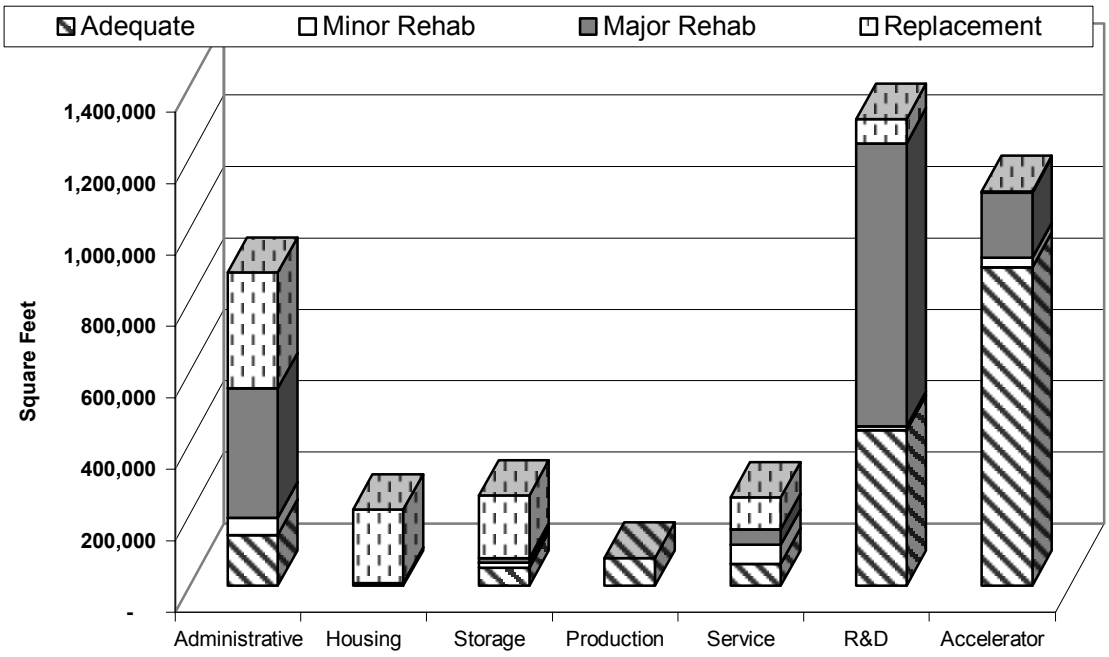


Figure D3 - Use & Condition of Non-Surplus Space – Using FIMS Data dated 4/30/00

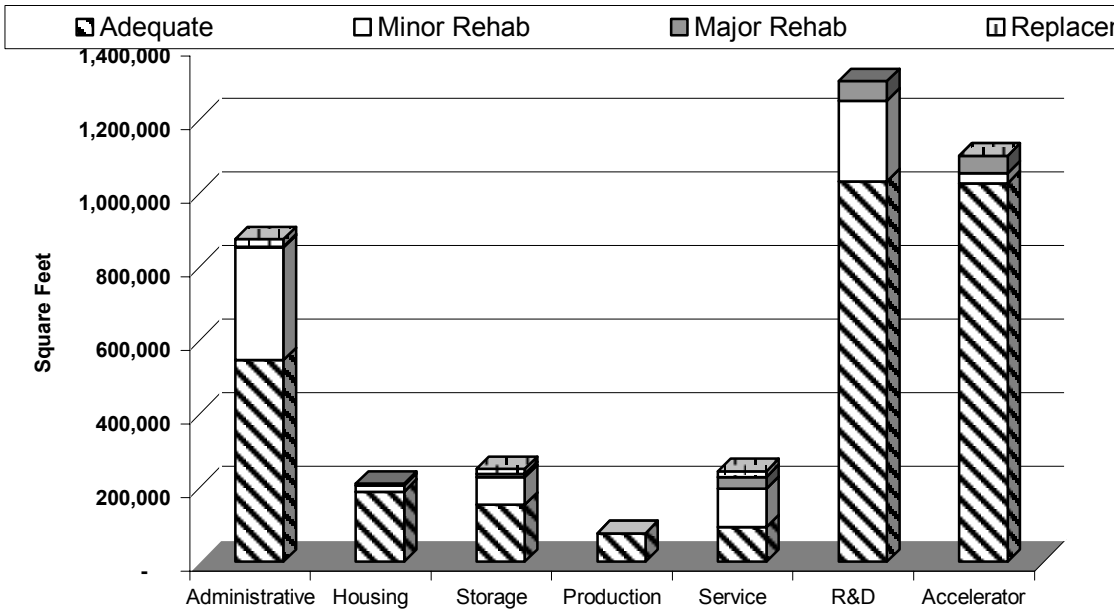


Figure D4 - Condition of Laboratory Space –Assessment from the Strategic Facilities Plan

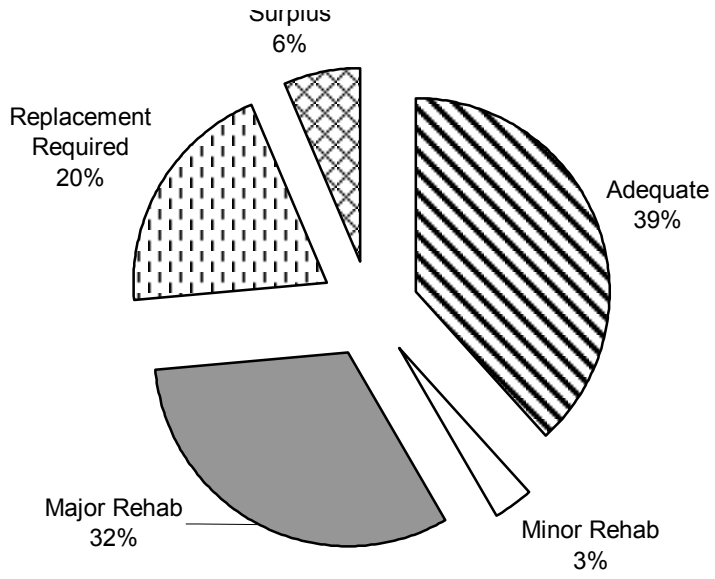
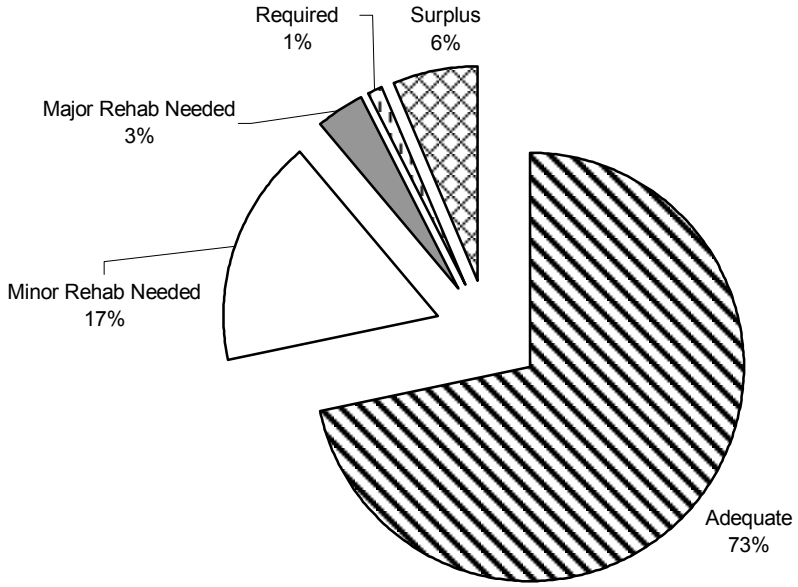


Figure D5 - Condition of Laboratory Space – Based on FIMS Data dated 4/30/01



BNL's assessment significantly decreased the amount of "adequate" space and increased the amount of space that needs replacement or major rehabilitation. Site-wide utility systems have

been a high priority for maintenance and capital renewal, for which we received good support in the past from the DOE's Multiprogram Energy Research Facilities Support (MEL/FS) program. General Plant Project (GPP) funds also were used to renovate smaller, more localized utilities. These projects ensured operational continuity. However, there are several remaining issues, such as the need for additional chilled-water and concern over the condition of the steam distribution system.

D.2 Trends

Buildings and Space Utilization: Approximately 78% of BNL's building space is at least 30 years old, and 34% is over 50 years. The costs of maintenance, repair, and capital renewal are high, and 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 construction related to the RHIC and small GPP projects. Consistent with plans to consolidate staff into better facilities, an effort is underway to make the use of office space in permanent buildings more efficient, thereby allowing 60-year-old wood buildings to be vacated. Over the past two years, we increased the use of office space in the permanent buildings by 11%. Since we anticipate that new construction will only replace existing buildings, the amount of space should not change significantly, and the number of buildings should decrease slightly as we replace small buildings with larger ones.

Portable Structures: There is no clear definition of trailers; 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 led to the disposal of approximately 120 unneeded portable structures during the first two years of the program. However, over the past two years, the number of portable structures has remained fairly constant.

Surplus Facilities: The number of contaminated surplus facilities did not change from 1994 until April 12, 2000, when a Memorandum of Agreement (MOA) was signed by DOE's Office of Science, Office of Nuclear Energy Science and Technology, and Office of Environmental Management that transferred nine facilities to EM for disposition. They were Buildings 704, 707A, 707B, 715, 750, and 751 and OSF assets ST0705, ST0707, and ST0752, part of the recently shutdown High Flux Beam Reactor (HFBR) complex. Other contaminated surplus facilities now under DOE-EM include the old Hazardous Waste Management Facility Complex (Buildings 444, 445, 446, 447, and 448), and the former Brookhaven Graphite Research Reactor (BGRR) Complex (Buildings 701, 708, and 709). Prior to FY 00, there were seven non-contaminated surplus facilities (Buildings 93, 168, 428, 625, 915, 917, and 960); within the past year, six more were categorized as surplus (Buildings 90, 91, 158, 207, 208, and 318). Presently, three surplus contaminated facilities are proposed for transfer to DOE-EM (Buildings 491, 650 and 650A).

The costs of surveillance for surplus facilities are not tracked separately by building in the Maintenance Management system (MP2); however, all maintenance costs are recorded in MPW, reported through FIMS, and updated annually. Surveillance costs for non-contaminated surplus facilities are nominal and funded by the site maintenance budget that receives monies from the space charge program.

Off-site Leases: Since 1996, BNL has had one existing lease for a 1000 sq. ft. apartment for staff involved in a program in North Carolina.

Maintenance: From FY 99 to FY 00, the deferred maintenance decreased 6% from $94 to $88 million. The decrease primarily reflects our continuing efforts to accurately identify deferred maintenance and sort out some overlap of deficiencies in maintenance projects and capital renewal projects. We are continuing this work this year, as a formal initiative. Since FY 97, the maintenance budget has increased 70%. Reasons for this rise include the additional maintenance required to support operational RHIC facilities, together with a heightened focus on maintenance that is evident in the establishment of a "recurring maintenance" budget in addition to the routine maintenance budget. The recurring maintenance budget is approximately $1.2 M/yr. Maintenance funds were curtailed from FY 95 to FY 98 as part of DOE's efforts to reduce overhead at the sites, and as BNL directed more overhead funds to meet emerging ES&H needs.

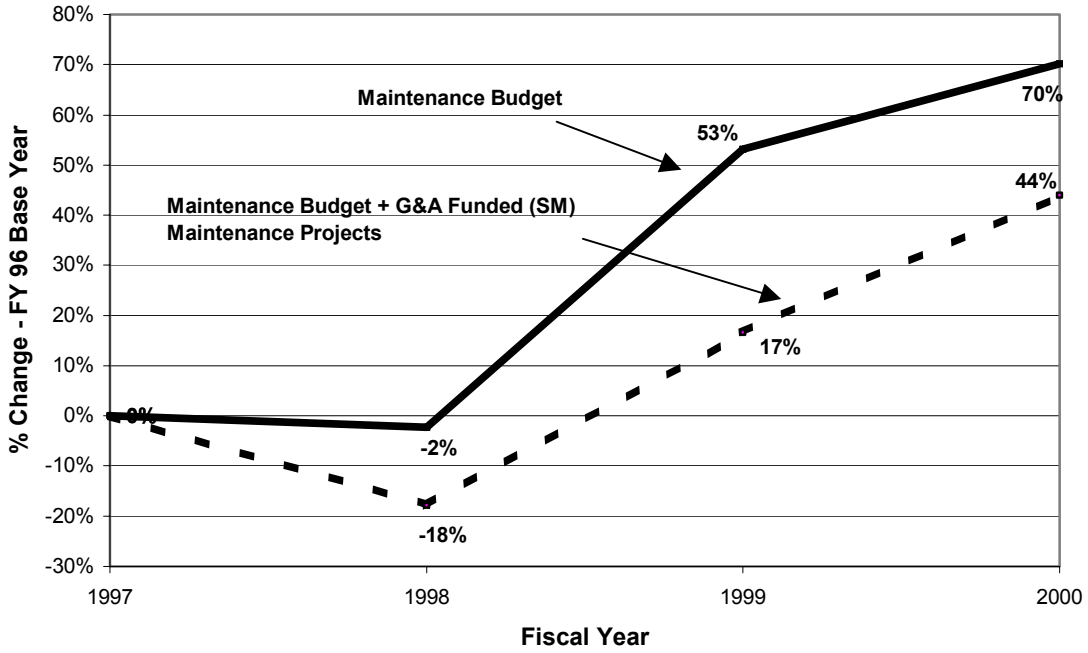


Figure D6 - Maintenance Funding Trend

D3. Site and Facilities Plans

During FY 00, BNL developed a new Site Master Plan, identifying projects that will assure that BNL will operate as a "Laboratory of the 21st Century." These projects will support existing and anticipated programs and the associated support functions. An outgrowth of the Site Master Plan is the Infrastructure Strategic Facilities Plan that details the implementation of the Site Master Plan's requirements over a 10-year horizon. Central to many of the proposed buildings is a strategy for consolidation from small 60-year-old wood buildings into modern multi-story facilities that are much larger. Facilities with this type of configuration will greatly improve operational and energy efficiency. Major general-purpose laboratory/office buildings, most of which are 35 to 40 years old, will be renovated. The structures are sound and have many years of useful life remaining, but the interior finishes and mechanical and electrical systems need replacing. Implementing these strategies will significantly reduce the backlog of maintenance and capital requirements of existing facilities. In addition, undertaking these repairs will ensure we have facilities of a quality needed to support continued world-class research (see Figure D-4)

at a level of efficiency conducive to attracting new researchers and sustaining existing staff. Furthermore, these facilities will be more easily maintained at achievable maintenance funding levels.

Implementing these strategies will address several of the issues that the Laboratory faces

- the lack of space for new RHIC users,
- the high costs of maintenance and energy of the old buildings,
- buildings that do not conform to current Life Safety codes and structural design codes for buildings,
- small facilities that do not easily allow reconfiguration or consolidation of work groups to optimize operational efficiency, and
- a significant backlog of roofing repairs and additional continuing requirements associated with small single-story buildings.

Funding levels have been relatively static for many years, and indeed declining when corrected for inflation. This shortfall 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 have become more difficult and expensive. The backlog of line-item projects totals over $566 M, with approximately $90 M in programmatic funding, $85 M in third-party financed construction (short- and long-term housing), and a balance of $391 M anticipated in MEL/FS funding. We note that this amount represents a total increment in MEL/FS funding of $330 M, or less than $33 M per year, assuming the historical baseline average of $5.5 M per year from the MEL/FS program. An important consideration in planning is the extent to which the MEL/FS program will support permanent science buildings and the level of support from the program offices.

Increased levels of GPP and/or MEL/FS Line Items will allow us to construct new facilities. The current GPP backlog is approximately $63 million. In addition, over the past few years, we averaged an outlay of approximately $10 million per year in new projects. This amount exceeds the funding average of slightly over $6 million per year, thereby increasing the backlog. To reduce backlogs, GPP funding levels will need to rise to at least $10 million per year. We propose that the baseline GPP remain at slightly over $6 M and be adjusted for inflation and that monies are provided to fund one "Super GPP" project, in addition to the baseline projects. "Super GPP" projects are those costing $2 M - $5 M. If they are funded from the GPP, it significantly lowers the number of projects that we could execute in a given year.

Figure D7 - Typical Laboratory Renovation, Before & After

Figure D8 - Impacts to Programs from Deteriorating Infrastructure

Response to roof leak ("Cow Bag"): Leaks demoralize workers & damage equipment equipment	*Mechanical System Needing Replacement Dirt particles discharge damaging scientific*

D4. Detailed General Purpose Facilities Plans and Resource Requirements.

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 outlined in the Strategic Facilities Plan from FY 02 to FY 06, are approximately $144 million (Table 13). Based on a ten-year average funding level of $5.5 million, a $116 million shortfall is expected by 2006. Section D.8.2 summarizes the MEL/FS projects.

Inadequate funding for the General Purpose Facilities program is extending 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.

Within the planning period, BNL proposes new programmatic facilities, including a User Research Center ($15.0 M) and a Center for Functional Nanomaterials ($82 M). In addition, there are several proposed MEL/FS projects for new buildings, including an Energy Sciences Center ($17.4 M) to consolidate related programs into new modern flexible-use laboratory/office space, and a multi-phased Research Support Center (four phases at $18.2 M each) to improve operational efficiency by consolidating support functions and allowing the demolition of 60-year-old inefficient wood buildings. In addition, the Research Support Center will reduce backlogs in areas such as Life Safety compliance, roofing, duct cleaning, and replacing mechanical equipment. A multi-phased Support Shops Complex (Phase I $5.5 M) will combine the functions of Plant Engineering and Central Shops into one area of the site, improving their overall operational efficiency and allowing the demolition of 60-year-old, inefficient wood buildings.

During the same planning period, BNL also proposed a series of projects to renovate its major laboratory/office buildings that, on average, are over 35 years old (Phase I $29.3 M, Phase II $14.3 M, and Phase III $25.3 M). While the buildings' shells and superstructures are sound and will last for another 50+ years, the buildings' interiors and mechanical systems have reached their end life and desperately need replacing.

BNL's utility systems are fairly reliable; however, to maintain this reliability, additional projects are proposed to replace aged components of the potable water and steam distribution systems ($8 M each). Furthermore, the Central Chilled Water Facility needs an addition ($8.5 M) to support planned facilities and restore firm capacity. To meet the requirements of the Clean Air Act, Halon fire-suppression systems must be phased out ($5 M). Other utility concerns that will become future priorities include:

- The condition and longevity of the Site Fire Alarm System that is rapidly becoming obsolete. (To address this issue a new planning team was formed to develop a long-term strategy with associated projects and costs.)
- Expansion of the BNL high-speed network backbone to include site-wide plant systems including fire alarm, energy management, and plant control systems.
- Electrical power quality and associated monitoring to ensure compliance with utility requirements.

While the trends indicate that maintenance funding has increased, this is somewhat misleading as the base year was during a period of extremely low maintenance budgets as funds were redirected to address higher priority ES&H needs. In addition, during this same period, several facilities related to RHIC became operational, increasing maintenance needs. The current deferred maintenance, which is mostly comprised of major maintenance projects, is more than 20 times the annual funding for those types of projects. In addition, with increased facility inspection, the backlog is growing. A significant portion of the maintenance backlog would go away if the capital renewal projects proposed in the Site Master Plan were constructed. Remaining backlog would be quite manageable, without increasing maintenance funding levels significantly.

D.5 Assets Management

The Laboratory maintains a comprehensive and cost-effective Assets Management Program efficiently encompassing our use, control, and disposal of assets.

Real Property: Real property records are maintained in the DOE's FIMS and reconciled with the Laboratory's financial records. During field surveys of the Facility Inspection Program, the accuracy of the FIMS records and building key plans are reviewed. Information on the buildings' conditions, deficiency lists, and requests for upgrades also are reviewed to assess each facility's life cycle and to identify those assets for which further capital investment is warranted or for which demolition is preferred. The Laboratory uses either the DOE's Office of Science landlord funds (through G&A) or the DOE's Environmental Management funds (direct funding) for demolishing buildings.

Personal Property: BNL undertakes 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 has 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 FY 98, BNL began a charge-back program that charges departments and divisions for their use of space, based on the BOMA Area Measurement Standard (ANZI Z65). It includes all buildings and portable structures. The rates for occupied spaces are adjusted each quarter. Each space is classified and assigned rates and categories as shown in Table D2.

Charging for space does have a benefit in terms of encouraging consolidation. This has been particularly true for those groups that have reorganized and who carefully considered the use of space as they planned their revised organizations. In FY 01, space charges dramatically increased as a result of the rapid rise of fuel costs.

Table D2 - Space Charge Rates and Categories

SPACE TYPE	DESCRIPTION	FY00 RATE, $	FY01 RATE, $
0	Common Space (corridors, bathrooms, electrical- and mechanical- space associated with operations of the facility.)	0.00	0.00
1	Normally unoccupied space, such as programmatic equipment support spaces, electrical- and mechanical- space associated with the operation of the program, and Storage spaces	3.30	3.85
2	Normally occupied space, including industrial space, such as machine shops, technical- and craft- shop areas; non-laboratory high- bay industrial areas, such as manufacturing, testing and assembly areas; and, commercial-type space, such as the Research Library	8.80	10.15
3	Normally occupied space, such as Offices, Laboratories, Conference Rooms, and Department/Division libraries.	12.90	14.90
4	Normally inaccessible spaces occupied by large research machine including associated tunnels, caves, etc. All maintenance is charged back to the occupant.	0.00*	0.00*
5	Housing. All maintenance is charged back to the Administrative Services Division.	0.00*	0.00*

* Maintenance is charged-back based on actual costs.

D.6 Energy Management

BNL has an aggressive energy management program that involves monitoring site-wide energy use, verifying energy billing, and allocating energy costs to individual departments. When funding is available, BNL also manages projects to lower the use of energy and coordinates demand-limiting efforts. There are several federally mandated goals and requirements for reducing energy use, lowering CFCs, conserving water, purchasing green power, and other energy-related issues. Most require BNL to make a significant effort in collecting data and reporting to DOE, and most are tied to various performance measures. Further, significant costs are associated with many of these requirements.

A number of major energy issues face the laboratory over the next five years; the most important is the availability of low-cost, reliable electric power. For over 20 years, BNL has

bought low-cost power from the New York Power Authority (NYPA). In June 2005, the existing contract will end. At this time, it appears that NYPA's ability to supply power beyond this date is questionable. BNL is evaluating several options for future power needs, including on-site generation. This issue is of significant concern because BNL's electric costs are projected to be over $22 million annually by 2005.

Another major energy issue for BNL is the requirement to increase the efficiency of energy use. The federally mandated goal is a 40% reduction in energy use per square foot by 2005, and a 45% reduction by 2010, measured against the 1985 baseline. These goals were significantly increased over the last few years. While BNL historically has done very well lowering the unnecessary use of energy, these goals are not economically practical at BNL. Moreover, the historical source of funding for completing energy projects no longer exists. DOE is currently directing sites to utilize alternative sources of funding to meet these goals. However, even if BNL attracts alternative financing, these goals still do not make economic sense. In fact, the problems will be exacerbated by the additional costs associated with alternative financing. Nonetheless, for several years, BNL has explored alternative financing for energy-related projects. Recent emphasis has been on using DOE's Super Energy Savings Performance Contracts (ESPCs). We contacted several contractors to begin initial discussions on whether or not this type of arrangement makes sense for BNL.

D.7 Third Party Funding/Financing

In developing the Site Master Plan, BNL reviewed the list of projects needs to determine which ones are best suited for the pursuit of Third Party financing and development. Projects to meet near-term requirements for additional housing and for a phased replacement of 60-year- old housing are likely candidates. BNL is monitoring ORNL's attempts to execute an agreement allowing state- and corporate-backed development. In addition, BNL met with the Long Island Housing Partnership (LIHP) which works with state and local officials to act as facilitators in developing legislation and financial support for housing projects. To support this effort, BNL will develop a Housing Master Plan that will specifically identify and document BNL's housing needs. This document will be used to facilitate communication with potential third-party funding sources and to give developers a basis for making specific proposals.

D.8 Strategic Facility Plan Projects

D.8.1 Programmatic Line Item Projects

Cyclotron Isotope Research Center (CIRC) - NE: The CIRC project will provide a new 20,000 square-foot building to house the cyclotron and its four beam lines. The building will have crane coverage over the cyclotron's vault to allow maintenance and repairs. The facility's walls will be 14-feet thick behind the target stations to minimize neutron flux outside the building. The walls surrounding the cyclotron itself will be 10-feet thick. The radiation-protection labyrinth throughout the building generally will have walls 5-feet thick so that the total thickness surrounding the cyclotron area will be 10 feet. The beam will be diverted to the four target stations by switching magnets located in the cyclotron's vault. The beam will be directed to the target through focusing- and steering- magnets. In the isotope production beam line (northwest cave), the targets will be located in the center of a concrete and metal shield; they will be installed and removed vertically from a hot cell, located on the second floor directly above the target station. The power supplies for the magnets will be housed with the cyclotron's power supplies. The mechanical equipment for ventilation and cooling water will be housed on the second floor of the facility. Recirculating water for cooling the targets, the cyclotron and systems

that potentially could contain radioactive material will be located in the vault to prevent cross-contamination. These systems will be contained in mechanical equipment rooms near their respective target station.

User Research Support Center - $14.3M (NP): A 75,000 square foot, four-story office building will be constructed next to existing Building 510 (Physics). The facility will be used by approximately 300 visiting scientists who will be working at RHIC at any given time, to coordinate the experiments, operate the detectors, and analyze data while working alongside Brookhaven's dedicated staff of about 150 scientists and support personnel. During short periods (e.g. workshops and collaborative meetings) an additional 100 to 200 visitors will come to Brookhaven for work involving RHIC. Proximity to the computing facility is essential for analyzing data, and BNL's research staff also will leverage the investment in this vital research machine. At present, Brookhaven does not have a facility in which we can consolidate the RHIC research activity.

Center for Functional Nanomaterials - (KC): With this project BNL will construct a new two-story laboratory/office building of approximately 82,000 gross square feet. The facility will include Class 10 clean rooms, general laboratories, wet and dry laboratories for preparing, fabricating, and analyzing samples. The equipment necessary to explore, manipulate, and make these nanoscale materials and structures is included. Also included are individual offices and landscape office areas, a seminar area, transient spaces for visiting collaborators with access to computer terminals, conference areas on both floors, and vending/lounge areas. The building also will have circulation/ancillary space, including a mechanical equipment area, toilets, corridors, and other support spaces.

D.8.2 General Purpose Facilities - Multiprogram Energy Laboratory/Facility Support

Energy Science Building $17M: This proposed new building for the Energy, Environment, and National Security Directorate will provide 16,000 square feet of laboratory, office, and support space. All floors of the facility will have individual offices, two-person offices, state-of-the-art laboratories, transient user-space for visiting collaborators with access to computer terminals, and conference rooms.

Chilled Water Ph II $8.5M: This project will increase the plant size and capacity to provide reserve capacity and the capability to easily add capacity for future planned facilities. The existing facility will be expanded to accommodate three chillers, while only one and related equipment will be installed as part of this project. While the facility could be expanded incrementally, it is far more efficient to increase the size of the facility as a single project. Other plant systems, such as cooling towers, need to be constructed to accommodate several chillers.

Research Support Center: Four Phases $72.8M: With this project, 281,000 square feet of modern office buildings, four buildings in close proximity, will be constructed using a four-phase approach. The new construction will consolidate organizations that support BNL's research and that are now spread among numerous small buildings, most of which are WWII vintage constructions. This project also will demolish aging, high-maintenance buildings most of which are 60-year old wood-frame buildings. They include the following: 120, 130,134, 184, 185, 194, 197, 355, 426, 459, 460, 464, 477, 493, and 527.

Roof Replacement Phase II $1.6M: BNL will fully replace the roofs on permanent structures that have reached their end-life. (Note: roofing projects associated with the buildings

identified for demolition are not included. However, if these buildings are not destroyed, then these other roofing projects also will be needed.)

Renovate Science Laboratories - 6 Phases $155.6M: BNL will renovate close to 800,000 square feet of permanent laboratory/office buildings, many built in the 1960s. These renovations include interior finishes, electrical and mechanical systems, and basic laboratory furnishings. Some changes will be made in the placement of interior partitions to make the facilities more flexible and adaptable to changing program needs. We will emphasize making the buildings more environmentally benign ("green") and energy-efficient. The project will be carried out in phases by prioritizing the buildings based on the mission needs and the building condition. This project will significantly lower both the GPP and maintenance backlogs.

Support Shops Complex- 3 Phases $20.9M: The Buildings, Administration, and Electrical and Mechanical maintenance shops of the Plant Engineering Division, that are now widely dispersed throughout the site, will be consolidated through this project. The new complex will be located near the consolidated Central Shops complex to allow sharing of resources and personnel. This move will vastly improve operational efficiency. This project also will support the demolition of aging, high-maintenance buildings, most of which are 60-year old, wood frame buildings. They include the following: 97, 244, 405, 422, 208, 321, 326, 339, 412, 423, 96, 406, 452, 455, and 528.

Central-steam Distribution - 2 Phases $16M: BNL will replace the aged steam distribution lines and associated condensate return lines and extend the steam distribution system to support multi-program growth in the northern area of the site. Many of the oldest sections of the steam distribution system have poor insulation, and there are leaks in the condensate return piping, lowering the system's efficiency.

Potable Water System II - $8M: BNL will replace the distribution lines of the aged potable water system. The most needy area is the housing area. We will explore the potential for using third party financing for this replacement in conjunction with third party housing projects.

Halon Replacement - $5M: BNL will replace Halon Fire Suppression Systems with other fire suppression systems. The Clean Air Act requires discontinuing the use of ozone-depleting chemicals, including Halon. The Department of Energy no longer permits its purchase. These systems must be changed to give BNL the continued ability to fight fires.

D.8.3 Buildings – Possible Third Party

Short-term Housing $25.2M: BNL will construct over 200,000 square feet of new housing in several phases; the additional housing to meet demand will be built first and the replacement facilities last. This type of housing will be geared toward the more than 3,000 visiting scientists per year who stay at BNL for a short time. Many of these users are here for only a few days, working shifts on beam lines. Proximity to the research areas and economical costs are the main determining factors. This housing likely will have shared support facilities, such as bathrooms and kitchens, and common spaces for entertainment and social occasions. Most of the BNL visitor housing is in recycled WWII army barracks. About 40% of the demand for housing is for short-term stays of only a few days. Many of these visitors prefer that their rooms have close proximity to their research space. Energy-efficient replacement housing will allow us to demolish obsolete structures, while providing appropriate quarters for guests. The existing short-term housing would be removed during the later phases of this project as the replacements are built.

Long-term Housing $37.8M: BNL will construct over 210,000 square feet of new housing in several phases; additional housing to meet demand will be built first and replacement facilities last. This type of housing is geared toward those visiting scientists and families who come to BNL for extended stays. Many require houses with several bedrooms. Since transportation tends to be less of an issue for such users, the housing could be located well away from the central site to allow a comfortable community-type atmosphere for families. This type of housing will likely be self-contained, with shared community-type facilities for entertainment and social gatherings. Energy-efficient replacement housing will allow us to demolish obsolete structures, while providing appropriate quarters for guests

D.8.4 Super GPP Projects (Projects > $2,000,000)

NISUS Wiggler Building - $2.0M: The proposed addition, 60 ft. by 80 ft. (4800 sq. ft.) for laboratory space, will consist of six laboratories and machine space. It will be a pre-engineered building, tying together the existing Building 729 and modular Building 728. To construct this facility, abandoned Well #1 will be closed and removed in compliance with regulations.

Medical Imaging - $4.3M: BNL will provide a 3,500 square foot building to house a 7-Tesla research Magnetic Resonance Imaging (MRI) machine. An additional 2,000 square feet of office space will be included to support the current and expanded multi-disciplinary research program. It will be located adjacent to the 4-Tesla MRI facility.

B/725 Addition - $3.0M: This is a second floor addition of approximately 3,100 sq. ft. above the existing west receiving area at the NSLS. It will house 12 individual offices, a conference room, and bathroom facilities. The existing roof structure must be structurally modified to support a second floor.

Information Technology - $3.5M: This addition to Building 515 will provide approximately 5,000 square feet of raised-floor computer space needed for several expanding programs, including RHIC, RIKEN, and ATLAS. Also, approximately 5,000 square feet of office and support space will be constructed to store tapes and to consolidate staff near the computer facility.

Central Shops Addition - $5.0M: This proposed addition of approximately 35,000 square feet will complete the grouping of all Central Shops research support work in one complex, together with offices for design, production, quality control, procurement, metals warehousing, metal cutting, drafting rooms, and business. We will demolish the former Army warehouses and masonry gymnasium.

Conference Center Addition - $ 5.0M: With this project BNL will add approximately 9,000 square feet to the existing conference facility at B/488 Berkner Hall. This addition will give us a single facility for large conferences (a capability we do not have) and will be configurable into smaller spaces.

Support Shops Complex - Site Div - $4.1M: Plant Engineering buildings are spread across the campus; many are WWII era structures inherited from Camp Upton. New facilities will reduce space by 15-20% and substantially improve operational efficiencies. The plan is to co-locate these facilities with the Central Shops complex and new warehousing function. This is a phased relocation of the operations of the Plant Engineering Site Division.

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

Table E1 - Annual Participation In Science Education Programs (As of 09/01)									
		FY1999			FY 2000			FY 2001	
	Total	Minority	Female	Total	Minority	Female	Total	Minority	Female
Post-secondary Programs									
UNIVERSITY/COLLEGE PROGRAMS									
Nuclear Chemistry Summer School	13	1	8	13	1	9			
Summer Students/ERULF	50	17	20	69	11	27			
Summer ERULF/Summer Supplemental Research Program (Students and Faculty)							63	7	27
Semester ERULF/Semester Research Program (Students)							5	3	3
SERS/ERULF SemEENSer	20	7	3	26	6	10			
College Mini-Semester							14	12	8
Special Groups: BSP	1						1	1	1
PST							6	5	4
COMMUNITY COLLEGE TA									
CCHP Summer Students/CCI	25	16	13	20	8	10	16	5	8
Faculty	1	1		0					
SCCC Co-Op	0			1			2	0	2
Northeast Consortium (SUMS) and CC Mini-semEENSers	16	13	9	23	14	10			
Pre-college Programs									
Community Summer Science (HS)	40	3	17	31	1	11	34	2	15
SemEENSer Research Interns	1		1	1					
Academic Year Research Interns							1	0	1
Women in Science and Engineering	28		28	35		35	31	4	31
Specialized Activities with Elementary, Middle School Partners							40	12	28
Museum Programs							24797	NR	NR
NYS Mentoring Program	20			20					
SDTA Special Services (teacher/admin)	250			32		23			
SDTA Special Services (students)	25	8	25	144	24	130			
MINORITY PIPELINE (SUMS)									
MHSAP/NIH Summer Apprenticeships	29	29	14	23	23		23	23	15
TECHNICAL ED/MST INT (PAST)									

Table E1 - Annual Participation In Science Education Programs (As of 09/01)									
		FY1999			**FY 2000**			**FY 2001**	
	Total	**Minority**	**Female**	**Total**	**Minority**	**Female**	**Total**	**Minority**	**Female**
MAGLEV Tech Ed Consortia (approximate)	300	NR	NR	300	NR	NR			
Technology Educator's Workshops	30			15					
MST Conference Workshops	40								
TEACHER ENHANCEMENT (PTEP)									
NYU Teacher Res. Association and	3	2	2						
NSF/DOE National Teacher Enhancement (NTEP)	3	0	3	3	0	3			
NSF Elementary MST (MSTe)	180	35	130	307					
HS Teachers' In-Service Course	20								
DOE/NSF Co-op Appointments	0			0					
TOTAL	**1095**	**129**	**273**	**1063**	**88**	**268**	**25033***	**74**	**143**
NR Note Recorded									
*** Now includes Summer Sunday Visitors in addition to other Museum Programs**									

Table E2 - Brookhaven National Laboratory Staff Composition
Effective October 2001

	PHD		MS/MA		BS/BA		OTHER		TOTAL	
	#	%	#	%	#	%	#	%	#	%
PROFESSIONAL STAFF										
Scientists	502	84.8	39	6.6	35	5.9	16	2.7	592	20.1
Engineers	79	16.4	173	36.0	164	34.1	65	13.5	481	16.3
Management & Administrative	58	9.7	155	26.0	157	26.3	227	38.0	597	20.3
Other Professional	5	38.5	3	23.1	2	15.4	3	23.1	13	0.4
SUPPORT STAFF										
Technicians	0	0.0	14	2.6	79	14.7	443	82.6	536	18.2
All Others	0	0.0	7	1.0	56	7.7	666	91.4	729	24.7
LABORATORY TOTAL	**644**	21.8	**391**	13.3	**493**	16.7	**1420**	48.2	**2948**	100.0

Table E3 - Brookhaven National Laboratory Equal Employment Opportunity
Effective October 2001

OCCUPATIONAL CODES	TOTAL		MINORITY TOTAL		MINORITY									
					WHITE		BLACK		HISPANIC		NATIVE AMERICAN		ASIAN/PACIFIC ISLANDERS	
GENDER	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Officials/Managers														
	316	80	20	9	296	71	8	3	4	2	0	0	8	4
	79.8%	20.2%	5.1%	2.3%	74.7%	17.9%	2.0%	0.8%	1.0%	0.5%	0.0%	0.0%	2.0%	1.0%
Professional Staff														
Scientists & Engineers	898	175	195	54	703	121	13	9	21	10	0	0	161	35
	83.7%	16.3%	18.2%	5.0%	65.5%	11.3%	1.2%	0.8%	2.0%	0.9%	0.0%	0.0%	15.0%	3.3%
Management & Administrative	61	153	8	22	53	131	5	13	0	4	1	1	2	4
	28.5%	71.5%	3.7%	10.3%	24.8%	61.2%	2.3%	6.1%	0.0%	1.9%	0.5%	0.5%	0.9%	1.9%
Technicians	492	44	49	4	443	40	21	2	17	0	2	0	9	2
	91.8%	8.2%	9.1%	0.7%	82.6%	7.5%	3.9%	0.4%	3.2%	0.0%	0.4%	0.0%	1.7%	0.4%
All Other														
	424	305	98	91	326	214	65	63	23	22	5	2	5	4
	58.2%	41.8%	13.4%	12.5%	44.7%	29.4%	8.9%	8.6%	3.2%	3.0%	0.7%	0.3%	0.7%	0.5%
Totals	**2191**	**757**	**370**	**180**	**1821**	**577**	**112**	**90**	**65**	**38**	**8**	**3**	**185**	**49**
	74.3%	**25.7%**	**12.6%**	**6.1%**	**61.8%**	**19.6%**	**3.8%**	**3.1%**	**2.2%**	**1.3%**	**0.3%**	**0.1%**	**6.3%**	**1.7%**

Table E4 - Subcontracting And Procurement				
Dollars in Millions-Obligated (1)	FY 2000	FY 2001	Estimated FY 2002	Estimated FY2003
Subcontracting and Procurement from:				
Universities	1.6	8.7	5.0	5.0
All Others	140.4	133.1	148.0	153.3
Transfers to other DOE Facilities	3.5	2.8	3.0	3.0
Total External Subcontracts and Procurement	**145.5**	**144.6**	**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	6.0	6.5
Percent of Annual Procurement	5.9	5.9
(1) Show total dollars obligated within each fiscal year.		